A Cloud Computing Based Platform for Sleep Behavior and Chronic Diseases Collaborative Research

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A Cloud Computing Based Platform for Sleep Behavior and Chronic Diseases Collaborative Research

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Abstract. The objective of this study is to propose a Cloud Computing based platform for sleep behavior and chronic disease collaborative research. The platform consists of two main components: (1) a sensing bed sheet with textile sensors to automatically record patient's sleep behaviors and vital signs, and (2) a service-oriented cloud computing architecture (SOCCA) that provides a data repository and allows for sharing and analysis of collected data. Also, we describe our systematic approach to implementing the SOCCA. We believe that the new cloud-based platform can provide nurse and other health professional researchers located in differing geographic locations with a cost effective, flexible, secure and privacy-preserved research environment.

Keywords. Cloud Computing, Service Oriented Architecture, Health Information Technology, Sleep Behavior

Introduction

Managing chronic disease is a large and growing problem for healthcare administrators in many countries around the world [1]. The mortality and morbidity associated with a chronic disease places a significant economic burden on countries. An American Diabetes Association report has shown diabetes management could cost the U.S. over $245 billion [2]. In Canada, the leading causes of death are often related to chronic illnesses. The costs associated with managing chronic diseases is estimated to be $80 billion annually, and these costs are expected to rise [3].

There are many factors that contribute to exacerbations of chronic disease. Numerous publications have demonstrated that sleep disorders are significant confounding factors in the interpretation of health effects among patients with chronic diseases [4-6]. Early discovery and effective treatment of poor sleep can improve chronic disease management. As well, collecting sleep behavior information from people with chronic diseases can provide specialists/experts with better understanding of the relationship between a chronic disease and sleep behaviors. For example, how

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does sleep behavior change prior to an asthma attack; what is the relation of sleep behavior to other chronic diseases such as COPD, heart disease and diabetes etc.

Unfortunately, a typical hospital or home setting does not provide easy access to continuous sleep recording instrumentation and equipment. Data collection and analysis of a patient's sleep behavior is often done manually. A typical process is as follows: (1) a nurse records a patient's sleep behaviors, respiratory symptoms (e.g. cough, rapid breathing, disturbed respiration) and vital signs using a paper documentation sheet (e.g. a spreadsheet); (2) the recorded notes are later transmitted to a database server through a data entering interface (such as an electronic health record); (3) the data is then manually transformed and integrated into an appropriate format for subsequent data analysis; (4) nurse and other health professional sleep behavior researchers need to go to a lab/computer room to access data/analysis tools through an interface application.

It is clear that this process is labor intensive for a nurse as it involves work to collect, input and transform the information. This process can be slow and error prone. Moreover, when data collection and analysis is involved in different geographic locations and a large number of participants (e.g. patients, nurses, other health professionals and researchers), the process needs a lot of manpower and becomes costly as well as cumbersome. Finally, the data process architecture usually uses laboratory-hosted servers in a distributed environment for data storage and analysis. This type of architecture has several drawbacks such as high IT maintenance costs and difficulty in integrating diverse types of data, software and hardware.

Many nursing and health informatics experts recognize that introducing Health Information Technology (HIT) for the purpose of health data collection and management will cut soaring costs and improve efficiency. Having this in mind, the aim of this paper is to propose a Cloud Computing based platform for distributed collection and analysis of chronic disease information and sleep behavior data for the purpose of engaging in collaborative research. The study focuses on remotely collecting sleep behavior information in older, chronically ill adults who have been diagnosed with a chronic disease(s). We have designed a sensing bed with textile sensors that can automatically detect a patient's vital signs as well as collect data about sleep behaviors. Then, a service-oriented architecture (SOA) is proposed for a data repository and sharing in a cloud computing environment.

The rest of the paper is organized as follows. Section 1 reviews previous related works. Section 2 presents our proposed service-oriented cloud computing architecture. Section 3 describes the proof-of-concept design. Finally, we conclude the study and discuss our future work in section 4.

