

# A Study of Smart Healthcare Service Model Based on Cloud Platform: Focus on Small and Medium Sized Hospitals

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## ABSTRACT

The objective is to propose a cloud hospital information system (cHIS) to allow small and medium sized hospitals to provide smart healthcare services and gain improved competitiveness. The research was conducted on cloud platform-based HIS service, mobile electronic medical record (EMR) service, personal biological record (PBR) service and healthcare big data service. Cloud computing technology was used for the HIS service to minimize the operating cost, IoT was applied to the mobile EMR and PBR services, and big data technology was used for the healthcare big data service to raise the efficiency in the clinical setting. This study examined the measures for promoting the use of cloud computing technology in the healthcare sector. If service providers can provide affordable, high-quality cloud healthcare services, such services will become high in demand despite hindrances. Thus, the architecture and service model of the cHIS were designed to minimize the operating costs through resource pooling achieved by virtualizing the hardware and application programs to promote affordability. Also, CloudSim was used to assess the stability and efficiency in relation to the data access time, service processing time and service wait time. First, the results of the experiment showed that an increase in the cloud storage disk and network bandwidths allows more users to be serviced. Second, it was found that the packet size had little to no impact on the system performance. Third, it was found that cloud-based distributed storage and processing was more efficient than using a web-based database in case of processing large amounts of data. The system presents economic advantages including maximized sharing of resources and minimized costs, enables real-time exchange of healthcare data, and promotes the use of collective intelligence for better healthcare services.

**Keywords:** *Cloud computing, Cloud hospital information system, Virtual machine, Personal biological record (PBR), Electronic medical record (EMR)*

## Introduction

Recently, mobile technology, Internet of Things (IoT), big data and cloud computing have been bringing forth new changes in the era of the Fourth Industrial Revolution, and these changes have been driving innovation in the service industry with the applications of information and communications technology. The

advances in cloud services, in particular, are allowing users to enjoy ICT-integrated services anywhere, anytime<sup>1</sup>. On the other hand, medical advances are increasing the average life expectancy of humans, which has in turn led to a phenomenon called population aging as well as a rise in geriatric diseases and chronic diseases, necessitating changes in the medical service environment<sup>2,3</sup>.

In line with this trend, research is being carried out to develop smart healthcare services integrated with the hospital information system, mobile technology and mobile communications technology to provide services without any constraints in terms of time and location<sup>4</sup>. However, if such services become common, small- and medium-sized hospitals may lose competitiveness,

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considering they have a limited budget to invest in such cutting-edge systems. There have been discussions on cloud-based healthcare services as a means to mitigate this issue for small and medium sized hospitals, but the proposed information system could not be commercialized, despite being future-oriented, due to technical limitations and information security issues<sup>5,6,7,8</sup>.

This study proposes a smartphone healthcare service based on a cloud platform, which maximizes the sharing of resources through the virtualization of resources and presents a hospital information system that is affordable yet excellent in quality to provide high-quality services to users, without the issues of security or healthcare information standardization.

### Related Research

**Concept of Cloud Computing:** Cloud computing is defined as “an ICT service model for receiving network services at fast speeds through interactions with service providers for sharing of computer resources such as servers, networks, storage devices, applications and services”<sup>9,10,11</sup>. The characteristics of clouding services from the user perspective are as follows: first, it is “on-demand self-service,” which means that users can use the computing resources available to the extent they desire anytime; second, it is “broad network access,” allowing users to use computing resources from anywhere simply by accessing the network; third, it is “location-independent resource pooling”; fourth, it is “rapid elasticity,” which allows users to acquire as much resources as they need; and fifth, it is “measured service,” meaning that users are charged according to the extent to which they have used the service<sup>12</sup>.

