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Mobile Healthcare Facility on Smartphone

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ABSTRACT

With advent of smart phones, users now have the power to access information and utilities at ease. In countries such as India, mobile users are growing exponentially. The increasing adoption of mobile apps for day to day activities is becoming inevitable. Therefore, it is now important to explore and evaluate provisioning models that can transform access to health services on smartphones. Traditional methods for deploying services on dedicated infrastructure require high maintenance and cost. Cloud infrastructure, which is gaining acceptance from health care industry, provides a cost effective option to host healthcare services. This cloud offering, when integrated with mobile applications, can create tremendous value for patients. This paper focusses on deploying healthcare services in cloud and enabling access through mobile apps that results in making those services smarter. Further, a light weight cloud based architecture is proposed, that connects mobile apps to health services hosted in cloud. The paper also evaluates test case implementation of cloud based patient diagnostic service that can be accessed from Android based smart phone. Critical factors such as patient's demographics and mobility are considered while designing the services. This proposed mobile implementation can be a key step towards deeper penetration of health care services in developing countries.

Keywords: Smart Healthcare, Cloud Computing, Mobile Applications, Mobility

1. INTRODUCTION

Cloud computing has seeped in some format into everyone's life. Any individual connected to the internet is leveraging the power of cloud either directly or indirectly. Most of the applications accessed via internet are capitalizing on cloud infrastructure. Thus, cloud has brought in a new paradigm under Information and Communication Technology (ICT). Its fundamentals are deeply rooted in Service Oriented Architecture [1] that provides flexibility for creating services based on the need of the consumer. Cloud provides service models such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) [2] that allows consumers to choose from three distinct layers (hardware infrastructure or application platform or readymade softwares). IaaS enables users to access resources (computing power, storage, network, etc.) to host applications and does not need to configure or manage those resources. In other words, the user specifies the infrastructure requirement and rest is taken care by the IaaS provider. Additionally the user is benefited from the pay-as-you-go model with no up-front costs associated. The PaaS model provides a development and deployment platform for running applications in the Cloud. The entire stack from infrastructure software platform is the responsibility of PaaS provider. SaaS model takes computing services to a level whereby users can use utilize readymade software for their business needs. SaaS providers own the entire stack of infrastructure to software applications and also provide tailored software services, need be. The users are charged on usage basis and extremely beneficial for processes that are standard in nature.

Another interesting trend in ICT observed is the growth of smartphone adoption. A study by Smsglobal [3] states that smartphone population will grow to 2 billion worldwide, with growth of 12% from 2015. A recent survey [4] indicates that mobile applications have gained a significant audience among various sections of society due to ease of access. However, due to resource limitations, mobiles are not equipped to perform complex

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time taking operations and store large data sets. Hence combing cloud computing with mobile becomes an ideal proposition, also known as mobile cloud computing [5]. Both computation and storage can be done extensively using cloud infrastructure, while mobile can primarily serve as an interface to display the results.

Though, several utilities can be accessed through mobile apps, the penetration of healthcare services has not been so great. Some healthcare institutions have come up with medical facility that provide preliminary information on smartphones, but these facilities are more informational in nature. Even as health diagnostics and treatment have advanced, the access to such advanced facilities is limited to the hospitals and other healthcare institutions. Patients have to go through a lot of administrative paperwork and commute to avail these facilities. This problem can be solved through the use of smartphones. Healthcare applications designed for smartphones that allow healthcare access to working professionals, aged and disabled patients can be a great boon for them. Such individuals require fast and easy access to services that reduces paperwork and commutation to seek medical treatment. The objective of this paper is to establish smart healthcare application using mobile technology and cloud computing that can provide easy access to such sections of people. This paper proposes cloud based architecture and leverages test case implementation to demonstrate how the users can benefit from such system implementation.

The rest of the paper is organized as follows. Related work in this area is described in section II. Cloud based architecture for healthcare app is presented in section III. Section IV details out the test case implementation and discusses results from performance testing of healthcare services on smartphones. Concluding remarks are given in the section IV.

