



FRAMEWORK FOR A CONTEXT-AWARE MOBILE E-HEALTH SERVICE DISCOVERY INFRASTRUCTURE FOR RURAL/SUBURBAN HEALTHCARE

^{#1}JOHN B. OLADOSU, GRADUATE MEMBER, IEEE, ¹JUSTICE O. EMUOYINBOFARHE, PhD

²SUNDAY. O. OJO, PhD AND ³MATTHEW O. ADIGUN, PhD

¹Department of Computer Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

²Research & Innovation Professor, Faculty of ICT, Tshwane University of Technology Pretoria, South Africa (sundojo2000@gmail.com or ojoso@tut.ac.za)

³Professor, Centre for Mobile E-Service for development, Department of Computer Science University of Zululand, South Africa (madigun@pan.uzulu.ac.za)

[#]Correspondence Author (johnoladosu@gmail.com)

ABSTRACT

Research efforts have produced a lot of applications and hardware devices for healthcare services especially in the developed world. However, much still left to be desire in mobile wireless healthcare research that produces semantic web services applications solution especially for the developing African countries. The first successful implementation of a mobile wireless application for the healthcare industry in the United States of America (USA) was announced on 13 October, 2008 by InfoLogic.

This paper presents our research in the design and implementation of a framework for cost cutting electronic healthcare delivery services for rural/suburban communities. This is achieved through the development of a semantic web services framework that would be deployed to provide wireless mobile healthcare delivery services and health management services for rural African communities. Currently no e-health application making use of semantic web services are known or reported in literature to have been implemented in any real life situation in Africa. The product of this research will be deployed in some selected rural communities in south-western Nigeria. Software artifacts will be implemented on the proposed framework. The software will be deployed for use by patients and healthcare practitioner in some selected hospitals in south-western Nigeria.

Keywords: *e-Health, Semantic Web, Service Oriented Computing, Telemedicine*

1. INTRODUCTION

The emergence of e-Health has been shown to reduce the cost of healthcare and increase efficiency through better retention and retrieval of records, better management of chronic diseases, shared health professional staffing, reduced travel times, and fewer or shorter hospital stays [13].

e-health is not only about telemedicine. besides telemedicine, e-health comprises an array of services, including hospital information (medical record) management system, customer service through internet, medical transcription, and health awareness through portals [17]. a medical record is a

very personal document that holds the information of a person's past illnesses, conditions, treatments, and the like, as well as the related medical history of close relatives. Medical records are usually kept and maintained by health care providers, but there are also people who opt to keep a personal medical record [14]. Medical records sound tedious, but they are important because they allow doctors to work quickly, efficiently, and accurately without having to ask the patients for the information they need again and again. A medical record can hold information on the treatments that are recommended for the patient, the care given to certain illnesses the patient has, and the various



medication that the patient can and cannot take [15].

The use of Internet has facilitated access to information anywhere/anytime. The healthcare domain is not left out in this information revolution. Web portals have been equally developed to disseminate health related information and educated healthcare practitioners and the general public.

Health Information System Project (HISP) started in 1994 in South Africa and is currently running in a number of developing countries in Africa and Asia. Hospital management systems developed under this project operate on fixed networks. There is no real life deployment of mobile Computing e-health system know in literature under this project or any other Africa-wide project.

Our proposed framework would be deployed on a Grid-based utility infrastructure. This infrastructure would address the following challenges among others [2]:

- ❖ The Failure of the PC Technology due to non-affordability (readiness, non-shareable etc.)
- ❖ Technology for the developing world should address Total Cost of ownership and operational cost.
- ❖ Practicable solutions need to be tailored towards existing success stories: pay-as-you-go basis, franchising that facilitates extending mobile business value network.

The infrastructure would leverage on the Ubiquity of the Mobile phone plus success of SMS as a viable means of communication.

Literature [4,5,10,12,11] identified the following research challenges, among others, in e-health domain: Mobile Computing Challenges, Mobile Web Services, Mobile Wireless Communication/Wireless Internet, Semantic Web/Ontology, Quality of Services, Interoperability, Multimodal User Interface, Middleware Services and Broker Services, Multiplicity, Identity management, Integration challenges, Flexibility and agility, Securing the solution, Scalability, performance and availability, Achieving the Common Hub. Most of the existing e-health applications are client-server based. This paradigm has limited relevance to today's anywhere/anytime services requirement. Virtually all existing mobile wireless e-health systems are at experimental/infant stage. Apart from this, development of policy/ethical dependent systems such as e-health require contextual consideration in

implementation/deployment. The combination of these factors have motivated this work.

This research will develop software solutions, frameworks, models, prototypes and artifacts which will address the above mentioned challenges in the Telemedicine, eHealth and mHealth domain. These outputs will be developed into commercial products to be marketed to the public through private-public-academia partnership.