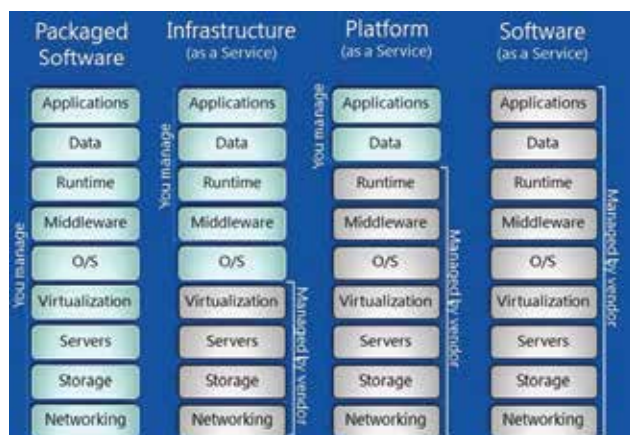


Figure 1: Cloud Computing Service Models

**Classification of Cloud Computing:** Cloud services may be classified into Infrastructure as a Service (IaaS),

Platform as a Service (PaaS), and Software as a Service (SaaS)<sup>12,13,14</sup>, as shown in Figure 1. Since the recent medical services emphasize personalization services, a cloud platform service model is emerging that enables user-oriented system configuration in the medical field.

**HIS based on Cloud Platform:** With the recent advancements of mobile ICT and the advent of the mobile era, WBAN(Wireless Body Area Network) and WWBSs(Wireless wearable biomedical sensors) are revolutionizing the healthcare service environment, and this is expected to lead to IoT-based ubiquitous pervasive computing even for hospital information systems (HIS)<sup>15</sup>. Population aging and a rise in geriatric diseases resulting from increased life expectancy and a surge in chronic diseases due to lifestyle changes are being observed worldwide<sup>16</sup>. Because of these trends, there is an agreement on the need for medical institutions to not only provide healthcare services for inpatients or outpatients visiting in person, but also offer remote services. To this end, it is necessary to develop a new mobile-based healthcare service model for medical professionals to monitor their patients’ daily lives anywhere, anytime and intervene in their health management by connecting to the patients’ smartphones using the emerging WWBS and WBAN and linking them with the hospital information system (HIS) via a mobile communications network<sup>1</sup>. In order to respond to the changes in the healthcare environment, a new technology for collecting and managing large amounts of data generated in IoT environments is needed.

### Method

**Overview of cHIS Smart Healthcare System:** A cloud hospital information system (cHIS) is expected to further upgrade healthcare services by creating a new market and business area through technological convergence, as the era of IoT that enables things to be connected anywhere, anytime is brought upon by ICT advancements. The architecture of the cloud platform-based smart healthcare system proposed in this study is shown in Figure 2.

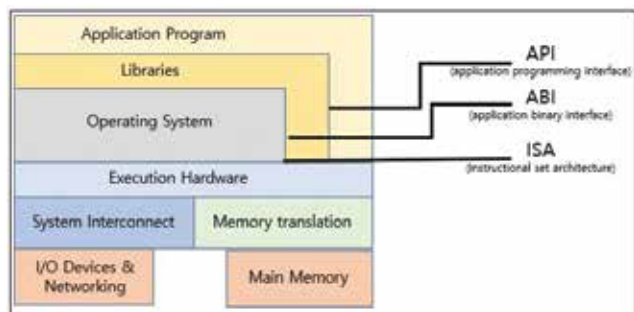


Figure 2: Healthcare service system architecture

**Configuration of the cHIS service model:** cHIS is comprised of cloud platform-based HIS service, Mobile EMR service, personal biological record (PBR) service, and Healthcare Big Data service.

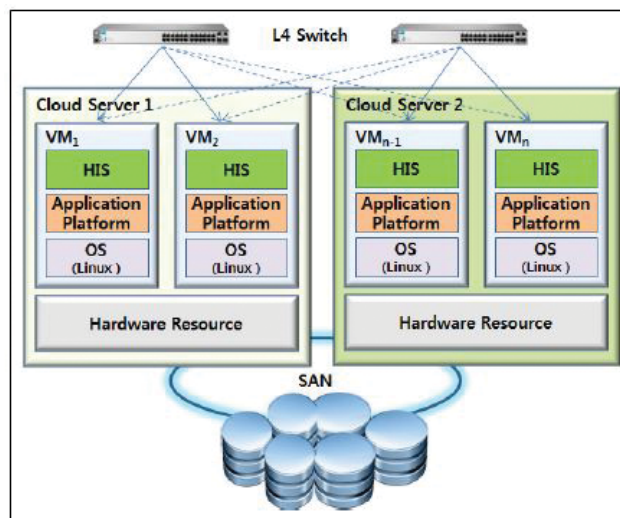
**1. Cloud platform-base HIS Service:** The cloud platform-based HIS services can be divided into four types: virtual machine technology that maximizes sharing and shared use of computing resources, grid computing technology that supports service stability, security-related technology, and application program.