2. RELATED WORK

Hu et. al. [4] surveyed applications, platforms and system architectures for mobile social network with special emphasis on mobile cloud computing. The paper discusses on the Application Programming Interfaces (APIs) that are commonly used in cloud providers such as Amazon Web Service (AWS). Another interesting work by Lin et. al. [6] which provides system implementation of mobile healthcare apps that analysis and storage of health data. The work focusses on monitoring of physiological data through a smartphone, which connects to different medical detection devices. A cloud database is used to store and analyze physiological data captured from smartphone. The result of analysis provides suitable physical exercises to individuals. Vashist et. al [7] explored latest smart phone based devices and applications to manage personalized healthcare monitoring and management. The use of cloud storage and analysis of healthcare data has been highlighted in the paper. But the interactions between the device applications are not delved into details. Wallis et. al. [8] researched on a specific use case of burn injury emergency care where technology can be leveraged. Smart phone app in conjunction with cloud services assist physicians in their decisions for appropriate treatments. The work is concentrated to a particular section of stakeholders (handling burn injury cases) and does not provide scope of extending it to other healthcare services. Lane et. al [9] have succinctly described and proposed *Backend as a Service* (BaaS) as the superior alternative to some of the existing cloud provisioning models. This work covers features of BaaS and differentiates it from IaaS & PaaS based on offerings. The evaluation provides a logical response to the demand for mobile applications and how to logically bring together individual API driven resources into a loosely couple stack. Costa et. al. [10] addressed recent trends around cloud infrastructure leveraged as backend for mobility solutions. Their work further evaluates mobile backend as a service (MBaaS) from the availability and performance perspective which can provide guidance to system administrators. Though the evaluation of the OpenMobster cloud platform as backend provides insights to failovers and recovery processes, it does not touch upon the impact of such evaluations on mobile services for healthcare.

While the above research papers attempt to establish application models and cloud architectures for healthcare mobile applications, the subjects concentrate on specific problem areas related to healthcare domain. As mobile applications are designed for fast access to services, the practical application scenarios in context to healthcare services that require easy and fast access are not addressed. Das et al [11]proposed an app, MedTravel, which provides mobile healthcare facilities, keeping the users' location as a centre. This paper extends the functionalities of this app with providing diagnostic center facilities also. In this paper, the proposed cloud based architecture explores the advantages of cloud models to simplify provisioning of healthcare services. Further, the architecture takes into account patient needs in defining services that will change the way they interact with healthcare entities such as hospitals and clinics. Also, this paper attempts to highlight application scenarios and interactions that can facilitate activities that are considered cumbersome from both patients' and healthcare providers' perspective.

3. CLOUD BASED ARCHITECTURE FOR HEALTHCARE APP

In research paper [12], a cloud based architecture was proposed for provisioning smart medical services. The architecture consists of four core layers, namely – *Service Presentation, User/Device Management, Service Connector* and *Core Services*, were detailed out with the importance and value that each layer brought to the service paradigm. However the benefit of such implementation can only be realized when the patients can access such services at their ease. This architecture can be extended to mobile applications. This paper proposes a more contextual architecture that focuses on the services that can be provisioned in cloud that can be accessed by users through mobile app. Figure 1 depicts the architecture with interactions with the mobile device. Besides, the sources of these services such as hospitals and clinics need to interact with the services as well. Details on various components of the architecture is as follows.

- **Cloud as Backend Service Platform:** Cloud serves as the platform for provisioning healthcare services. These services can be provisioned on PaaS. The services are grouped under two logical layers and details for each of the layers are as follows.

1. **Medical Service Layer:** This layer provides core healthcare services such as *Registration Service, Appointment Bookings, Diagnostic Service, Prescription Service, Test Report Service and Medicine Ordering*. *Registration Service* takes care of patients, physicians as well healthcare organizations such as hospitals, clinics and diagnostic centers. These entities need to registers for the first time. Relevant information such as patients' demographics enables services to provide contextual facilities. The *Appointment Bookings* service allows patients to enter symptoms, select an appropriate physician in their vicinity for appointments. *Diagnostic Service* is intended for physicians to record ailments and prescriptions or tests after physical examination. The *Test Report Service* is intended for diagnostic centers to upload and view pathological results.*Medicine Ordering*, as the name suggests, enables patients to order medicines from hospitals and pharmacy stores. Figure 1 provides a list of such services which can be deployed in cloud. These services provisioned in cloud can use underlying computing resources for processing and storing information about healthcare providers (for example, hospitals, clinics, etc.) and the consumers that includes patients.
2. **Mobile Services Layer:** This layer provides mobile specific services that are used to manage and maintain smartphone applications. Services such as *User Management*, *Data Sync up, Upgrade* and *Data Backup* fall under this layer. The *User Management* service manages authentication and authorization of service consumers. *Data Sync ups* allow users to keep updated information on their mobile storage. The *App Upgrade* service, as the name implies updates any new features, versions of the smartphone application released over a period of time. The *Data Backup* service facilitates consumers to preserve data pertaining to physician visits and diagnostic information. Once the mobile application has been downloaded and installed on the smartphone, the services in this layer are automatically activated, either on a periodical basis or as need basis. These services are typically executed in the background, which means, the users will not have to invoke them

explicitly. For instance, *Data Backup* service is typically invoked after certain interval of time. This interval is set by the user during the initial installation of the application.

