Framework for the Development of a Radio Frequency Identification (RFID) based System for Supporting Vaccine Distribution and Uptake in Resource Poor Environments.

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ABSTRACT
Child Mortality in Africa has been attributed to the lack of access to major vaccinations as and at when due. Leveraging on cheap existing platform, RFID Technology, the overall availability of these vaccines to rural areas in sub-Saharan Africa can be improved. The goal is to create a practical system for improving vaccine uptake in pregnant women in sub-Saharan Africa, with Nigeria as a case study, and in all reducing child mortality.

Keywords- RFID, Africa, Resource poor environment, Vaccine, Vaccination, Uptake and Distribution.

1. INTRODUCTION

Child mortality rates are falling, but not quickly enough. Between 1990 and 2008, the death rate for children under the age of 5 decreased by 28 per cent, from 100 to 72 deaths per 1000 live births, which means that, worldwide, the number of under-five that die each day reduced by 10 000. Many countries have shown considerable progress in tackling child mortality. Almost one-third of the 49 least developed countries have managed to reduce their under-five mortality rate by 40 per cent or more over the past 20 years. Coming down to Africa, since, 1990, child mortality rates have dropped by more than half in northern Africa, western Asia and the Caribbean.

By contrast, little or no progress has been made by countries, especially in sub-Saharan Africa, which have unacceptably high rates of child mortality.While under-five mortality rates have declined by 20 per cent, since 1990, in sub-Saharan Africa, high fertility rates and the slow pace if reducing deaths mean that the absolute number of children who have died has actually increased, from 4million in 1990 to 4.4million in 2008. Sub-Saharan Africa is home to one-fifth of the world's children under the age of five, and it has accounted for half of their 8.8million deaths in 2008.

Most of the causes of child death are related to malnutrition, illiteracy, lack of access to adequate primary health care and infrastructure, such as water and sanitation, vaccination, immunization, in many developing countries. For example, pneumonia, diarrhoea, malaria and aids accounted for 43 per cent of the deaths in under-fives in 2008, and more than a 3rd of all child deaths were attributed to under nutrition and lack of immunization and vaccination .(UN Department of Public Information DPI/2650D SEPTEMBER 2010.)

2. INFANT MORTALITY IN AFRICA.

Take Nigeria, the most populous black nation in Africa, immunization coverage is far from optimal. Nigeria accounts for half the deaths of measles in Africa, the highest prevalence of circulating wild poliovirus in the world, and the country is among the ten countries in the world with vaccine coverage below 50 per cent, having been consistently below 40 per cent since 1997(Inadequate Immunization Uptake in Nigeria: A Multilevel Analysis of Individual and Contextual Determinants). A study (Uptake of Childhood Immunization among Mothers of Under-Fives in South West Nigeria)showed that some of the factors affecting the uptake of vaccine in pregnant women include:

- Culture - 99.6% said that their culture supported it.
- Husband Support - 99.4% said their Husbands supported it.
- Long Queues - Most said they were discouraged by the long queues in waiting to get the vaccination.
- Payment for vaccination - Most said that they turned away because they had to pay for it.
- Long Distance - being a rural area, most said that the distance of the clinic to their residential area discouraged them.
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As we can clearly, sub-Saharan Africa needs to develop programs that solve these aforementioned problems adequately. This is the reason why this research is on the way, as it seeks to use an mobile/ RFID based system to improve vaccine uptake in pregnant women and children, and thereby improve the access of infants and mothers to adequate primary health care and infrastructure in sub-Saharan Africa. In sub-Saharan Africa, the greatest problems are access to basic primary health care and infrastructure, illiteracy on the part of parents and non-availability of these different vaccines that children.

In addition to providing access to primary medical health care, the research will also seek to educate parents, (especially mothers), using their own native language about the importance of immunization and vaccination, also provide basic medical and nutritional supplements to combat malnutrition as is the case in sub-Saharan Africa.

The reason why the RFID technology will be a great benefit is mostly due to its easy integration and structure, ability to read/write information remotely. This technology can help a group of 10 -50 persons made up of doctors, nurses, etc, have a reach of over 500 different persons. For this research, a case study will be carried out in one of the rural areas of western Nigeria in a bid to show why this technology will help reduce infant and maternal mortality rates in sub-Saharan Africa. However, what this research will not do is to track unsuspecting citizens or to use any of their information negatively and for the scope of this research RFID chips will not be implanted/ embedded in any human being.

3. RFID IN PERSPECTIVE

One of the most intriguing fact about RFID is that it is not a new technology. In 1945, Leon Thevenin while working for the soviet union invented an espionage tool that transmitted incident audio waves and audio information. Even though this device was used as a covert listening device, and not an identification tag, it is considered to be a predecessor of RFID technology because even though it was passive, it became energised and activated by waves from an outside source. A similar device, the IFF transponder was used over sixty years ago by the united kingdom, by the allies in world war ii to identify aircraft as friend or foe. Another early work explaining RFID is the landmark paper by Henry Stockman, titled "communicating by means of reflected power" (proceeding of the IRE, pg 1196 01208), but the first commercial application involving RFID was in the 70's and 80's and they were concerned with asset identification in single location.

