DESIGN OF A CONCEPTUAL FRAMEWORK FOR A MEDICAL TELE-MANAGEMENT SYSTEM (MTMS) IN RESOURCE-CONSTRAINED SETTINGS

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ABSTRACT

Medical tele-management is an emerging field of study in tele-health that proposes an interactive and proactive disease management approach which combines tele-monitoring and tele-consultation services through an information and communications technology (ICT) supported partnership. It is aimed at minimizing the burden of health management both for the patient and physician, especially in developing countries. However, existing solutions in form of systems and frameworks exist singly either as tele-monitoring or tele-consultation systems and majorly in developed countries with dedicated and adequate ICT resources and infrastructure. Hence, this paper presents the design of a Medical Tele-Management System (MTMS) which serves as a framework that combines both tele-monitoring and tele-consultation services within an information and communication technology resource-constrained setting.

Keywords- *Medical tele-management, resource-constrained, service-oriented computing, tele-monitoring, tele-consultation.*

INTRODUCTION

The emergence of telemedicine has been shown to have potential benefits and tremendous capabilities in bridging the gap of access to quality healthcare services and at the same time reduce cost (Kifle, 2006). Telemedicine covers a wide range of applications in areas such as Tele-consultation, Tele-monitoring, Tele-education, Tele-management (combination of Tele-monitoring and Teleconsultation), Tele-Oncology, Tele-dermatology, Tele-Ophthalmology and Tele-Radiology (Malindi, 2011).

Medical tele-management is the combination of tele-monitoring and tele-consultation services for a more robust healthcare service package (Perakis and Koutsouris, 2009). The synergy of both services offers the possibility to continuously monitor outpatients with chronic conditions for proper post-treatment management to avoid relapse and a deteriorating health condition and at the same time provide a platform where health workers/professionals in rural settlements can consult or interact with their counterparts in urban areas.

The advent of the internet, mobile wireless communication, and all other related enabling technologies have served as a platform for various information and communication technologies (ICT) service deliveries which have now resulted in the "e" (electronic) and "m" (mobile) computing paradigms. These paradigms have become the major drivers in business (as in e-business, e-commerce), banking (m-banking, e-banking) and education (e-learning), etc. The healthcare sector is not left out in this information revolution as we have concepts like e-health, m-health, and telemedicine. However, it has not enjoyed significant application of ICT (unlike the e-commerce and e-business), especially in most developing nations due to its stringent requirements in terms of dedicated ICT resources.

Studies have reported that most developing countries are characterized by inadequate network resources (Malindi, 2011; Kifle, 2006) like poor telecommunications infrastructure such as bandwidth (Bashshur, Shannon and Sapci, 2005), impact of the internet (Mbarika, 2005) and hence are said to be resource-constrained. Mobile phones are suitable as they are cheaper than personal computers (PCs) and they require minimal technical know-how (Kappiarukudil and Ramesh, 2010).

The following are research challenges identified, among others, in existing standard telemedicine frameworks and systems (López-García *et al*, 2010; King, 2009; Zhang, Thurow and Stoll 2014):

Non-flexibility of knowledge representation: knowledge models are tightly coupled to technology such that the addition of a new parameter such as a monitoring sensor would demand a total re-design and implementation of some sub systems.

Also, most of the existing frameworks, architectures, models and systems that serve as solution to the problem of access to and quality of healthcare services exist singly either as monitoring or consultation systems making them inadequate to effectively manage patients with chronic health conditions especially in emergencies.

In order to solve these problems, this research designed a multi-tier architectural framework and model of the medical tele-management system using the domain driven design concept, thereby giving rise to a solution that can harness the strengths of both tele-monitoring and tele-consultation services and also leverage on the ubiquity of the mobile devices. In addition, the focus of this research was to use ICT not only to provide clinical services/resources to a widely underserved patient population, but more importantly to improve the quality and continuity of care by developing a robust system capable of bridging the gap between health care providers and patients and at the same time alleviating the isolation of rural health workers.

