IST-Africa 2012 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2012
ISBN: 978-1-905824-34-2

mHealth in Senegal: The Voices project

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Abstract: This paper describes an ongoing mobile health (mHealth) pilot in Africa. This project is part of a larger European Commission (EC) funded project, VOICES, which explores the potential of mobile, wireless, web and speech technologies to improve social, health and rural development in African countries. The mHealth part of the project aims at investigating how mobile and speech technologies can strengthen epidemiological surveillance in Senegal. Four mHealth applications are being developed. One application deals with epidemiological data collection from peripheral biomedical laboratories, two applications aims at delivering educational content to laboratory technicians, and the last application has to do with providing them with expert support.

Key Words: VOICES, mHealth, Mobile phone, Voice technologies, Senegal, Biomedical laboratories, Epidemiological surveillance, Medical training.

1. Introduction

This paper presents the mHealth pilot of an ongoing European Commission funded project1 named VOICES (VOIce-based Community-cEntric mobile Services for social development2). MHealth refers to the use of mobile and wireless technologies to improve health systems. It is widely recognized as a strategic element for achieving health-related Millennium Development Goals (MDGs) in low and/or middle income countries (LMICs) an is being applied in diverse contexts such as patient monitoring, health surveys and patient data collection, epidemiological surveillance, health awareness raising, mobile telemedicine, public information campaigns among others [1, 2, 3]. The VOICES project, which involves 11 partners, aims at exploring the potential of using mobile phones and speech technology to improve social development in African countries (Mali and Senegal) in two domains: agriculture and health. The rationale of using speech technologies is that voice-based interfaces have been identified for their potential to increase access to information services in developing countries, particularly for illiterate people [1]. Another goal of the project is to build a toolbox for the development of voice services that will be made available to local communities and entrepreneurs as Open Source. As for the health pilot, the objective is to investigate how mobile and speech technologies may strengthen the Senegalese epidemiological surveillance system. This pilot involves an industrial partner (Orange), an academic one (ESMT), a French NGO (Fondation Mérieux) whose main mission is to strengthen local capacities in developing countries to reduce the impact of

1 The second pilot is agriculture in Mali, which is investigated by another team of the project.
2 For more information on the project see: http://www.mvoices.eu/

infectious diseases on vulnerable population, and the Senegalese National Network of biomedical Laboratories (RNL).

The remainder of this paper presents the context and the objectives of the mHealth pilot; then we describe the mHealth use cases we have elaborated in the context of Voices, the technological infrastructure that will be used in this project, and the issues raised by the sustainable integration of mHealth applications in national health systems. We conclude this paper by discussing lessons learned so far and describing future work.

2. Context and objectives of the mHealth pilot

Infectious diseases are the most important cause of death, invalidity and morbidity in Senegal. For example, malaria and tuberculosis are real public health problems (e.g. each year around 600,000 cases of malaria are recorded, of which 5000 are deadly). Therefore, efficient epidemiological surveillance is crucially important to control and reduce the propagation of infectious diseases. In Senegal, national biomedical laboratories, which are organised in three levels (17 national level laboratories localized at Dakar, 15 regional level laboratories, and 90 district level laboratories), play an important role in epidemiological surveillance. To strengthen this role, a National Network of Laboratories (RNL) has been created with the help of Fondation Mérieux, thanks to financial aid from the Agence Française de Développement (AFD). This network is part of a multinational network (RESAOLAB3: West African Network of laboratories) that involves two other African countries (Burkina Faso and Mali). This network aims at strengthening epidemiological surveillance, quality management in medical laboratories and training of laboratory technicians in these countries. As for epidemiological surveillance, this network is currently watching nine diseases: brain fever, cholera, shigelloses, tuberculosis, malaria, syphilis, HIV, measles, poliomyelitis. The goal of the mHealth pilot of VOICES therefore lies within the framework of RESAOLAB. It aims at exploring how mobile and speech technologies may enhance epidemiological surveillance by strengthening the transmission of epidemiological data between peripheral laboratories and the RNL, and the capacity of lab technicians to detect epidemic diseases, particularly by extending their medical training. We are aware of the fact that improving epidemiological surveillance through mobile technology in developing countries has been already investigated in many mHealth initiatives. However, compared to these initiatives we are aware of, the application of mHealth to medical laboratories is quite new.

