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Cover Page Footnote

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Research Paper

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ABSTRACT

In the recent past, developing countries have experienced major technological advancements including high mobile phone penetration. With the implementation of innovative technological solutions (e.g. mobile-based systems in key economic activities such as agriculture), there is need to develop models that software developers and researchers can use to design solutions. This paper aims to study the implementation of mobile systems in agriculture and presents a model for designing such applications. This study shows that models exist for general mobile applications design and development, although none specifically suits mobile agriculture applications. A model for designing and implementing M-Agriculture applications is presented. The model concentrates specifically on dairy farming and shows how various stakeholders in this sector can share a mobile platform that meets their various needs.

Keywords

Mobile Applications, M-Agriculture, Dairy Farming, Java ME, Short Messaging Service (SMS)

INTRODUCTION

Agricultural development in developing countries is critical because it has particular and direct significance in attaining the first Millennium Development Goal (MDG), which is to eradicate extreme poverty and hunger, and the seventh MDG, which is to ensure environmental sustainability (Gitau, Kimenju, Kibaara, Nyoro, Bruntrup and Zimmerman, 2008). Even though agriculture plays a key role in the economy of most African countries, it faces major challenges including poor agricultural practices, inefficiencies in information delivery, reconciliation of records between farmers and traders, and lack of information on best practices to farmers. Agriculture is a key economic activity in Kenya, as is the case in most African countries. Over 80 percent of the Kenyan population live in the rural areas and derive their livelihoods, directly or indirectly, from agriculture (Alila and Atieno, 2006). Among the most active aspects is the dairy sector. According to the Food and Agriculture Organization (FAO), Kenya produced slightly higher than 1 million metric tons of milk in 2008 (FAO, 2009).

Despite agriculture being the backbone economic activity in a number of African countries, it faces numerous challenges that hinder the exploitation of its full potential to the economic contribution. Some challenges that farmers encounter include lack of an effective way to collect farm produce data, record farm input expenses, track medical expenditure on their livestock as well as expenditure on farm chemicals and receive information from other stakeholders (e.g. agriculture advisers). Some of the problems outlined in the previous statement can be tackled using available technology among farmers, such as mobile phones.

In recent years, mobile technology has been widely adopted in most parts of the world. Currently, developing countries are also recording high mobile penetration rates. Figure 1 shows the mobile penetration in Kenya between May 2009 and March 2010 as recorded by the Communications Commission of Kenya (CCK , 2010).

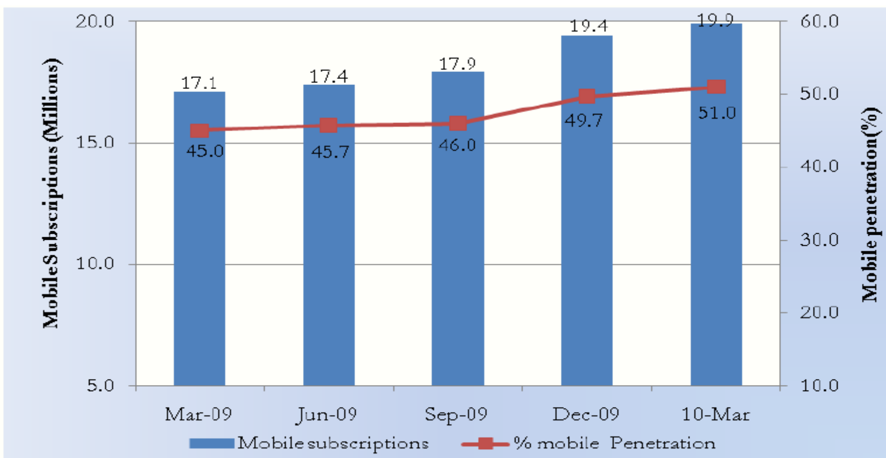

Figure 1. Mobile Penetration in Kenya between May 2009 and March 2010 (CCK, 2010)

This research paper aims to study how solutions can be created using mobile technology that will help in addressing some of the problems faced by farmers. This paper also proposes a design model for such applications that can be adopted by software developers.

Section one of the paper gives an introduction. Section two of the paper highlights existing implementations of Information and Communication Technology (ICT) and mobile technology in agriculture, while Section three elaborates on an existing mobile application model. In Section four, the methodology used to carry out the research is elaborated on, followed by a discussion of the research observations in Section five. A model to design and develop m-agriculture applications is then proposed in Section six, followed by a final section on the application of the model in dairy farming. Concluding remarks and a few acknowledgements end the paper.

ICT AND MOBILE TECHNOLOGY IN AGRICULTURE

M-Agriculture

M-Agriculture refers to the provision of agricultural services and information, using mobile devices such as cell phones, Personal Digital Assistants (PDAs), tablets and other handheld communication or computing devices. Mobile devices have been used to perform weather monitoring from remote areas. Crossbow Technology (2004) highlighted on a solar-powered wireless sensor network, which was providing weather information in fields. A remote application server relayed data from sensor network to local users via Wireless Local Area Network (WLAN) and to remote users via cellular network and the Internet.