Hence, this research presents a framework for a system that allows real-time monitoring and tele-consultation sessions, particularly in low-resource settings.

RELATED WORKS

Malindi (2007) developed a framework for providing quality video in a rural telemedicine system. The research solved the problem of transmission of telemedicine videos even in rural settings where infrastructure and ICT resources are low. However, the problem of mobility was still left unsolved and so, future work suggested that the study should incorporate mobility in order to accommodate those health professionals who are not always static, like paramedics who most of the time are in ambulances on the road with patients, so that the physician can start diagnosing the patient while still on the way to the hospital. Furthermore, Malindi's research could not be used to remotely monitor patients as it is essentially a tele-consultation tool restricted to physicians.

Oladosu, Emuoyibofarhe, Ojo, and Adigun, (2009) developed a "framework for a context-aware mobile e-health service discovery infrastructure". The framework was to provide semantic e-health services deployed through wireless mobile platforms in rural and suburban areas. While the implementation of this framework helped to solve the problem of mobility, issues such as remote monitoring, video conferencing and knowledge sharing were not addressed.

Zhang, Thurow and Stoll (2014) developed a knowledge-based telemonitoring system for remote health care to address the problem of scalability using context-aware middleware. This was to ensure that a new sensor device can be easily added to the system with relative ease. However, this solution was not adequate enough as it gave rise to further problem of context conflicts in the process of constructing ontologies and reasoning conditions.

Mugoh and Kahonge (2015) developed a telemedicine system for the management of blood pressure (BP) among hypertensive patients. The beauty of this system is that it is mobile-phone based such that patients can transmit their BP condition to the doctors from the comfort of their residence using their mobile phones. The telemedicine system achieved an uptime of 98.46%, downtime of 0.37%, reliability score of 0.9 and availability of 99.82%.

However, data collection in this mobile telemedicine system was done manually; patients would have to enter their vital signs (BP readings in this case) to the interface of the mobile application at intervals of the day. Further work suggested automatic transmission of the BP readings from the Wrist BP Monitors to the android application on the mobile phone via Bluetooth technology.

RESEARCH METHODOLOGY

In this paper, a multi-tier service oriented architecture and model was proposed for the medical tele-management system. Domain driven design was employed in developing the multi-tier software architecture and its system model.

A. Framework architecting and model development

Figures 1 and 2 show the overall architecture and model of the developed framework for the proposed medical tele-management system. The diagram displays how the components are functionally and logically related. With special consideration for user roles and activities, as well as scenarios of possible use and users' expectations for such a system, patients and medical practitioners are the intending major users of the system and they can be in any of the possible locations.

A patient can access the system in the comfort of his home, office, market or even on a public transport. This is made possible by the integration of mobility in the design of the system as humans are nomadic in nature. At the core of the framework lies the data center situated in a clinic or just a dedicated data center in a community and accessible by a group of users in that community. In this case, an assisting operator can render help, especially where there needs to be a little more sophistication in the tele-consultation session. These centers then have to be supplied with relatively simple clinical measurement devices necessary to obtain the basic medical data like blood pressure, temperature, pulse rate, weight, etc to support tele-consultation. The role of the staff is to capture data from the patients, send them to the consulting specialist in real-time via the text chat or audio-visual devices.