Another objective of VOICES is to develop mobile services that are economically and technologically sustainable. More precisely, the goal is to identify the most appropriate economic model for each pilot and developing open technological infrastructure and software toolbox that can be appropriated and used by local people.

Lastly, VOICES implements a co-design approach by integrating local partners. The goal is to ensure that local partners will acquire appropriate expertise on relevant mobile ICT technologies, opening up opportunities for local innovation. To this end, the development of the mHealth applications is being taken in charge by a local academic structure - the ESMT4 (Multinational School of Telecommunications). Orange provides the technological platform (Emerginov, see section 3) for developing and testing the mHealth services.

3 http://www.fondation-merieux.org/resaolab-network
4 http://www.esmt.sn/

3. mHealth use cases

The first step of the pilot was to understand end-users' work activities, needs and issues in order to determine what kind of mHealth applications may be useful for them. We then undertook field trips in Senegal. We visited three laboratories (one regional lab and two district labs) and interviewed the RNL staff, lab technicians and head doctors of health centres.

Regarding epidemiological surveillance, these field trips allowed us to understand how laboratories collect and transmit data to the RNL. Peripheral laboratories have to fill in and send via email two types of forms. One form is used for collecting epidemiological information about monitored diseases on a weekly basis. This form comprises different items: the ID of the laboratory, diseases that have been detected, name of the patient, the date of the biological sample was taken, date of delivery of the sample, quality of the sample, pathogens that have been detected, date of delivery of the result, date in which the document has been sent to the RNL. Note that when a case of monitored disease is detected, the laboratory informs the head medical doctor of the health centre or the hospital in which the laboratory is located. The second epidemiological form is used to collect information about monitored diseases on a monthly basis. However, this system is not fully operational at the district level, particularly because of the lack of technical communication means (non internet access, no computer) in district laboratories.

Concerning training, laboratory technicians, particularly those working in under equipped peripheral laboratories (with no computer and no internet connection), expressed a need for continuous training. Moreover, in these laboratories, technicians do not receive the RNL's quarterly bulletin, which contains educational information (e.g. information about a disease or a lab procedure). Given that laboratory technicians have mobile phones, mobile services that deliver educational content have therefore the potential to complement the training program being implemented by the network of laboratories and to enable all laboratories technicians to have access to educational information broadcasted by the RNL through the quarterly bulletin.

Four use cases emerged from the field study. One use case deals with epidemiological surveillance, two are about training, and the last one has to do with expert support.

As regards disease surveillance, the use case is a follows: laboratory technicians use a mobile phone for entering and transmitting epidemiological data that are currently collected via the weekly form to the RNL (Figure 1 describes this use case). The head doctor of the health centre or the hospital is informed by SMS. Data sent by laboratories is transferred to a database to which the RNL has access. Our main hypothesis is that laboratories with no computer and no Internet access will collect and transmit epidemiological data. The RNL will then collect more data than in the current situation. In this use case, two kinds of user interfaces will be compared: a graphical interface and a voice interface. The goal of this comparison is to investigate the added value of voice interfaces in terms of performance (speed, accuracy) and ease of use for data entry. In the graphical interface scenario, lab technicians launch a widget application and enter data either through the phone's keypad or by selecting items via a touch screen, depending on the kind of data that should be entered (see Figure 2). The voice interface is based on an IVR (Interactive Voice System) and DTMF5, which refers to a mechanism for navigating voice user interfaces using the phone's numeric keypad. We have chosen this mechanism because several studies have shown that this mode of interaction with IVR systems dominates in terms of performance and learnability, and DTMF is preferred to speech input [4]. In the voice scenario, lab technicians call an IVR system, which invites them to enter epidemiological data by using

5 This acronym stands for Dual-tone Multi-Frequency.

their phones' keypad or by recording messages (e.g. for entering the patient's name); the system's prompts and outputs use text to speech technology. Note that the graphical interface will be tested on touch-screen smart phones that will be provided to the laboratory technicians by the project.