2. MOTIVATION/JUSTIFICATION

Healthcare is intrinsic to human existence. With the evolution of telecommunication technologies and miniaturization of flexible and high power mobile computers, novel electronic health applications are enabled [3, 21,20].

The choice of this research endeavor is justified with the following points:

- ❖ Inappropriateness of Existing e-health applications for wireless mobile users
- ❖ Need by users especially tourist to have automatic primary and secondary healthcare services discovery in a location they are not familiar with
- ❖ Infancy of e-health research
- ❖ Peculiarity of African Contextual e-health challenges
- ❖ Inappropriateness of existing e-health application for wireless mobile users

Existing practical implementation of e-health application have not addressed mobile wireless application, most are implemented on generic client-server environment. In order to address today's nomadic users, more mobile wireless e-health applications are on increasing demand.

A. Provision of Automatic Primary and Secondary Healthcare Services discovery

Many subscribers of web services are tourist who may not be acquainted with the location where they are using hospitality services on the web infrastructure. Provision of context-aware healthcare services will be a value-added service to subscribers. Users might already have been insured in the national or regional health insurance scheme. This guarantees payment for healthcare services they will receive. If they are not already insured, the proposed infrastructure could be optionally linked with health insurance services for registration of new insurance holders.

B. Infancy of e-health research

InfoLogix announced on *13 October 2008* that the first successful implementation in the US of a



mobile wireless application for the healthcare industry running on the SAP NetWeaver Mobile 7.1 offering is now live at Baylor College of Medicine (BCM) in Houston, Texas [22]. This mobile health service is limited to selected hospitals in the USA. This shows that research in e-health domain is still at infant stage.

C. Peculiarity of African Contextual e-health challenges

Solutions developed for other continents are not designed with African peculiarity and cannot work for Africa due to the following factors:

- ❖ Ethno-Linguistic Diversification
- ❖ Poverty level [18]
 - 25 sub-Saharan African countries spend less than \$10 per person per annum on Health
 - “Africa has 24% of the burden but only 3% of health workers commanding less than 1% of world health expenditure.” (*WHO World Health Report, 2006*)
- ❖ Lowest Doctor-to-Patient ratio: 31 African Countries have fewer than 10 Physicians per 100,000 people [18].

All the above points explain why research in e-health in Africa needs to be intensified.

3. RELATED WORKS AND TECHNOLOGIES

A. Triple Space Communication Project

[6,7,8,9,16,23]. The primary objective of Triple Space Communication (TripCom) is to develop a highly scalable, semantically enhanced communication infrastructure which is the result of the integration of Tuple Space, Semantic Web (triple), and Web service technologies. It is being sponsored in the EC 6th Framework Programme through the Information Society Technologies (IST) project number: IST-4-027324-STP. The research is on-going.

B. Existing eHealth applications in Developing Countries: A framework [1]

Using 5Cs Acronym

Content: EHR, referral system, HMIS, CME/e-Learning and Telemedicine platforms etc

Community: Online Communities of Practice, Knowledge networks

Communication: Web services; voice and data tools

Connectivity: wireless/mobile ICTs- Opportunities for eMobility WG

Context: Cultural, end-users, social, organizational economics issues etc.

C. EU/EC eHealth for Developing Countries [1]:

Mobile/Wireless Technologies

- MOCCA: The Mobile Cooperation and Coordination Action (MOCCA) an initiative by EU in translating wireless and mobile technologies to developing countries under the IST FP6 in a report. This is a previous EU-IST FP6 programme that appropriate wireless/mobile technologies can be employed for providing connectivity in developing countries. The success of EHAS eHealth project is an illustration of this

- European strength in wireless networks can be employed like Alcatel Broadband Initiative, Ericsson and Nokia initiatives

Wireless/Mobile tools in Developing Countries (Africa)

- Wireless technologies use: GSM/GPRS/3G, WiFi, WiMAX, WLL (Fixed or Mobile CDMA), Broadband wireless, Satellite, VSAT (Mobility vs Universal Access)

- Mobile devices: PDAs, Smartphone, Cellular phones, Tablet PCs, Laptops, smart cards, memory sticks, USB keys, sensors.

mHealth impacts in Africa: Case Study 1

- UHIN (Uganda)

Started in 2003 and has continued to expand within & beyond the Country (Mozambique). Uses existing GSM/GPRS/ WiFi links with PDAs to support (community) health workers (HWs) creating a regional eHealth network. It uses solar panels for power. The project is for Primary Health Care service provision. Provides learning materials, health information and e-mail (upcoming) to HWs. Enables timely response to health system needs, diseases outbreaks and enhances organisational health planning and resource allocation.

mHealth impacts in Africa: Case Study 2

- Cell-Life (South Africa) started in 2003 by two universities in SA. A multiplatform system for the therapeutic and logistics management of HIV/AIDS population uses Mobile devices (Cellphones &