- **Mobile App:** The mobile app consists of an extended version of MedTravel App [11] that interacts with cloud services and a local database. The service consumers download the app installers on their smartphone. On running the installers, the app is setup and configured on the smartphone. The initial setup can be done offline, however, to register for healthcare services, the consumer required internet connection and any subsequent interaction with cloud based services. The cloud based healthcare services are invoked on user tapping a particular region on the smartphone. The communication with cloud services requires the device to be connected to the internet. The communication protocol uses a light weight data interchange format, Javascript Object Notation (JSON) [12]. This format is human readable and easy for devices to parse information. The app also comprises of a database that is required for storing local information about the device user.

The architecture provides seamless access to services and management of communication with different consumers. PaaS offerings from Google and Amazon such as Google App Engine and Amazon Web Services, can be leveraged to provision such services. Mobile applications can be implemented using the Software Development Kit (SDK) for Android and iOS platforms. The architecture is designed in a way to establish most commonly used services that are accessed by user groups such as working professionals, aged and disabled patients. Consider an application scenario where a busy working professional catches mild cough and cold. For this relatively mild illness, he may not choose to seek a physical appointment with a physician. In case if the illness is aggravated, he considers to seek appointment. With this mobile enabled service, this individual can download the mobile app from the app store and register for the first time using Registration Service. Once the registration is complete, he then opens the Appointment Booking service to enter symptoms and can choose if he requires physical consultation. If he chooses for offline consultation, he can seek a