In addition, mobile technology has been used for geo-referenced environmental monitoring. Vivoni and Camilli (2003) developed a wireless prototype system to acquire, store, display and transmit real-time geo-referenced environmental data between multiple field teams and remote locations. Field teams with hand-held data collection units communicated to each other or with a field station server through a WLAN. Also, a dual-frequency mobile phone was used to send data. Motorola Labs have also developed a system that can be used to sense agricultural, environmental and process parameters (Perkins, Correal, and O'Dea, 2002).

In addition, Lee, Burks and Schueller (2002) came up with a silage yield mapping system that included a moisture sensor, a Global Positioning System (GPS) and a Bluetooth wireless communication module. Besides spatial data collection, mobile technology has been used in precision irrigation. Using similar technology, Cugati, Miller and Schueller (2003) developed an automated fertilizer application for tree crops. The system had a GPS input module and real-time sensor data acquisition. It also had a decision module for estimating the optimal amount and spread of fertilizer and an output module to regulate the rate of fertilizer application. In this system, the various modules communicated via Bluetooth network.

Liu and Ying (2003) introduced a greenhouse monitoring system using Bluetooth technology. The system was used to collect environmental data from a sensor network in a greenhouse and transmit it to a central control system. Butler, Corke, Peterson and Rus (2004) developed a moving virtual fence algorithm for herding cows, where each animal in the herd is given a smart collar consisting of a GPS, a PDA, a radio unit and a sound amplifier. The location of the animal was determined using the GPS and was verified by measuring the proximity of the cow relative to the fence boundary. If a cow would approach the fence, it would be presented with a sound stimulus, driving the cow away from the fence.

Short Message Service (SMS) is also a widely used application of mobile technology in agriculture. Farmers can interact with experts and systems via SMS (e.g. to receive weather updates and information on best practices on various sectors of agriculture). In Rwanda, the eSoko project was launched in 2009 to allow farmers to access prices of different agricultural commodities via SMS (Hellstrom, n.d.). An SMS service that brings information on demand and supply to farmers and extension workers has been developed in Uganda (Hellstrom, n.d.). In Ghana, farmers in Tamale are able to send a text message to learn corn and tomato prices in Accra, which is more than 1,000 kilometers away (Aker & Mbiti, n.d.).

Besides agriculture, ICT and specifically mobile technology has been widely used in other sectors of development especially in developing countries. In such places, mobile technology has been majorly viewed as a reaction to different challenges and different limitations usually infrastructure, poverty, distance and sparsity (Deb, 2011). Moreover, other limitations exist such as cost, which provides a barrier towards the diffusion and adoption of new technology in the developing world (Rogers, Liddle and Han, 2007). In education, M-learning has become popular especially in developing countries. Projects such as eCandle (Rogers et. al, 2007) have been launched to enhance learning in the developing world using technologies such as mobile devices. In addition, mobile technology has been implemented within the health sector in developing countries. In Malawi, those affected by HIV and AIDS can receive text messages daily, reminding them to take their medicines on schedule (Aker and Mbiti, n.d.). Another area of implementation of mobile technology in development is health systems. The emerging development of mobile health systems in the last decade has been made possible due to the recent advances in wireless and network technologies and ubiquitous computing systems (Kyriacou, Pattichis, Pattichis, Panayides and Pitsillides, 2006).

Further, Aker and Mbiti (n.d.) identified five potential mechanisms through which mobile phones can be used for economic benefits to consumers and producers in Sub-Saharan Africa. These mechanisms include the use of mobile phones to improve access to and use of information, thereby reducing search costs while improving coordination among agents and increasing market efficiency; an improvement of firms' productive efficiency due to the increase communication by allowing the firms to better manage their supply chains; the creation of new jobs to address demand for mobile-related services, thereby providing income-generating opportunities in rural and urban areas; facilitating communication among social networks in response to shocks, thereby reducing households' exposure to risk; and finally the usage of mobile phone-based applications and development projects to facilitate the delivery of financial, agricultural, health and educational services.

Jensen (2007) notes that the introduction of mobile technology in fishing activities in Kerala, India, has led to the reduction of fish prices dispersion and a decline in waste. Jensen (2007) noted that the fishermen's profits rose by eight percent, the consumer surplus increased by six percent and the consumer prices declined by six percent. Closely related to the findings by Jensen (2007), the findings of Aker (2010) noted that the introduction of mobile phones reduced the dispersion of grain prices by ten percent. Muto and Yamano (2009) also found out that mobile phone coverage was associated with a ten percent increase in farmer's profitability in the bananas market.

In addition, mobile phone coverage has been associated with developments in the job market. In Kenya, the CCK (2008) suggested that the rise of formal employment in the private and telecommunication sector from by 130 percent between 2003 and 2007 could be associated with mobile phone penetration.

Moreover, mobile phones have been used in disaster management and rescue missions. The popular implementation of this is Ushahidi, a crowdsourcing system developed in Kenya. The platform has been used in activities such as rescue missions and monitoring election violence worldwide. The information is then translated into a graphical map that can be viewed from anywhere over the Internet.

In agreement with Aker and Mbiti (n.d.), it is clear that the introduction of mobile phones in agriculture and other trade sectors has increased the traders' welfare, by increasing their sales prices, as they were able to take advantage of the spatial arbitrage opportunities.