PDAs) with 3G/GPRS/SMS networks. Enables community health volunteers to assist their fellows in HIV+ management. Enables organisational planning for drug supply and emergency situations

mHealth impacts in Africa: Case Study 3

- MindSet Health (South Africa) started about 2002. Uses DVB wireless satellite technology to provide health education (eLearning) to rural health workers in clinics and hospital (datacasting) through PCs/Laptops and health promotion to patients and citizens through large screens and TVs (broadcasting) in clinics and community settings in form of documentaries, drama etc. Delivers information on all aspects of health (TB, HIV, Malaria etc). Improves health workers' capacity and empowers citizens' to keep healthy.

mHealth impacts in Africa: Case Study 4

- EHAS (Peru) started in Peru in early 2000 with joint collaboration between a Spanish and two Peruvian universities & MoH and an international NGO. Initially with HF/VHF but now with long distance WiFi wireless links connected with Laptops creating a regional eHealth network. It uses solar panels for power. It is for Primary Health Care service provision. Provides learning materials, e-mail and voice communication and teleconsultation to HWs, organisational health information & data exchange. Enables timely response to health system needs, diseases outbreaks and enhances organisational health planning and resource allocation.

Telemedicine impact in Africa: Case Study 5

- NASRDA (Nigeria) Telemedicine Uses SAT1 to perform telesurgery at designated hospitals throughout the country making use of experts from University College Hospital, Ibadan and University of Maiduguri Teaching Hospital.

Most of these initiatives and research are at infant stages and are insufficient to solve African medical care problems; hence the need for more research participation in this emerging technology.

4. RESEARCH METHODOLOGY

The following scientific approach was used to realize the goal and objectives of this research:

Requirement Definition. Infrastructural Model Architecting and Development.

A. Requirements Definition of the Proposed Infrastructure

This section provides the high level technical requirements that should be fulfilled by the proposed application infrastructure. We discuss the consequences of these requirements for the proposed application architecture that is situated on top of the infrastructure.

The list presented below gives the context requirement, user management requirement and service provisioning requirement of the proposed infrastructure.

i. Context Requirement

The infrastructure shall be capable of gathering context information of different sorts and from different sources without user intervention. The infrastructure shall be capable of inferring new context information from other context information possibly coming from multiple different context sources. The infrastructure shall be capable of predicting context behavior (future values of context information) based on context information possibly coming from multiple different context sources.

Context sources may offer context information in different ways, according to different interaction patterns. For instance, a certain source may provide a continuous flow of information values, while another may trigger events whenever a context change occurs.

ii. User Management Requirement

This requirement follows from the assumption that in order to allow privacy control, the system should not keep information about the user that the user himself/herself is not aware of. The user should also be capable of modifying at least the most sensitive pieces of this information. The infrastructure shall allow the users to sign on to the system as either a known user or an anonymous user (a user without known identity). The infrastructure shall be capable to organize users in ad-hoc groups by means of context aware parameters. Users are linked into groups based on context information (e.g., interest, location, etc.).

iii. Service Provisioning Requirement

The infrastructure shall allow users to find registered services. The infrastructure shall allow users to define their own set of subscribed services based on available services and service providers.

The infrastructure shall deliver the services as defined by users. The infrastructure shall allow service providers to publish their services according to a regular schema that facilitates search (matchmaking) and composition.