First, Virtual machine (VM) technology isolates the application program (application programs) into a certain hardware or another VM using virtualization technology as a means to maintain independence. Computing resources comprised of several clusters are pooled, and virtual resources are allocated dynamically according to the requirements of the application programs for shared use. VMs may be classified according to the level of virtualization into process VMs and system VMs, as shown in Figure 3.



**Figure 3: Key Implementation Layers**

Second, Grid computing could be defined as a distributed and parallel system designed to satisfy the quality of service demands of users in relation to capability, performance, availability and cost by dynamically sharing, selecting and combining the distributed resources<sup>17</sup>. In this study, a single physical server was designed to allow installation of up to sixteen VMs. As shown in Figure 4, the system was designed to have two different servers connected with an L4 switch and two VMs for each server for a total of four VMs to service a single hospital as a means to ensure service stability. Because cHIS must be operated as a fault-tolerant system 24/7 all year round and allow users to access its services anytime, anywhere, a fault-tolerant architecture was realized through network, server and VM redundancies.



**Figure 4: The Structure of cHIS's VM**

Third, A cloud service requires a security isolation policy for the purpose of preventing unlawful access, conflict between tenants, as it is a multi-tenant service<sup>18</sup>. In the case of the cHIS in question, system VM was adopted and it is set to provide SaaS-type services. Thus, security measures with respect to data and network security, data locality, data integrity, data access, authentication and authorization are needed<sup>19</sup>. To this end, the system was designed to operate security policies including a hardware server certificate, virtual server certificate, user certificate, and network device certificate.

The fourth cHIS application, the service-oriented architecture (SOA) and component-based design (CBD) principles were applied. Also, it is important for cloud service providers to minimize the cost of initially setting up a new service model and the maintenance and repair costs for the existing service users. For this purpose, it was ensured that the abstraction, loose coupling, autonomy and statelessness of the services, which are key to the SOA, would be maintained, and the services were divided into a hospital-specific layer (HSL), optional service layer (OSL) and core service layer (CSL), as shown in Figure 5. HSL was designed as a standard component that would be unique to the hospital depending on whether it specializes in acute medical conditions, nursing or rehabilitation, while OSL was designed as a component that could be selected according to the hospital size and the scope of services it provides, and CSL was designed as a core component that must be included in this study.