M-Agriculture in Kenya

The Sygenta Foundation established Kilimo Salama (Swahili for safe agriculture), a program aimed to support smallholder farmers in dealing with weather risks by developing and piloting agricultural micro insurance products (Webb, 2010). This project was done in partnership between Sygenta Foundation for Sustainable Agriculture, UAP Insurance and Safaricom Ltd.

Murray (2010) reported on the impact of mobile technology on farmers through the Kenya Farmers Helpline. From the call center, agricultural experts talk to farmers from across the country, addressing various issues regarding agriculture. Using a mobile phone, pastoralists and cattle traders in Kenya can access market trends from the National Livestock Marketing Information System (NLMIS) run by the ministry of livestock (Mwangi, 2010).

Why a Mobile Phone over PC?

Mobile computing devices have advantages over the use of a Personal Computer (PC), especially in the developing world. The cost of acquisition of a typical mobile phone is lower than that of a PC as are the recurring cost. It is also easy to learn how to use a mobile phone, even for computer-illiterate people. This fact makes a mobile device the most appropriate medium to introduce technology to users who are not computer savvy. Another advantage of mobile phones is the high penetration of mobile phones in the developing world. Compared to the number of PCs, mobile phones have a relatively higher infiltration level. For example, Kenya recorded a mobile phone penetration of 51% in the first quarter of 2010 (Mwaura, 2010). Moreover, mobile devices provide an environment for real-time interaction either between a number of systems, people or mobile devices. This interaction ensures a more effective and timely way of delivery and acquisition of information, a key requirement in efficient M-Agriculture applications.

However, mobile devices have a number of challenges. To start with, despite the high mobile phone penetration in the developing and developed world, there is still a large population that cannot afford a mobile phone or any other mobile device that can be used for M-Agriculture. Besides the cost barrier of the penetration of mobile technology in the developing world, other barriers (e.g. social factors) are still common in some markets. Also, in most developing countries, poor network is prevalent especially in the rural areas. Most mobile operators concentrate on the densely populated urban areas before deploying good quality network coverage in the rural areas. Usability issues may also be a challenge to most users. Typically, mobile phones are characterized by small screens, small keypad areas and limited input and output characters (e.g. per SMS message). These constraints limit the usage of mobile phones in mobile agriculture applications, since the systems have to be developed in consideration to the above-mentioned constraints.

AN EXISTING MOBILE APPLICATION MODEL

Various models and frameworks have been developed in the area of mobile applications. Examples include a framework for the emerging mobile commerce applications (Varshney and Vetter, 2001), the mobile agent platform (Lee, 2010), the Mobile-D (Abrahamsson, 2005) and the Mobile Applications Development Framework (Unhelkar and Murugesan, 2010).

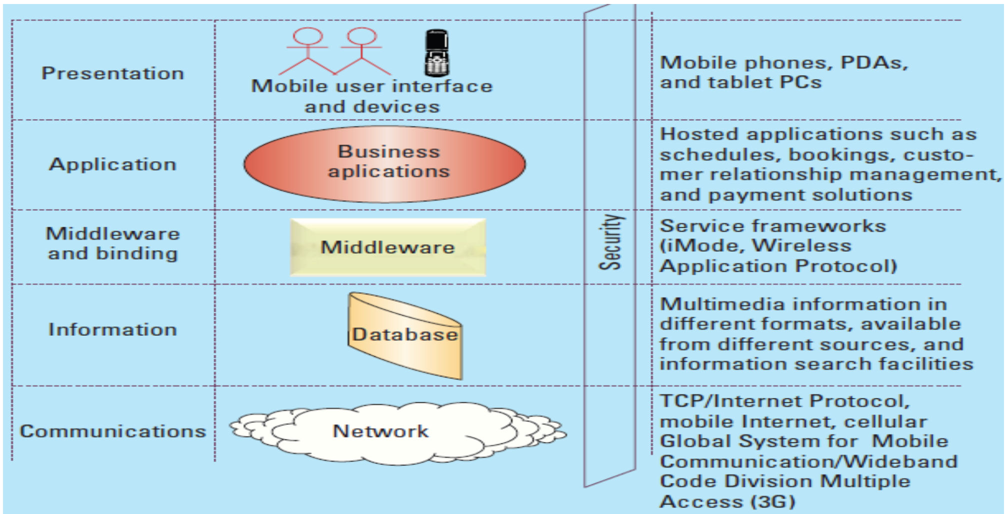

Figure 2. The enterprise mobile applications development framework (Unhelkar & Murugesan, 2010)

Unhelkar and Murugesan (2010) developed a framework to be used for enterprise mobile applications. This framework was meant to provide a systematic and comprehensive solution to mobile applications development and maintenance as shown in Figure 2. According to Unhelkar and Murugesan (2010), Mobile Applications Development Framework (MADF) brings together elements of software architecture and design and the required supporting communication infrastructure (network and protocols) and different types of information accessed across multiple sources. It considers the usage of communication infrastructure, e.g. Transmission Control Protocol (TCP) and Internet Protocol (IP). Depending on the range of communication, the model also suggests the usage of mobile telecommunication standards (2G, 2.5G, 3G or 4G), Bluetooth and also Wireless Voice Over Internet Protocol (VoIP) technologies. The framework brings out important aspects that should be considered in developing mobile applications that can handle complex business logic using a middle tier, transfer data back and forth over the mobile network and also facilitate data storage to a database. It also allows multiple-access to the application's backend either from a single mobile application or a suite of applications. MADF presents a good reference point towards implementing mobile applications and gives clear pointers on the basic components of a mobile applications development model (Unhelkar and Murugesan, 2010).

