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Healthcare Information Technology & Cloud

Evolution, Status and Future

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***Abstract*— The term "cloud computing" is heard by almost everyone in some context or the other. It is a technology that was born in the last decade and has already taken its place in the current business world. Cloud is a new way of providing access to the computing resources over the web which is based on the "pay as you go" model. Because of the characteristics of cloud like on-demand, "metered service", elasticity and cost efficiency, organizations have already started moving their services to cloud. Interestingly, cloud computing is most widely used by the organizations whose implications can have greater effect on the society. Education and social media are some domains which marks the presence of cloud computing. But recently, cloud computing has attracted the organizations in the healthcare domain. It is a domain of great research as it requires the presence of right information at the right time which can save a human life. Although the advancement of cloud in health care domain is not very rapid due to challenges like security and trust of medical records, there are some great solutions and patient-centric service that has been developed and in successful use. This paper throws light on the evolution of cloud in healthcare, opportunities and challenges of using cloud, what key things should be considered while moving to cloud and finally an exploration into the future of healthcare.**

Keywords*— *Healthcare Information Technology (HIT), cloud computing, Electronic Health Records (EHR), eHealth, Interoperability, Data Security, Virtualization, Grid Computing, Analytics, Health Information Exchange

I. INTRODUCTION

Cloud or utility computing is a new emerging computing paradigm that provides computing resources over the internet. It offers several features which attracts the potential users like metered service ("pay as you go"), scalability, broad network access of software and hardware resources, virtualization of server and storage devices [1]. Some of the examples of commonly used applications based on this technology are Google Docs and Drop Box. This technology has obviated the need for organizations to maintain and update their own computing resources.

When it emerged, many people, including eminent IT professionals like Larry Ellison (founder of Oracle) and Richard Stallman (creator of GNU OS) doubted the potential of this new technology. But industry slowly started accepting this technology and education industry marked its beginning. Due to the features and services it provides, it has grabbed a place in every industry and many organizations. Then recently, it attracted the health care industry and pharmaceutical and medical research organizations or businesses engaged in finding cures and helping patients have started test and explore the potential of this new innovation [1]. Health care is the most critical area that requires a lot of information and computing power to improve the human health.

The need of the hour is to have a solution or system to store medical data that can be analyzed, shared remotely and can be used for medical research and emergency medical situations. The organizations are already focusing on developing such systems and are providing patient-centric services and this industry is on a boom. The main concerns that contribute to the slow growth of cloud in this industry are security and legal issues. The medical firms have the personal patient data or records and research data which are difficult to be trusted on the service provider. Again, the patients are the legal owners of their records and sharing it without their knowledge is illegal. But new solutions are being developed and this industry has decided to move forward with it. According to a research done by Market and Market, the cloud computing in health care industry is expected to grow to $5.4 billion by 2017 [60].

This paper will move forward with explaining the basics of cloud computing and its architecture, justify the need of cloud computing in healthcare, how it evolved, its applications and services, opportunities and challenges via a 4-aspect model and help identify the points to consider before moving to cloud and finally exploration into the future work.

II. WHAT IS CLOUD COMPUTING?

We have heard this term cloud and cloud computing so many times but there is no common definition when it comes to cloud computing and in fact, there has been much discussion in academia and industry about what cloud computing actually means. The US National Institute of Standards and Technology (NIST) has developed a working definition that covers the commonly agreed aspects of cloud computing. The NIST definition – "*Cloud computing is 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. This cloud model is composed of five essential characteristics, three service models, and four deployment models*" [69].

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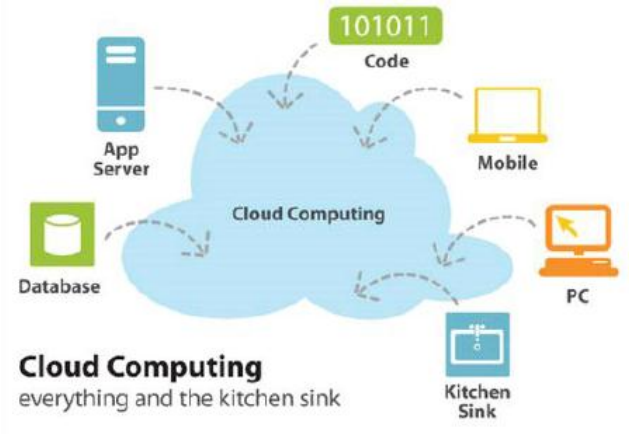

Fig. 1. Cloud Computing Overview

A. Characteristics

1) On-demand self-service

A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider [69].