B. Infrastructural Model Architecting and Development

i. Overall Project Architecture

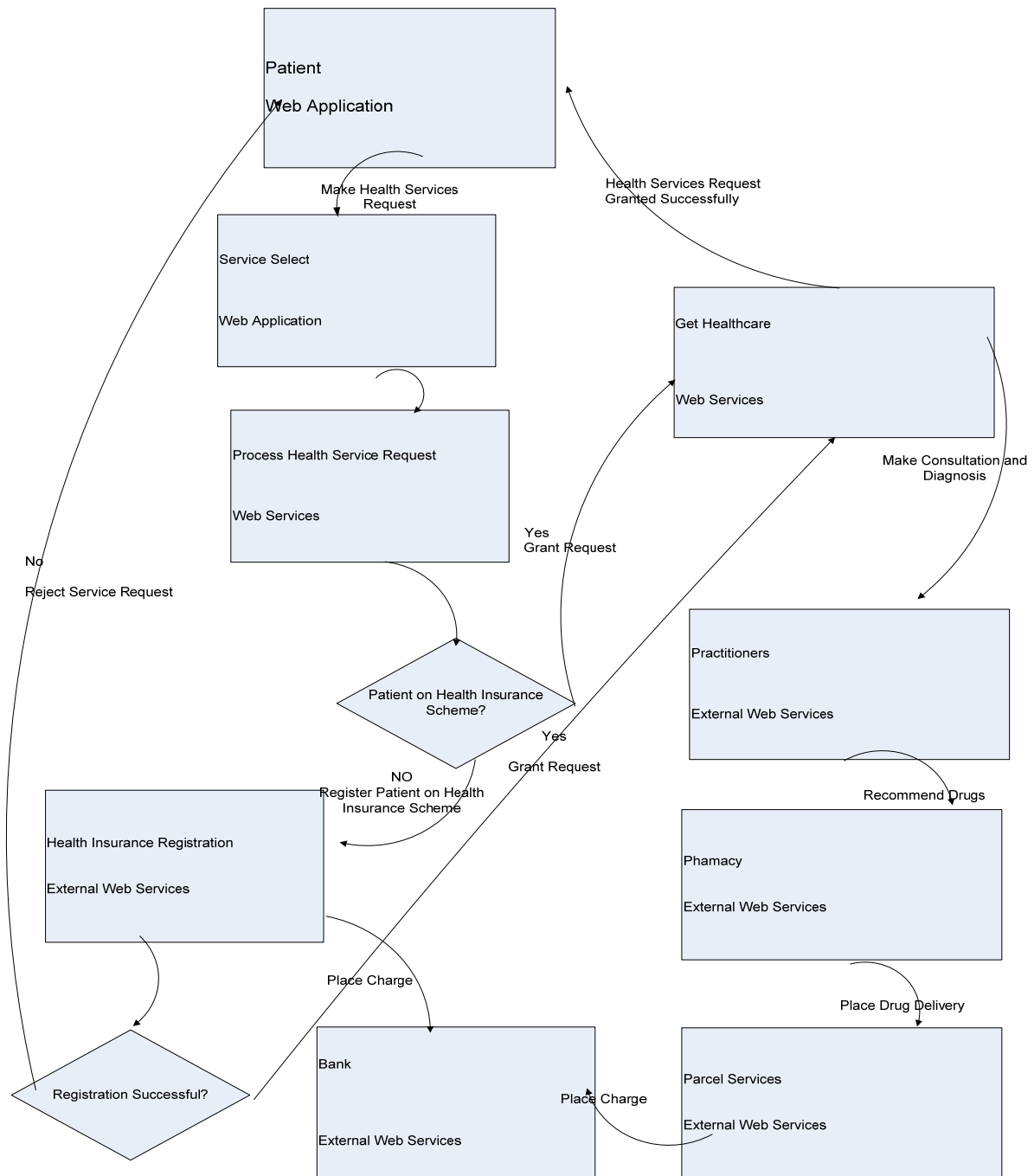


Figure 1: Model of the Proposed Service Oriented E-health Framework

Figure 1 shows the overall system architecture of the proposed infrastructure. The diagram shows how the components are logically and functionally related. The design is such that applications in each module could invoke the services linked to it with or without human intervention. Modules indicated as Web Services would be hosted by our local server while External Web Services may exist as Internet services to be invoked at runtime. The overall functional structure of the framework is summarised as follows: E-health services are automatically detected by user's mobile devices. A patient requests E-health services and selects from the list of services offered. The capability of the patient to pay for service through the National or Regional health insurance scheme is ascertained either by authenticating the user's credentials in the health insurance database or by registering him/her as a new insurance holder. If the patient is not registered and cannot be newly registered on the health insurance scheme, the request for e-health services is rejected. If insurance authentication is valid, the e-health service is granted. The e-health services could be as simple as a patient-doctor consultation interaction and drug recommendation and delivery from the pharmacy to the patient's doorstep (the parcel delivery services handles this). Services could involve some other healthcare practitioners such as medical laboratory diagnosis. In this case the patient would have to visit a medical lab or the service is brought to him. The results of any such secondary care would be loaded to patient's online medical record to enable next level of medical care. It is assumed that patient's medical history is available for anywhere/anytime access to facilitate the healthcare services.

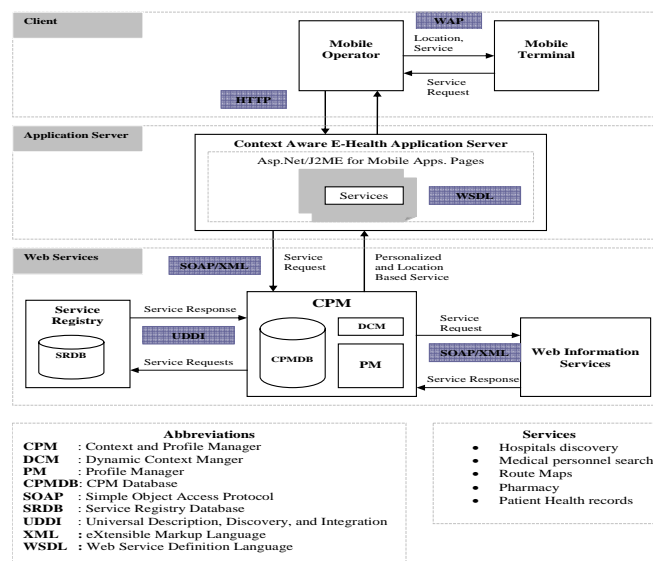
ii. Application Framework Overview

In Figure 2, the overview of the context-aware application is presented. It gives a visual representation of the functional relation of the system components. The architecture for the research infrastructure is based on existing architectures. It is based on the traditional mode of data transfer on mobile phone which involves the use of the 2.5G and the 3G technologies. Semantic web services is incorporated as a novel technology.