Just like MADF, other existing models are not specific to M-agriculture applications. These models, therefore, do not demonstrate how the various stakeholders can interact on a single platform or the structure of the system to allow for seamless communication and information sharing among the users involved.

METHODOLOGY

The development of mobile solutions in the agriculture sector has not been done widely and is still taking shape. There was a strong case to use case study approach since it supported the objective of implementations of mobile systems in agriculture and gather information from a specific case that will guide in developing a model to be used in designing mobile systems in agriculture. Yin (2003) states that in a case study research, there is no universally acceptable number of cases and a case study could be based on a single case or many cases. Moreover, the validity of case studies can be enhanced by the strategic selection of cases rather than their number (De Vaus, 2001). On the other hand, case studies are often viewed as particularly appropriate where research and theory are at their early, formative states and lack a strong theoretical base (Benbasat, Goldstein and Mead, 1987). Yin (1989) goes on to indicate that case study research gives the opportunity to study a phenomenon within its real life context.

In Kenya, dairy farming is one of the most active sectors of agriculture. According to FAO (2009), dairy farming has the highest total income than any other agricultural activity in Kenya. With a high mobile penetration in Kenya, most dairy farmers have mobile phones that they use mostly for communication purposes. These two factors make dairy farming a good area to study when it comes to the implementation of mobile agriculture systems.

While gathering data in a case study approach, Yin (1984) suggests using at least six sources of data such as documentation, archival records, interviews, direct observations, participant-observation and physical artifacts. Other researchers such as Shanks (2002) also recommend that case studies may combine several data collection techniques such as interviews, observation, questionnaires, and document and text analysis. However, Cavaye (1996) acknowledges that data collection in case study research can be tedious and time consuming and therefore careful planning is crucial. To accomplish the data collection required in this research, three methods were used: documentary exploration, observation and field interviews. These methods were chosen because of their high chance in providing accurate information, which will be helpful in understanding the scenario on the ground, as well as to provide information that is useful in coming up with an effective M-Agriculture model.

The questionnaire and field interviews were aimed at collecting information on mobile phone services within Kenya, mobile devices among the target stakeholders, the usage and experience with general mobile applications and the usage and experience with M-agriculture applications. It was necessary to gather data that would inform the research on the various aspects of the used theoretical foundation. Information on mobile devices among stakeholders was necessary in establishing what kind of user interfaces should be developed for various categories of users. Other device capabilities gave data that could be used to decide what kind of middle tier business applications can be developed for different M-agriculture applications. The kind of information format that could be handled by the mobile devices among the stakeholders within agriculture was also established. Data on communication aspects were also gathered including the reliability of Global System for Mobile Communications (GSM) networks such as 2G or 3G, which highly determine the speed of network access between a mobile application and its corresponding business application. The questionnaire consisted of 15 questions, which were a combination of open-ended questions and close-ended questions. They were given to farmers while interviews were administered to veterinary officers, the agro-veterinary dealers and the agricultural officers.

Purposive sampling was conducted to select participants for the study. Information was collected from various stakeholders in the dairy industry, including 150 farmers, 10 veterinary officers, 2 agricultural officers, 2 agro-veterinary dealers and 4 milk processors. Information was also collected from government bodies that were necessary to give information on agriculture and mobile technology, such as the Kenya Dairy Board, Communications Commission of Kenya (CCK) and Ministry of Agriculture.

The coding scheme in the questionnaire and survey facilitated a smooth process during the analysis. The answers to open-ended questions were categorized into groups and coded in the same way as close-ended questions. The data were entered into the Statistical Package for Social Sciences (SPSS) computer software for analysis. Once the results were keyed in, data cleaning followed to identify inconsistencies.

Descriptive analysis was done, where the distribution of responses to each variable were described. This was followed by cross-tabulation analysis with the aim of identifying associations among various variables.

RESEARCH OBSERVATIONS

Among the interviewed people, mobile phone penetration in farmers was 96% with only 4% without mobile phones. These percentages indicate a very high opportunity for the usage of mobile agriculture applications among farmers. The other participants (namely veterinary doctors and agro-veterinary dealers) owned mobile phones, thus representing 100% penetration. This statistic shows that all the stakeholders of dairy farming have mobile devices with them and could therefore be included in a mobile agriculture system targeting dairy farming.