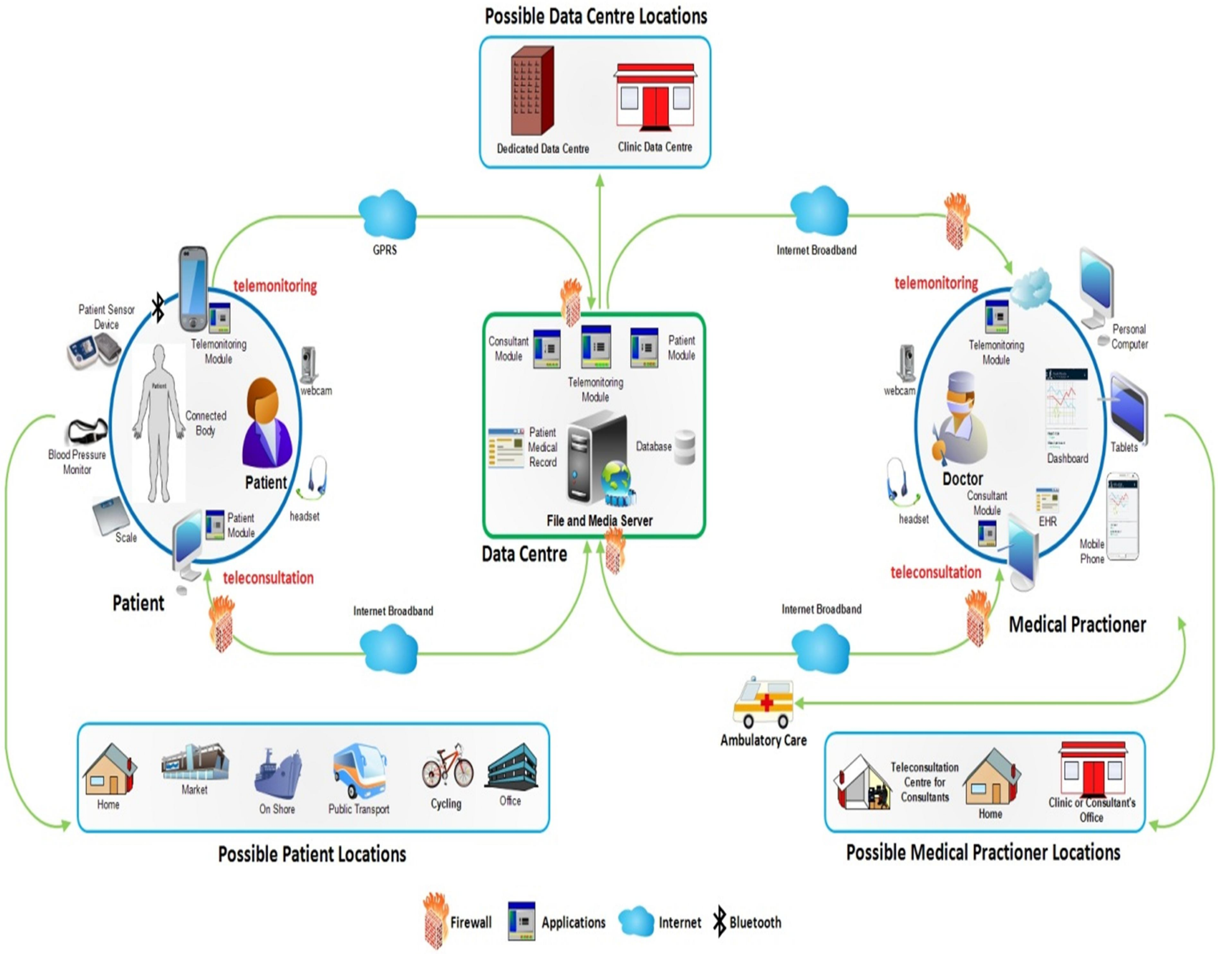

Figure 1: The Tele-management System Architecture

The complete functional structure of the framework is summarized as follows: an eligible system user who can either be a patient or a medical staff will login into the system after registration. The patient uses a Patient ID to log in while the staff uses the staff ID to log in, all of these are communicated to the respective users at the point of registration. If the login is successful, then the system acquires the required permission which confirms whether the person attempting to login in is a staff or a patient. If the user is a staff, the system loads the appropriate modules for the staff like Add/Update Staff Profile and Add/Update Patient Profile Module. If the user is a patient, he/she is presented with an interface to select service type which can either be Tele-monitoring or Tele-consultation.