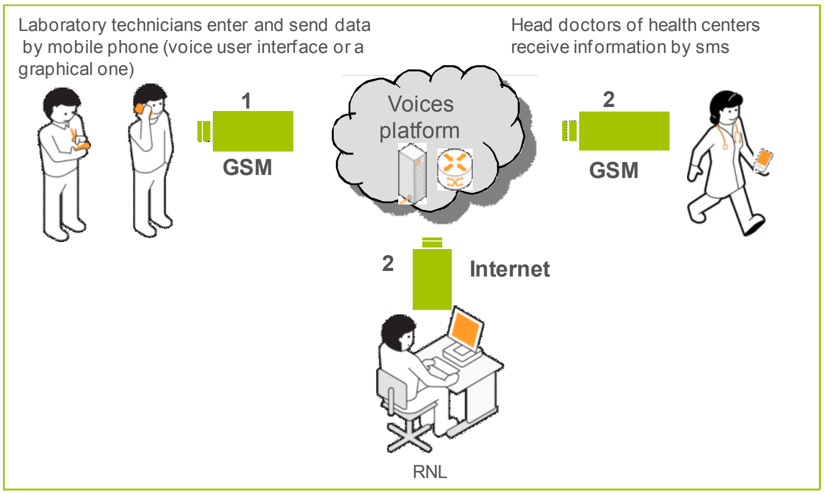

Figure 1: Epidemiological data collection use case

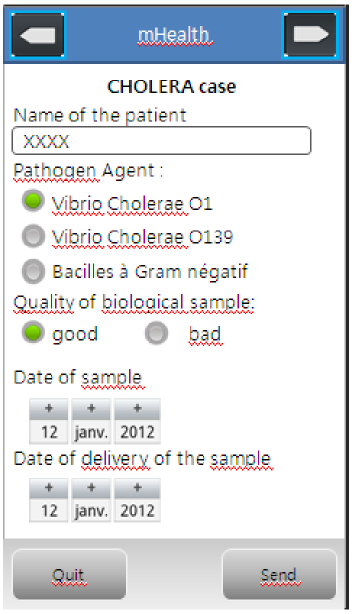

Figure 2: screenshot of the graphical interface

This use case raises privacy and security issues given that it involves the usage of sensitive medical data, including identity information (name of the patients). It should be noted that this piece of information is part of the user requirements gathered from the field study. In the mHealth application, these data are protected at different levels. At the data entry level, data are not stored on mobile phones, at the data transmission level, the system use security services provided by GSM network, and at the data storage level, access to data is password protected. In comparison to the current situation in which these data are transmitted without any specific security mechanism, the use of mobile phones and the GSM network increase privacy and security of epidemiological data transmission between the RNL and peripheral laboratories.

As for training, one use case scenario consists in developing laboratory technicians' knowledge through vocal quizzes to (Figure 2). These quizzes aim at training them in different topics concerning biomedical analysis and procedures. The scenario of this use case is a follows: a person from the RNL staff creates a quiz for example about a disease or a medical test. He then issues it to laboratory technicians through the Emerginov platform. Laboratory technicians receive an SMS inviting them to take the quiz. They dial a phone number and take the quiz. The system analyses the answer and provides feedback. In the second use case, called "information of the month", educational information (e.g. about a disease or a technical procedure) is broadcasted to laboratory technicians in the form of voice messages (figure 3). The scenario of this use case is a follows: a person from the RNL staff creates an educational content (e.g. about a disease or a medical test) in the form of a vocal message. He records the message and then issues it to laboratory technicians through the Emerginov platform. Laboratory technicians receive an SMS inviting them to listen to the message. They dial a phone number and listen to it. Note that the content of quizzes and educational information will be created by the RNL on a regular basis. These contents must be seen as complementary to other training means and educational tools (e.g. face to face training, quarterly bulletin).