However, there was a difference in the type and model of devices owned by the studied group of people. The Nokia mobile phones had the highest percentage (56.3 %) of mobile phone models owned by the respondents, meaning that more than half of the respondents owned Nokia mobile phones. Motorola mobile phones were the second most popular among the respondents, garnering 17% of the total number of respondents. Samsung mobile phones closely followed Motorola with 15% of the population owning various models of the Samsung mobile phones. Also, 5.5% of the respondents owned various models of Ericsson mobile phones, while 2.3% of the respondents own the ZTE mobile phone, locally known as kabambe. The LG mobile phones as well as Mi mobile phones also had the same number of ownership as ZTE, with each being owned by 2.3% of the respondents. The Dorado mobile phone was owned by 4.7% of the respondents, while the iPhone and Bird mobile phones were owned by the lowest number of respondents. They both had only 0.8% popularity among the respondents. The collected data show that if the mobile agriculture applications could be optimized for the Nokia mobile phones, a larger number of people could benefit than if it were optimized for another mobile manufacturer's devices. Moreover, Motorola and Samsung could also be considered as a platform to target for a considerable group of farmers at 32%.

The reliability of the mobile network is a critical success factor in the usage of mobile agriculture applications. Figure 3 shows the general failure rate of the various mobile networks that service the respondents. Figure 3 shows that 61% of the respondents' network hardly fails, while 17% fails once per month. Eight percent of the respondents reported that their network fails once per week or once per two weeks. Only six percent of the respondents said that their network fail daily. The relatively low failure rate shows that the majority of the service providers have put measures in place to facilitate the deployment of mobile applications, which run on their subscribers' mobile phones, allowing them to send and receive information.

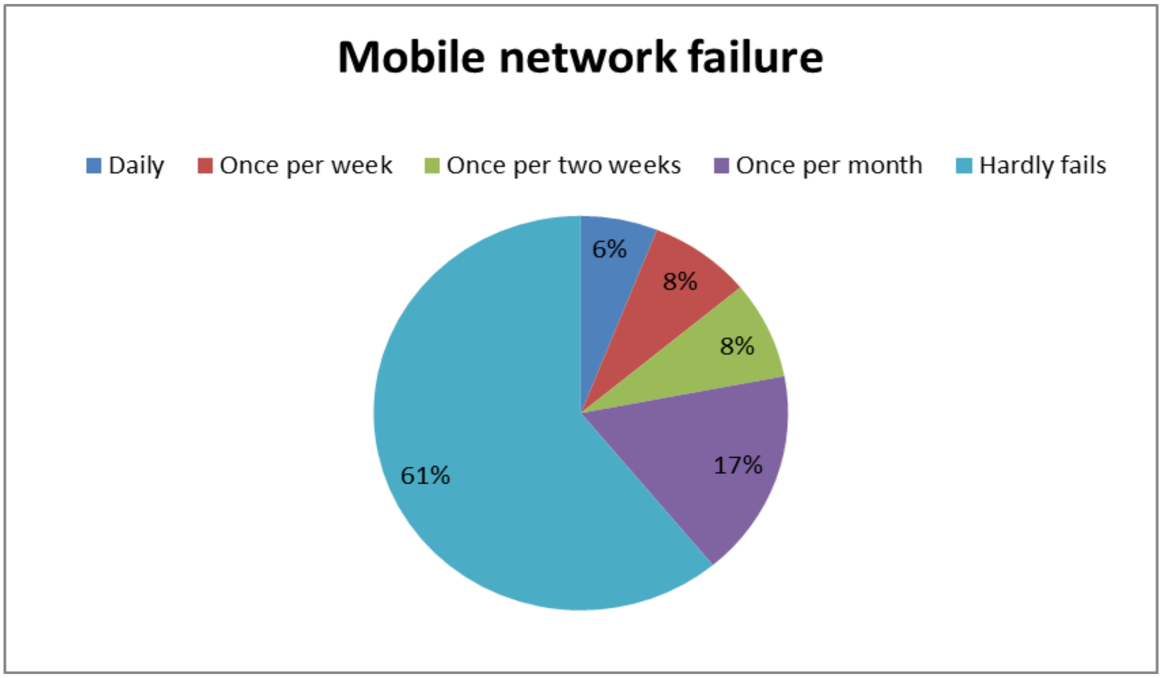

Figure 3. Mobile network failure rate

A total of 54% of the mobile phones owned by the respondents had data capability (Internet access), while 46% did not have data capability. The high percentage of data enabled phones indicates that developers of mobile agriculture systems can develop business applications and middle-ware services that communicate with the mobile applications. This high percentage also means that there can be reliance on remote information storage, e.g. in a relational database. Information can then be sent or retrieved from the remote storage via the mobile-based system. However, 46% of the respondents would require mobile agriculture applications that use another means of communication other than data (e.g. SMS), since all the mobile handsets owned by respondents could support SMS. Existing models such as MADF described earlier do not provide a clear way within the model on how to separate the applications that are installable on the mobile device from the ones that require other communication media such as SMS. It is important that the mobile applications developer can trace the communication of a mobile system from the device to the business application based on the supported technology at the device level.

