Design and implementation of an electronic mobile poultry production documentation system

Article *in* Computers and Electronics in Agriculture · March 2011

DOI: 10.1016/j.compag.2010.12.016

Farag Sallabi
United Arab Emirates University

Moustafa Amin Fadel
Agricultural Research Center, Egypt

A. Jaffar
Abu Dhabi School of Management

Computers and Electronics in Agriculture xxx (2011) xxx–xxx

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Design and implementation of an electronic mobile poultry production documentation system

Farag Sallabi[a,*], Moustafa Fadel[b], Ahmed Hussein[b], Ahmad Jaffar[a], Hazem El Khatib[a]

[a] Faculty of Information Technology, United Arab Emirates University, United Arab Emirates
[b] Department of Aridland Agriculture, United Arab Emirates University, United Arab Emirates

ARTICLE INFO

Article history:
Received 8 December 2009
Received in revised form
12 December 2010
Accepted 23 December 2010

Keywords:
Mobile computing
Agriculture
Traceability
Poultry
Handheld device
Internet

ABSTRACT

Documentation is a major component of any traceability system where traceability is defined in the ISO Regulation 8402:1994 as the ability to trace the history, application and location of what is under consideration. Traceability systems are record keeping systems designed to track the flow of product or product attributes through the production process or supply chain. All international supply chains are forced to comply with traceability requirements. In this paper, we develop and implement an end-to-end mobile application prototype that traces the poultry production. This application consists of front-end and back-end systems. At the front-end, the worker uses a GPRS enabled handheld device (cell phone, PDA, etc.) to capture information on poultry operations collected at a remote chicken farm and transmit it to a back-end server in the main office. Through customized application the back-end server analyses all information received from the front-end and based on a built-in business process and business rules, intelligently updates various stakeholders of any breach of bio-security measures that requires immediate attention. The proposed system administrators can also access this application via Internet for management decision making. The back-end system consists of web server, defined business application logic and database server.

1. Introduction

Globally heightened consumer awareness of food safety issues, and warranted demand for "safe quality food" has forced many countries to adopt new protocols such as traceability and bio-security measures in order to avoid the cost of expensive disasters. Investments in the poultry production sector in the United Arab Emirates, in addition to the mandated responsibility to protect the nation's natural resources, made it urgent to develop a traceability system for poultry farms in the country. A bio-security network should therefore be established to protect the poultry industry's physical components, in addition to enhancing consumer confidence in national poultry products. The traceability system is the first step in a potential National/Regional system to accurately map and identify poultry production units' premises and to monitor and provide emergency response to a bio-security alert. In this research, prototype development and prove of concepts data collection were carried out to record selected activities in a remote poultry production site and transmit value adding information to a central application server in another site. Production supervisors are responsible for collecting data and documenting the daily routine procedures specific to the poultry production system (FAO, 2007).

The ISO standard 8402:1994 (ISO, 1994) defines traceability as the ability to trace the history, application and location of what is under consideration. According to EC (Regulation, 2002), the Council of the European Union defined it as the ability to trace and follow food for human consumption, feed for animal consumption, animals destined for human consumption or ingredients, through all stages of the supply chain. This paper defines Traceability as the ability to follow and document the origin and history of a food or feed product. Traceability systems are record-keeping systems designed to track the flow of products or product attributes through the production process or supply chain (Peres et al., 2007; Sparks, 2002). All international Food supply chains are forced to comply with traceability requirements. Modern packing houses and food supply processing plants have to be tied with traceability requirement or find it very hard to be in business (Gledhill, 2002).

Production units' compliance with hygienic regulations to assure outbreak controllability should be monitored by governmental agencies to protect the public health and economy. An electronic documentation and traceability system should be developed to document the various production practices. The advent of new technology such as GIS could be employed to collect

* Corresponding author at: Faculty of Information Technology, United Arab Emirates University, Al-Ain, P.O. Box: 17551, United Arab Emirates.
Tel.: +971 50 7235185.
E-mail address: f.sallabi@uaeu.ac.ae (F. Sallabi).

0168-1699/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.compag.2010.12.016

the necessary information via the proposed traceability system, providing an excellent bio-security monitoring tool for local animal production units. Any traceability system should include a documentation protocol of daily activities and an early warning system. These are essential tools to maintain market access, enable value chain management, provide the means of product differentiation, and support bio-security control protocols to enable the appropriate authorities to handle any outbreak in its initial stages.

The major objective of this research paper is to develop and implement a low-cost prototype application for documenting poultry production activities using a WiFi/GPRS (General Packet Radio Service) enabled PDA (Personal Data Assistant) as part of an integrated digital information handling and processing network. Poultry house(s) supervisor(s) will be responsible for data entry into a PDA that may be used for various poultry production houses in the same company. This should be facilitated with specially developed user-friendly software to reduce time and transcription errors. The collected data will be categorized into production and managerial information. Specific production information should be recorded and printed as a barcode according to the international codes to be available in case of emergency. This national plan will enhance disease preparedness by providing the ability to quickly trace birds exposed to disease, thus permitting rapid detection, containment, and elimination of disease threats. The rapid control of bird disease is essential to preserving the environmental assets in addition to domestic, regional and international marketability of UAE poultry products. It is fundamental for wildlife protection and controlling any foreign or domestic disease threat to have a system that identifies individual birds or groups, the premises where they are or were previously located, and the date of entry to those premises. Furthermore, in order to achieve optimal success in controlling or eliminating any animal health threat, the ability to retrieve that information within hours of a disease outbreak confirmation and to implement intervention strategies is necessary.

This prototype can be extended to be used by all poultry production farms throughout United Arab Emirates (UAE). In the future, the collected data from these poultry houses will be uploaded into a Central Server managed by UAE Food Control Authority (FCA) utilizing a GIS/GPS premises identification system in order to monitor birds' health issues by giving relative position of farms and relate geographic spatial relationships of various production units in disaster management protocol. This database would allow specialists to put different pieces of information together to: predict outbreaks, relate similar symptoms to similar causes in different units, warn units about similar trends between units, and reduce the uncertainty factor when dealing with outbreaks. The collected data will be available online for managerial analysis and food control purposes. Food control authorities can monitor all poultry production units throughout the country and may use it to protect the whole industry by taking appropriate action as early as possible. Alerts on critical parameters, such as mortality rates, disease outbreaks, may be helpful to predict potential risks as well as provide an early warning system in emergency situations. It also enables the corresponding authority to relate potential risks to production input factors such as feed or bird source, and vaccination. The developed model provides a low-cost, easy-to-use documentation system employing already existing GSM networks available in most Arab countries, without extra infrastructure costs.