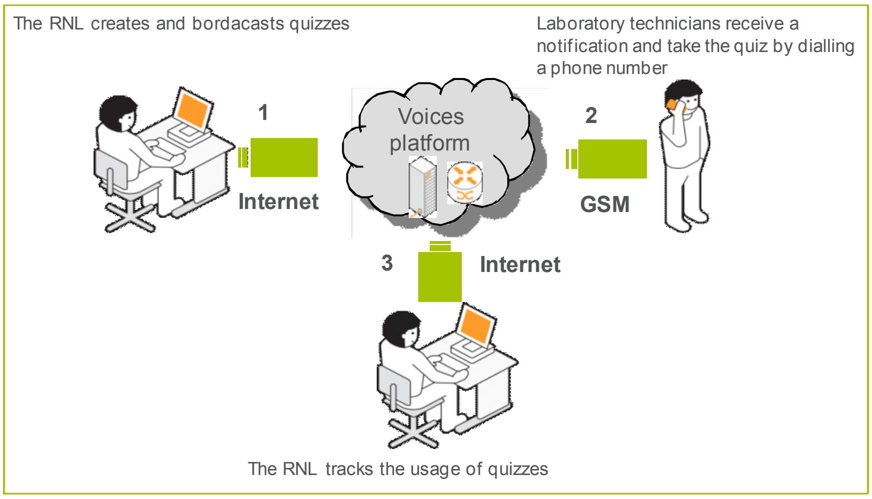

Figure 3: Quiz use case

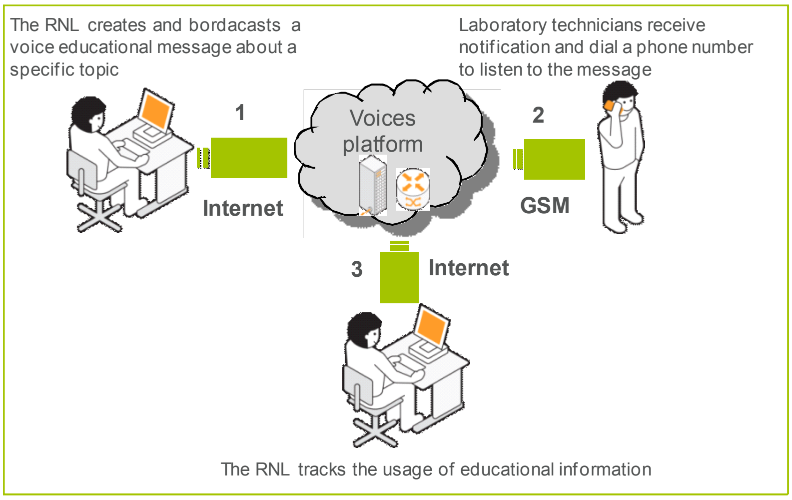

Figure 4: Information of the month use case

The fourth use case deals with expert support (figure 4). Lab technicians need sometimes to call medical experts about a particular medical test (e.g. how to perform it) or test results (e.g. when a laboratory technician is uncertain about his/her interpretation of a medical result). The goal of this use case is to expand this support by enabling laboratory technicians to post questions on a vocal server. The scenario of this use case is as follows: a laboratory technician uses his/her phone to post a question. He/she dials a number and then is invited by an IVR system to submit his/her question in the form of vocal message. The system records his/her question and is transferred to the RNL via the Emerginov platform. The question is treated by a person from the RNL, who then looks for an expert to find the appropriate answer. When an answer is found, the person from the RNL records it in the form of a voice message and issues it through the system; the lab technician is notified by SMS that the answer can be listened to. He/she then has to call the IVR system in order to listen to the answer.

