

## Medical Applications and Healthcare Based on Cloud Computing

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### ABSTRACT

Cloud computing supports mobile and collaborative applications and services. Increased storage, high automation, flexibility, and reduced cost are a few advantages cloud computing offers. Using cloud computing can improve healthcare services delivery for patients. In this paper, the categories and service models of cloud computing, its technology intelligence, diverse applications in medical services and healthcare, and biometrics-based authentication for information security were presented. Issues related to privacy, security, barriers to applications, and compliance with acts in healthcare were also presented.

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## 1. INTRODUCTION

### 1.1. Concept and Characteristics of Cloud Computing

The National Institute of Standards and Technology (NIST) defined cloud computing as: “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [1] [2]. Cloud computing is a style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet [3]. More than virtualized technology, cloud computing offers innovative ways to collect, manage, store, and share information with a prospective cut in information technology (IT) infrastructure and staff costs [4].

The essential characteristics of cloud computing are [5]:

- *On-demand self-service*: a consumer can provision computing capabilities, such as server time and network storage, as needed.
- *Broad network access*: broad range of network accessibilities by various client platforms.
- *Resource pooling*: the provider’s computing capabilities are pooled to serve multiple consumers using a multi-tenant model. Resources are dynamically assigned and reassigned according to consumer demand.
- *Rapid elasticity*: capabilities can be rapid, elastically provisioned, and in some cases automatic; the consumer capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

- *Measured service*: cloud systems automatically control and optimize resource use by leveraging a metering capability.

## 1.2. Advantages of Cloud Computing

Cloud computing services provide access to a computational infrastructure on an on-demand, variable cost basis, rather than a fixed cost capital investment into physical assets. Many cloud storage services use low-cost, commodity storage in a distributed architecture [6] [7].

The cloud computing systems offer an illusion of infinite on demand computing resources, making room for expansion resources when needed. Hardware and software services are more efficiently handled than in other high performance computing (HPC) infrastructure as they can be added and released dynamically [8].

With the use of cloud computing there is rapid deployment of cost-cutting, productivity-enhancing, and transparent applications. Healthcare organizations, public sector organizations, and large and small enterprises are adopting cloud computing [9]. Summarized below is a list of several most important advantages of cloud computing [10] [11]:

- Faster implementation at lower costs: it requires minimal in-house information technology resources for implementation and ongoing maintenance.
- Capital-efficient cost model: pay-as-you-go subscription model—a user is paying only for what he or she uses.
- Web services provide easier integration of disparate data sources to drive analytics, reporting, and collaboration.
- Scalability: flexible and elastic solutions can extend functional capability and computing power as needed.
- Cost savings in minimizing the need to anticipate hardware, bandwidth, and other technology needs.
- On demand resource allocation from an entire network to fit a specific need and minimizing the need to maintain onsite staffing resources.
- Broad network access and resource pooling to increase the efficiency of the network and minimize the waste of information technology (IT) resources.

Research and development of cloud computing has been focused on topics such as safety, mobility, multi-tenancy, identity management, security, data management, and open interfaces [12]. This paper focuses on the technology intelligence and applications of cloud computing, biometrics-based authentication, privacy, security, and barriers in medical services and healthcare.

## 2. TECHNOLOGY INTELLIGENCE, CATEGORIES AND SERVICE MODELS OF CLOUD COMPUTING

Cloud computing is a business model and technology platform, which is the result of evolution and convergence of many created and independent computing methods and technologies, including utility computing, on-demand services, grid computing and software-as-a service [12].

Cloud computing has a dynamic and flexible architecture that makes it possible for a scalable information technology capacity to be provided in services and delivered over the Internet to a number of external users. Services and information exist in a shared, dynamically scalable set of resources based on virtualization technologies and/or scale-out application environments [13].

An important feature of cloud computing is scalability, a key technology that enables the virtualization [14]. In the most general sense, the concept of virtualization describes the development environment and methodology for the sharing of computer resources into multiple independent execution environments or associations of several resources in a smaller environment. It applies one or more different concepts or technologies such as software division, time-sharing, partial or complete hardware simulation, emulation, and many others, with the aim of separating the logical interfaces from physical resources [12].