The rest of the paper is organized as follows. Section 2, presents a literature review of traceability systems and IT technologies used in mobile computing. The system prototype is detailed in Section 3, while testing results is presented in Section 4. Finally the paper is concluded in Section 5.

2. Literature review

Golan et al. (2004) stated that the characteristics of good traceability systems vary and cannot be defined without reference to the system's objectives. Different objectives help drive differences in the breadth, depth and precession of traceability systems. Breadth describes the amount of information the traceability system records. Depth of traceability system is how far back or forward the system tracks. In many cases the depth of a system is largely determined by its breadth. Precision reflects the degree of assurance with which the tracing system can pinpoint a particular food product's movement or characteristics.

The Traceability Manual Poultry Industry (2005) listed the minimum records that must be kept by the poultry producer as follows:

- Records of Internal Audits of Traceability Systems.
- Records of Training Activities Related to Traceability Systems Operations and Responsibilities.
- Inventory Records in Sectors.
- Records of Breeding Management.
- Records of Bio-safety Declaration of Access to Sectors.
- Records of Maintenance Activities.
- Records of Clean Up and Sanitization Activities.
- Records of Pest Control.
- Records of Bait Control.
- Records of AVMO (Veterinary Medical Officer) Visits.
- Records of Necropsies.
- Records of Pharmaceutical and Vaccination Usage.
- Poultry Production Records.

Opara (2002) reported that a traceability chain exists when all the activities and measurements are fully integrated in the supply chain by appropriate information system. This system enables vital value-adding information to be captured, transmitted, stored, retrieved, analyzed and effectively reported at any link within the supply chain. In order to achieve this, it requires computers, database for data entry, storage and processing, and software to drive the information system and to provide interface with the user.

Smith et al. (2005) reported that traceability of livestock, poultry and meat, in its broadest context, could eventually be used: (a) to ascertain origin and ownership of animals and meat; (b) for surveillance, control and eradication of foreign poultry/animal diseases; (c) for bio-security protection of poultry/livestock population; (d) for compliance with guidelines/requirements of international customers; (e) for compliance with country-of-origin labeling requirements; (f) to isolate the source and extent of quality-control and food-safety problems; and (g) to reduce product recalls and make crisis management protocols more effective.

The falling costs of telecommunication devices has made wireless computing affordable to businesses and individuals. Due to the rapid growth of personal mobile communication devices such as PDAs and pocket PCs (Steinfield, 2004; Mei, 2005) more and more wireless mobile applications are developed and there are considerable opportunities for ubiquitous computing growth. Ubiquitous computing is an emerging paradigm of personal computing, characterized by the shift from dedicated computing machinery to pervasive computing capabilities embedded in our everyday environments. The pervasiveness and the wireless nature of devices require network architectures to support automatic, ad hoc configuration.

Mobile services and computing require integration of diverse technological and service providers. Knowledge necessary to build such complex services is often developed in several locations and cuts across the boundaries of firms, industries and countries. Mobile computing has generally been built on the concept of being able to connect anytime and anywhere (Kalakota et al., 1996; York

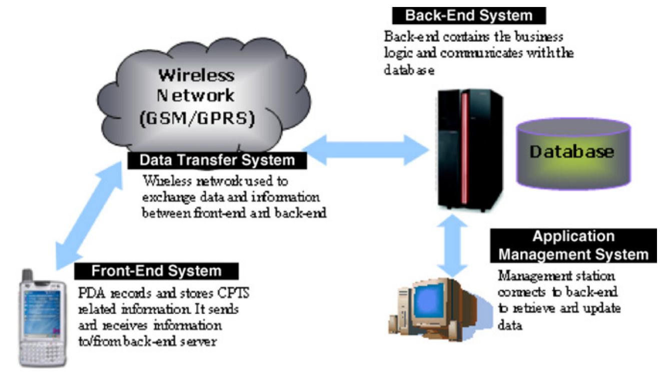

Fig. 1. Overall system architecture.

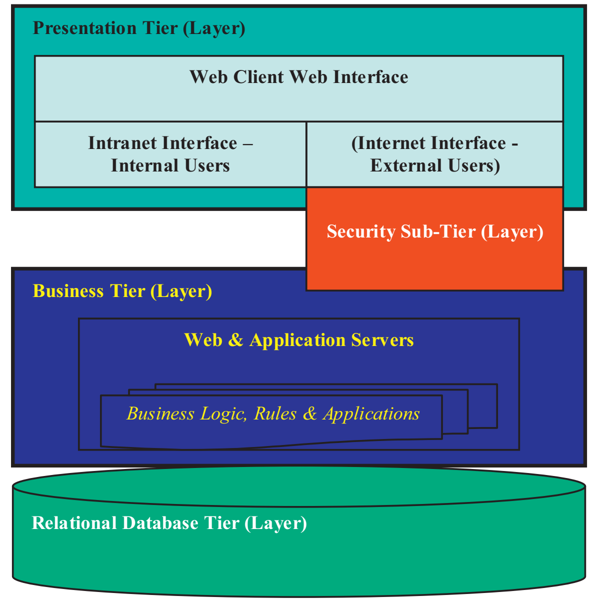

Fig. 2. Three-tier system architecture.

and Pendharkar, 2004) Researchers predict that mobile computing will be a significant area of information technology (IT) and human–computer interaction (HCI) research, development, and application. Conservative estimates based on the 2000 Census report suggested that by 2006 10% of USA workers will be completely mobile, with no permanent office location. As advances in technology increase coverage, data speeds, and usability, greater user acceptance will motivate development of new applications that are more feasible in the maturing mobile computing environment (Barbash, 2001; Turisco, 2000).

3. Prototype system design and implementation

The development of this prototype encompasses considerations involving the design of the overall system architecture to support the intended research objectives. The system architecture provided an insight on the proposed system front-end for the poultry production workers, the mechanism to handle data transfers as well as the back-end that supports the application. It also highlights application management system that supports the poultry production operation paradigm.

3.1. Overall system architecture

The overall prototype consists of four parts as shown in Fig. 1; front-end system, data transfer system, back-end system, and application management system. The mobile front-end system is deployed on a handheld device that is embedded with GSM/GPRS connectivity. The handheld device is used as an input device to collect and transmit poultry production related data to the back-end server. The GSM/GPRS network is used in places where there is no direct connection to the Internet. The back-end system receives and stores data in a database system.

In this paper, we propose a technical solution to the back-end system and the software bundles in the handheld device as well as the database system. The proposed solution is based on three-tier architecture as shown in Fig. 2. The solution is divided into three layers.

