A Mobile Architecture For Childhood Vaccine Preventable Illnesses
Expert System

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ABSTRACT

Globally, vaccination against childhood communicable diseases through the Expanded Program on Immunization (EPI) is one of the most cost-effective public health interventions put in place by various governments to eradicate and remedy the menace caused by to childhood illnesses and diseases. Despite government continuously efforts to provide these vaccines free, most pregnant and nursing mothers especially in developing countries are ill-informed of the gains and needs of participating in effect vaccination of the young child. Also, the limited number of qualified health care providers against the increasing population, poor access to quality health care facilities, poor sanitary culture and lack of electronic medical records of patients that have received any form of vaccinations had hampered the smooth delivery and administration of these vaccines in developing countries. To this end, searching for innovative technologies and methodologies for the administration and universal coverage of child immunization will among other processes improve the quality of services given by health care provider to both mother and child. This research blends child vaccination processes with the innovative power of telemedicine to provide a software system framework that will both provide an alert mechanism on available child vaccine for a specific period and advisory services to nursing mothers. It will help to furnish health care provider with medical decisions and data for effective vaccination planning. It will also assist the government to budget properly towards sustaining effective child vaccination based on the evidence available in the centralized Electronic Medical Records.

Keywords: Effective Immunization, Immunization coverage, Electronic Medical Record.

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I. INTRODUCTION

The global menace of vaccine preventable illnesses and diseases such as Diphtheria, Tetanus, Pertussis (whooping cough), Measles, Smallpox and Polio has accounted for over 29% of death of children under five (5) years. Effective Immunization was recorded as the most successful public health initiatives and it has helped to avert an estimated 2-3 million life-threatening diseases and death that disproportionately affect children [1]. UNICEF reported that 123 countries had immunized over 90% of infants against measles in 2011 and vaccination had resulted in a 71% drop in measles deaths worldwide between 2000 and 2011. UNICEF added that new promising vaccines for children against Rotavirus, Haemophilus influenza B, Hepatitis B and Rubella diseases had been introduced in 31, 177, 180, and 130 countries respectively.

Approximately 82% of newborns in these countries were protected against neonatal tetanus through immunization. Despite these amazing track successes recorded, many countries are yet to introduce important vaccines such as the rotavirus and pneumococcal vaccines because of insufficient funding, underperforming cold chains or difficult access to vulnerable children who resides in rural areas. More also, unavailability of vaccines, poor or inaccessible health services because of increasing population, poor information on immunization (when and why patient most bring their children for immunization) have resulted to over 30 million children unimmunized worldwide and over 70% of these unreached children lived in Afghanistan, Chad, the Democratic Republic of Congo, Ethiopia, India, Indonesia, Nigeria, Pakistan, Philippines and South Africa [2].
Dr Temi Adekunle highlighted challenges inhibiting the effective coverage of immunization as inadequate awareness and sensitization especially in remote locations, poverty, limited funding, poor healthcare system and lack of adequate monitoring [4]. One strategy to properly inform families, increase awareness and provide updates of immunization coverage to the health care system globally is to create or design innovative methodologies and technologies that will facilitate the collection and dissemination of immunization information remotely and intelligently.

This can be achieved by enabling wireless and web based applications that collect vital health information from patients (pregnant mothers and newborn babies) irrespective of their location to a centralized Electronic Medical Record Server database or centre; and an expert system who intelligently analyze the transmitted information and provide informed decisions and recommend appropriate plan of actions for patients. Harnessing these opportunities will accelerate the global immunization coverage and will improve the healthcare systems thereby building applications that will be integrated into existing medical processes in designated healthcare institutions that will be accessible by mobile users. It will also afford collaborations between the developing country health care system and the developed countries. In this research, we propose a software framework that will blend information on vaccine preventable illness administration, treatment and control with telemedicine powered by Information and Communication Technology (ICT) to provide an immunization alert and expert system to families globally.

2. LITERATURE

2.1 Background of study
Child mortality has fallen significantly in many low income countries but however, sub-Saharan Africa continues had experienced the slowest fall in mortality rate among children[5]. UNICEF and WHO in the state of the world’s children report noted that 8.1 million children across the world who died in 2009 before their fifth birthday lived in developing countries and died from a disease or a combination of diseases that could easily have been prevented or treated [3]. It also noted that, half of these deaths occurred in just main five countries- India, Nigeria, the democratic republic of Congo, Pakistan and China- with India and Nigeria both accounting for one third of the total number of under five deaths worldwide. The report described the declining rate as disturbing and grossly insufficient to achieve the MDG goal by 2015 as only 9 out of the 64 countries with high child mortality rate are on track to meet the MDG goal [6]. Effective communication among communities was recommended by UNICEF as a measure that will help curb childhood illnesses and deaths [1].