Many technologies facilitate cloud computing, but key among them is virtualization technology, which allows entire operating systems to run independently of the underlying hardware [15]. The concept can be described as: when a single physical server simulates being several separate servers, each one of the simulated servers is called a virtual machine. Some benefits of virtualization are the need for less hardware and less power consumption across the virtualized enterprise [16].

Providers of cloud computing offer a wide variety of services, including web-based software, data storage, and built-in MapReduce capability, facilitating the use of distributed computing for developers without in-depth knowledge on parallelization. MapReduce is a programming framework for processing

large data sets on clusters of computers. This provides an efficient and fault tolerant means of solving large-scale computing problems in a cloud computing environment [17].

The NIST listed four categories of cloud as follows [5] [18]:

- *Public cloud*—resources and services are available to the general public over the Internet; solutions tend to be preconfigured and offer less flexibility but are typically lowest in cost.
- *Private cloud*—the cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party, which allows for more control over the infrastructure provisioning, security and management of the cloud resources.
- *Community cloud*—services are controlled and used by a group of organizations sharing mutual interests, which supports a specific community that has common concerns.
- *Hybrid cloud*—combination of two or more clouds (private, community, or public), sharing services and/or data between clouds; this provides the most flexibility because it takes advantage of the public, private, or community models.

Three service models of cloud computing were introduced by NIST [5] [8] [19]:

- *Infrastructure as a Service (IaaS)*—the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources, which can include operating systems and applications; divided into compute clouds and resource clouds—compute clouds provide users access to computational resources such as CPUs, virtual machines and utilities while resource clouds contain managed and scalable resources as services to users(in other words, they provide enhanced virtualization capabilities).
- *Platform as a Service (PaaS)*—provides computational resources via a platform upon which applications and services can be developed and hosted—typically makes use of dedicated APIs (Application Programming Interfaces) to control the behavior of a server hosting engine that executes and replicates the execution according to user requests.
- *Software as a Service (SaaS)*—means offering software and hosted applications over the Internet; the capability provided to the consumer is to use the provider’s applications running on a cloud infrastructure.

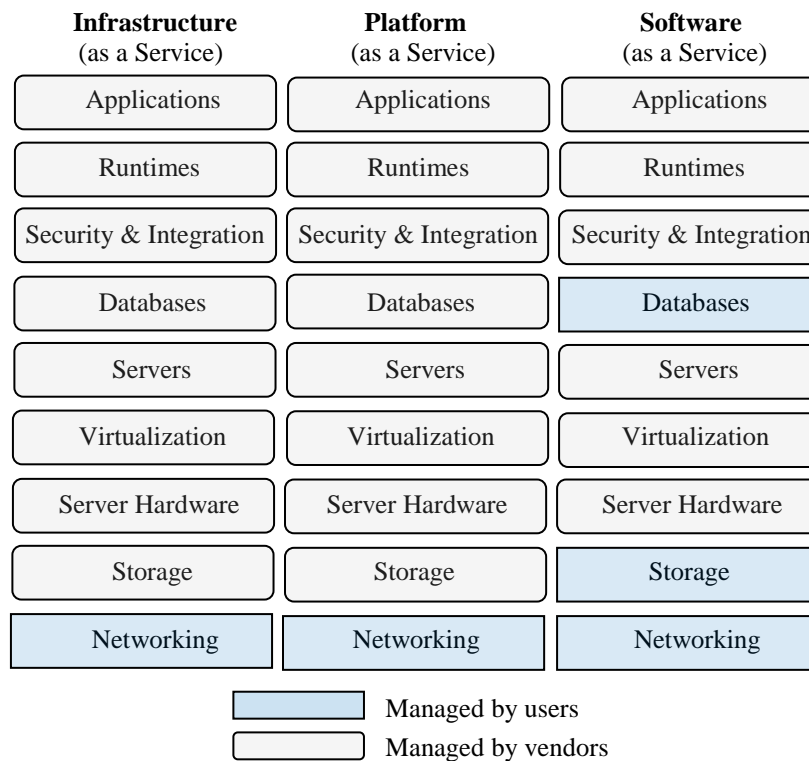


Figure 1. Cloud services

Figure 1 shows cloud services. SaaS permits users to run online applications. The vendors own the applications and the users pay fixed subscription fees. PaaS permits users to create their own cloud

applications, providing all the execution and compilation of software as well as operating systems. IaaS permits users to run any applications they want on cloud hardware of their choice [8].

