

# Cloud Computing for Medical Applications & Healthcare Delivery: Technology, Application, Security and Swot Analysis

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**Abstract-** The healthcare domain in developing countries like India has started utilising latest emerging technologies such as mobile computing and cloud computing. Large volume of data is collected, stored, processed and retrieved in patient digital multimedia data called Electronic Health Records (EHRs). The electronic health records consist of images of patients which are of high security concern. It include patient's private data consisting of scanned images/reports, x-rays images, pathological reports etc.. Availability of patient record during every visit to the hospital thus improves the quality of treatment. Cloud computing when used in Healthcare sector reduces the cost of storage, all time availability and quality. Cloud infrastructure for Security of data and legal issues related to patient's privacy is not yet clear. Security for a large volume of data with efficiency is required as data of the patients are confidential in nature.

**Keywords**—cloud computing in healthcare

## I. INTRODUCTION

The healthcare industry has traditionally been considered to be a slow adopter of technology. Many belonging to healthcare environment have not yet adopted technology completely in their environments. Most of the application and focus has been on Hospital Information Management System (HIMS), Picture Archival Communication System (PACS), Laboratory Management System (LMS), Inventory Management System (IMS), Online Billing System (OBS) for payment & reimbursement and digitization of medical records etc. These modules are not yet implemented in a form of centralized system or only partial digitization occurred due to shortage of IT budgets, lack of infrastructure and manpower. Investments in information technology infrastructure compete with other priorities like radiological, pathological, microbiological equipments etc.

### A. Evolution of Cloud Technology

Technology is evolving fastly and has penetrated in human lives that now it is absorbed in the system in a more rapid manner. Tele-communication has brought lot of revolution in terms of data transfer and accessibility. More changes happens when mobile phones evolves with data communication support. It has brought revolution in our lifestyle. Applications like Social-Media, Video Communication has raised our expectations on communications, data, content, and

applications. Now we look for instantaneous and ubiquitous access to information like Anything, Anytime and Anywhere.

### B. Characteristics of Cloud

Cloud computing is pay per usage service and has raised the expectations of the users over conventional and traditional approaches. Cloud deployment has reduced recurring cost needed for sustenance and maintenance of infrastructure. User now need not have to bother about the up-gradation of equipment and application software and other resources. Cloud is identified by the his characteristics as mentioned below.

- **Ability to provide service over a Network:** ICT Infrastructure to applications is delivered and available as a service over the various communication media over Multi-protocol Label Switching (MPLS), Virtual Private Network (VPN), Shared Access or Dedicated Access using Wireless-Fidelity (Wifi), Fiber Network, Ethernet, Integrated Service Digital Network (ISDN), Very Small Aperture Terminal (VSAT). Services operate consistently, regardless of the underlying systems
- **Ability to be Flexible, Scalable & Elastic in nature:** Requirement and demand of the user is fulfilled and can further scale up as and when needed. Resources can be upgraded with least involvement under pay per usage policy.
- **Ability to make a pool of Shared Resources:** Multiple organizations can shared the same pool of resources allowing the same systems and applications to meet the demands of a users of similar groups or like minded people simultaneously and securely.
- **Ability to utilize services broadly:** Wide range of devices like Smart Phones, Laptops, iPad, Mobile devices etc are now available for accessing internet. Applications, Services and Resources available in cloud can now accessed through all the above mentioned devices
- **Presence of various Service Models:** Service models for clouds are Software as a Service (Saas), Infrastructure as a Service (Iaas), Platform as a

Service (Paas) and are available for private, public, hybrid, and community clouds deployment models.

- **Presence of Controlled and Measured Service:** Cloud Services are controlled and optimized automatically with a provision of measured services and resources.

## II. CLOUD TRANSFORMATION MODELS

Cloud computing are available in different transformation models out of which user can select type of cloud depending on the need of organisation. It is classified into private, public, hybrid and Community Cloud.

### A. Public Cloud

The public cloud is deployed in public domain and it provides services on software applications, storage and other services. It is for masses where numbers of customers are more generic in nature and pay as per usage model. Unlimited storage space is provided by public cloud and Size of the cloud infrastructure is huge. It is utilised with high speed public internet bandwidth and ownership, hosting, operation and maintenance is entirely with third party service providers. Services offered by public cloud are for all clients of small, medium and enterprise organisations and networks. Elastic Cloud Computer by Amazon, App Engine by Google, BlueCloud by IBM and Azure Services platform by Windows.