- **Presentation layer**: This layer provides a friendly mobile client interface and administrator interface with various functionalities providing an easy access to the core of the system. These client components enable the user to interact with the second-tier processes in a secure and intuitive manner. The Application Server supports several client types. Clients do not access the third-tier services directly. For example, a client component provides a form on which a front-end user provides information and data to the back-end.
- **Business layer**: It includes the functional modules and business logics. Clients connect to the back-end database through this layer. This layer may also connect to other databases for executing inquires. Multiple client components can access the second-tier processes simultaneously, so this application logic layer must manage its own transactions.
- **Database layer**: This is where poultry production relational tables that store the captured various operational value-adding information. Some static master data are entered by the system administrator while transactional data are entered by the mobile client at the field.

The proposed solution is designed to be scalable, flexible, highly available, and ready for future needs and expansions with a solid and robust infrastructure. The proposed solution is developed according to J2EE standards, using Web Services and XML for communications, and enforcing security from end-to-end. The following is a list of distinguishing features that the back-end system will support:

- **Web-Services Technology**: This is an emerging technology that includes XML, SOAP, WSDL and UDDI.
- **Security**: Firewall log enrichment and real time intrusion detection.
- **Open system**: Easily integrated with third party components.
- **Platform independence**: runs on any hardware/operating (Windows, Linux, Solaris, etc.).
- **Vendor independence**: Compliance with J2EE standard which can run on any J2EE container.
- **Flexibility**: Allows the implementation of new functions and features.
- **Reliability**: Allows services to be available 24×7.
- **Scalability**: Allows the system to easily scale up in terms of number of users.

3.2. System dataflow

The main contention driving the operational use of this proposed poultry production traceability system (PPTS) is to facilitate various effective management operational decision makings. While this may be varied from one operation to another, the system

Please cite this article in press as: Sallabi, F., et al., Design and implementation of an electronic mobile poultry production documentation system. Comput. Electron. Agric. (2011), doi:10.1016/j.compag.2010.12.016

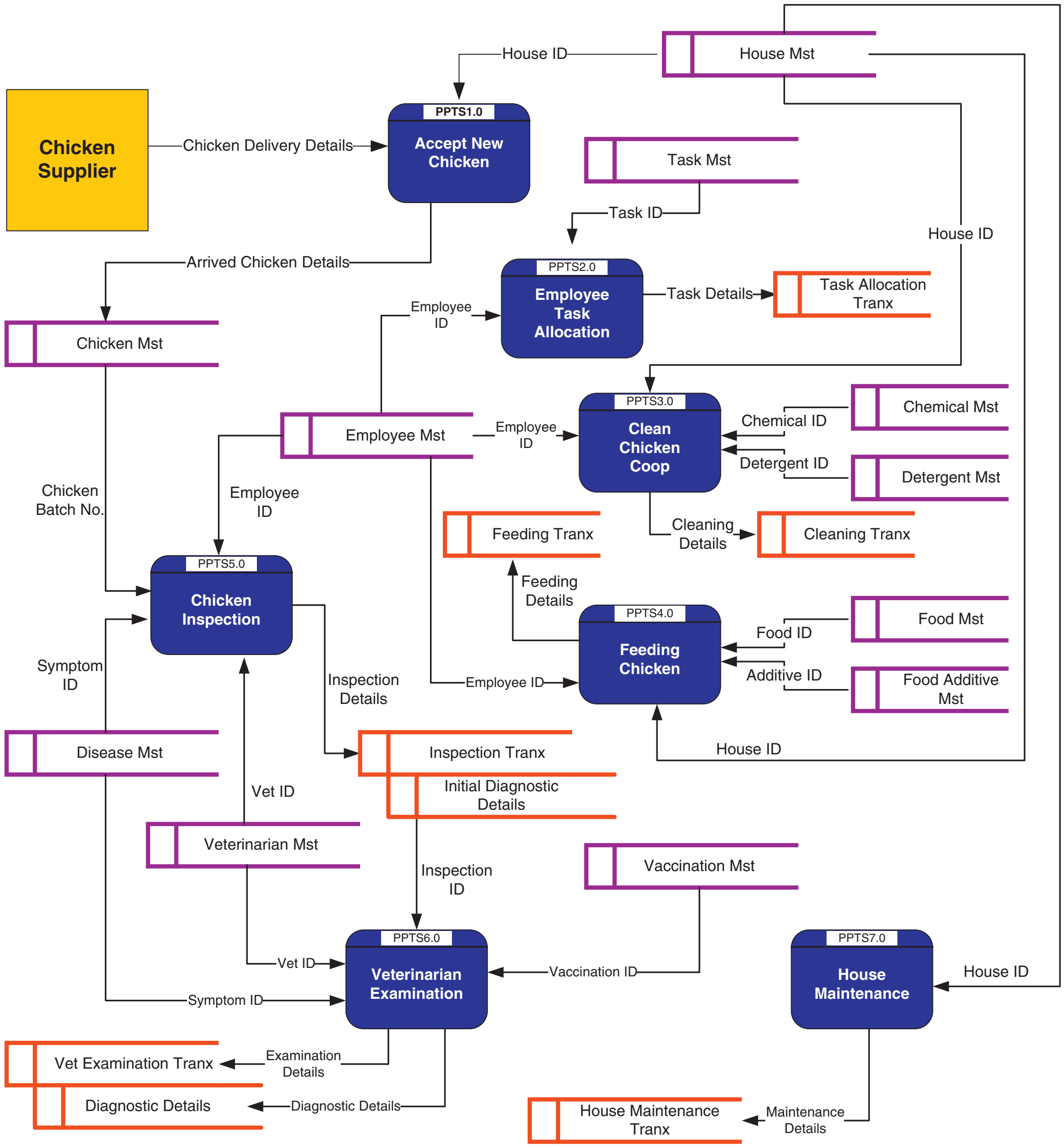

Fig. 3. Poultry production traceability system dataflow.

will be automated to alert stakeholders against defined situational problems that may lead to potentially breach of any bio-security measures. Such operational constraints are not limited to events such as potential hazard leading to spreading of diseases among chickens in the farm or equipment failure. The intention is to allow poultry management to react in a timely manner to avoid any catastrophe through the analysis of various captured operational information. As a prove of concepts, the proposed business process system flow, see Fig. 3, has been limited to focus on maintenance of various facilities within a typical chicken farm and captures operational activities that will facilitate various required traceable documentations. Future expansion is necessary to inject intelligence within the system to pre-empt potential breach of bio-security measure and propose, if not an interim solution, counter measure to prevent any adverse catastrophe. Fig. 3 also includes dataflow to demonstrate the types of information that can be captured for management reporting purposes. The following sections highlight the various elements within the proposed prototype system.