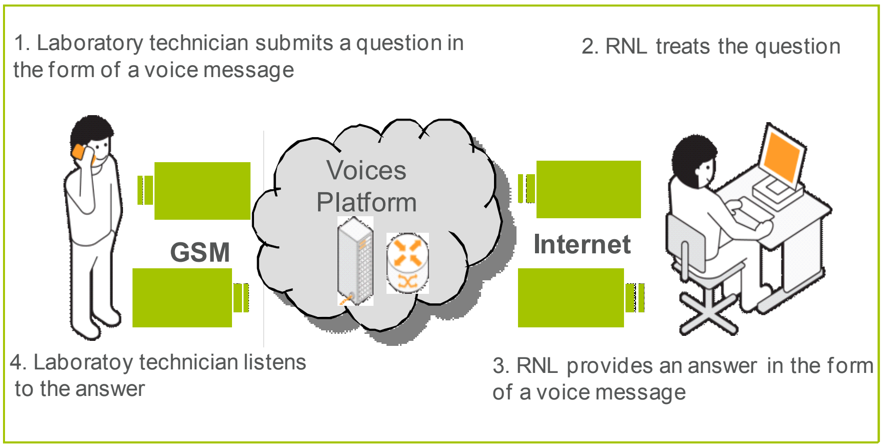

Figure 5: Expert support use case

Epidemiological data sent via mobile phones, statistics (frequency of use) about the usage of quizzes, educational information and questions posted by laboratory technicians will be stored in a database. This database will be accessed by the RNL through a web interface which will provide several functionalities for creating quizzes and educational information campaigns, accessing to and treating technicians' questions (fourth use case), browsing the existing list of past questions and answers, visualizing and filtering collected epidemiological data.

4. Technology Infrastructure

The technical challenge consists in providing a sustainable infrastructure allowing rapid prototyping through a simplified access to web and Telecom bearers. The choice of free software components based on open standard was agreed to ensure the technical sustainability beyond the life of the European project. In fact, any code developed within the project can be quickly re-used, even in production context, thanks to the choice of mature open source solutions (licence free, available support in Africa). It was thus decided to use the Emerginov framework. Emerginov is an IP multimedia infrastructure initiated by Orange labs. It is also a community and aims to become a reference open source forge for developing business micro services. The Emerginov infrastructure is based at 95% on open source components. Content shall be under creative-commons and the wide use of open standard is encouraged (HTTP, VXML[6]). The telecommunication enablers are abstracted to allow any student in computer science to be able to quickly interact with the platform.

4.1 The infrastructure

The goal of the infrastructure is to provide a bridge between Mobile and IP worlds. Additionally the architecture shall be open, shared and duplicable.
We distinguish 5 main parts

6 VoiceXML

- Telecommunication functions: these functions consist in all the gateways between traditional telecommunication infrastructure (SMSC7, switch) and the IP8 platform.
- Routing functions: the platform supports two signalling protocols, SIP9 for VoIP10 telecommunication and HTTP(S) for web
- Media functions: these functions may include the management of vocal announcements, voice mail, conference bridge, voice recognition
- Content function: these functions include social network, a multimedia library usable by all the developers, promoting content under creative common license or in public domain.
- Administration functions: mainly supervision

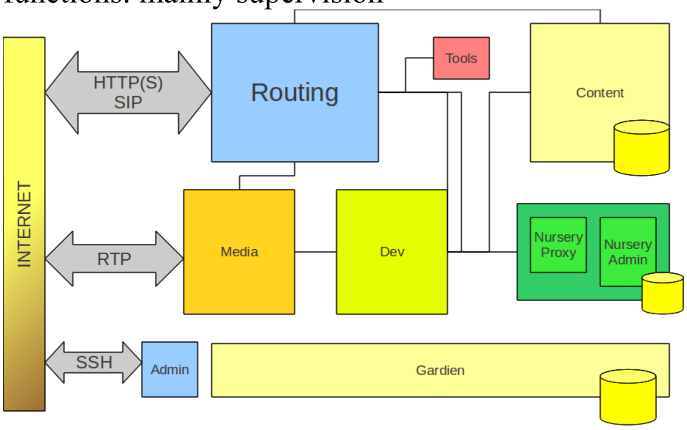

Figure 6: The infrastructure

The telecommunication functions require dedicated hardware. All the other IP functions are virtualized to save power supply and optimize the machine usage.