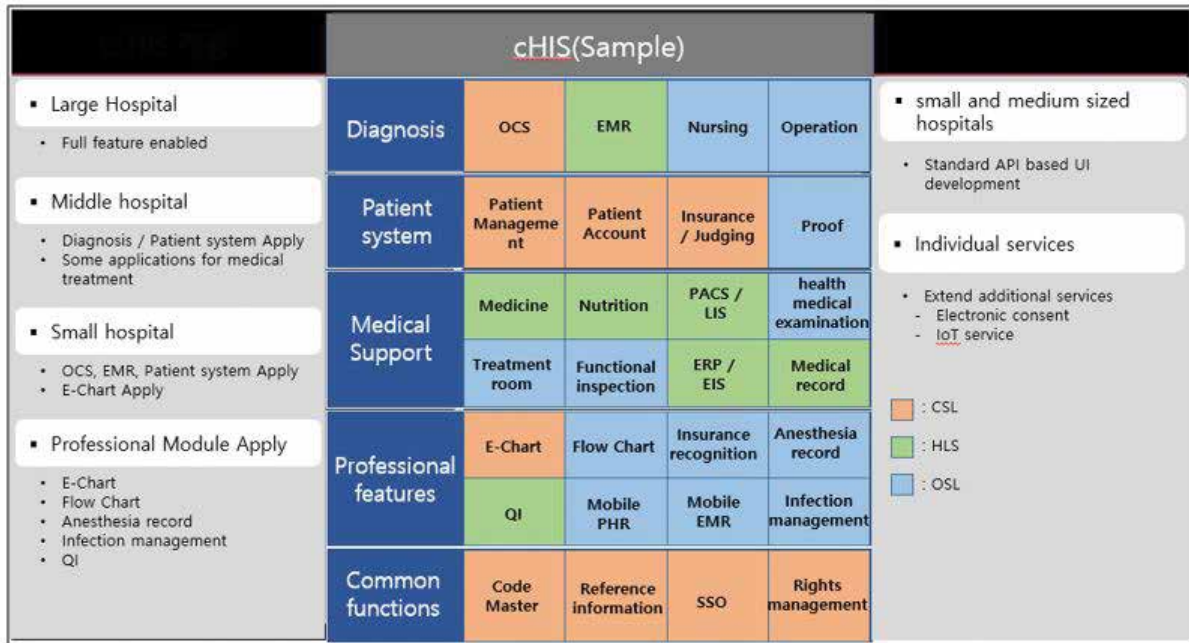


Figure 5: The cHIS Service Components

- 2. Mobile EMR Service:** In order to provide a patient-oriented mobile EMR service, an optimized environment that facilitates the securing and application of optimum content must be provided for a mutual interface between the hospital EMR system and the mobile EMR devices used by the medical staff. In this study a personal health record (PHR) app for management of medical information and personal life logs, an app for chronic disease management, and various other healthcare applications were set up on the cloud to be used in healthcare services and patient management.
- 3. PBR Service:** A personal biological record (PBR) service enables personalized healthcare services for patients by collecting and analyzing their individual biometric information to send the data to the medical institution in question and allowing the medical institution to use the real-time data to make a diagnosis, predict the patient’s health condition, take preventive measures, treat the disease and so on accordingly.
- 4. Healthcare Big Data Service:** The healthcare sector is already equipped with the technology to amass digital data and the basic IT infrastructure, and thus there is more interest in how the collected data should be integrated, managed and analyzed. Unless these issues are resolved, big data will be useless in the field of healthcare.

In this study, clinical data extraction and verification measures were prepared centering on diseases for the purpose of collecting clinical, genomic and life log data to be managed as healthcare big data on cloud. In order to apply CDSS technology for AI analysis of healthcare data consisting of genetic, clinical and health information of patients to the cHIS for improved efficiency in the clinical setting, the cloud infrastructure and open platform necessary were designed.

**Result**

**Experiment Environment:** An experiment was carried out using CloudSim to prove the efficiency of cHIS in providing smart healthcare services based on a cloud platform. Since cHIS is a cloud system accessed and used by multiple hospitals simultaneously, the most important matter considered in the experiment was the stability of the system in terms of data access time, service processing time, and service wait time. CloudSim is a simulator for simulations of providing services in a cloud computing environment, and it consists of cloud resources as well as a user interface, cloud service and VM service.

Distributed users use equation 1 to support even services from cHIS systems. Equation 1 calculates a packet reception ratio between a user and a server in order to assign a priority according to a service request. Therefore, if you make a reservation, you will be given priority over the receptionist on that day.

$$P = RA + RD \quad (\text{equation 1})$$

Where :

P = Priority

RD = Receive Data

$$RA = \int_{cr}^{\text{out}} (-a(t-b)^2 + c)dt$$

cr = Priority of service requested at the same time

out = When the user's service processing is completed

$-a(t-b)^2 + c$  = Packet reception rate

Time allocation is required to give uniform transmission opportunity, and time allocation method is defined using Equation 2.

$$T = \frac{UT \times RT}{ET} \quad (\text{equation 2})$$

Where :