Requirement Specification

From the architecture, there are four main components required for the full development and implementation of the architecture:

- **Mobile Terminal:** The mobile application resides on the mobile terminal using both its memory and processing power.
- **Mobile Operator:** The mobile operator is responsible for providing the General Packet Radio Service (GPRS), which the mobile terminal uses in transferring its data.
- **Application Server:** The application server is responsible for the following:
 - Authentication and authorization.
 - Context extraction.
 - Message switching and transfer.
- **Service Registry:** The service registry is responsible for keeping the database and monitors it.

**Figure 2: Overview of Application Framework**
(Adapted from [16])

Application System Modelling

The model is designed to suit the architecture and the requirements. The application server component is responsible for the message switching and transfer, authentication and authorization. The model is divided into three tiers, which is the mobile device, application server and the service registry.

Client Tier

The client tier consists of the mobile device and the mobile network operator. The mobile device

lodges the mobile application allowing it to interact with the server side using the GPRS service provided by the mobile network operator.

Application Server Tier

The application server tier consist of the MEDICA Application server which is responsible for the execution of requests from the client side, processing it and sending the response to the client tier.

Web Services Tier

The web service tier consists of the service registry which manages the health database majorly for authentication and authorization.

iii. The Use Case Analysis of the Model

The structure of the proposed model can be identified using the model analysis which includes use-case diagram, class-based elements, and the behavioral elements. The use-case scenario of the infrastructure to be developed in this research is presented in Figure 3 showing the application server, class activity for the service registry and the client side.

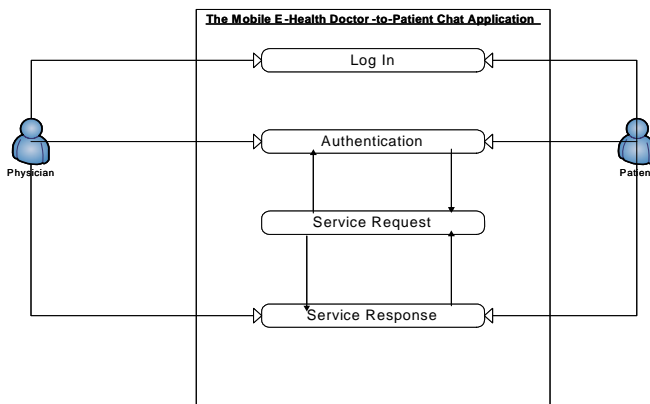


Figure 3: Use Case Diagram for Mobile E-Health Doctor-Patient Chat Application

In Figure 4, there are two main actors within the system: the physician and the patient. The clients logs in to the service and get authenticated, making them ready to request services and receive responses.

iv. Message Flow Diagram

The infrastructural message flow diagram is shown in Figure 4. The mobile operator provides the GPRS service for the mobile terminals (the physician and the patient). When the user logs in,

the user information and context are sent to the application server, which lodges the web applications (servlets and server pages) for authorization and authentication. After the user has been authenticated, the user is eligible to request service and send messages. The application server switches the message from the user to another user (from a patient to a physician).

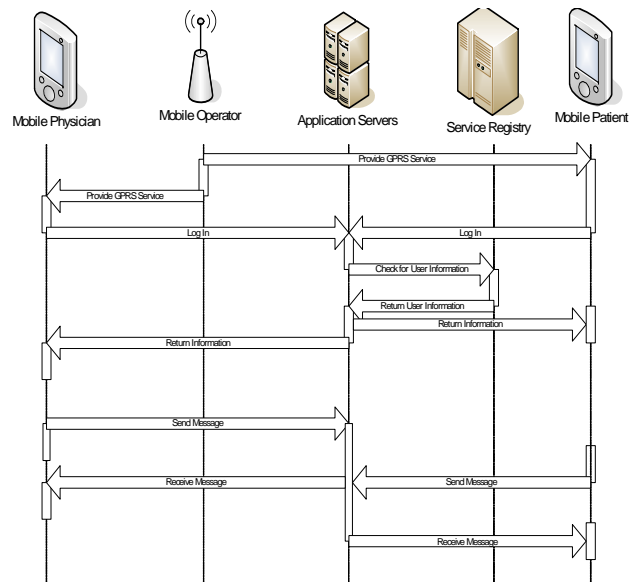


Figure 4: Message Flow Diagram

5. EXPERIMENTAL SYSTEM IMPLEMENTATION

Presented here is the result of an experimental Patient-Doctor interactive mobile application deployed on our proposed framework.