### **3. CLOUD COMPUTING IN MEDICAL SERVICES AND HEALTHCARE**

#### **3.1. Data Management, Data Access and Data Sharing**

##### **3.1.1 Data Management**

Cloud storage is a data storage service that can involve the long-term storage and archival of information such as clinical data, medical images, and scanned documents. Cloud storage can be private, public, or hybrid [20].

Service providers provision and maintain the cloud at an off-site data center while users access software and services remotely via the Internet using the Web or other mobile devices. Cloud-to-cloud services ensure the ability for systems to consume data and Web services from other systems, particularly other clouds – often taking form as a hybrid cloud. Because healthcare data is held in so many disparate systems, and no two systems are alike. Cloud-to-cloud services contribute to no loss in translation and guarantee a higher degree of data quality and accuracy [11].

Cloud-based platforms permit real-time collaboration between providers resulting in data management with more agility by healthcare organizations. The use of cloud services contributes to faster data management in connection with patients and more efficient monitoring of chronic diseases [12] [21].

##### **3.1.2 Data Access**

When patient information is stored in the cloud, medical providers can access lab and radiology results as well as any other pertinent test results during any time frame and at any location. For home health nurses, the cloud works to their advantage, giving them immediate access to real-time data, enabling them to document visits and chart updates in real-time as well, releasing them from the time-consuming daily synchronization routine. Cloud computing offers information which is more readily accessible to the provider and supports users so that the emergency room (ER), intensive care unit (ICU), various medical nursing units, ancillary departments such as lab and radiology, and other departments such as a an attached nursing home for example, and so forth, have access to the same type and amount of information. This real-time access and readily accessible information results in faster response for information requests, improved care coordination, better decision-making, and a higher quality patient care [20] [21].

For medical institutions, having cloud access can also mean access to specific data for which patients have given consent and more accurate information about the health of patients; it is much easier and faster for patients to manage information related to their health [12]. IBM and ActiveHealth Management worked together to create the Collaborative Care Solution based on cloud computing technology. This works with existing infrastructure and reduces the need to invest in a new network yet gives organizations the flexibility of cloud systems as they need to improve the overall quality of care [22].

##### **3.1.3 Data Sharing**

In medical informatics, cloud resources can be categorized into compute cloud, storage cloud, and data cloud. Compute cloud consists of resources like hardware, software, central processing unit (CPU), and operating system; while storage cloud provides database and large capacity hard disk to store digital images from radiology departments located in different places. All information stored in data cloud such as digital images and patient information can be easily retrieved. Services provided by cloud resources should be highly reliable, scalable and accessible from any location. In the medical field, digital images are produced in an ever increasing volume for diagnostics and valuable routine wellness purposes. Of these images, some might be used by other radiologist or other providers from other hospitals [23].

The cloud broker was applied to optimize the use of resources in the cloud by goal-based request. The broker is referred to as a set of functionalities like allowing discovery of resources in a distributed computing environment, selecting suitable resources, and sending the selected resource to users, etc. For example, the integration broker for heterogeneous information sources (IBHIS) can be used to integrate data from various autonomous agencies and allows only medical practitioners, radiologists, and pharmacists to access the resource broker; the service level agreement (SLA) broker negotiates between the resources provider and the user. The user can submit service request to broker from any location. Then, Virtual Machines (VMs) will take place virtually and connected to one physical machine in distributed environment to meet the accepted service request [23].