[7] anticipated that scaling up the use of existing vaccines in 72 of the world’s poorest countries could save 6.4 million lives and avert $6.2 billion in treatment costs and $145 billion in productivity losses between 2011 and 2020. Models of vaccine-preventable disease burden frequently include immunization coverage levels among their components [8, 9,10].

Immunization coverage levels and trends are therefore indicators for monitoring the performance of immunization services locally, nationally and internationally and it provides guided strategies for eradicating, eliminating and controlling vaccine-preventable diseases. It also identifies areas of immunization systems that may require additional resources and attention. It assesses the need to introduce new vaccines into national and local immunization systems [11]. Effective coverage levels of vaccine preventable diseases and deaths are global indicators for tracking progress towards achieving Millennium Development Goal 4-to reduce child mortality and it provides a viable blueprint for immunization service delivery and disease control [31].

Currently, Nigeria is among the ten countries in the world with vaccine coverage rates below 50 percent and half of the 5% of death of children caused by measles in Africa occurs in Nigeria [5,12]. The country also has the highest prevalence of circulating wild poliovirus in the world [13,14].

2.2 Challenges of immunization coverage in developing countries
The developed countries already have their experiences of effective immunization coverage [11]. In developing countries, [15] stressed that healthcare problems resulting from different factors such as economic; poor planning or poor implementation of health policies; problem of availability, accessibility, affordability, and sustainability of health facilities; and weak referral system had plagued e-health system. He suggested that the use of communication equipment like mobile phones will help facilitate referral system. However, low standard of living and poor sanitary practices have increased child mortality caused by vaccine preventable blight and death in some developing countries [6].

As a panacea, [16] proposed an intervention package component of Performance Management and Demand Creation using SMS reminders to patients and staffs. Also, embracing innovations in telemedicine and e-health services will provide low cost access to health care facilities and effective instant SMS alerts messages and health tips on proper health styles to patients irrespective of their locations from the health care providers will help improve health care delivery [17].
2.3 Vaccine-preventable childhood diseases

According to [1], the common vaccine preventable childhood diseases were:

Diphtheria: a serious disease caused by a poison made by bacteria. It causes a thick coating in the back of the nose or throat that makes it hard to breathe or swallow.

Hepatitis B: a serious infection that affects the liver. Hepatitis B cause chronic liver disease and put people at high risk of death from cirrhosis of the liver and liver cancer.

Haemophilus influenzae type B (Hib): Hib can cause severe pneumonia, meningitis and other serious diseases almost exclusively in children under the age of 5.

Measles: a highly contagious respiratory disease caused by a virus. Measles causes fever, runny nose, cough and rashes all over the body. About one in 20 children with measles also gets pneumonia.

Pertussis (whooping cough): a highly contagious respiratory disease, which produces violent, uncontrollable coughing which often makes it hard to breathe. Pertussis most commonly affects infants and young children and can be fatal, especially in babies less than 1 year of age.

Pneumococcal: a disease that caused pneumonia, meningitis, or blood infection. Polio (poliomyelitis) mainly affects children under five years old. One in 200 infections leads to irreversible paralysis.

Rotavirus is the leading cause of severe diarrhea in infants and young children. Globally, it causes more than half a million deaths each year in children under 5.

Congenital Rubella syndrome (CRS) is a lifelong disabilities disease. Children whose mothers have rubella during the early stages of pregnancy often contract (CRS) and are at risk for other developmental problems such as congenital heart disease and mental retardation.

Tetanus is an extremely deadly and paralyzing disease. Mothers and newborns contract tetanus when deliveries happen in unhygienic conditions – as can be the case in remote and underdeveloped area. Tetanus is also a fatal disease. It is a bacteria causing weakness and paralysis when allows to fester in a deep dirty wound.

Tuberculosis (TB) is a disease that typically attacks the lungs. Tuberculosis causes pulmonary infection but can spread to many other organs causing serious illness, death and disability.

Yellow fever is found in tropical climates and is transmitted to humans by the bite of an infected mosquito. Up to 50% of people who develop severe illness and are not treated may die.

2.4 Vaccination Schedule

[4] reported that the Bacilli Calmette Guerin (BCG) is administered to a child at birth or as soon as possible after birth, Oral Polio Vaccine (OPV) is given at birth and also at six, 10, and 14 weeks of age. OPV can also be received any other time, especially during the immunization weeks. Pentavalent vaccine is a combination of five vaccines-in-one that prevents diphtheria, tetanus, whooping cough, hepatitis b and haemophilus influenza type b, all through a single dose. She added that the Hepatitis B vaccine is given at birth, sixth and 14 weeks; Measles vaccine is administered at nine months of age and Yellow Fever, also at nine months. The Pneumococcal Conjugate Vaccine (PCV10) is a vaccine that prevents diseases caused by the pneumococcal bacteria.