In addition, it was also discovered that 51% of the respondents had Java enabled mobile phones while 49% did not. This finding meant that slightly over half of the population would benefit from Java Micro Edition (Java ME) mobile agriculture applications, while the rest would not be able to operate such an application on their mobile phones. Since majority of the mobile devices would allow the installation of an application such as Java, it is important that a model provides the provision to implement application servers that connect with a database server while providing the possible implementation technologies at the server side depending on the mobile platform. The communication to the application server through such applications should be clearly demarcated from the communication from the mobile device using other means such as SMS. The latter would require the services of an SMS Server to be provided within the model. The survey showed that a majority of farmers belong to groups that have information systems that keep their records. Consequently, there was the need to provide a way to integrate the existing information systems with the mobile agriculture system to allow information sharing and reduce data redundancy.

It was observed from documents review that government bodies and non-governmental bodies on agriculture matters are keen in keeping statistics on the ground concerning agriculture. However, it is an expensive exercise for them, and it heavily relies on exercises such as a National Census for large populations or data collection exercises conducted for a small population. It is, therefore, important for an M-agriculture model to make a provision for government and non-governmental bodies to retrieve information from a centralized location that may help in decision-making and national planning. Moreover, the inclusion of other wireless devices besides mobile phones such as laptops needed to be clearly shown within a model.

The adoption and usage of a mobile agriculture application would be more successful if the target population has experience in using other mobile applications (e.g. games, social network applications, mobile banking and money transfer applications) and other information oriented information (e.g. weather, dating or news). According to the study, 56.9% of the respondents who owned mobile phones had used other mobile applications (e.g. a game, informational, social network application or money transfer application). Some of the services on these applications are crucial to the stakeholders, such as mobile money transfer. Therefore, a model should allow the inclusion of services such as mobile banking and mobile money transfer services to allow payments among the involved stakeholders in the ecosystem of a mobile agriculture system.

The respondents reported to have used their mobile phones for the following agriculture related activities: ordering animal feeds, getting market prices for the farm produce, making mobile payments to workers and agro-veterinary dealers, inquiries on veterinary services, getting information on animal breeds, getting information on the gestation of a cow, looking for available farm workers, getting information on farm machinery, finding market for the farm produce and getting advice from various sources, such as agricultural officers, veterinary officers and the Internet. In addition, the respondents gave suggestions on how they would like to use their mobile phones to enhance their farming experience. These suggestions included selling and marketing their produce via the mobile phone, checking the market prices for various products, accessing information on best practices in farming, requesting various veterinary services, making payments to workers, agro-veterinary dealers and other stakeholders via the mobile phone, communicating with farm workers via the mobile phone, ordering for farm inputs (e.g. fertilizers) via the mobile phone, obtaining weather conditions via the mobile phone, inquiring about transport services, forming a mobile-based farmers community that allows sharing of information, accessing mobile based record keeping services, getting information on disease outbreaks and control via the mobile phone and getting information on farm machinery via the mobile phone.

THE PROPOSED M-AGRICULTURE MODEL

The available network infrastructure, type of devices and user experience are among the things that determine the most favorable components of the mobile agriculture architecture. The most appropriate mobile device should be selected based on the information that is being transmitted to and from the mobile device. For example, multi-media files, such as images and video, require mobile devices to have more memory and processing speed than mobile phones that are designed to handle text only.

The components of the mobile agriculture architecture must include choices that will make it easy to integrate with other platforms (web, mobile and desktop) on agriculture. Also, the available bandwidth is a determining factor that affects the type of data that is transmitted within the network. For example, to transfer a video file, more bandwidth is required than for text, which requires far less data to send or receive. Consequently, the business and technical requirements of the application were to be considered and the necessary adjustments done to accommodate any specific needs of the whole agriculture mobile architecture. Following the discussion, Figure 4 shows the proposed M-Agriculture model.