3.2.1. Poultry operations within the business layer

This system confined itself to prove of concepts in strategically aligning poultry production process to optimize the use of GSM wireless network communication. While the current focus is on document traceability, its future expansion will incorporate system intelligence as highlighted above. The current emphasis is to document and trace operational activities as abbreviated in Fig. 3 with initial PPTS < 1.0 till 7.0 > . The process inception is triggered upon the arrival of chicken from supplier, where the initial documentation will capture the bio-production information on the accepted poultry with the assigned poultry house ID, where the chicken will be housed. This information will be stored within the Chicken Mst file. In a typical daily operation, employees will be notified of the various tasks (PPTS2.0) that are necessary to be carried out by individual employee for the day. These include cleaning of the chicken houses (PPTS3.0), feeding of the chicken (PPTS4.0) and chicken inspection (PPTS5.0). On a periodical basis, veterinarian inspection (PPTS6.0) and the chicken houses maintenance (PPTS7.0) will be carried out. All of these activities will be documented to capture

Please cite this article in press as: Sallabi, F., et al., Design and implementation of an electronic mobile poultry production documentation system. Comput. Electron. Agric. (2011), doi:10.1016/j.compag.2010.12.016

various value-adding data required by the poultry management in their operational decision making. For instance, upon chicken arrival to the farm, the initial documentation will determine the health nature of the batch received and will be used as the basis to monitor the progress of the chicken in the future. This will be used as reference to the set of data captured during the daily inspection. This captured information is categorized as production information, servicing the daily poultry operational needs. On the contrary, a correlation between the health status of the chickens can be traced back to the type of chicken feeds and the general cleanliness of the chicken house (particularly with the type of chemical used for cleaning) will be analyzed every time when chicken have been found to be unhealthy. Similarly, types of maintenance done to the chicken houses will also be analyzed and trace back to isolate potential cause of unhealthy chicken. Such manipulation of information constitutes the category of managerial information where data analysis is done by the farm management team rather than the operational workers.

It is critical for poultry management to document these activities as a precautionary measure and be certain of the health quality of the chicken. Should a bio-security measure is breached, poultry management will be able to trace back the potential cause/s and implement counter-measure for such breach. Availability of structured information within a customized information system allows management to make timely decision to avert catastrophic circumstance. This is evident at the point of Chicken Inspection, where operational data entry via a PDA with a direct link to the system back-end, will prompt immediately of a potential disease based on the symptom recorded. In turn through the back-end, the proposed system can automatically triggers a delivery of an urgent SMS to various stakeholders' mobile phone for their immediate reactions. This allows for rapid detection, containment, and elimination of disease threats within the initial hours from the confirmation of a disease outbreak. At the same time, such information directly allows management to plan and manage the operation better. These computerized value adding activities allows poultry industry to achieve operational effectiveness beyond process efficiency.

3.2.2. Structured data within database layer

Supported by separately maintained master files (abbreviated with **Mst** in Fig. 3) containing various static information, the PPTS will eliminate transcription error through pull-down look-up data where a user can simply select the required information from these master files. The key intention is to facilitate unskilled workers with effective yet simple user-friendly data-entry system. On the contrary, the transaction files (abbreviated with **Tranx**) will store the various dynamic data depicting the day-to-day operations. Such data formed the main trust in deriving the documentation traceability of the poultry operations.

In a typical daily operation within PPTS5.0 Chicken Inspection, with reference to Fig. 4, apart from the *Employee ID* (of the assigned employee to perform this task) extracted from the **Employee Mst**, the *Chicken Batch No.* for the inspected chicken will be extracted from the **Chicken Mst**. Should the employee identified unhealthy chicken, the *Symptom ID* from **Disease Mst** will be used to record the health status of the identified chicken. Such information, among other data, will be stored within the Inspection Tranx with a uniquely assigned Inspection ID as its master key. The detail information on what action/s was/were taken by the employee in relation to the inspection information will be stored in a corresponding Initial Diagnostic Details transactional file. This *Inspection ID* will be associated directly to the *Inspection Diagnostic Action ID*. The latter is based on the number of action/s taken to overcome the identified symptom.

These various transactional files will be manipulated by PPTS based on the defined operational logics to facilitate poultry management in their effective and timely decision making. For instance, it will correlate historical information concerning a specific batch of chicken, over a due course of time, to the type of food given, its inspection history particularly concerning veterinarian examination as well as the cleanliness and the suitability of the house to determine potential counter measure to overcome the problem concerning the identified unhealthy chickens.

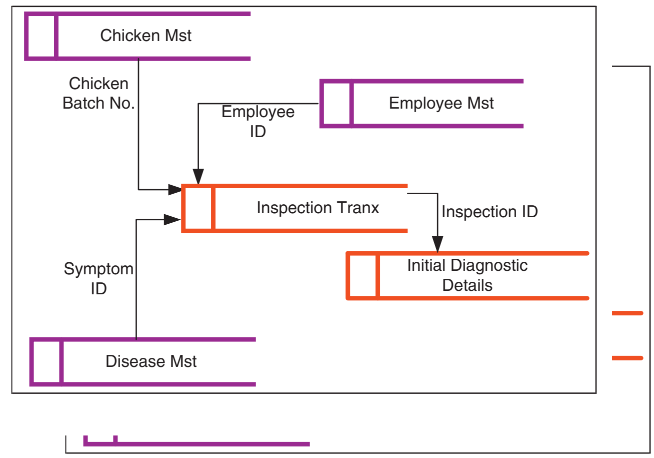

Fig. 4. Sample relational database schema.

3.3. Back-end system

Fig. 5 below depicts the main components that are implemented at the back-end system. Mobile front-end client communicates with the application server that in turns communicates with the database system to retrieve information or update the database. The Back-end server supports HTML clients as well as J2ME clients. HTML clients connect to the back-end to update and maintain database and user accounts.

3.3.1. Data management layer

The data management layer provides the underlying infrastructure for the application and provides the integrated components required to fulfill the system requirements. The system is configurable depending on a range of factors, including the proposed configuration, projected volumes, message throughput, and data retention periods. Table 1, lists the different attributes exchanged between the front-end and the back-end systems.