OPV10, Chicken pox (optional) and Measles vaccine (MMR) are administered between 15 to 18 months. MMR is the measles, mumps and rubella vaccine. Measles, mumps and rubella are very common highly infectious, conditions that can have serious, potentially fatal complications, including meningitis, swelling of the brain (encephalitis) and deafness. Meningitis and Typhoid fever (optional) are administered after 24 months. Meningococcal vaccine is a vaccine used against Neisseria meningitis, a bacterium that causes meningitis, meningococcal. Septicemia and rarely carditis [18].

2.5 Related Literature

According to [19], the modern healthcare system focused more on patient centred approach than traditional hospital based system. The adoption of Information and Communication Technology (ICT) in health sector have powered amazing health innovations such as telemonitoring and remote monitoring and these innovations have demonstrated a 50% reduction in mortality and over 50% in productivities within the health care systems [20,21]. Telemedicine consists of the transmission of vital health data from a remote location to another location for data interpretation and decision-making and it has increased the quality of life in heart failure, diabetes mellitus, rhythm disorders, psychiatric diseases and blood pressure [22,23,24]. Remote monitoring is an interesting and useful area that needs a lot of research in order to come up with solutions that benefits humanity- increase the monitoring performances while looking for economical solution and reduce inconveniences to patients [25].

A remote medical monitoring system using sensor and GPRS to collect and process physiological data from patients with a view to providing medical advice and decisions was proposed by [26], [27] developed an ambient-intelligent patient room where the nurse interacts intelligently with the patients based on evidence from patient’s surroundings/environments. A paper titled “Mobile Application for Diabetes Control in Qatar” was presented by [28] and it reflected on using mobile technology and applications to help diabetes patient in Qatar to manage their disease using glucose monitoring and diet management. [29] designed a secure based mobile healthcare system where patient data are encrypted using elliptic curve
algorithm which will be decrypted in the mobile phone. A robust framework for intelligent remote blood pressure monitoring and control was proposed by [17] such that patient vital signs are collected remotely, analyzed by an expert system and intelligently classifying the patient blood pressure.

3. SYSTEM ARCHITECTURE

Based on evidences that effective immunization communication among communities and health care providers can help address the challenges of vaccine preventable childhood illnesses, a call for a systematic approach using best software modeling methodology became very paramount.

The proposed system consists of four modules as depicted in figure 1: the patient/user model, the doctor module, the health institution module and supporting partners module. The patient module (see figure 2) includes the devices for collecting physiological data from patients and a Remote User Interface (RUI) application where the patients can access the server if they have Internet service. The devices include medical related devices like: glucometer for measuring the blood glucose level, thermometer for measuring temperature, and weight scale; a java enable mobile phone to lunch the RUI application and connect to the server where they can instantaneously receive immunization health tips and SMS alert based on their health status.

Figure 1: Proposed system architecture
Figure 2: Overview of Patient Module

Figure 3: Overview of Doctor Module

Figure 4: Overview of Hospital Module
Doctor module includes all health care professionals, nurses and other health workers that are involved both in immunization and performing of clinical services as shown in figure 3.

Health Institutions module consist of Hospitals and the Electronic Medical Record (EMR) server (see figure 4). The EMR server has the expert system for effective communication and decision on immunization issues. The EMR was maintained and analyzed by an expert system and it controls the entire system. The EMR was implemented using open source database-MySQL- and JAVA programming language. The knowledge base of the EMR SERVER is where the physiological parameter will be analysed in the form of rules; each rule represents particular childhood disease knowledge which is based on the age of the patient. The inference engine looks for rules with conditions that will result to true based on the given fact (data from the user) and fire such rule.

The supporting partners module are organization and international partners actively involved in immunization such as WHO, UNICEF, Immunization Partners in Asia Pacific (IPAP) (see figure 5).

4. SYSTEM MODELING
According to [30], the Unified Modeling Language (UML) is the de-facto for object oriented design methodology and it depict the functionality of a system. UML was used to capture and model most of the functionalities in the proposed system. Two main UML diagrams- Structure diagrams and behavior diagrams was applied. Structure diagrams include class diagrams, object diagrams, component diagrams, and deployment diagrams and they are used to describe the relationship between classes. Behavioural diagrams describe the interaction between the users and the use case. Behavioural diagram includes use case diagrams, state-chart diagrams, collaboration diagrams, sequence diagrams and activity diagrams. The Use case captures the standard flow of events within the system (see figure 6). In the diagram, there are two types of users; the remote patient who is wearing a wireless sensor and the healthcare experts in an ICT healthcare institution. Restriction using password was used to limit access to information on the EMR server.