### B. Community Cloud

Community Cloud is for collaborative group of people which is managed either internally or by the third party. It is deployed either inside the organisation or deployed externally. Ownership rely with group of people or may have been hired from outside under mutual consent. The cost of deployment of community cloud is higher than public cloud but is cheaper than private cloud as the cost is shared among institutions involved in collaborating group. Number of users are more than private clouds but lesser than public cloud. Community Cloud thus can be shared by all the government institutions or partners or member of a similar group or community

### C. Hybrid Cloud

Hybrid cloud is a fusion of public clouds and private cloud. It has flexibility and has an advantage of multiple deployment models. Both public locations and private locations are used to deploy hybrid cloud. It is managed and controlled by users of private players as well as public players who are part of this cloud. IT organizations uses hybrid cloud for scaling cloud size by connecting existing clouds available in different geographical regions. Optimal utilization, Data-Centre consolidation, Risk transfer and 24X7 availability and Security are more prominent features in hybrid cloud over public cloud.

### D. Private Cloud

Private cloud is a cloud build by a single organisation and has restriction in usage for people outside the organisation. It is deployed, hosted and managed internally or may be outsources to third party under maintenance contract. Depending on the deployment, Private cloud is on-premises private cloud and external hosted private cloud. Users are charged on the basis of per Gigabyte (Gb) or Per Terabyte (Tb) usage. Data stored in the private cloud can be shared amongst users of an organisation. Outside sharing is limited due to usage of VPN, MPLS configuration, Network Security by implementation of firewall policies etc. Private cloud has provision of customization with strict security measures and dedicated resources. It is comparatively better than other cloud deployment models in terms of data security risk and reliability. It is less elastic in nature than other models. Popular examples of private cloud include Amazon Virtual Private Cloud (Amazon VPC), Microsoft Private, Eucalyptus Cloud Platform and IBM SmartCloud Foundation

## III. CLOUD SERVICE MODELS

Cloud service usage is offered as Software as a Service (SaaS), Platform as a Service (PaaS) & Infrastructure as a Service (IaaS). Depending on the requirement and need, user can choose the desired service models.

### A. Software as a Service (SaaS)

Cloud service provided to the user limited to the usage of software application installed in cloud infrastructure is Software as a Service (SaaS). Applications are accessible through Public Internet and are configured in such a way that user needs least technical assistance from cloud service provider. Measured metrics like number of concurrent users in the network, bandwidth consumption and duration for the usage of application helps cloud service provider to charge on pay per usage. User need not have to think about the upgradation of the software and can migrate to newer version as and when it is available.

### B. Platform as a Service (PaaS)

PaaS is better option when infrastructure platform is required to run the services or application. Programming tools with supporting tools used to build cloud infrastructure applications like Digital MRI analysis, X-rays dashboard built on Microsoft Azure and Digital Pathology System for archival of pathological slides.

### C. Infrastructure as a Service (IaaS)

IaaS gave more permissions and liberty to the user. User can select computational resources like speed, number of processors etc, data storage area with backup option, operating system configuration, communication network transmissions, and inputs from other diagnostics test and devices. Conventional IT infrastructure is just like a chassis of any vehicle. All infrastructure resources like applications, data, middleware, operating system, virtualisation, data center server, storage and networking devices are controlled and

manipulated by the user. IaaS is like a rental vehicle. Applications, Middleware, Operating System are managed by the user and rest is managed by the cloud service provider. SaaS is like a public vehicle. All applications, resources and infrastructure are managed by cloud service provider. User cannot control anything. PaaS is like a rental vehicle where only application and data part can be managed by the user and rest is managed by cloud service provider.

#### IV. CHALLENGES IN CLOUD TECHNOLOGY

##### A. Addressing Challenges in Healthcare

Healthcare is far behind in adoption of advance technologies like cloud computing, big data analytics and mobile computing. Workflow in healthcare institutions and hospitals depend on patient files, prescription and reports in a form of film-based radiological & pathological images, handwritten patient diagnosis and patient history, fragmented IT systems. Inter-collaboration and intra-communication between different departments, wards and OPD clinics are really challenging. Patient Confidentiality is also a big issue in implementing cloud technology.

##### B. The Digital Divide:

India has diversified geographical region with digital divide between Urban and Rural region. Most of the best hospitals equipped with latest technology, infrastructure and manpower in terms of adoption of new technology for high quality of healthcare services. Rural hospitals lacks basic infrastructure which is below the recommended norms in terms of availability of doctors patients ratio in relation to the population. Most of the doctors, nurses, administrators and other paramedical staff working in the rural hospitals are not exposed to technology due to lack of funds, policy and infrastructure. Uniform healthcare technology adoption can only be done by the sustained efforts from both the government and private sector. Cloud technology with IT in hospital can make healthcare applications like EMRs, HIS, PACS and others affordable and easily accessible.