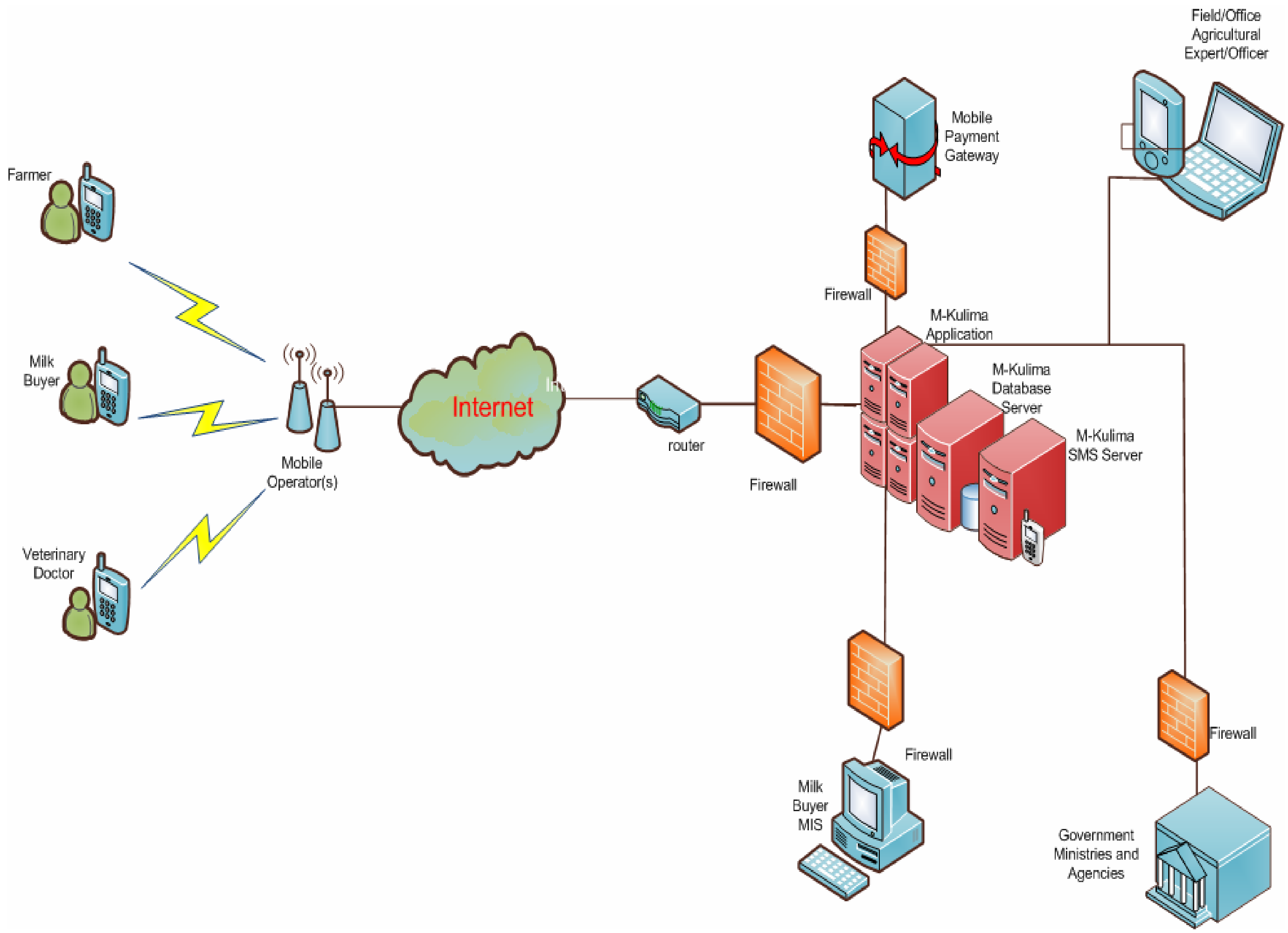

Figure 4. *M-Kulima* model for designing and implementing mobile applications in dairy farming

The proposed model has been given the name M-Kulima, from the Swahili word Kulima, which means the practice of farming. As shown in Figure 4, the farmer, the milk buyer and veterinary doctor access M-Agriculture services from their mobile phone and communicate with the application server via the Internet, using either data or SMS communication. The mobile operator is responsible to route the communication between the mobile equipment (e.g. mobile phone) with the application server.

The communication protocol between the mobile equipment and the application server via the mobile operator's network is Hypertext Transfer Protocol (HTTP). The data services provided by the mobile operator, e.g. Enhanced Data Rates for GSM Evolution (EDGE) and Universal Mobile Telecommunications System (UMTS), allows this action to take place via a mobile phone's General Packet Radio Service (GPRS) capability. Secure network connections are established between the application server and other entities accessing on the platform, e.g. the milk buyer's Management Information System (MIS), the agriculture expert and the payment gateway. The integration of a payment gateway allows the farmer and the milk buyer have a payment platform in the architecture. Using an existing payment gateway, the farmer and the milk buyer can carry out transactions (e.g. payments for milk delivered and purchase other services). Moreover, the veterinary doctor and the farmer also get a platform where they can carry out transactions without the need to access a different mode of payment.

In addition, other entities within the platform can carry out financial transactions among themselves. This ability gives the leeway of expanding the architecture to include financial organizations (e.g. banks) and agriculture service providers, such as animal feed manufacturers. Any communication between the application server and an external system has to be filtered by a firewall to ensure the security and integrity of information. The secure connection established should be end-end and should not allow any unauthorized access by individuals or network nodes that are outside the established network. An encryption process for each of the outgoing information needs to be carried out to reduce the possibility of theft or malicious alteration of information.

Application of Proposed M-Agriculture Model in Dairy Farming

The proposed mobile agriculture architecture was designed to accommodate the stakeholders in the dairy industry, whose needs were identified in this research. The model offers an interaction platform between the farmer and other key stakeholders of the dairy industry, e.g. the milk processor, the veterinary doctor, the agricultural officer and the government. Each of the involved entities in the architecture needs to use a mobile equipment to communicate with the core system via a mobile telecommunication network.