2) Broad Network Access

Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations) [69].

3) Resource Pooling

The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, and network bandwidth [69].

4) Rapid Elasticity

Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time [69].

5) Measured Service

Cloud systems automatically control and optimize resource use by leveraging a metering capability1 at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service [69].

B. Service Models

1) Software as a Service (SaaS)

The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user specific application configuration settings [69].

2) Platform as a Service (PaaS)

The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment [69].

3) Infrastructure as a Service (IaaS)

The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls) [69].

C. Deployment Models

1) Private Cloud

The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises [69].

2) Community Cloud

The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises [69].

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3) Public Cloud

The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider [69].

4) Hybrid Cloud

The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds) [69].

Cloud computing services can be provided by a service provider through their data centers (public cloud) or end users using cloud software installed on their own data center (private) or a combination of both (hybrid cloud).

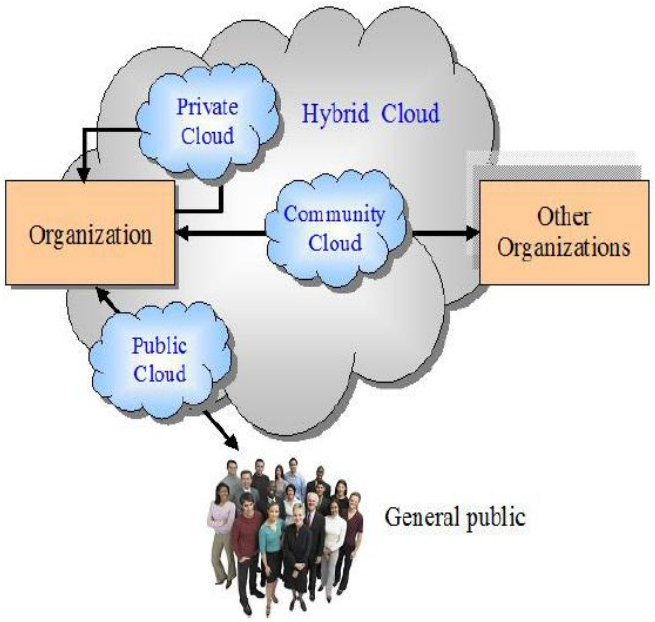

Fig. 2. The Cloud Computing Deployment Models

D. Cloud Computing key concepts

1) Virtualization

Virtualization means an abstract representation of the physical and logical resources including storage devices, servers, network and software [2]. It is a layer that maps the visible resources onto the resources of underlying layer on which it is implemented. The idea behind this is to pool all the resources at first and then allocate the virtualized resources as per the requirements. It is more cost efficient as it virtualizes the need of hardware devices in a more cost efficient way rather than buying it. This is one of the main reasons why organizations prefer to use cloud.

2) Grid Computing

Grid computing is to use software to combine the computational power of several computing devices (possibly geographically separated) connected in a grid in order to solve a problem. Then problem is solved on the whole grid [1].

E. Architecture

Just to give an overview of how cloud works, its architecture can be broadly divided into two parts which are connected over the internet:

1) Front End

It refers to the client side of a cloud system which consists of applications and user interfaces. It can be accessed through a web browser and this is how a user access services over cloud [3].

2) Back End

It refers to the whole cloud infrastructure and the system which contains all the resources including virtual machines, network and storage devices [3]. The customer's access to the back end is limited depending on the type of service that is being provided.