3.3.2. Application management system

The application is supported by an extensive user management functions for the administration of databases, users, passwords, and access permissions. Two major types of users are supported by the system; Administrator and Super Users. Each user has his unique

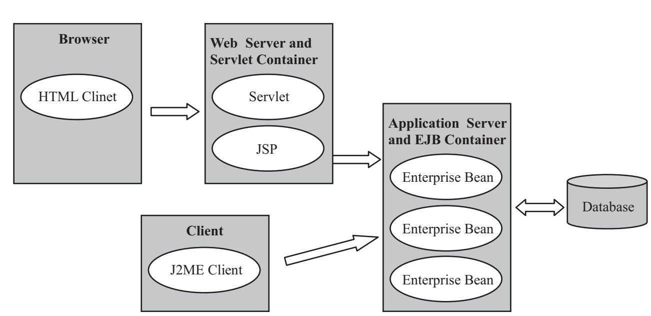

Fig. 5. Back-end main components.

Please cite this article in press as: Sallabi, F., et al., Design and implementation of an electronic mobile poultry production documentation system. Comput. Electron. Agric. (2011), doi:10.1016/j.compag.2010.12.016

Table 1
Data exchange model between the device and the back-end system.

Attribute	Type	Description	Length
vexmID	String	P.K. (Veterinarian_Exam_Trans)	5
inspID	String	P.K. (Inspection_tranx)	5
vetID	String	P.K. (Veterinarian_mst)	5
hseNo	String	P.K. (House_mst)	5
mhseDate	String	“Date in String” e.g. 20/01/2008	10
mhseTime	String	“Time in String” e.g. 12:10 PM	8
isymActionID	Integer	–	5
disID	String	P.K. (Disease_mst)	5
isymAction	String	–	100
isymActionDate	String	“Date in String” e.g. 20/01/2008	10
isymActionTime	String	“Time in String” e.g. 12:10 PM	8
empID	String	P.K. (Employee_mst)	5
inspDate	String	“Date in String” e.g. 20/01/2008	10
inspTime	String	“Time in String” e.g. 12:10 PM	8
inspNoDead	Integer	–	5
inspWeight	Integer	–	5
inspHealthStatus	Character	–	1
chkBatchNo	String	P.K. (Chicken_mst)	10
chkType	String	–	30
chkCost	Double	–	12
chkArrivalStatus	String	–	30
chkDelivDetails	String	–	100
chkAveWeight	Integer	–	4
chikDistTravelled	Integer	–	4
clnTxnNo	Double	P.K. (Cleaning_tranx)	10
detID	String	P.K. (Detergent_mst)	5
chemID	String	P.K. (Chemical_mst)	5
clnDate	String	“Date in String” e.g. 20/01/2008	10
clnTime	String	“Time in String” e.g. 12:10 PM	8
fcID	Double	P.K. (Feed_chicken_tranx)	
chkFoodID	String	P.K. (Chicken_feed _mst)	5
fadID	String	P.K. (Food_additive)	5
fcDate	String	“Date in String” e.g. 20/01/2008	10
fcTime	String	“Time in String” e.g. 12:10 PM	8
fccfAmt	Double	–	10
fcfadAmt	Double	–	10
mhseID	String	P.K. (House_main_trans)	5
mhseDate	String	“Date in String” e.g. 20/01/2008	10
mhseTime	String	“Time in String” e.g. 12:10 PM	8
mhseMainType	String	–	30
mhseProblem	String	–	100

User-ID and Password. The administrator can create and manage super users while each super user can create and manage internal users. Each user of the system is associated with a profile that is used to grant or restrict user access to the system functions.

For security reasons, all users' logs are captured and logged into the system database. If the User-ID is valid, but the password is invalid and entered 3 times, that user is locked out until an administrator or super user unlocks it. This event is logged also in the database.Our system will provide security control functionality, which will include the following:

- Users will be authenticated when attempting to communicate with the system. The system solution provides the capability of managing the authentication information associated with each authorized user.
- Maintaining authentication information for each authorized user.
- Providing user security and the capability to restrict access to data and transactions.
- Our system solution will be able to identify and authenticate a user before permitting the user to access the system.
- The system verifies the user's privileges based on the user profile before permitting the user access to system functions and data.
- Providing a flexible, easy way to define user profiles on access control.
- The authentication information (e.g., password) will be able to be reset. The system administrator should have the authority to reset the authentication information.

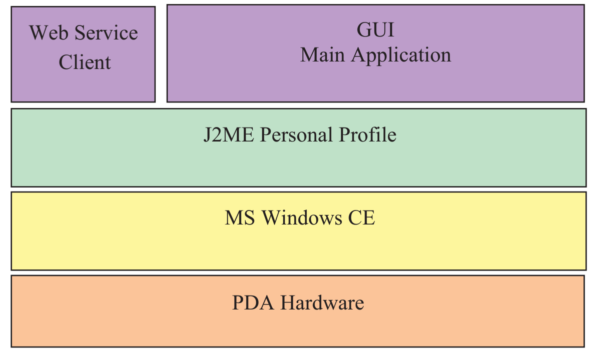

Fig. 6. Front-end components.

- The system administrator will be able to set up user classes that allow users access to specific transactions in specific domains.
- Logging of all login activities reporting on security (audit trails, etc.).

3.3.3. Security support

The end-to-end application will be supported by a security sub-layer, which includes several security mechanisms and layers to secure data and end-to-end communication. Security solutions involve the use of SSL encryption, firewalls, access control, logging of transactions and auditing. The proposed solution security will be consisting of different security zones, in which some content can be accessed anonymously, while other content can be secured and exchanged in encrypted format, and can be only accessed by authorized users. The user will be first authenticated from his/her user name and password, and then he/she will be presented with a list of portlets that he/she can access/use. Security features can be grouped into the following categories:

- **Authentication**: When a user accesses secured client (user) interfaces, he/she will be challenged for a username and password to verify his/her identity before he/she is allowed access, while allowing for single-sign-on login capability.
- **Authorization**: This allows for supporting proper (configurable) user access control levels, via an integrated LDAP based user configurable profile support.
- **Communication security**: HTTPS is the proposed communication security protocol. HTTPS uses an extra secured layer (SSL) on top of TCP to secure communication between a client and a server. Where user entity receiving a communication using SSL has an available public key and a private key known only to the entity itself. Any messages sent to an entity are encrypted with their public keys. A message encrypted by the public key may only be decrypted by the private key so that even if a message is intercepted by a felonious third party it cannot be decrypted. Further, certificates are used to sign communications, thereby ensuring that the public key that is used does belong to the correct user entity. They contain a user entity's name, public key and other security credentials and are installed on the server end of a SSL communication to verify the identity of the server.

3.4. Mobile front-end system

The PPTS application consists of two front-end applications; web based application for system administrators and mobile application for field supervisors. Fig. 6 shows the software and hardware components required for the PPTS application. The mobile front-end is designed to run on a PDA with Windows CE and J2ME personal profile. The following subsections describe the application layer software components.