1. Review of the Literature

According to the U.S. National Institute of Standards and Technology (NIST) definition [7]: "Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service-provider interaction". From a service point of view, cloud computing includes three archetypal models: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). To deploy cloud computing, NIST listed four models: public cloud, private cloud, community cloud and hybrid cloud. The main advantages of adopting

cloud computing for HIT service and research are that it provides a wide range of computing resources on demand anywhere and anytime, and eliminates any up-front commitment by cloud users thereby allowing users to pay for use of computing resources on a short-term as needed basis. This approach dramatically reduces new IT infrastructure and maintenance costs for users.

Previous studies have reported on the application of cloud computing to improve healthcare services and research. For example, Rolim et al. [8] proposed a cloud based system to automate the process of collecting a patient's vital signs data via a network of sensors connected to legacy medical devices, and to deliver the data to a medical center's "cloud" for storage, processing, and distribution. The main benefits of the system are that it provides 7 day a week real-time data collection and has eliminated the need for manual collection work and the possibility of introducing typing errors, in addition to easing the deployment process. Nkosi and Mekuria [9] described a cloud computing protocol management system, which provides a multimedia sensor signal-processing and security service to mobile devices. The system has relieved mobile devices from executing heavier multimedia and security algorithms in delivering mobile health services. According to the researchers, this will lead to improved utilization of ubiquitous mobile devices for societal services and will promote health service delivery to marginalized rural communities. Rao et al. [10] reported a pervasive cloud initiative called "Dhatri" which leveraged the power of cloud computing and wireless technologies and has enabled physicians to access a patient's health information anytime and anywhere. Reddy et al. [11] proposed a Health Monitoring System to collect a patient's health data from various sources and publish them to a cloud based Telemedicine Repository. This system is supported by conferencing capabilities between remote patients and medical practitioners in different hospitals. More recently, Kuo et al. [12] developed a cost effective, flexible, secure and privacy-preserved cloud based platform for researchers in different geographic locations to allow for exploration of diverse medical data for liver cancer research via the Internet.

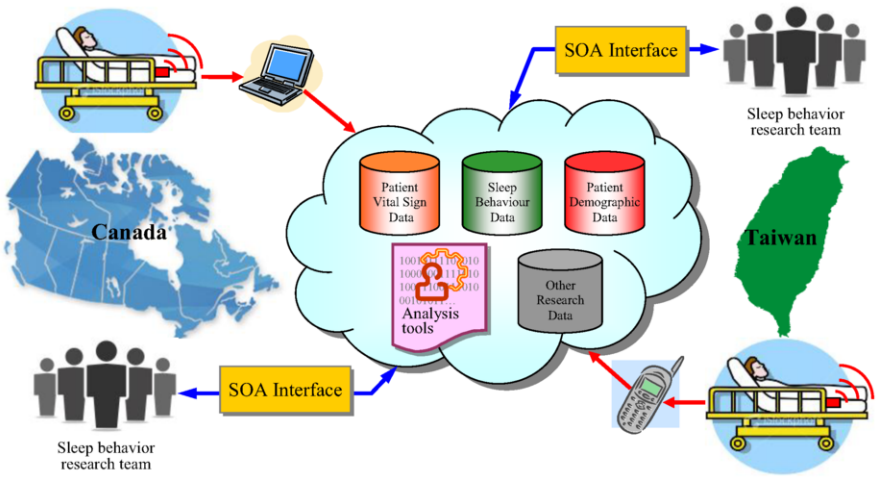

Figure 1. The cloud computing based collaborative research platform architecture

2. The Cloud Computing Based Collaborative Research Platform

The proposed collaborative research platform consists of two main components as shown in Figure 1: (1) a sensing bed sheet with textile sensors to automatically record patient's sleep behaviors and vital signs, and (2) a service-oriented cloud computing architecture (SOCCA) for data repository, sharing and analysis.