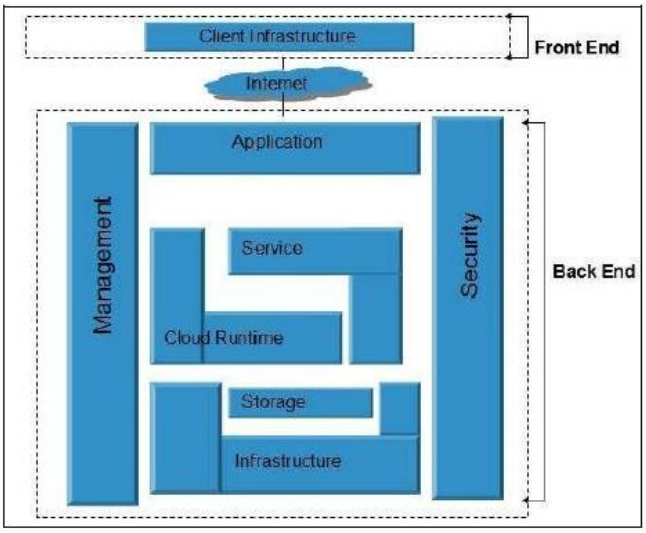

Fig. 3. Cloud Computing Architecture

F. Related Terms

- *Hypervisor*
  Also known as virtual machine monitor (VMM), it is a physical layer that allows multiple virtual machines to run on a physical machine which can be of either bare-metal or hosted.
- *Software Oriented Architecture (SOA)*
  It is a mechanism which links different components implemented as independent services through messages. SOA has benefits such as it is language independent as it uses XML, agility as it can recombine and integrate the components quickly and it can also enable the integration between new and old components [2].

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III. CLOUD COMPUTING IN HEALTHCARE

Increase in levels of life expectancy has left many developing countries with an ageing population which needs the health care resources at the time when these resources (healthcare professionals and organizations) are being stretched to serve the increased demand [1]. The data in healthcare organizations is increasing exponentially including organization data, patient records and medical history and research data. This industry needs to manage and process pica bytes of data and the availability of right information at the right time can save a human life.

More than ever, the healthcare services need to maintain data and coordinate between different healthcare units because of the high mobility of people. The systems or solutions available at present or those that are non-cloud based is not able to satisfy today's requirements. This situation has prompted many healthcare organizations to look for more innovative and cost effective solutions. There is a need of a solution which can automate the collection and storage of patient's medical records, provide remote access to them whenever required and allow access to only authorized people. Moreover, the system needs to be able to analyze and visualize the data in order to enhance the diagnosis or help in the treatment. Many organizations had developed solution based on cloud to provide patient-centric services. Cloud has the potential to address many problems mentioned in the next section.

A. Why Healthcare needs Cloud based solution?

- Most healthcare systems are still based on paper records. Paper records are complex to store and manage and its access can only be provided in person and is usually not available for research purposes due to financial constraints.
- Even if the records are digitized, their portability is usually nor properly planned and organized. At most, they can only be accessed within the same organization.
- Remote access is also an issue. There is no limit to where and when a requirement for a medical record can arise. So the system does not needs to scaled for a city or a country but worldwide.
- If an organization would go on to setup its own infrastructure to process and analyze the pica bytes of data it has, it would be very expensive as that data requires very high computing resources and most of the mid-level healthcare service providers cannot afford that expense.

B. Benefits of Cloud

Cloud due to its features like scalability, virtualization, pay as you go and many more is being used as a new platform to provide the services and it has been able to address some of the problems being faced by the healthcare organizations such as infrastructure management, cost efficiency and dynamic needs. The following points show the benefits of using cloud.

- Due to its feature of on-demand, cloud provides access to computing and large storage facilities required to huge amounts of medical records which is not provided in traditional systems.
- Supports a large number of electronic health records (EHR) which can digitize all the information related to a patient and its medical history.
- Facilitates the sharing of EHRs whenever required to provide improved healthcare facilities
- Analyzes and visualizes patient records and extracts some meaningful information out of it which can accelerate the process of diagnosis and treatment
- Cloud enables users to create hundreds or even thousands of virtual machines i.e. computing resources on the click of a button, unlimited storage space and right software functionality

A research done by HIMSS Analytics shows (figure 4) the prime factors for why organizations are moving to the cloud [70].