Please cite this article in press as: Sallabi, F., et al., Design and implementation of an electronic mobile poultry production documentation system. Comput. Electron. Agric. (2011), doi:10.1016/j.compag.2010.12.016

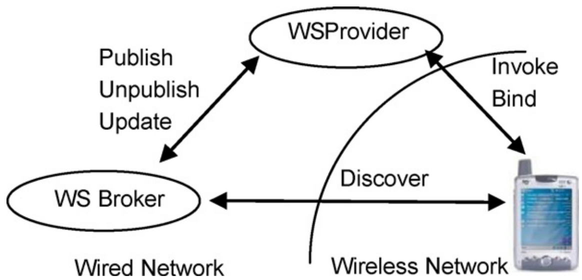

Fig. 7. Web service protocol.

3.4.1. Main application

The main application (MA) controls process flow and handle coordination between the other components. It is implemented as a J2ME Personal Profile application, which is suitable for most PDAs. The MA provides a graphical user interface to PDA users to communicate with the back-end system. Each PPTS activity is implemented as a J2ME Panel that includes the necessary components for the subject activity. All Panels contain Submit button which once clicked all data will be transferred to the back-end.

3.4.2. Web service client component

Web service (WS) is a software technology that enables application-to-application remote interactions over the internet. It provides standard protocols for communication between heterogeneous software applications regardless of their platforms. The WS model as depicted in Fig. 7, involves standards for describing, advertising, discovering and binding WS. These standards are Web Service Description Language (WSDL), the Universal Description, Discovery (UDDI), and the Simple Object Access Protocol (SOAP) (Curbera et al., 2002). In this work, the mobile user acts as a WS requestor. The WS client at the PDA device consumes the WS provided by the web service provider. The web service client interacts with the web service provider using web service protocols over a wireless network (for example WLAN, WiMax, UMTS, GSM/GPRS).

4. System evaluation

Two types of system evaluation were carried out in the UAE experimental farm. The first test focused on assessing the system from the engineering point of view via evaluating communication system performance, while the other one focused on evaluating the system from the operational point of view. The purpose of the field evaluation is to find out if the system is effective enough to document the needed data efficiently. The performance of the system was assessed according to the criteria set by Salman et al. (2003), which states that the system should be tested for its usefulness, simplicity, flexibility, quality of data, positive predictive value, acceptability, sensitivity, timeliness, and stability. The back-end and front-end applications were developed and implemented in-house. The back-end application was developed and implemented in Java using Netbeans integrated development environment (Netbeans, 2010). The front-end application was implemented in Java 2 Mobile Edition (J2ME) Personal Profile using IBM Websphere Studio Device Developer 5.7 (WSDD) (IBM, 2010). The back-end and database system were deployed on Sun application server at the same server machine. The following sub-sections describe the testing scenario and the testing results.

4.1. Testing scenario

The application was deployed and tested for four days in the experimental farm of the Faculty of Food and Agriculture, UAE University. The experimental farm contains five poultry houses with a total capacity of about 18,000 birds (layers and broilers). Field tests were carried out in the poultry house number 1 and house number 2 that contain about 3000 layers each. One house is equipped with a semi-automatic system and the other house is operated manually. The farm is covered with a Wi–Fi wireless network, which is used for connecting the PDA with the back-end server.

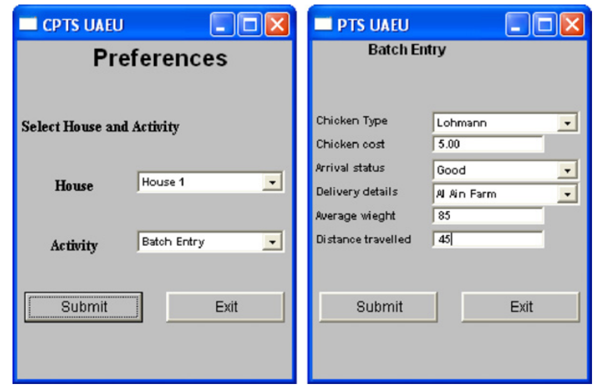

Fig. 8. Preferences and new batch entry interfaces.

The back-end and database system were deployed on the same server machine that is located in the Faculty of Information Technology, UAE University. The server machine is given a public IP address to enable connections from outside the Faculty and from GPRS network. The mobile front-end application is deployed on HP IPAQ 6340 that has built-in GSM/GPRS modem and Wi–Fi modem. The database is first populated with some testing data like poultry house information, employee information, feed information, cleaning information, etc. Subsequently, the PDA is connected to the back-end system from a remote area using GPRS and Wi–Fi connections, to test the performance of both wireless networks. One field supervisor was trained on using the application. The testing was conducted for four continuous days. The same events that were recorded by the PDA were recorded manually on papers.

After the field supervisor runs the application and logs into the system, he will be able to see information, listed in drop down menus, related to the poultry houses and types of activities under his supervision. He selects the house ID and the type of activity to be performed (feeding, cleaning, etc.), as shown in Fig. 8. Fig. 8 shows also the batch entry activity, the field supervisor completes the transaction and click on submit button to transfer the entered information together with the poultry batch number, where the timestamp of the batch is created, to the back-end system that stores them in the database. The application then goes back to the Preferences screen where the supervisor may perform another transaction. Fig. 9 depicts the poultry feed and house cleaning activities.

4.2. Results and analysis

This section provides the results and analysis of both operational and communication network evaluations based on the testing scenario described above.

4.2.1. Operational evaluation

Table 2 lists the transactions performed for the cleaning process. The cleaning took place in House1 and House2 (HSENO) by two workers Emp1 and Emp2 using the listed chemicals Quaternary ammonium (quat) and Povodone Iodine 10% (iodo) as specified by the attribute (DETID), and the commercial brand names (CHEMID). Each operation has a unique timestamp CLNTXNNO. Timing of each

Table 2
Cleaning process.

CLNTXNNO	EMPID	HSENO	DETID	CHEMID	CLNDATE	CLNTIME
20101128111030	Emp1	House2	quat	Pine	2010-11-28	11:10:30
20101128111427	Emp2	House2	quat	MPD	2010-11-28	11:14:27
20101128111652	Emp1	House1	quat	MC	2010-11-28	11:16:52
20101128123333	Emp1	House1	iodo	MC	2010-11-28	12:33:33
20101128123815	Emp2	House2	iodo	MC	2010-11-28	12:38:15
20101129113054	Emp2	House1	iodo	MC	2010-11-29	11:30:54
20101129113348	Emp2	House2	iodo	MC	2010-11-29	11:33:48
2010113064637	Emp1	House1	iodo	MC	2010-11-30	6:46:37
2010113064811	Emp1	House2	iodo	MC	2010-11-30	6:48:11
201011301155	Emp2	House2	iodo	MC	2010-11-30	11:05:5
2010113011450	Emp2	House1	iodo	MC	2010-11-30	11:04:50
201012172325	Emp1	House1	iodo	MC	2010-12-01	7:23:25
201012172336	Emp1	House2	iodo	MC	2010-12-01	7:23:36
2010121124318	Emp1	House1	iodo	MC	2010-12-01	12:43:18
2010121124329	Emp1	House2	iodo	MC	2010-12-01	12:43:29

Table 3
Cleaning chemicals information.