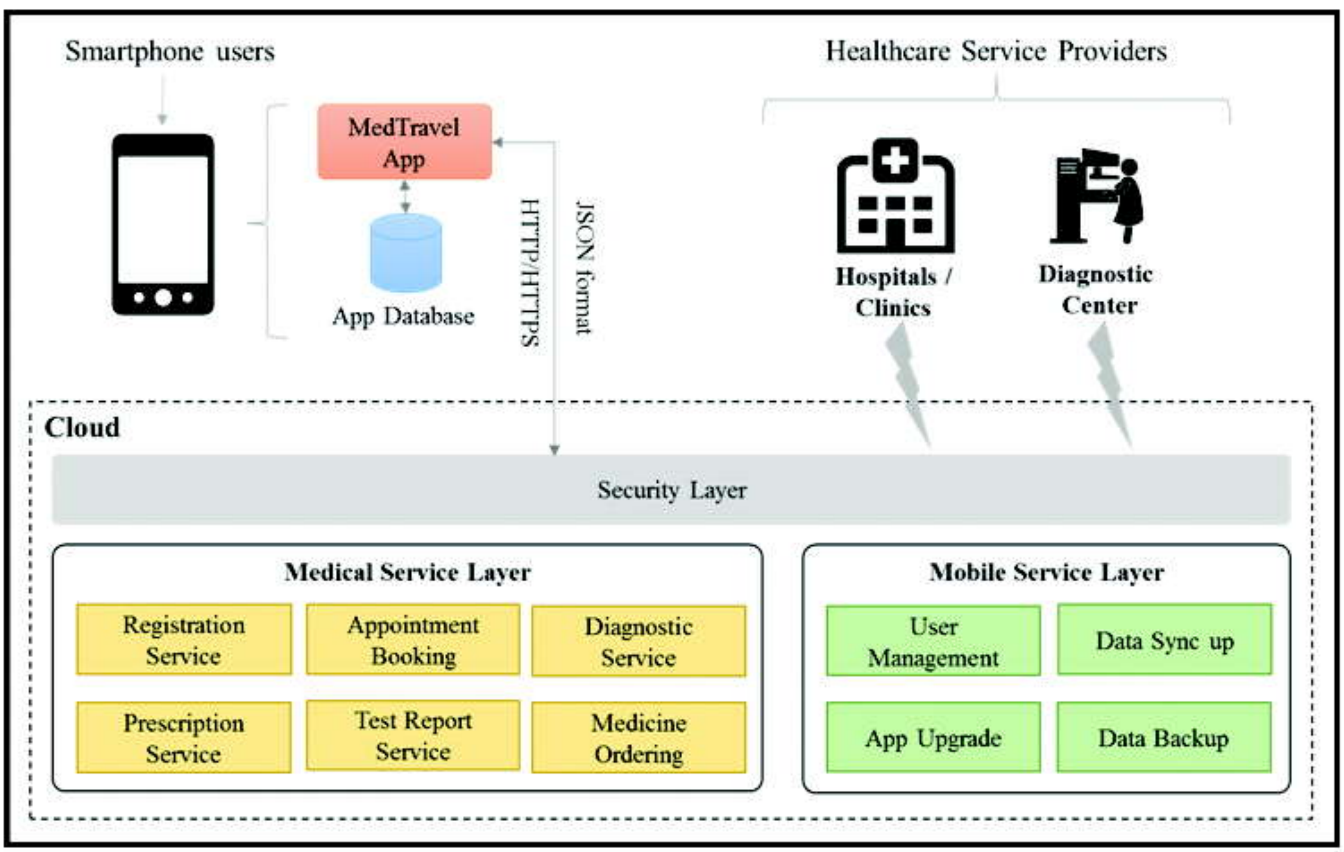

Figure 1: Lightweight Cloud based Architecture to support Mobile apps

physician's advice appropriate. In case he chooses for physical consultation, the app provides suitable time he wishes to see a physician. Based on the symptoms, the service recommends nearby physicians and availability matching to the timings of the individual. The working professional can then choose from the options and select appropriately. The whole process takes few user interactions on the mobile and reduces the hassle to call or visit clinics for booking appointments. Therefore, only for consultation, physical presence may be necessary, otherwise choosing a physician and appropriate hospital or clinic can be done remotely. In the next section, a test case implementation is discussed along with performance results of the mobile application.

4. TEST CASE EVALUATION

This section describes a test case implementation for smart healthcare application for mobile devices. The healthcare services provisioned on cloud infrastructure - Google App Engine (GAE) [13] and these services are accessed by a light weight mobile app on Android smartphone. The GAE implementation is based on the layered architecture, leverages Google Cloud storage – Datastore, a NoSQL database offering from Google and stores structured as well as unstructured data. The communication protocol among the services and eventually with the mobile interface is through Javascript Object Notation (JSON) [14] and user authentication and authorization is handled through OAuth 2.0 [15] standards using JSON Web Tokens [16]. This choice is made due to the fact that both these standards are lightweight and extensible. Patient information is stored in the Datastore. The mobile interface is developed using Google Android SDK that creates a local storage in users' mobile when the app is installed.

This implementation considers textual details about the patient, such as symptoms, history of ailments and medicines prescribed by physicians. The first time patients are required to register through the mobile app interface. Once the registration details are confirmed, they can view the services based on the authorization. The services visible to the users are –*Patient Registration, Appointment Bookings, Diagnostic Service, Prescription Service, Test Report Service and Medicine Ordering.* Figure 2a demonstrates the services that are visible to the users. Through this implementation, the users can perform booking of appointments, entering of symptoms, viewing diagnosis, prescriptions and test reports. When the patient

Figure 2a: Mobile App Interface for Healthcare services

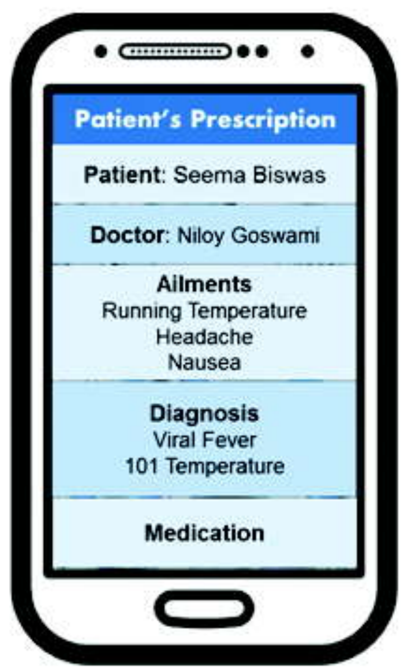

Figure 2b: Prescription Service View on Mobile

undergoes diagnosis from a physician, he then can view the prescription details on the mobile interface as depicted in figure 2b.