ImageZone is a cloud-based medical image sharing platform designed to provide a digital alternative to the traditional methods of sharing radiology images on hard copy films and CDs. The platform allows healthcare providers to securely access and share patient medical images, such as X-rays, mammograms, MRIs, ultrasounds and CT scans, in real time [24].

### 3.2. Reduced Work load and Saved Costs

Users in the private cloud have the greatest amount of control; the greatest savings and resource capability are achieved with the public cloud. For health plans and healthcare delivery organizations, the flexible hybrid model seems to offer the best of both the private cloud and the public cloud. Payers can use cloud services for everything from claims processing to care coordination [25] [26].

Up-time requirements for advanced clinical applications along with an explosion in data access requests from health insurance marketplaces and care organizations have ensured that data center collocation is a trend due to the increased costs of data center security construction and personnel, especially if hospitals develop their own a data centers. The Internet bandwidth is provided by a collocation partner, saving Internet protocol costs. Annual hardware costs and Internet service provider costs are also reduced. There is no need to upgrade storage hardware; archival storage costs are reduced [20]. The back-up of critical patient files and other important data is becoming less costly and far less difficult to maintain, driving the overall cost of documentation lower. Cloud computing significantly reduces costs in healthcare while keeping a consistent higher patient service quality [26] [27].

Relieved of the burden of managing hardware, storage, and maintenance, IT departments that use cloud computing are able to focus solely on applications and servicing their end-users. Therefore, IT staffing burdens are eliminated and certain IT staff can be reallocated to other areas [20].

### 3.3. The Wireless Technology for Cloud, and Cloud computing in EMR/EHR and Telemedicine

Wireless devices can provide real-time data to the cloud for the practice of evidence-based medicine across a broader population. Cloud computing accelerates effective connections between primary care providers and home care [4]. Wireless body area sensor network (WBASN) is an emerging technology which uses wireless sensors to implement real-time wearable health monitoring of patients. It is helpful in implementing mobile health (m-health). WBASN for health monitoring consists of multiple sensor nodes that can measure and report the user's physiological state. WBASN was used to collect and send data to the cloud server. The sensory parameters were fed into a neural network engine running as a cloud service that fused information from multiple disparate sensors to determine whether the patient is in a "danger state". The union of mobile computing and cloud resources has been one of the popular research areas [28]. Medical providers, administrators, and external stakeholders have used cloud computing for telemedicine [12].

Many healthcare organizations have turned to the cloud-hosted electronic medical record (EMR) or revenue cycle management systems because vendors offer continuous updates, security patches, and a predictable operating expense model [26]. From the healthcare executive's viewpoint, cloud-hosted computing could offer a solution to an often stubborn resistance to widespread adoption of the EMR as planned. However, many healthcare executives and experts believe that cloud services can improve the attitude toward EMR adoption as well as improve the platform on which patient information is shared [22].

### 3.4. Cloud Services in Disaster Recovery

For the cloud user who has outsourced the processing of its data to a cloud provider, it is important for both parties to have an understanding of the cloud provider's disaster recovery plan [16].

The EMR can be stored in a CD and downloaded onto a computer. If the EMR is cloud-based, it can be accessed from a computer at any other geographic location. For example, in the midst of catastrophic events, many healthcare providers are able to continue vital patient care and keep essential communication using the EMR cloud. Surprisingly, during a hurricane, physicians could still use the EMR cloud for billing, writing and transmitting prescriptions, checking patient medication lists, and consulting with the patient about all their medical conditions [29].

The experience of New York University Langone Medical Center, which had to evacuate 300 patients during the height of the storm Hurricane Sandy due to power outages, shed light on the lifesaving benefits of the EMR cloud. The cloud EMR is not only a lifesaving tool during a disastrous storm; it can also enhance a physician's ability to care for patients as a vital long-term tool [29].

### 3.5. Privacy, Security and Compliance with Acts

One of principal concerns about cloud storage is data security. A data breach is a loss of unencrypted electronically stored personal information. Both cloud providers and cloud users want to avoid a data breach because of the significant harm it can cause both to the users and to the providers. For data protection, many cloud storage vendors offer encryption for data both in transit and at rest [7] [16].