(1) The Textile Sensor Bed Sheet

We designed a sensing bed sheet with textile sensors to automatically record patient's vital signs, bed/wake up time, sleep duration, and variation of sleep positions [13]. There are many ribbons fixed on the bed sheet, and a control box is mounted on the bed. Each ribbon has a sensor on it, and the sensor has an independent input port that connects to a micro processer for further signal analysis and transmission to a mobile phone (through Bluetooth) or PC (via USB). For example, in Figure 2, the red dots represent the textile sensors. On the vertical there are 3 ribbons and on the horizontal there are 3 ribbons. Each ribbon has a sensor (red dot). When the ribbon is pulled upon by human weight, the sensor detects different signals indicating the patient's different sleep positions as well as vital signs. Those signals are then sent to a remote data controller through Internet or via a cell phone. The sensing bed is similar to a traditional bed. It doesn't place a sensor on the patient's body so the patient is kept comfortable.

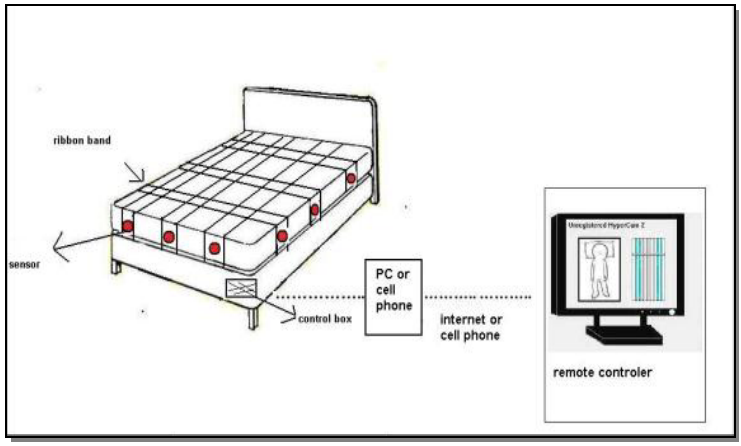

Figure 2. The textile sensor bed sheet and communication components

(2) The Service-Oriented Cloud Computing Architecture

Service Oriented Architecture (SOA) is an application architecture where all information services are defined using a description language that is called to perform a business process. Each (program) interaction is independent on every other interaction and the interconnect protocols of the communicating devices. In other words, the infrastructure components that determine the communication system does not affect the interfaces. As the interfaces are platform-independent, users can access computing services using any language in any operating system from any device. In SOA, services can be reused across multiple applications, thus providing savings and improved ability

to make changes faster and more cost effective. On the other hand, cloud computing is about providing ease of access to and usage of services. SOA and cloud computing share many common principles, but also differ significantly in their role in IT architecture. Given these differences, SOA and cloud computing complement each other very well.

In our collaborative research, the same study environment (textile sensor bed sheets, smart phones, PCs) will be built in both Taiwan and Canada. The two parties will share the collected data and applications through the cloud computing architecture. If healthcare providers or researchers want to access remote resources (e.g. collected data or applications), they just request web services through the SOA standards-based interface by applying web standard languages such as Extensible Markup Language (XML), Web Service Definition Language (WSDL), Simple Object Access Protocol (SOAP), and Universal Description Discovery and Integration (UDDI) [14] .

The simple scenario in Figure 3 shows how to apply the architecture for information services. In this scenario, a chronic disease specialist in Canada uses his iPad to query a patient's demographics information and health status (vital signs); a telehealth nurse in Taiwan uses a smart phone to query how many hours of sleep the same patient has on a certain day (e.g. 15/09/2013); and a sleep behavior researcher in Canada uses his lap top computer to determine if there is a correlation between sleep hours and health status of the patient. Querying patient demographic information, vital signs, sleep hours and associated data are defined as (information) services. The specialist's tasks involve looking at patient demographic information and vital signs using the query service; the telehealth nurse's work requires a sleep hour query service; and the researcher's job involves using the vital signs and sleep hours query service. Using SOA, services are reused by different applications. Applications supporting a specific workflow reference one or more services, and each service communicates with the systems/databases to which it is related. Thus the main benefit of the SOCCA is that users no longer need to switch between systems to complete a workflow, and data is naturally synchronized across processes and supporting systems when conducting international research.