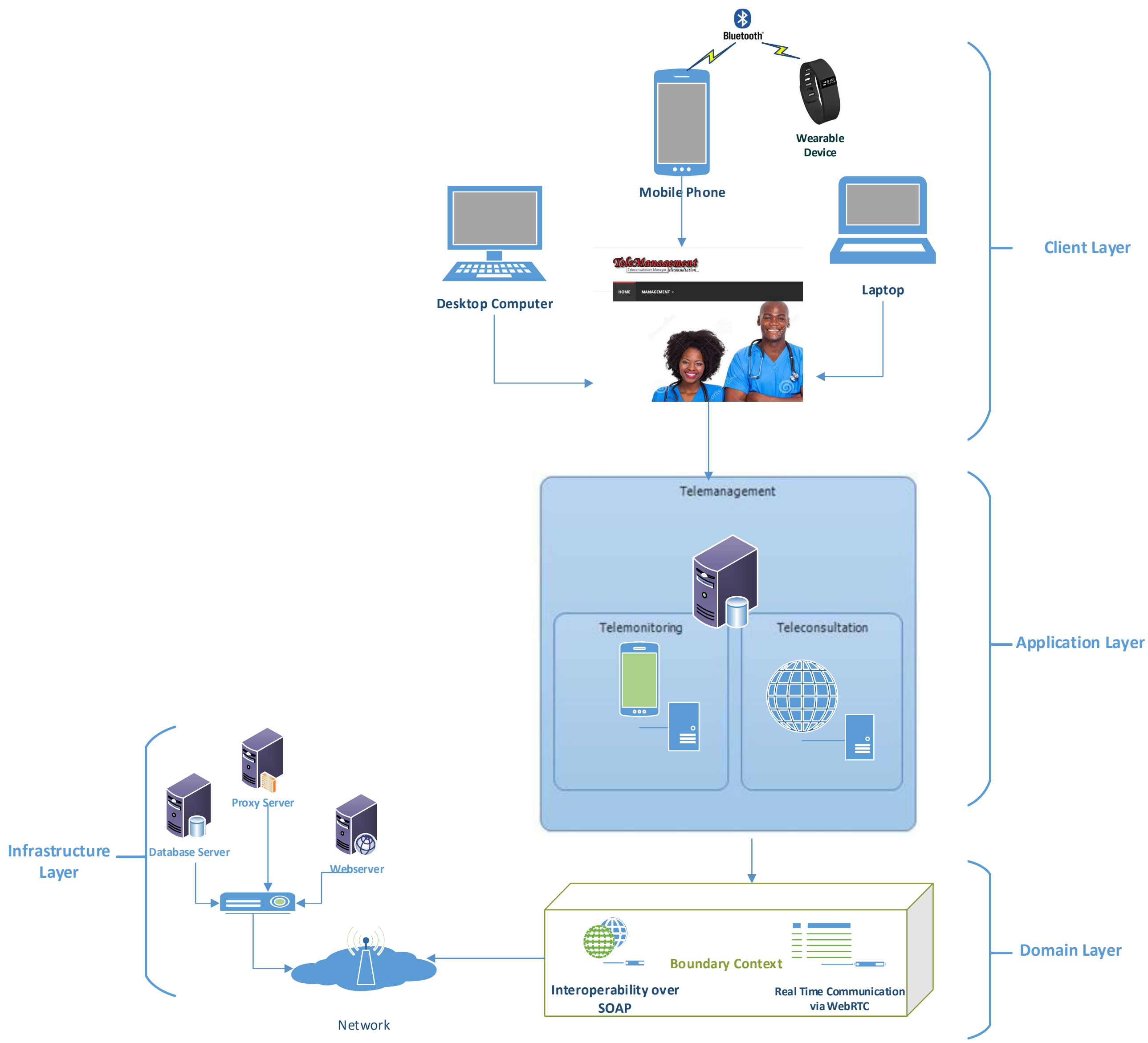

Figure 2: System Model

The framework has been so designed to allow remotely located patients to be monitored. It also allows them to initiate consultation with a physician in another geographical location. The various devices such as the mobile phone, PDA, laptop or even a desktop computer are clients needing a service. Authentication into the system is via patient identification number (patient ID) generated at the point of registration. Authorization is by Role-Based Access Control (RBAC) to specify access rights and privileges to the system. Security considerations were based on the open Secure Socket Layer (SSL) library and Public Key Infrastructure (PKI) management.