CHEMID	CHEMNAME	CHEMSUPL1	CHEMSUPLCONT1	CHEMSUPL2	CHEMSUPLCONT2
MC	Multi clean	Bio technology int.	Dubai	Bio technology int.	Biotechnology int.
MPD	Multi purpose detergent	Falcon chemicals	Dubai, 04-88014	Bio technology int.	Dubai, P.O. Box
Pine	Pine disinfectant	Clenco company			

task appears in the (CLNTIME) column, farm manager can follow the jobs done by each worker in his farm accordingly. Table 3 mentions the detailed information about the used chemicals such as commercial brand name, supplier and contact information. This important information, which is saved in the database, will be needed in case of emergency or Biosecurity alert.

After using the system for four days, the participated field supervisor was questioned on the operational performance of the system. Below are the responses of the operational performance:

- **Usefulness**: The collected information is useful for different stakeholders. A farm manager can follow from his desk whatever happens in each of the poultry houses he has in the farm. On the other hand, food control authorities can receive a copy of some of the collected data if needed.
- **Simplicity**: It took only one hour to train a supervisor with a high school level of education. According to his feedback, he was comfortable working with it. Language might be a problem while most of the available PDAs in the market may not support local languages.
- **Completeness of the collected data**: some of the important data should be collected automatically in a fixed sampling rate such as house temperature, humidity and Ammonia concentration, integrating the system to additional wireless sensor networks to complete the collected data should be considered in future research work.
- **Acceptability**: The willingness of users and organizations to participate in the surveillance system of the success of such a system. Technicians showed positive acceptance towards the system after short demonstration while they were concerned about the timely data entry as it may interrupts the flow of work. Organizational acceptance is driven with improving documentation quality, timing and cost. In some cases, managers may accept to use the system for managerial reasons only and refuse to share the collected information with local control authorities.
- **Timeliness**: documentation interval is not standardized in this system, while it collects most of the data when it happens except the regular Vet inspection which was not included in this test. System performance in this criterion depends on user efficiency. As shown in Table 2, user performance was not stable. He entered just two cleaning entries in 29-12-2010 where four events actually took place that day (two cleanings per house).
- **Stability**: the application was very stable during the four-day testing period, as noted by the field supervisor.

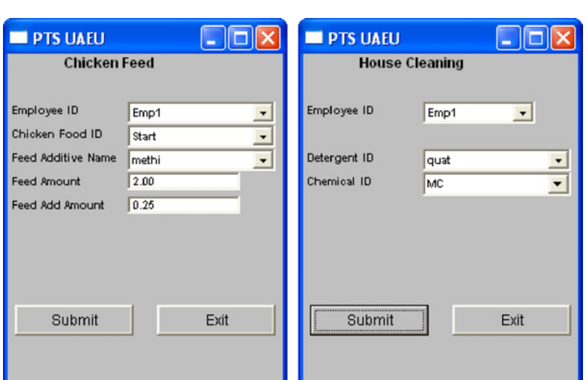

Fig. 9. Chicken feed activity and house cleaning activities.

4.2.2. Network evaluation

To evaluate the performance of the communication network and to monitor the flow of application data in the network, we used a packet sniffer called Wireshark (2010). The packet sniffer was configured and ran on the server machine to capture all traffic coming from the front-end device (PDA). Fig. 10 shows the transport control protocol (TCP) flow graph for one transaction (conversation) between the PDA and the server. This is for chicken house cleaning update transaction, the whole conversation including protocols overhead is show in Fig. 11. The transaction required 12 packets to commit and update the cleaning database table. The packets transmissions are depicted in Fig. 10, which shows the time taken for each packet, the type of packet, the application port number of the PDA (1131), the application port number of the server (8080) and the length of each data segment. According to the TCP mechanism, the client must first send a SYN (synchronization packet) to the server to start establishing a connection. The sever returns a SYN, ACK to acknowledge the receipt of SYN and it is ready for the con-

Time	Client(PDA)	Server
0	SYN (1131) ----------------->	(8080)
0	SYN, ACK (1131) <-----------------	(8080)
0.125	ACK (1131) ----------------->	(8080)
0.001	PSH, ACK - Len: 163 (1131) ----------------->	(8080)
0.209	ACK (1131) <-----------------	(8080)
0.201	PSH, ACK - Len: 478 (1131) ----------------->	(8080)
0.021	PSH, ACK - Len: 689 (1131) <-----------------	(8080)
0	FIN, ACK (1131) <-----------------	(8080)
0.182	ACK (1131) ----------------->	(8080)
0.001	ACK (1131) ----------------->	(8080)
0.204	FIN, ACK (1131) ----------------->	(8080)
0	ACK (1131) <-----------------	(8080)

Fig. 10. TCP flow graph.

```
POST /webservice/CPTSManagerService
HTTP/1.1
Host: 192.168.200.40
Connection: close
Content-Type: text/xml; charset=utf-8
Content-Length: 478
SOAPAction:

<soapenv:Envelope xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/">
        <soapenv:Body>
        <ns1:updateCleaningTrans xmlns:ns1="urn:CPTSManagerService/types">
        <Double_1 xmlns="">2.010112911305 4E13</Double_1>
        <String_2 xmlns="">Emp2</String_2>
        <String_3 xmlns="">House1</String_3>
        <String_4 xmlns="">iodo</String_4>
        <String_5 xmlns="">MC</String_5>
        <String_6 xmlns="">2010-11-29</String_6>
        <String_7 xmlns="">11:30:54</String_7>
        </ns1:updateCleaningTrans>
        </soapenv:Body>
        </soapenv:Envelope>
HTTP/1.1 200 OK
X-Powered-By: Servlet/2.5
Server: Sun Java System Application Server 9.1_02
Accept: text/xml, text/html, image/gif, image/jpeg, *; q=.2, */*; q=.2
Content-Type: text/xml;charset=utf-8
Date: Mon, 29 Nov 2010 07:21:34 GMT
Connection: close

<?xml version="1.0" encoding="UTF-8"?>
<env:Envelope xmlns:env="http://schemas.xmlsoap.org/soap/envelope/"
        xmlns:xsd="http://www.w3.org/2001/XMLSchema"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:enc="http://schemas.xmlsoap.org/soap/encoding/"
        xmlns:ns0="urn:CPTSManagerService/types">
        <env:Body>
        <ns0:updateCleaningTransResponse>
        <result>true</result>
        </ns0:updateCleaningTransResponse>
        </env:Body>
        </env:Envelope>
```