##### C. High cost of implementing and managing multiple diverse infrastructural components:

Traditional technology requires entire infrastructure and manpower to run. Up-gradation of network in the stages also increases the cost of implementation as multiple communication paths laid down different path or have different data flow. Computer network, telephony network, pagers, nurse call systems, public address (PA) systems etc. requires a different set of infrastructure which needs to be clubbed into common integrated network infrastructure, which can create the health connect network. Integrated IT network thus helps diverse entities to collaborate and communicate effectively. The cloud can act as the foundation for health connect network to support a range of simple, complex and critical applications. The cloud technology in hospitals and healthcare providers helps to use the applications, hardware,

and services on a pay per usage model, which allows them to cut down expenditure cost and deploying expensive technology.

##### D. Data Centre Virtualisation for Healthcare

Medical application like EMR, HIS, PACS, Telemedicine, Tele-Surgery, Robotic Surgery, Image Guided Surgery, Digital Pathology System and other advanced clinical applications needs more bandwidth for data transmission and more space for storage. Storage and management of such kind of medical application needs central storage infrastructure which works in distributed architecture. Most of the educational materials of hospitals are multimedia contents which have lots of audio, video and animations along with text. Patient data itself is a heavy data and needs to preserve for a longer period. Cloud technology thus provides a scalable infrastructure for hospital's data center. This advancement of cloud is changing the way of healthcare providers and they are aware with the benefit of using cloud technology. Advancement in technology is changing the way as maintaining huge data centers needs lot of investment and human resources. Patient data confidentiality and security issues are also in risk if opted cloud technology. Patient data stores in the remote cloud facility, sensitive data could be lost, misused. Technology integrators and providers needs to build robust security and disaster recovery features into the cloud technology.

##### E. Cultural Issues and Change Management:

Healthcare facilities have been dependent on legacy systems and most of the process needs up-gradation. Technological changes in the infrastructure needs upgradation of existing systems and because of lack of funds and a tendency to avoid capital expenditure on new technology. Training is needed for acquiring knowledge about the new system as Shift in technology needs behavioral changes.

#### V. CLOUD COMPUTING IN HEALTHCARE

Healthcare applications for cloud has telemedicine, electronic medical records, medical imaging like Digital Pathology, Tele-dermatology that are consumed or integrated by healthcare providers, payers and customers over a cloud. The primary focus is to offer IaaS to their internal stakeholders. It will increase agility and managing its applications and the infrastructure. Administrative applications like Registration, Billing, Scheduling and Reimbursement are well suited for the cloud. This would let healthcare players focus on providing cost effective and efficient healthcare services. In many cases these services is composed of existing applications, infrastructure, and workflows that may be located anywhere in a cloud configuration to a set of consumers that can either be permanently or temporarily connected into the cloud. The service connections is provisioned for high levels of security and is monitored to precise endpoints to enable accurate

billing, usage and metering information for the individual services.

## VI. HEALTH APPLICATION IN CLOUD

### A. Telemedicine

Cloud storage is a data storage service that can be used for storing /sharing patient data during tele-consultation, Tele-followup and tele-education programme. Telemedicine system consist video conferencing, medical consultation software called telemedicine software and medical attachments which facilitate to record heartbeat, ECG, pulse rate, SPO<sub>2</sub>, Blood Glucose, NIBP, Pathological Slides, X-Ray Scanner and Dermatology Camera. Software deployed in a cloud permits real-time collaboration via software based video conferencing system like people-link, Clearone®, Webex of CISCO® and patient data exchange through telemedicine software during virtual OPD or Tele-OPD. Remote telemedicine center or primary health center (PHC)/ Community health center (CHC) at remote location connect to the server deployed in a cloud data center via available internet connection like high speed broadband or 3G Data Card. Data acquired at remote center is pushed to the cloud database along with all relevant patient health record. Doctors at super specialist connected to cloud database after providing username and password and gave consultation using telemedicine software.

### B. Cloud based 12 Lead ECG for Tele-Cardiology

Cloud based 12 Lead ECG based telemedicine service as compared with the traditional ECG tele-consultation can realize interoperability across various mobile and fixed devices. It greatly enhances the convenience of ECG interpretation and the efficacy of tele-consultation, as it enables cardiologists to interpret ECG ubiquitously, to access patients' current and past ECG records across hospitals via centralized cloud database, and to provide pre-hospital diagnosis in time. Apparently, this service advances clinical work and research on 12-lead ECG telemedicine with ECG interoperability, as it establishes an open tele-consultation platform from clinic to person and from hospital to hospital.