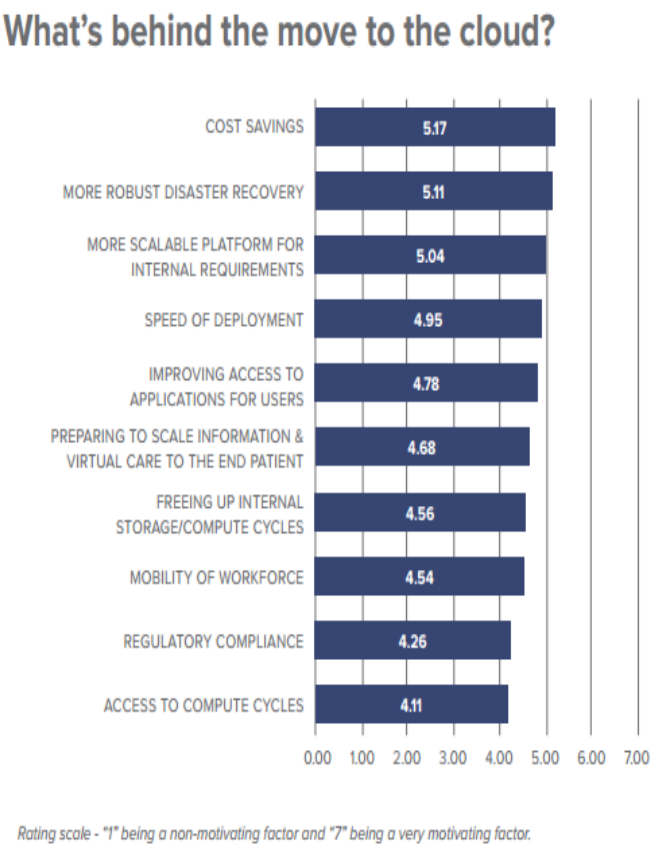

Fig. 4. Reasons for moving to Cloud, HIMSS Analytics

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C. Evolution and Status

Cloud has already marked its presence in the healthcare industry. Many solutions are now evolved and being used successfully. It all started when organizations started putting efforts and working together to build such systems that can enable easy access by medical and health care organizations to a wide range of information such as Electronic medical records (EMR), medical history and laboratory data [1]. Many people proposed and many companies worked on such systems. Some of the efforts are described below.

- In [10], Rolim et al proposed a cloud based system that can automate the collection of patient health records through sensors connected to the common medical devices and send that data to cloud for storage, processing and distribution. The proposed system would be available 24x7 so that it can collect vital data in real time without any efforts on human side.
- In [11], Nkosi and Mekuria described a protocol management system which offers multimedia sensor signal processing to mobile devices so that they no longer have to do all the heavy computation. The proposed system would promote the use of mobile devices in providing healthcare services.
- In 2010, IBM and ActiveHealth Management, a subsidiary of Aetna developed a clinical information management system named "collaborative care solutions" to provide easy access to electronic medical records (EMR). The developed system offers visualizations to show trends which can help in diagnosis. The system also provides advanced analytics to measure organization's performance with the national standards.
- In 2010, GE Healthcare (part of giant US General Electric group and one of the most prominent medical technology companies) and Med Cloud launched "centricity practice" which provides a self-service portal for patients through which they can remotely access their personal records and communicate with their care providers.
- In [12], Rao et al mentioned an initiative named "Dharti" which uses the power of cloud computing and wireless technologies to provide access to patient health records anytime and from anywhere.
- In [13] , Koufi et al proposed a emergency medical system for Greek National Health Service to integrate the health records system with emergency services so that the records can be accessed by physicians in case of emergencies.
- In 2010, Dell partnered with Practice Fusion to provide EMR management services for small and medium level enterprises (SMEs).
- In 2010, the US government under the Health Information Technology for Economic and Clinical Health (HITECH) declared to remove paper based systems and provide each American citizen with an EMR by 2014.
- In [14], Aliva Garcia proposed a framework based on cloud computing for colorectal cancer imaging and research.
- In [15], Bateman and Wood have done an experiment with 100 nodes hosted on Amazon's EC2 service to assemble a full human genome with 140 million individual read requirements using a sequence search and alignment by hashing (SSAHA) algorithm.
- In [16], Kudtarkar also used Amazon's EC2 service to perform a genome-to-genome comparison for computing the orthologous relationships. The computation costed 40% less than expected.
- In [17], Memom et al used cloud computing to find the impact of G-quadruplexes on Affymetrix arrays.
- In 2011, the UK government proposed a system to provide the National Health Service (NHS) patients access to their electronic medical records (EMR).
- In [18], an ePrescribing solution is proposed in which a physician who is connected to the system can access the Personal Health Records (PHR) and read all the medical history of each patient. It can also suggest a list of drugs. The proposed system would check it with the patient's allergies and if no issues occur, would forward to patient and pharmacies for processing.
- In [19], a model is proposed as in integrated electronic medical record (EMR) to enable the sharing of patient records in different medical units. The system allows access to any healthcare and government organization nationwide.
- In [20], The Laboratory for Personalized Medicine of the Center for Biomedical Informatics at Harvard Medical School to manipulate enormous amounts of data in record time.
- Not just the academic researchers but also the big companies have heavily invested in this domain to offer medical record services. Example - Salt Lake City-based Spearstone's health care data storage application and DiskAgent uses Amazon Simple Storage Service (Amazon S3) and Amazon Web Services (AWS) [21].
- The American Occupational Network is digitizing health records and updating its clinical processes using a system jointly developed by IBM and MedTrack systems By using the system, the organization has decreased its cost by 80% [22].
- The US Department of Health & Human Services' Office of the National Coordinator for Health Information Technology is working with Acumen Solutions to implement electronic health record (EHR) systems across United States [23].
- Telstra and the Royal Australian College of General Practitioners are working on to develop and eHealth cloud which would host healthcare applications including clinical software, decision-systems, management systems and prescription software [24].
- In Europe, IBM, Sirrix AG security technologies, Portuguese energy and solution providers Energias de Portugal and EFACEC and San Raffaele Hospital (Italy) are working with Trustworthy clouds to develop patient centered home health care service which would monitor and assist patients remotely [25].