The evaluation is further conducted to test the performance of the cloud based services. The choice of mobile app performance testing tools was based on the Apache JMeter [17] features that was used in earlier research work. Automated testing platform, provided by Sauce Labs [18] is based on Selenium Web API open source framework, was chosen for this evaluation. The tool was set up in Android (version – Marshmallow) based smart phone that could access cloud based service via internet 4G connection (having a maximum download speed of 4Mbps). A *Patient Prescription* service based on the proposed architecture was provisioned on Google App engine (GAE). Performance testing for*Patient Prescription view* service was conducted for the time period of 8 hours with an interval of 10 minutes. In other words, the testing tool triggered access request to the service after every 10 minutes and response time was captured. Simultaneously internet speed was monitored during this test duration to make sure that the speed does not drop significantly, which in turn will impact response times. The average response time obtained was 519 milliseconds with minimum and maximum response times at 398 and 678 milliseconds. The results obtained are at par with the response time standards for similar services provisioned in cloud. Figure 3 depicts the performance graph and response times obtained for the test duration.

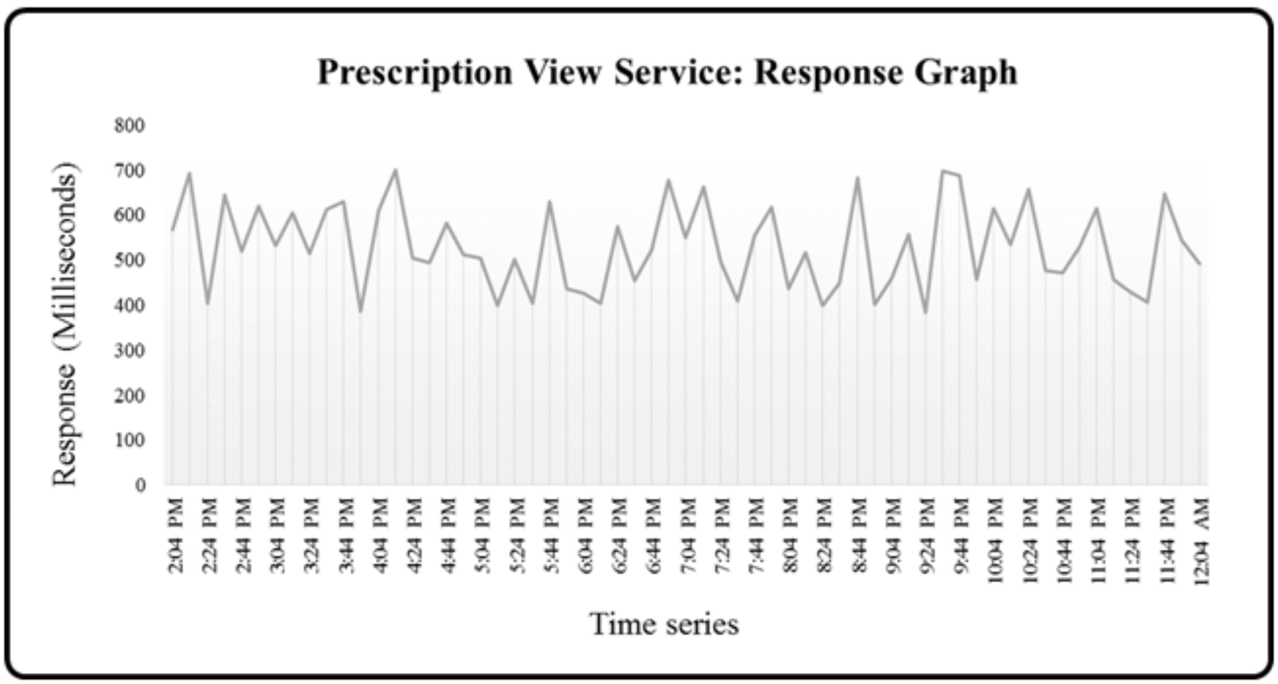

Figure 3: Response Time Graph for Patient Prescription Service on Android (version 6.0, Marshmallow) Smartphone

4. CONCLUSION

Cloud computing is a paradigm shift in the way computing infrastructure and computations are performed. Healthcare service providers can take advantages of cloud to establish cheaper and sustainable services for the patients. However, in order to extend the reach of such services among people, there is a necessity for a medium that is easily accessible. As the smartphone adoption in the developing countries is ever increasing, the use of this device to cater healthcare services is inevitable. This paper proposes light weight mobile cloud architecture that is a step forward in realizing easy access of healthcare services. The sections of people such as working professionals, aged and disabled patients, shall greatly be benefited from such implementation. This paper discusses some of the recent research work in this domain and establishes cloud based architecture for mobile healthcare application. This work explores the architecture with test case evaluation using Google App Engine and demonstrates easy access of healthcare services on Android based smartphone. The paper also discusses the test case and results from specific interactions along with performance measurement of the service in cloud using graphical analysis. The future scope of this work will be focused on evaluating functional and non-functional requirements for health care services that are designed for smartphones.

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