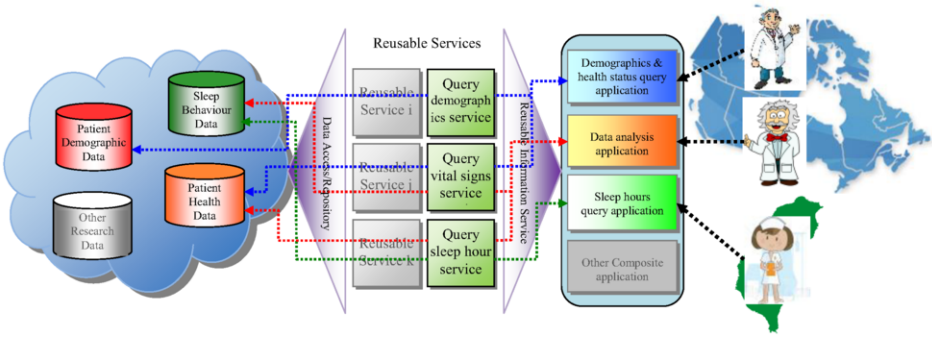

Figure 3. The SOCCA service workflow

3. The Implementation Approach

We modify the cloud computing strategic planning model proposed by Kuo [15] for accessing cloud computing services. The service accessing process includes four steps:

Step 1. Identify the service requirement

This step is to analyze the current status of the research data collection, sharing and analysis process, and identifies the fundamental objective of service improvement. The analysis provides us with a well-defined scope for the process problem being faced and what cloud service (SaaS, PaaS or IaaS) is suitable for process improvement.

Step 2. Select a cloud provider

Choosing a proper cloud provider is the most important part of a cloud implementation plan. Different providers may offer different service models, pricing schemes, audit procedures, and privacy and security policies. This study will compare different offerings and evaluate the provider's reputation and performance. Also, the provider should be able to give assurances of the quality of the service and follow sound privacy, security, legal practices and regulations. In this step, a cloud deployment model (private, public, community or hybrid) will be determined, too.

Step 3. Evaluate and deal with cloud challenges

Kuo's study [16] indicated many potential challenges for undertaking cloud projects. This step will use the potential challenges as indicators to evaluate the new architecture. Among the cloud challenges, data security and privacy are the main concerns. Cloud computing is a shared resource with a multi-tenancy environment for capacity, storage and network. The centralized storage and shared tenancy of physical space mean that sensitive data may be subject to malicious hacking. Also, most cloud providers replicate users' data in multiple jurisdictions. This increases data redundancy and independence from system failure and provides a level of disaster recovery. Nevertheless, each jurisdiction may have different laws regarding data security, privacy, usage, and intellectual property. Those regulations could make a great impact on a cloud application. Fortunately, many references are available for handling security and privacy issues [16-18].

Step 4. Follow-up

The last step is to evaluate the new architecture's performance based on the pre-defined performance indicators. We will set up performance indicators and targets beforehand, and the service quality of the new architecture is measured against the performance indicators. If the new service condition is not satisfied, we will review what facts hinder objective achievement, and propose methods to improve the SOCCA.

4. Conclusion

The collection of patient sleep behavior information can provide specialists/experts with a better understanding about sleep behaviors in relation to chronic diseases. Currently, the methods for monitoring and analyzing patient's sleep behavior data are manual or semi-automatic (i.e. some data is collected by hand and other data is collected using medical devices). Cloud computing provides a new way of delivering computing resources and services. Many managers and experts believe that it can improve healthcare services, benefit healthcare research, and change the face of HIT [16]. However, few nursing informatics and health professional researchers have systematically studied the application of cloud computing on health using a distributed, collaborative approach. In this paper, we propose a cloud-based platform for researchers in different geographic locations for sleep behavior data collection and management via the Internet. The main contributions of this study are to:

(1) Propose a new cloud computing architecture for researchers in different geographic locations to allow for easy collection and accessing of data about sleep behavior in patients who have chronic illness.
(2) Present a systematic approach to migrating from traditional to cloud-based services.
(3) Provide a practical international collaboration between academic institutes and healthcare providers.

Future work will involve implementing the cloud computing architecture, and domain experts will be involved to access the usability and workflows emerging from the use of the new model. This should increase the value of our work in that we will be able to determine how generalizable the approach is.

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