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Recent research indicates that 75% of chief information officers reported that they will need and use cloud computing in the near future [26, 27].

In addition, a report by the European Network and Information Security Agency (ENISA) indicated that the cloud model would see huge global investment in health care [28].

A survey done by HIMSS Analytics shows (figure 5) what all services are moving to cloud as in 2016 [70].

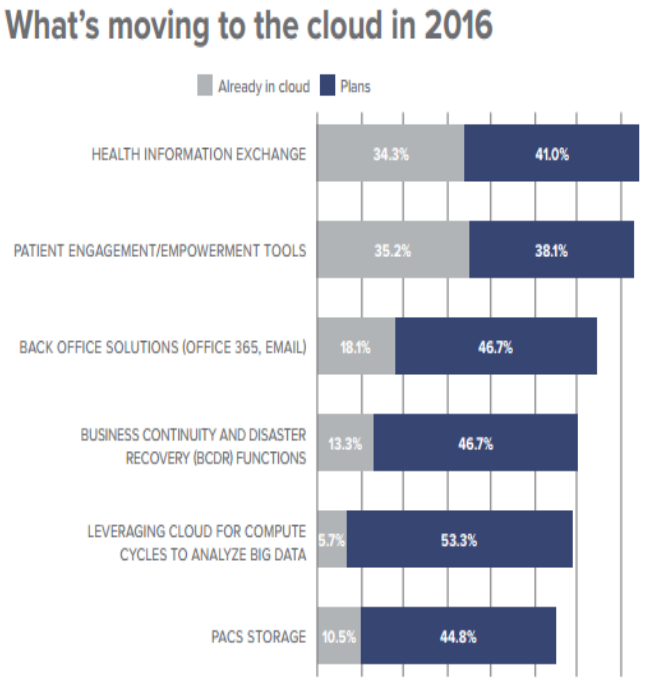

Fig. 5. Adoption of Cloud in Healthcare

IV. APPLICATIONS AND SERVICES BASED ON CLOUD COMPUTING

Healthcare industry has started using the solutions based on cloud to provide patient-centric services and is expanding now. There are services for automated collection and storage of electronic health records (EHR), processing and visualizing results to enhance the process for treatment cure. The industry is using novel applications which satisfy these common requirements of authentication, authorization, data capture, data confidentiality and audit trail [1]. The common architecture for such applications would consist of three layers mentioned below [1].

1) Top Layer: It consists of following elements

- *The Data Bucket*
  This component would be like a data store which will hold all the patient records and provides service like creating, reading, updating and deleting.
- *Identity Mapping*
  This component would map the patient or user with their records and allows access only to the authorized personnel.
- *Access Control*
  This component would allow patients to restrict access to their own records as they are considered to be the sole owners of their records.
- *Audit Trail*
  This component would gather logs from applications about its usage.

2) Middle Layer
This layer would be the single point of communication (SPOC) that would authorize and issue service tokens to patients to access their records.

3) Bottom Layer
This layer would consist of all the security and authentication protocols that are going to be used in the system. It would have all the information on the application is going to meet the authorization requirements.

The following are some of the applications and services that are being provided in healthcare industry.