### C. Video Cloud services for Telemedicine & Telehealth Services

It enables video conferencing from the device, location and network of your choice and avoids investing in additional infrastructure through existing telemedicine cart, Smartphone, tablet, PC or Mac and Video Cloud handle the rest. Cloud-based video can be accessed from any device with a data connection and browser and share video throughout organization in just a few minutes on HIPAA compliant privacy and security

### D. Clinical Research

Medical research is based on the data collected from the patient time to time. These data can be archived in any application software with database software as backend. Data can be made available to the researcher for clinical research from the centralized cloud archive.

### E. Electronic Medical Record

Hospitals and physicians are starting to see cloud-based medical records and medical image archiving services coming on line. The objective is to offload a burdensome task from hospital IT departments and allow them to focus on supporting other imperatives such as EMR adoption and improved clinical support systems

### F. Collaboration Solutions

Early successes of cloud-based physician collaboration solutions such as remote video conference physician visits are being trialed. Extending such offerings to a mobile environment for rural telehealth or disaster response is becoming more real with broader wireless broadband and smartphone adoption. Cloud technology supports collaboration and team-based care delivery and the ability to use applications based on business model requirements and a common set of clinical information

### G. Big Data

Healthcare organizations turn to cloud computing to save on the costs of storing hardware locally. The cloud holds big data sets for EHRs, radiology images and genomic data for clinical drug trials. Attempting to share EHRs among facilities in various geographic areas without the benefits of cloud storage could delay treatment of patients

### H. Health Information Exchange

Health information exchanges (HIE) help healthcare organizations to share data contained in largely proprietary EHR systems. Organizations can now accelerate the deployment of HIE via a linkage to a strategic cloud implementation

### I. Medical Imaging

Medical Imaging includes storage, sharing and computation of images. Cloud based Picture Archival and Communication (PACS). It even provides flexible radiology round the clock<sup>8</sup>. Medical imaging in the cloud thus help the patient by sharing the information among group of medical doctors for expert opinions.

### J. Mobile Cloud Computing

Mobile Cloud Computing integrates cloud computing into the mobile environment and overcomes mobile devices limitations in terms of storage, security and privacy issues. These limitations and challenges are overcome by

incorporating advanced technologies like high speed broadband like 3G, 4G, Wifi & WiMax connectivity and can be used to improve patient outcomes through quality services.

#### VII. SECURITY ISSUE IN HEALTHCARE

Cloud security has been assessed by identifying / gathering risk based upon the literature. Various security issues are included in table 1.

Risk1	Policies and its changes
Risk2	Legal, Ethical and Privacy laws
Risk3	Different Geographical Regions or countries having different laws
Risk4	Security loop holes by various cloud provider
Risk5	Emerging Technology with their loop holes
Risk6	XML Signature attacks / Flooding
Risk6	Failure of Cloud access tools / communication media
Risk7	Flooding attacks by virus / malware programs used by hackers
Risk8	Distributed Denial of Service (DDoS)
Risk9	Bad IP Addresses / References
Risk10	Cloud bankrupt / Change in ownership
Risk11	Technical failure / Downtime
Risk12	Process interlocking
Risk13	access of data by unauthorised users / third party
Risk14	Cloud Based Privacy and security
Risk15	IP & Port Scanning

Table 1: Possible risks in cloud for healthcare applications

#### VIII. SWOT ANALYSIS FOR ADOPTING CLOUD COMPUTING SERVICES IN HEALTHCARE

The acronym SWOT stands for Strength, Weaknesses, Opportunities and Threats. SWOT analysis is an efficient way to find the strength and weakness of organizational capability and has been used extensively in various decision making processes.

Strength	Weakness
Cost Effectiveness, Innovate, Flexible, Cost Reduction,	High Speed Internet, Integrated with local

Energy Saving, Better Control, Ability to expand	software, Lack of commitment to control QoS, Legal, Ethical and Privacy Laws
Opportunity	Threat
Latest technology, Minimum Investment, Adaptive to future requirement	Data Security, Loss of Connectivity, Integration with another platform is hard, Lack of Standards

Table 2: SWOT Analysis for cloud computing in healthcare

#### IX. CONCLUSION

Cloud applications transform the system from capital-intensive to pay per usage model. Cloud improves information management and reduces operating risks. Cloud provide enterprise IT resources to healthcare providers of all size across all geographical regions. Cloud is the latest technology with minimum investment adaptive to future requirement. It is cost effective, energy saving and flexible. Cloud can only be accessed by high speed internet. Hospitals and other healthcare providers need to adapt quickly to the emerging technologies and collaborate more effectively.

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