Privacy and security are very important, particularly in light of the increased attention being paid to the Health Insurance Portability and Accountability Act (HIPAA) and compliance due to the mandatory data breach reporting, auditing program, and penalties under the Health Information Technology for Economic and Clinical Health (HITECH) Act as well as the requirements of HIPAA compliance for meaningful use

certification [10]. The HIPAA security rule safeguards patient privacy through technology, procedures, and policies. The key to a successful and compliant implementation of a cloud computing solution begins with a detailed due diligence procedure and risk assessment. HIPAA requires that any third party that needs access to an organization's healthcare information must sign a business associate agreement and this applies to cloud computing vendors as well. Any exposure of unsecured information requires a breach notification to the patient [30]. The HITECH Act requires notification of a breach of unencrypted health records for all covered entities that are required to comply with the HIPAA [16]. Moving IT operations to the cloud also requires careful due diligence to maintain compliance with the Gramm-Leach-Bliley Act (GLBA). The Gramm-Leach-Bliley Act (GLBA) has impacts on information security. For example, financial institutions must take reasonable steps to guarantee that the cloud services provider is capable of the appropriate safeguards as defined in GLBA [30].

The organization needs to negotiate a strong contract with the cloud provider that protects its interests. The cloud vendor should also be required to provide detailed reporting which includes all access to the servers and storage by anyone within their organization. The contract should include strong financial penalties in case there is a breach. For the healthcare executive, it should be clear that cloud adoption and achievement of HIPAA compliance do not have to be in conflict [31].

Cloud computing can reduce risk through encryption, firewalls, and intrusion detection resulting in an improvement in HIPAA privacy and security compliance. With cloud computing, data is more secure, making records safer and more permanent [20] [27]. ImageZone is a cloud-based medical image sharing platform adhering to all HIPAA compliance standards, and is equipped with sophisticated encryption and compression technology that allows secure image sharing, routing and viewing via a single online community [24].

### 3.6. Biometrics-based Authentication

Authentication is the process of reliably determining the identity of a person or determining that something is genuine. Authentication is a requirement to comply with all of the major federal regulations such as HIPAA and GLBA, but can be easily overlooked when companies design their cloud services strategy. The lack of an identity management system can introduce risks and hidden costs, adversely affecting any cloud services implementation. Authentication and managing identities have been very important in the cloud [30]. Complexity increases as a company adopts multiple cloud-based solutions where users are required to use different identities to perform their daily work. The increasing number of user accounts and passwords will increase complexity and cost if a company utilizes multiple cloud providers [30].

Generally, there are three authentication methods: possession, knowledge, and biometrics. Possession can be a certain physical object, e.g., keys or magnetic strip card. Knowledge refers to secret knowledge, such as passwords, answers to questions, etc. Biometrics refers to automated methods of verifying or identifying the identity of a living individual based on physiological or behavioural characteristics. Unlike possession or knowledge, biometrics uses human measurable traits that are difficult to share, steal, forge, or change. Biometrics includes face, fingerprint, signature, voice, iris, retina, and DNA recognition.

Some of the authentication methods used in medical applications and healthcare are photo, password (personal identification number, PIN), birth date, name, insurance card, social security card or number, identification card, wrist bands, bar coding, and radio frequency identification technology (RFID). Personal data and patients' health information in EHRs should be protected; however, data breaches, and medical identity theft as well as fraud have occasionally occurred. Biometrics is the best method of securing information while granting authorized staff access to it.

Advantages of biometrics in healthcare are protecting patient record information with accurate authentication, eliminating costs for password maintenance, reducing fraud into hospital business applications and workflow such as your insurance verification systems. Identification for security also helps avoid unnecessary or duplicate tests or treatments, which prevents the patient from receiving unnecessary tests or procedures, preventing unwarranted risks and expenses [32].