a) The Farmer

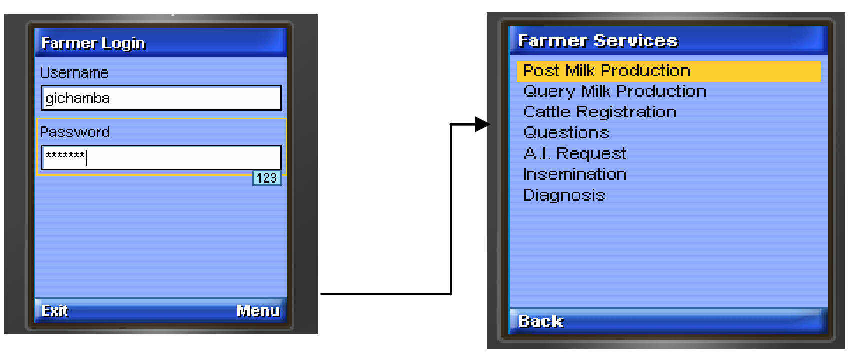

Figure 5. Farmer application features

From the mobile phone, the farmer is able to query for their milk sales records for a period of time via SMS. The farmer is also capable of requesting services, such as artificial insemination from a veterinary doctor, and record milk production for a particular day. The farmer can also register cattle at this stage. In the case where farmers have queries to the agricultural officer, the milk buyer or the veterinary doctor, they may send it from the mobile phone.

b) Milk Buyer

The milk buyer could either be a milk processor or a co-operative society. Using a mobile phone, the milk buyer is able to record the amount of milk the farmer has brought at the collection center on a particular day and at a specific time. The milk buyer is also able to retrieve the farmer's information, e.g. their profile, amount of milk brought to the buyer within a given period of time, as well as answers any questions the farmer might have. The buyer is also required to post the current price of milk for the farmers to view.

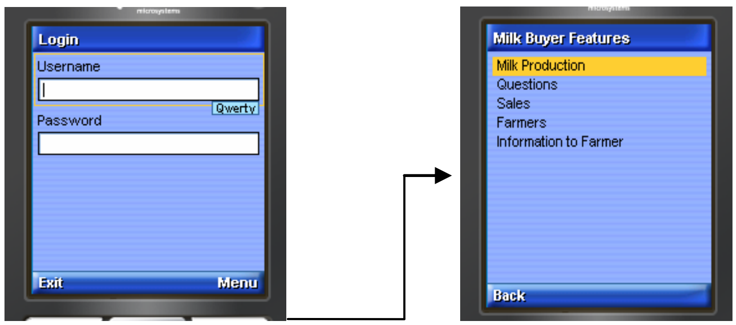

Figure 6. Milk buyer application features

c) Veterinary doctor

From a mobile phone, the veterinary doctor is able to retrieve artificial insemination requests, locate the farmer and establish the breed wanted. After visiting the farmer to attend to a cow, the veterinary doctor uses the mobile application installed on a mobile phone to record the visit, details of the cow that was inseminated and the particular bull name and bull number that was used to give the insemination service to the cow. Moreover, the veterinary doctor can keep records concerning cattle de-worming, spraying of pesticides or dipping. In case a cow has been attended to for any medical reasons, the diagnosis is recorded by the veterinary officer using a mobile phone.

d) Agricultural officer

The agricultural officer is able to provide information on various best practices that are applied in dairy farming over a period of time. The best practice could be targeting various animals (e.g. dairy cattle), and the officer can also post advice on how best the animals can be bred.

Figure 7. Agricultural officer application features

e) Government Agencies

A government agency such as the Ministry of Livestock and Fisheries can use the application in order to know the number of cows in a certain area. This information would help the government in its planning structures. The government would also be able to respond to queries that have been posted by farmers, as well as give farmers the best practices that they should follow in order achieve a maximum yield in milk production. In the event that the government wished to inform the farmers about a disease outbreak or quarantine, the model could be used to do a direct communication to the involved stakeholders (e.g. farmers or veterinary doctors).

SECURITY DESIGN

The data transmitted among the stakeholders within an M-Agriculture architecture must be secured in such a way that information cannot be intercepted and modified. Several measures have been put in place to ensure maximum security of the data.

a) Data Security

Any sensitive information that is transmitted from the various mobile applications installed (e.g. on the agriculture expert or veterinary doctor's mobile phone) is encrypted. For example, the passwords of all the stakeholders are encrypted using the Message Digest 5 (MD5) algorithm. Other encryption algorithms can be used to secure any transmitted information among the various entities of the model.

b) Database Security

At the database level, the database management system requires the creation of user and various roles assigned to them. Strong password policies should be forced at the database level to reduce the possibility of intrusion and malicious damage of data. Sensitive data fields, such as stakeholder passwords, have to be encrypted in the database.

c) SMS Security

The security of an SMS is controlled by the mobile service provider. In most cases, different technologies are applied by the network service provider to ensure that any SMS transmitted in the network is safe and free from interception.

CONCLUSION

Mobile technology can be applied in agriculture to improve the various processes that are involved between the production of produce in the farm, buying and processing. The presented M-Agriculture model presents a workable solution towards the design and implementation of mobile applications in dairy farming.

From the research, it is evident that most of the areas with inefficiencies (e.g. access and sharing of information) can be addressed using mobile technology. The designed model can be used by software developers to create mobile applications that are focused on dairy farming and to implement the various business processes involved in that agricultural sector. The model can also be adopted by policy organizations and government agencies in their proposals on the usage of technology as a key driver towards economic growth.

Moreover, researchers can use the proposed model as a basis for improvement towards existing mobile application development models and frameworks or to develop new ones. Further work may be done to test the model in other areas of agriculture, e.g. crop farming. Also, agri-business components can be added to the model to enable the participation of other agriculture stakeholders who were not included in the presented model.

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