The 3rd era of RFID commenced in 1998, when researchers at the Massachusetts institute of technology(MIT) Auto-ID centre began to research new ways to track and identify objects as they moved between physical locations. This research had a global outlook centred on radio frequency technology and how information held on tags could be scanned and shared with business partners in near real time. Today, the Auto-ID centre has helped make RFID economically viable and affordable for tracking and other purposes.

4. PROPOSED SYSTEMS DESIGN

a) Tags: As described above, the tags used must have read/write compatibility.
b) Readers: As described above, the readers will be stationary, residing in the test location.
c) RFID Middleware: consists an Electronic Patient Records System(EPRS), Database Management System and an SMS Server System.
d) Mobile Wireless Network with Voice capability.

A conventional and well known model used for patient compliance is the Self Regulation Model (SRM) (Guanlin et al, 2006). The operation is via negative feedback loop through the patient. Regimen-uptake is examined by the patients self reports compared with the recommended treatment regimen. Non compliance can be detected when there is a disparity between the recommended and actual treatment regimen. Compliance is facilitated through social networks (Using the social construction theory; the use of reminders and alerts (Based on associative theory) and questionnaires based on self-perception theory. While these contributions are noteworthy, it is imperative to assert that in a resource poor environment, most patients do not possess the skill, experience, resources and motivation to use the compliance facilitators prescribed by SRM. We propose to develop a robust means of integrating low cost location detection system alongside biometric technology to enforce compliance, provide real-time alerts/signals that will tremendously improve uptake with infant vaccination and connect healthcare givers/vaccinators with target populations using a Location Aware Request Response mechanism (LARRM).

The basis for using the LARRM Mechanism for the development of low-cost mobile platform is to leverage on existing mobile networks and explore ICT4D2.0 scientific imperatives by adding wireless/web functionality and digital/geographic mapping tools (Google maps) to legacy technologies such as radios and televisions in places that are out of the reach of mobile technologies. This will assist to provide timely information on the availability and location of infant vaccinations offering in a bid to improve participation, enhance coverage and facilitate adequate penetration of the exercise. To overcome the challenges of unimodal biometric systems, Multi-biometrics regimen will be engaged for enrolment, verification and identification of infants. This will be stored in a database as a set of robust infant biometric data that can be used to validate infant patient information with the aim of identifying individual infants for vaccination uptake and promoting compliance with respect to vaccine-preventable diseases. Google Android technology and other smart phones with in-built GPS and accelerometers will be engaged to provide location information in environments where phones are available.

We expect that the project will be successful as it will assist in overcoming the specific factors identified as militating against effective uptake and compliance with infant vaccination regimen such as lack of information, the challenges of positively identifying individual infants for developing world vaccination programs and connecting vaccine availability with target population.

5. EXPERIMENTAL PLAN AND TESTING

The initial effort will be geared towards evaluating the success of vaccination in the research locations by tracking the number of children that have been vaccinated, their effectiveness cum efficiency with a view to connecting vaccine availability with target population. This will be followed by development of a biometric database to assist in verification and authentication of existing patients with future growth in mind.

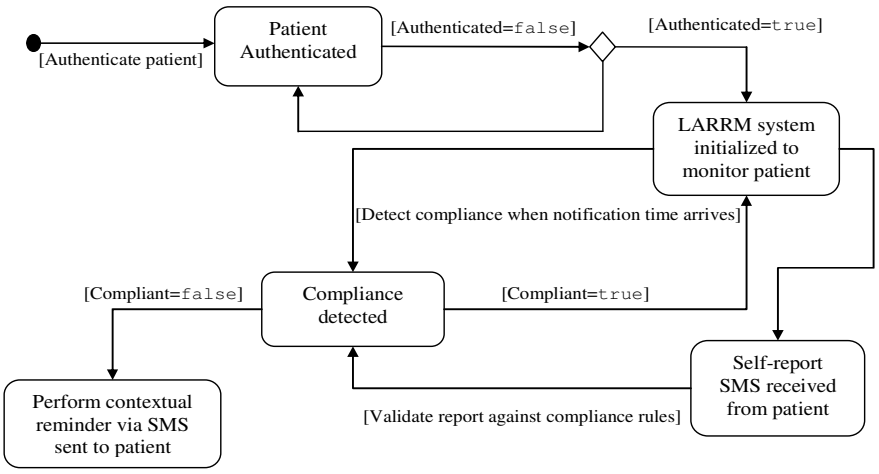

Figure 1: The LARRM Mechanism for Ensuring Uptake and Compliance of Vaccination in the Developing World

In places where there are no cell phone access we shall employ radio jingles and leverage on existing telecommunication infrastructure in combination with Radio Frequency Identification Tags (RFID tags) placed in homes with infants whose biometrics have already been taken connected to antennas and radio sets/megaphones (powered by solar cells/solar panels) to provide beeping information which eventually generates announcements in local languages to inform parents of imminent vaccinators visits, time and location. We will use the Social Learning Theory (SLT) as a basis for assessing incremental and transformative changes occasioned by the use of mobile and telecommunications technology on compliance intervention strategies for the distribution and uptake of infant vaccination

5.1 Data Generation

Comprehensive information on local population depicting the ratio between vaccinated and vaccinatable infants of the chosen locality as well as basic patient demographics, treatments, diagnoses, laboratory, and other test data.