Automation of Short messaging service (SMS) alerts sent on immunization vaccines and special health tips are sent to patient mobile devices from the medical experts system. The system’s operations and interactions among subunits are depicted using Sequence Diagram (see figure 7). The user logs in with unique ID generated by the EMR. This will enable the user to be connected to the system which is equipped with WAP application that runs on the devices and converts it to readable format that will be transmitted via gateways. The application establishes an internet connection to the database web server in the EMR.
Figure 6: Use case diagram of the system

- User Log in with password
- Owners Profile is displayed
- View list of Patient available
- Collect health data
- Analyze health data
- Treatment
- SMS ALERT

Patient

Doctor
5. SYSTEM IMPLEMENTATION AND DEPLOYMENTS

This software system consists of Remote Users Interface (RUI) application and Web Enabled Vaccine Preventable Expert System (WEVPES) application. Both applications were implemented using JAVA Software Development kit (SDK) 7.0 and Netbeans 8.0 was the Integrated Data Environment (IDE) used for the development of the server and Remote User Interface (RUI). mySQL was the database server used for holding the EMR. The WEVPES was deployed and tested on HP Compag 500B computer system with windows 7 operating system and XAMPP Version: 1.8.3 server installed and configured for proper functionality.

The Remote User Interface (RUI) is a java archive file (jar) that runs in various java enabled mobile devices. For the purpose of this work, a mobile phone simulator was first used to execute the jar file and all patient signs from the simulator were sent to the hospital EMR database. Later a Nokia 5300, Nokia 502, TECNO phones was used to run the RUI and connections were established to the server via internet/Bluetooth connection. The minimum hardware configuration for WEVPES to run is a Pentium IV system with 512MB RAM and 250GH hard disk running windows XP or later version. The minimum hardware configuration for RUI to run is any portable mobile java enabled device with appropriate Bluetooth/internet connections.

Figure 7: Sequence diagram of the system
6. SYSTEM TESTING AND REPORT GENERATION

6.1 Web Enabled Vaccine Preventable Expert System (WEVPES) Interface

The screenshots for WEVPES application are depicted in figure 8a-d

![Figure 8a: WEVPE home Page](image1)

![Figure 8b: WEVPE Book An appointment](image2)

<table>
<thead>
<tr>
<th>Name</th>
<th>Speciality</th>
<th>Timings</th>
<th>Area Covered</th>
<th>Appointment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Kaleb Imadi</td>
<td>Pediatric</td>
<td>PM to PM</td>
<td>Dr. Kaleb Imadi</td>
<td>Make an Appointment</td>
</tr>
<tr>
<td>Dr. Mohammed Isah</td>
<td>Gynaecologist</td>
<td></td>
<td>Dr. Mohammed Isah</td>
<td>Make an Appointment</td>
</tr>
</tbody>
</table>
Figure 8c: WEVPE mobile data queue

Figure 8d: WEVPE Geo-location of patient based on address from GUI
6.2 Remote User Interface (RUI) Interface
The screenshots for RUI application are depicted in figure 9a-e.

Figure 9a. RUI welcome page
Figure 9b. RUI Login Page
Figure 9c. RUI user Address page
Figure 9d. RUI user health data
Figure 9e. RUI User data sent to WEVPES
Figure 9f. RUI user receives SMS from WEVPES EMR server
7.0 CONCLUSION

In this study we demonstrated the gains of improving effective immunization coverage in developing country like Nigeria through mobile remote monitoring. It was glaring that remote monitoring will help improve better health care delivery towards meeting the yearning of citizens who cannot easily access health institutions because of distance, and limited health care providers. For critical situation, the patient’s location can be geo-located using the address supplied by the users. Also, special health SMS alert are instantly sent by the EMR based on the age of user supplied during remote monitoring from the RUI. The system is an interactive expert system that provides a more precise solution that will address immunization coverage problems, maintained a centralized database that track the progress of immunization schedule and inform physicians of current health condition of patient as regards to evidence provided from physiologic data remotely sent via the RUI. Childhood vaccination against common childhood vaccine preventable illnesses such as Measles, Whooping cough and Polio (poliomyelitis) can be identified and patient (child) can properly book an appointment to see a doctor. A system of this magnitude should be introduced into Nigeria general health care system (hospitals, clinics, maternity) to help ease the work of physicians and combat childhood preventable illnesses and death.
REFERENCES