T = Assign Time

UT = Maximum Time

$$RT = \int_{cr}^e (a(t-b)^2 + c)dt$$

$$ET = \sum_{i=0}^n RT_i$$

cr = Time at which to calculate the time allocation

$e = UT + cr$

$a(t-b)^2 + c$  = Error rate during communication

i = Number of Users

**Experiment Result:** When small and medium sized hospitals use the cHIS to request a service for patient care, fast response and accurate service processing are highly important. Accordingly, the impact of the cloud disk and network bandwidths on the overall system performance was analyzed in this study by assessing the data packet loss rate according to the data packet size. Also, we experimented on service processing latency and service processing time for the experiment of service processing efficiency requested through each EMR. As a result, an increase in the cloud storage disk bandwidth and the network bandwidth allows a greater number of users to be serviced. However, the results also indicated that a bottleneck may occur in either one of these bandwidths in such cases, and this must be considered when designing the system. Also, the data packet size, which had been expected to have an effect on the system performance, was found to have little to no impact, based on the results of the experiment. This

could be explained by the fact that as the data packet size grows larger, the streaming request time intervals increase, but the delay in each queue also increases, and these two effects cancel each other out.

The results of an experiment comparing the method of integrating and operating solely a web-based database and the method of storing and processing the data in the form of an image using a distributed storage on a cloud system. The results show that the cloud system is more than 20% faster, on average, than the web-based DMBS in processing the service requested by the user. Also, when there is heavy workload, the queue wait time for processing is 3.8% less when it is processed based on cloud, rather than the web-based DMBS. In other words, a prolonged queue wait time for a requested service indicates a delay in service processing, and thus, in the case of large amounts of data, the method of storing and processing data on a cloud-based distributed storage proposed in this study is more efficient than the conventional web-based data storage and management method.

## Conclusion

In the healthcare service sector, in particular, there is a surge in demand for new types of services incorporated with advanced ICT including mobile technology for geriatric and chronic diseases that have been on the rise due to population aging. Most small and medium sized hospitals today have set up a healthcare information system independently for management and storage of the related data. However, setting up an information system that can meet the patients' demands for high-quality healthcare services is economically burdensome for such hospitals. In addition, individually established healthcare information systems have low interoperability due to the heterogeneity of the models and tools used. As such, small- and medium-sized hospitals face difficulties in meeting the service demands due to limited business management resources and weak capacity for rendering IT services. Based on these factors, a cloud hospital information system (cHIS) designed to provide smart healthcare services based on a cloud platform was proposed in this study as a means to improve the IT service environment of small and medium-sized hospitals, thereby helping them secure or maintain competitiveness. This proposed architecture presents economic advantages to the users by maximizing the sharing of resources, while minimizing maintenance and repair costs, and a security isolation policy is

implemented to resolve issues concerning security and privacy. To this end, the HIS service requirements of small- and medium-sized hospitals were derived, and the service components were designed from the SOA and CBD perspectives in order to propose an architecture that can minimize the maintenance and repair costs. Thus, a VM architecture for maximized sharing of computing resources and the model for implementation and operation thereof were proposed.

In the case of the system proposed in this study, the data generated at small- and medium-sized hospitals are backed up on a cloud data storage periodically for integration in order to manage the healthcare big data. Web-based data management resolves the issue of heavy loads on the server for the processing of healthcare data, the amount of which increases continually. Lastly, from the aspect of data integrity, a web-based database may lead to Data corruption as a result of diverse types of SQL attacks. Also, even with respect to the data process speed MapReduce is used for data scheduling and load balancing, as the data continue to accumulate, and this resolves the issues of data processing and load balancing. However, the virtualization principle of the logical isolation concept applied to the cHIS requires that some of the EMR features be physically isolated, with an excessive emphasis on privacy, and this is in conflict with the Medical Service Act of Korea. Accordingly, there is a need for a legal framework for the proposed cHIS service in addition to technical supplementations from the ICT perspective. Therefore, it is necessary to improve the level of virtualization and upgrade the system according to the new requirements in a follow-up study.

**Ethical Clearance:** Not required

**Source of Funding:** Self

**Conflict of Interest:** The authors declare no conflict of interest.

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