Biometric methods, for example, fingerprint scanning and palm vein scanning, have been used in hospitals and healthcare systems to reduce insurance-card fraud, identify patients, and link patient data in various healthcare institutions. This eliminates unnecessary repeated clinical laboratory tests. The lifetime EHR thus goes wherever the patient goes and they are not tied to one assessment center any longer [33] [34] [35]. Sometimes, a single biometric method has limitations such as noisy sensor data, distinctiveness, or non-universality. A multimodal biometric method can be applied by using multiple biometric traits. After suitable normalization of scores, multimodal biometric fusion was performed at the matching score level using weighted scores [36].

### 3.7. Some Barriers of Cloud Computing and the SWOT Analysis

Although cloud computing offers numerous benefits, it takes time for some people to accept it, especially for those without any knowledge and background in cloud computing. 10 top obstacles to users' trust in the cloud approach are: availability of service, data lock-in, data confidentiality and audibility, data transfer bottlenecks, performance unpredictability, scalable storage, bugs in large-scale distributed systems, scaling quickly, reputation fate sharing, and software licensing. Data jurisdiction, data interoperability, and some legal issues are also potential major concerns [37]. Fear of vendor lock-in is really a concern. Every storage service provider has its own proprietary *application programming interface* (API). In some situations, the user might also want to define metadata associated with a data set, such as aging information or security parameters. The lack of common API would create problems if a storage service provider were to suddenly shut its doors [7].

The SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis is a well-known strategic planning methodology used by organizations to ensure that both positive factors and negative factors are identified and addressed. Table 1 shows the SWOT analysis of cloud computing and lists some positive and negative factors. In Table 1, Strengths and Opportunities are positive factors; Weaknesses and Threats are negative factors [22].

Table 1. The health cloud computing SWOT analysis

Strengths	Opportunities
<ul style="list-style-type: none"> <li>➤ A trend to adopting advanced health IT</li> <li>➤ With manager's support</li> </ul>	<ul style="list-style-type: none"> <li>➤ Lower upfront cost</li> <li>➤ The capability of rapid Elasticity and ubiquitous access to health resources</li> </ul>
Weaknesses	Threats
<ul style="list-style-type: none"> <li>➤ Insufficient evidence of successful application</li> <li>➤ Lack of domain experts to evaluate its feasibility</li> </ul>	<ul style="list-style-type: none"> <li>➤ Lack of trust</li> <li>➤ Lack of mandates or regulations to support full cloud adoption</li> </ul>
Internal	External

## 4. CONCLUSION

Cloud computing facilitates convenient, on-demand access to a shared pool of virtual computing resources, including networks, servers, storage, applications, and services. Flexibility and cost-containment are two important factors in employing cloud-based computing systems. Users scale storage dynamically and pay for only what they use. Cloud computing is capable of rapid elasticity and ubiquitous access to health resources. Cloud computing offers fast data management of patient information, offers providers and patients fast and easy access to medical and healthcare data, facilitates secure data sharing, reduces work load, and significantly saves costs.

The wireless technology can be used to collect and send data to the cloud server; cloud computing can improve EMR/EHR and telemedicine. During disasters, physicians can use the EMR cloud for billing, writing and transmitting prescriptions, and assessing patient medication lists and patient status. In medical services and healthcare, cloud computing needs to maintain compliance with some acts such as HIPAA, HITECH, and GLBA for data security and privacy protection. Biometric methods, for example, fingerprint recognition and palm vein scanning, can enhance authentication and information security. Although cloud computing has great potential, there are barriers restricting its application and expansion. Government' investment and policies help remove some barriers. Advances of sciences and technology are expected to overcome the barriers.

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Ms. Cheryl Ann Alexander is a graduate of the University of Phoenix where she earned a dual Master's degree in Healthcare Administration and Nursing, and she is currently a doctoral candidate and will graduate soon. She is Chairman of the Board of Technology & Healthcare Solutions, Inc., a nonprofit research and consultant firm located in Greenwood, MS, US, which promotes technology solutions as methods to reduce costs and errors in healthcare management and improve quality care. She has extensive clinical knowledge in a wide variety of clinical backgrounds, and a firm grasp of engineering and technology concepts through continuing education and workshops. She is a member of both engineering and healthcare organizations, and is working as guest editor for a leading journal in engineering.