The Application Clients

The client side is divided into two main sides:

- The Physician Suite
- The Patient Suite

These two sides follow the same principles in their operation but different in some aspects such as connection mode, data security and the interface.

The Physician suite is designed for the physician such that the physician can provide medical advice, diagnosis and prescriptions.

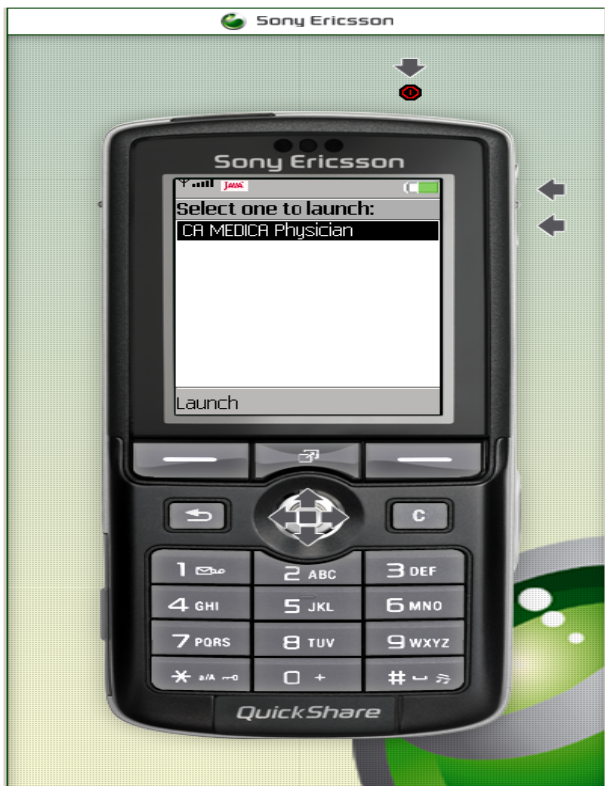


Figure 5: The Mobile Physician Suite on a Sony Ericsson K750i Emulator

The suite implements the following protocols:

- The Log In Protocol
- The Message Protocol

The Log in Protocol

The Physician suite log in to the server supplying valuable information such as; the username, the ID, the password and the context settings. This information is sent to the server via HTTP request to the server for authentication, validation, storage and acknowledgement.