Emerginov architecture has been designed to address any Orange affiliate in Africa. Two core platforms have been installed: one for East Africa and one for West Africa and as many local gateways (vocal and SMS access) as required.

For the project Voices, we then relied on the West African platform hosted by Sonatel in Senegal and a local gateway installed in Orange Mali, allowing SMS and vocal access through local numbers in Mali.

4.2 A community promoting free software.

Free software was the only way to achieve our goals for two main reasons: the design and the adoption of the platform.

The design shall be cost-effective. It shall also integrate the possibility of a local support. Free software selected on the platform can all be considered as mature. Local expertise already exists and academic resources, that can be considered as future support, have also a high knowledge of the selected components. Free software was also imperative to facilitate the adoption of the components then to simplify the developments themselves. In fact any student was able to download any of the components and could thus start developing in a local environment before pushing his/her code to the platform. Free software is an opportunity for the operator to provide innovation in emerging countries.

In addition of the server framework, Emerginov includes a client toolbox in order to help local developers to quickly design and implement micro services. This toolbox

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7 Short Message Service Center
8 Internet Protocol
9 SIP stands for Session Initiation Protocol (SIP)
10 Voice Over IP

consists in a USB key or a client virtual machine based on Virtual box. The complementary features of the server and the client was also possible through the choice of free software as the server and client tools could be legally use at the same time and shared between any members of the innovation community. On the USB key the developer could find all the server components, as well as an emulated Mobile network thanks to 3 VoIP local clients.

The choice of an USB key was also motivated to allow local user to be able to develop on shared resources (students in computer room) and in weakly connected mode. In fact developers can develop everything on the key, and, when the network is available, they can upload their service that is automatically deployed on over the top of the operator network. Then it is relatively easy to quickly deploy a service that any Mobile user can reach from this USB key.

5. Conclusion

One of the endeavours of the project presented in this paper is to investigate the potential of mHealth in Senegal. More specifically, the goal is to explore how mobile and speech technologies can strengthen epidemiological surveillance in this country. Fourth use cases have been elaborated from a field study that had important implications for the design of mHealth applications that will be tested in this pilot. At the outset of it, it was supposed that voice-based services in Wolof, which is Senegalese local language, would be useful in this context. Instead, the field study disproved this hypothesis because French is the main language used by lab technicians and the RNL during their work activities. So, our conclusion was that the voice interface should work in French. One lesson we can draw from this result is that developing voice-based services in developing countries' local languages depends heavily on the context of use, including the abilities and the nature of end-users' activities.

As shown in the literature [1, 2], the success, adoption and sustainability of mHealth systems depend not only upon their usability and usefulness for end-users but also on other important factors such as the involvement of local policy-makers and health authorities, the economic model, cost-effectiveness, data security and privacy to ensure that health data are properly protected, the implementation of the applications within the health system and the transition from pilot to large-scale deployments. All of these aspects will be carefully considered in the pilot in order to ensure long-term sustainability of the mHealth applications described in this paper.

The next steps are to finalize the development and test the four mHealth applications described in this paper. Two six-months trials are planned in 2012: The first trial is under way. The evaluation will address different issues, for example: usability (performance, ease of use, etc.), users' experience, consequences of the usage of the applications on lab technicians' work activities, and consequences on the RNL's activities.

Acknowledgments

All of the individuals and institutions that participate to this project: The Senegalese National network of Laboratories (Prof. Iyane Sow and Dr Mouhamadou Lamine Dia), laboratory technicians we met during the field trips, The ESMT, and Fondation Mérieux. This research is funded by the European Commission through the EU FP7 VOICES project (No. 269954, www.mvoices.eu).

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