Fig. 11. Cleaning update conversation.

nection. Then the client finishes this three-handshake process by send an ACK, which indicates that the connection is established. The client then pushes (PSH) the data segment to the server. After each PSH, the server must send ACK to indicate the receipt of data. The process continues till all data segments are sent to the server after which the client closes the connections with the server and gets ready for another transaction. This process took on average around 0.9 s. The conversation, Fig. 11, contained overhead data that are necessary for the operation of the Hypertext Transport Protocol (HTTP) and the Web Services protocol that are used to connect the back-end with the front-end. The actual data (payload) that is needed to update the database is shown in bold.

The values of different network performance measures of the chicken house update transaction are listed in Table 4. According to these observations, we state that the HTTP and Web Services protocols incur considerable overhead on the transferred transaction payload. Throughput and time delay are very adequate for such application. The application does not require strict real-time transmission. The only concern is the amount of overhead presented by the HTTP and Web Services protocols, which hindered us from using the GSM/GPRS wireless network. Therefore, our recommendation in such applications is to have wireless LAN (Wi–Fi) installed in the farm to facilitate access to the Internet with high speed and low transmission cost.

Table 4
Conversation summary statistics.

Parameter	Value
Number of packets	12
Total time	0.944 ms
Avg. packets/s	12.707
Avg. packet size	168.167 bytes
Total bytes	2018
Conversation bytes	1330
Avg. bytes/s	2136.895
Avg. MBit/s	0.017

5. Conclusion

A poultry production documentation system is developed in this research work to collect, store, maintain and process data. The system consists of four sub-systems, the front-end system, the data transfer system, the back-end system, and the application management system. Field tests were conducted the UAE university experimental farm. Extensive testing and debugging were run on the developed system to monitor its operational and communication network performances. The system provides an easy and accurate way of documenting the data related to daily activities of the poultry houses. The entered data is transferred in real-time to the back-end server that saves them in a database system. The archived data is available to the manager or control authority specialist for making appropriate decisions at point of need during crises or a major disease outbreak. The system was evaluated in the field on two poultry houses in the experimental farm. It was noted during the evaluation of the system that the success and the accuracy of the documentation mainly depend on user efficiency and dedication. As a future plan, we intend to deploy wireless sensors in the poultry houses to collect data like temperature, humidity, ammonia concentration, etc. and send them to the back-end server in standardized sampling rate.

Acknowledgements

This work was financially supported by the Research Affairs at the UAE University under a contract no. 02-01-6-11/07. Thanks should be extended to Faculty of Food and Agriculture staff for their help in the evaluation stage.

References

Barbash, A., 2001. Mobile computing for ambulatory health care: points of convergence. Journal of Ambulatory Care Management 24 (4), 54–60.

Steinfield, C., 2004. The development of location based services in mobile commerce'. In: Preissl, B., Bouwman, H., Steinfield, C. (Eds.), Elife After the dot.com Bust, 2004. Springer, Berlin, pp. 177–197.

Mei, C., 2005. Location-based-service roaming based on web services. Advanced Information Networking and Applications 2 (28–30 March), 277–280.

Curbera, F., Duftler, M., Khalaf, R., Nagy, W., Mukhi, N., Weerawarana, S., 2002. Unraveling the web services web: an introduction to SOAP, WSDL, and UDDI. IEEE Internet Computing 6 (March/April (2)), 86–93.

FAO, 2007. Technical meeting on highly pathogenic Avian Influenza and human H5N1 infection, 27-29 June 2007, Rome.

Gledhill, J., 2002. Tracing the line: using information technology to reduce costs while meeting industry requirements. Food Processing (March Issue), 48–57.

Golan, E., Krissof, B., Kuchler, F., Calvin, L., Nelson, K., Price, G., 2004. Traceability in the U.S. Food Supply: Economic Theory and Industry Studies. USDA Agricultural Economic Report Number, 830.

International Organization for Standardization, 1994. ISO standard 8402:1994, http://www.iso.org.

Kalakota, R., Stallaert, J., Whinston, A., 1996. Mobile agents and mobile workers, 29th Annual Hawaii International Conference on System Sciences, pp. 354–365.

Opara, L., December 2002. Engineering and Technological Outlook on Traceability of Agricultural Production and Products. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development IV.

Peres, B., Loiseau, N., Montet, G., March 2007. Review of the current methods of analytical traceability allowing determination of the origin of foodstuffs. Food Control 18 (3), 228–235.

Regulation No (EC), 2002, 178/2002 of European Parliament 28/09/2002 for food safety issues, Formal EU Newsletter 1.2.2002 L 31/1.

Smith, G., Tatum, J., Belk, K., Scanga, J., Grandin, T., Sofos, J., 2005. Traceability from a US perspective. Meat Science 71, 174–193.

Sparks, 2002. Food Traceability: Standards and Systems for Tracing and Tracking Food and Agri-products. Sparks Companies, Inc., Memphis, TN.

Traceability Manual Poultry Industry, 2005. Version III Sponsored by APA (Asociacion De Productores, Avicolas De Chile A. G.), Chilean Pork & Poultry, and GS1.

Turisco, F., 2000. Mobile computing is next technology frontier for healthcare providers. Health Care Financial Management 54 (11), 78–80.

York, J., Pendharkar, P., 2004. Human-computer interaction issues for mobile computing in a variable work context. International Journal of Human–Computer Studies 60, 771–797.

Netbeans, 2010. http://netbeans.org/ (accessed December 2010).

IBM, 2010. WebSphere, http://www.ibm.com/developerworks/websphere/ (accessed December 2010).

Salman, M.D., Stark, K.D., Zepeda, C., 2003. Quality assurance applied to animal disease surveillance systems. Revue scientifique et technique (International Office of Epizootics) 22 (2), 689–696.

Wireshark, 2010. http://www.wireshark.org/ (accessed December 2010).

Please cite this article in press as: Sallabi, F., et al., Design and implementation of an electronic mobile poultry production documentation system. Comput. Electron. Agric. (2011), doi:10.1016/j.compag.2010.12.016