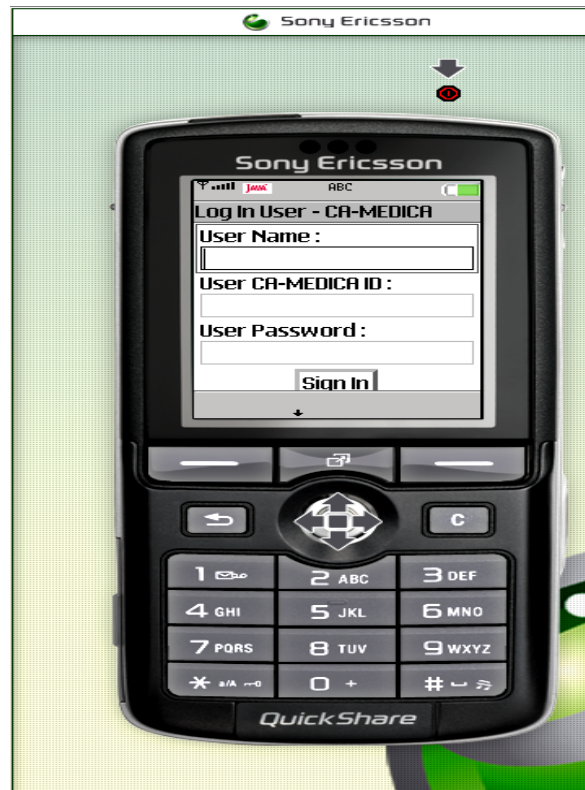


Figure 6: The Mobile Physician Suite Log in Page

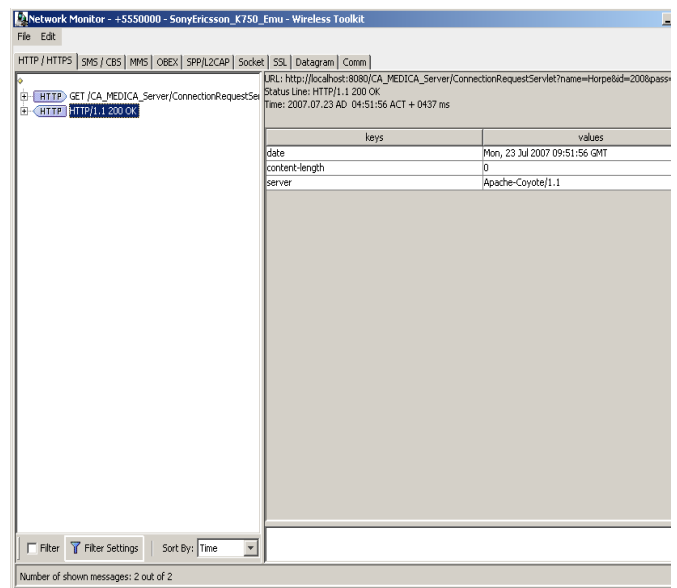


Figure 7: An HTTP Network Monitor showing connection success

The Message Protocol

This protocol send message to the server via HTTP requests and the reception of the message sent acknowledged.



Figure 8: The Chat Centre Page

The request is acknowledged with the message in the inbox, provided there is a message, if not, the request rejected.



Figure 10: The Physician Suite receiving messages from a patient

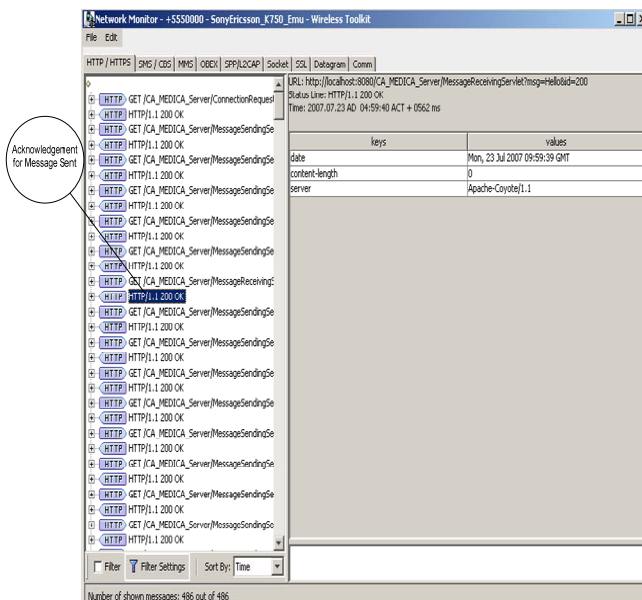


Figure 9: An HTTP monitor showing message sending protocol

The protocol also time sends out request to the server requesting message in the client's inbox.

The Patient Suite is designed for patient to request medical advice from the physician. The suite also implements protocols just like the physician suite

The patient suite log in to the server using the user name, the ID and the password.

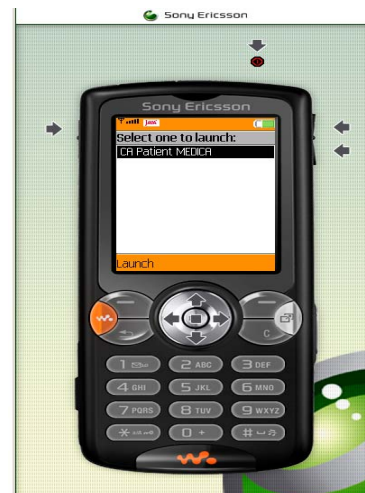


Figure 11: The Patient Suite



6. CONCLUSION AND FUTURE WORKS

This research has design a framework for a context aware mobile e-health services. Some experimental mobile applications have been developed based on the framework. A new insight into e-health application with a shift in paradigm from the generic use of videoconferencing and ISDN lines or broadband internet with no context aware content has been proposed. This research will provide a novel solution to e-health care delivery services for indigenous African communities as the mobile devices are more affordable than the PC technology to an average low income earning African. The next direction in this research is to get into partnership with sponsoring healthcare and government organizations to realize live implementation of software solutions developed in this research. The systems will then be deployed for practical usage in some selected rural/suburban African communities starting in Nigeria. Comments on this research, suggestions to refine the process, and suggestions for specific system architectures, operational concepts and grand strategies to consider in the research are invited.