The problem of non-flexibility of knowledge models can be solved using the multi-layered domain driven design model. Domain driven design is a software development technique that partitions a complex program into layers with each layer providing loose coupling to the layers above. A typical architectural solution for domain-driven designs contain four conceptual layers which are the: presentation, application, domain and infrastructure layers as shown in Figure 2.

The presentation layer

This can also be referred to as the User Interface layer. The tele-management system can be accessed in two modes, that is, either with the use of a smartphone or a personal computer. This tier is responsible for displaying and presenting information to the user and interpreting user commands across smart mobile devices and personal computers. Here, the browsers on the access devices would be responsible for presenting the markup from the web server as web forms. The presentation layer has codes capable of rendering JSP pages to mobile devices and ASP pages to the PCs.

The application layer

The application layer is thin in terms of domain logic - it harmonizes all the objects of the domain layer to execute the actual work. It holds all the application codes and logic responsible for the execution, processing and sending of requests from clients. This is made possible using service-oriented architecture, and particularly, the simple object access protocol (SOAP). The applications supported by this layer are essentially the tele-monitoring, tele-consultation and EMR applications.

The domain layer

It is the heart of the software because it contains the business rules and logic as well as represents concepts in the problem domain. It is also responsible for the interoperability of the system with web services and other systems. This layer is composed of the various classes, aggregates, methods and repositories built.

The infrastructure layer

Contains code related to data and network access. This layer is composed of everything that exists independent of the application such as external libraries, database server, application server, web server and proxy server. This layer also acts as a supporting library for all the other layers. Without it, the system would not be able to run successfully on implementation.

B. Devices used to achieve medical tele-management

For the tele-monitoring aspect of this work, two (2) biomedical sensing devices would be used, they are: Blood Pressure Monitor by A&D and Fit bit charge HR device. The blood pressure monitor would be used to measure the blood pressure of the patient. Very high or low blood pressures suggest imminent danger upon the patient under tele-monitoring and it is measured in millimeters of mercury (mmHg). The Fit bit device senses patients' vital signs like the heart rate measured in beats per minute (bpm). It is also capable of measuring the activity level and sleep rate of the monitored patients. The readings would be communicated at periodic intervals to the mobile phone via the Bluetooth protocol and further transmitted to the medical server; the devices are as shown in Figures 3a and b respectively.

The tele-consultation aspect of this work would be experimented and achieved in two modes. The first mode is through the use of the inbuilt webcam and internal microphone of the personal computer. The second mode is the use of external device like the two-way audio surveillance camera by TP-LINK whose diagram is as shown in Figure 3c. This second mode is necessary to cater for desktop systems and monitors without webcams. The 2-Way Audio Surveillance Camera (TL-SC3130) is such that it allows two clients to connect, rendering both audio and visual functionalities which are used to facilitate tele-consultation. The client on one end connects to the user camera, and the user also connects to the client's camera, each using the other's IP address to connect.

Fig 3(a) and (b): The acquired blood pressure monitor (UA-767-PBTCi) and Fit bit ChargeHR (FB405) respectively

Figure 3(c): 2-Way audio surveillance camera (TL-SC3130)

CONCLUSION AND FUTURE WORK

In this paper, we have been able to design a conceptual framework for a medical tele-management system which is characterized by both tele-monitoring and tele-consultation services in real-time. Other advantages include flexibility of knowledge models thereby supporting scalability. The system can be adopted for remote health management of patients with multiple chronic diseases. It is recommended that future work may be geared towards implementing the developed framework and model with live data and evaluating the performance of the medical tele-management system.

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