- Individual biometric identity data verifiable on the fly to determine the level of compliance, vaccine penetration, efficacy of the vaccine and a digital map of the case studies will be produced. If successful, the LARRM based mechanism would be developed as a mass produced low cost device for rapid and accurate dissemination of vaccination information and model for the effective measure for the uptake and distribution of infant vaccination in the developing world.

5.2 The Pilot System

How the pilot system will operate and function will be described in the "General System Description". Some key benefits of the system are:

a) Searching for patient records will be easy and more simplified.
b) The system will allow for easy modification of any data entered on the system, and that to be sent out.
c) The information can be easily accessed remotely.
d) The system will be conveniently cross-referenced, maintained and updated, and protected.
e) Most importantly, the system will help reduce infant mortality rates in the Country be making sure that the important vaccines are taken at the appropriate time during infant development.

5.3 General System Architecture.

The Database

The database system will be computed-based, php run or any other thing. It might even be in form of a software. The basic idea is that the database stores information of each patient (child & patient) as regards personal information, location information, health history and any other relevant information. To overcome negligence on the part of the person operating the database, I think it will be necessary to use clinic cards that will be held by the patients so that we can have access to information from two different sources, which will reduce errors.

Computer Nnetworks
This comprises of the RFID software and hardware systems that will be located at the hospital or clinic premises. The sole purpose is to interface the information from the reader/interrogator to the database and also send and update information through the reader to the tag. The mode of communication is through Mobile Data Transfer through the GSM Network. The authentication protocol for reading information on the tag will basically be by File Transfer Protocol, as this will save cost of communication through the Mobile GSM Network.

Reader/Interrogator
This will send the signal to the tag and read responses from the tag. They will generally transmit their information/observation to the computer network running the RFID middleware or software. The reader will also capture and process tag data. An important aspect of the transmission of information between tag and reader id the frequency, which defines the data transfer rate. It should be noted that higher frequency means smaller antenna, smaller tag size, greater range but higher cost. I would recommended that the microwave 2.45ghz and 5.8ghz should be used. Though it might be subject to poor performance around liquids and metals. The reader will be situated at strategic positions in the test area so that it can read for the tags in that specific geographical location. For example, reader R1 might serve for tags T1,T2,T3,T4,T5 respectively while reader R2 will serve for tags T6,T7,T8,T9,T10 and both make up the RFID cloud.

Tags
When a tag is interrogated, data from its memory is retrieved and transmitted. Tags can perform basic tasks of read/write from/to a memory location. There are two types: active and passive, but for the scope of our project, active tags should be used because they have more range, more complex information exchange and richer processing capabilities. The only problem with the active tags is the battery life.

Table 2: Tagging:

Attribute	Characteristics
Design	IC based (so as to store information)
Type	Active (requires battery to operate the IC and to communicate with the reader. It also offers highest range and accuracy. Though it is costlier than passive tags.)
Memory	Read/write type

To fit this description and also for patient satisfaction, tags that come in form of Wristwatches should be employed as this removes the problems attached to privacy and general acceptance of the RFID technology.

SMS SERVER.
In addition, an SMS Server will be needed basically to send text messages to patients reminding them of appointment times to come for vaccination. The idea is that the SMS will remind the patient of the time for the vaccination, day, doctor, name of vaccine, e.t.c. Better still the Mobile SMS Network should have Voice-Capability so that the text message will be read out or a phone call in the native language of the people in that particular geographic location. To accomplish this we can either use the Mobile Med Alert System as described in "The Design of a Mobile-Based Alert System for Outpatient Adherence in Nigeria" or tweak its architecture to suit our purpose, but I must say that the architecture of the Mobile Med Alert System is good enough to give us what we need exactly.

6. CONCLUDING G REMARKS

We have proposed and discussed a framework for the design of radio frequency identification- based system for supporting vaccine distribution and uptake in resource poor environments. Although research has shown that non-compliance in most advanced countries is caused by financial reasons (Harris Interactive, 2001), in resource-poor environments such as sub Saharan Africa, a casual interrogation of nursing mothers on non-compliance to vaccination regimen for infants revealed that lack of information, monitoring, lack of knowledge of medications , confusion with medication and forgetfulness are major factors responsible for non-compliance. The development and implementation of our proposed system is expected to use a location aware request response model to ensure compliance to vaccination schedules and adequate coverage of mapped-out geographical location for effective and efficient uptake and distribution of immunization vaccines for infants.

REFERENCES

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