REFERENCES

- [1] Adesina Iluyemi, (2007) *Mobile/Wireless eHealth for Health System/Workers development in Africa: Opportunities for eMobility ETP* Being a paper presented at eMobility Mobile Communications & Technology Platform Staying ahead! 2nd Workshop on Shaping the Future of Mobile and Wireless Communications Rome, Italy, September 25 2007.
- [2] Adigun M.O., (2007) *ICT Infrastructure for Electronic Commerce and Services: A Case Study of Rural SMEs in South Africa*, Department of Computer Science, University of Zululand, Presented at the Second International Conference on Application of Information Technologies to Teaching, Research and Administration, September 2007, at Obafemi Awolowo University, Ile-Ife, Nigeria.
- [3] Air2Web, (2002) "The Possibilities of Wireless Healthcare", Whitepaper, Ed., 2002.
- [4] www.ehealthonline.org.
- [5] Alonso G., F. Casati, H. Kuno, and V. Machiraju, (2004) *Web Services: Concepts, Architecture and Applications*, Springer Verlag, 2004, available, ISBN 3-540-44008-9.
- [6] Cerizza D. (2006) "Towards European Patient Summaries Based on Tripple Space Computing", A workshop paper @ in Proc. Of 1st European eHealth Conference 2006
- [7] Della E. Valle, D. Cerri, A. Ghioni, and D. Cerizza (2006) *Seamlessly and Securely sharing health care data with Triple Space Communication*, The Int'l Trade Event and Conf. for eHealth, Telemedicine and Health ICT (Med-e-Tel), Luxemburg, 5-7 April 2006.
- [8] Della E. Valle, D. Cerri, A. Ghioni, D. Cerizza. (2006) *Triple Space Communication an infrastructure for seamlessly and securely sharing healthcare data*. In the Official Journal of the European Association of Hospital Managers, November 2006.
- [9] Emanuele Della Valle, Dario Cerizza, Reto Krummenacher, Lyndon J. B. Nixon, Elena Paslaru-Bontas Simperl and Doug Foxvog, (2006) *A proposal for Building the European Patient Summary using Triple Space Computing* Workshop for W3C Semantic Web Health Care & Life Sciences; International Semantic Web Conference (ISWC) Athens Georgia Nov 6 2006.
- [10] Eichelberg M., T. Aden, J. Riesmeier, A. Dogac, and G. Laleci, (2005) *A Survey and Analysis of Electronic Healthcare Record Standards*, ACM Computing Surveys, December 2005, Vol. N 20YY pp. 1-47.
- [11] Emuoyibofarhe O. Justice, (2007) *E-Health: Research and Development Issues in Developing Countries* Context Business Opportunities and Prospects eHealth Seminar Presented at Faculty of Engineering and Technology LAUTECH Ogbomoso July 31 2007
- [12] Fortunov Ilia, (2006) *Connected Healthcare Framework: A Stable Foundation for Agile Healthcare* © 2006 Microsoft Corporation
- [13] David P. McClure, (2007) *e-Health and America's Broadband Networks An Examination of How Broadband Services Enhance Health Care In America*, A publication of US Internet Industry Association, August 14, 2007



- [14] <http://www.gov.ns.ca/nsarm/star/primary.asp?prm>
- [15] <http://www.VisionaryMed.com>
- [16] Krummenacher R., E. Simperl, L. Nixon, D. Cerizza, E. Della Valle, (2007) *Enabling the European Patient Summary Through Triplespaces* In 20th IEEE International Symposium on COMPUTER-BASED MEDICAL SYSTEMS, Maribor, Slovenia, June 20-22, 2007
- [17] Mishra S.K., (2007), “‘E’ for Excellence; ‘e’ for Health”, eHealth Vol. 2 No.1, pp. 36-37, January 2007
- [18] Maurice Mars, (2007) *Sub-Saharan Africa: Is Telemedicine A Viable Solution ?*, A Seminar paper presented at Nelson R Mandela School of Medicine, University of KwaZulu-Natal, South Africa, 2007
- [19] Motsamai Modise, (2006) *Development of a Context Aware Tourist Application Server*, Being an M.Sc. Thesis submitted to the Department of Computer Science, Faculty of Science and Agriculture, University of Zululand, KwaDlangezwa, 3886, R. S. A., December, 2006
- [20] Ross P., "Managing Care through the Air", *IEEE Spectrum*, pp. 26-31, 2004.
- [21] Tachakra S., X. Wang, R. Istepanian, and Y. Song, (2003) "Mobile e-Health: the Unwired Evolution of Telemedicine", *Telemedicine Journal and e-Health*, vol. 9, pp. 247-257, 2003.
- [22] www.ehealthonline.org, (2008), “*Novel wireless application goes live 13 October 2008*”
[http://www.ehealthonline.org/news/news-details.asp?News=News=Novel wireless-application-goes-live&NewsID=15621](http://www.ehealthonline.org/news/news-details.asp?News=News=Novel_wireless-application-goes-live&NewsID=15621)
- [23] Nixon L., E. Simperl, D. Cerizza, E. Della Valle and R. Krummenacher, (2007) *Enabling Collaborative eHealth Through Triplespace Computing* In the 16th IEEE International Workshops on Enabling Technologies: Infrastructures for Collaborative Enterprises (WETICE), Workshop on Interdisciplinary Aspects of Coordination Applied to Pervasive Environments: Models and Applications (CoMA), Paris, France, June 18-20, 2007.