A. Data Management

The data in the healthcare industry is growing exponentially. Organizations in Healthcare industry have a lot of information (in pica bytes) that needs to be stored and processed. When it comes to data, this industry requires an efficient and effective system to manage that huge amount of data which includes but not limited to patient records, medical history, human resources, medical research and accounts and billing. The traditional infrastructure is not able to handle such requirements and setting up new in-house system would incur a huge investment on trained IT staff and storage infrastructure. Hence this data needs to be moved to cloud. Moving data from traditional infrastructure to cloud based storage services provide the following benefits:

1. Cloud provides unlimited storage which can be provisioned as per the demand.
2. The data on cloud would be available 24x7 with the ease of management.
3. It can be accessed remotely from any web device connected to the web.
4. Physicians can share this data with other physicians for decision making.
5. As cloud is based on distributed storage, the access and retrieval would be faster than traditional systems.

A Research conducted by HIMSS Analytics (figure 6) shows the preference of cloud vendors for back office solutions [70].

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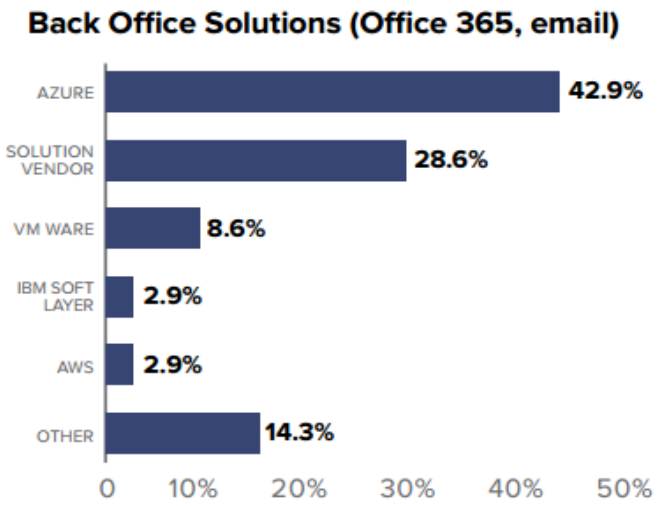

Fig. 6. Comparison of Cloud Vendors

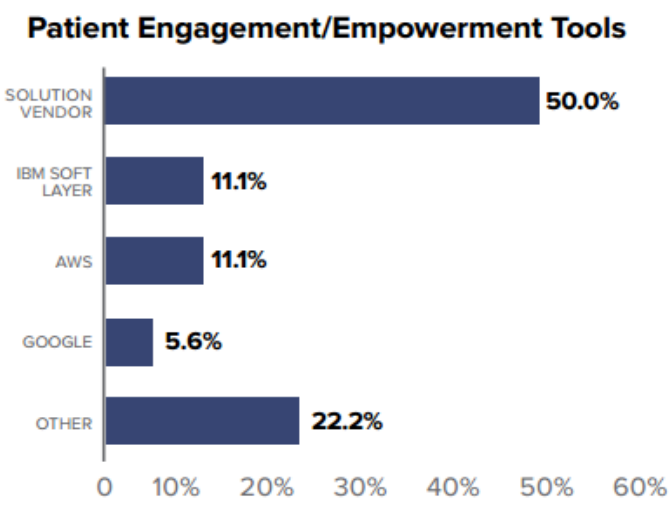

Fig. 7. Comparison of Cloud Vendors

B. Electronic Health Records (EHR)

EHR is a more systematic and organized way to represent patient's data. It consists of a repository for each patient which consists of all the medical history related to that patient. The data in an EHR may consist of remote monitoring of patients to store all data in real time like their heart rate, blood pressure etc. This is the major step towards digitizing the patient records and is usually proposed to be spread nationwide. The system would do visualizations based on this data which are helpful to physicians and health care professionals. The objective is to offload a burdensome task from the hospital's IT department and build a support system to maintain EHRs. The benefits of cloud based EHR systems are:

1. Patients information captured this way can be very useful when they visit their consultants.
2. The health data collected this way can be used to build warning based applications. Example – an application would inform the closed ones of the patients when certain measures like BP would cross the normal limit.
3. A nationalized EHR system would reduce the redundancy of data as each organization would not have to separately create repositories for every patient.
4. As the EHR records are present on cloud, it provides more cost efficient way to provide remote access to patients to their EHR and its management.
5. The EHR visualizations like bar graphs and line curves can be used by physicians or consultants to get more insights on a patient's health and enhance the diagnosis.

A Research conducted by HIMSS Analytics (figure 7) shows the preference of cloud vendors for patient engagement solutions [70].

C. Tele-Medicine

Due to the fast life a today's human is living in, the Healthcare information technologies has moved a step forward to provide the services to their patients beyond the scope of physical medical centers. Telemedicine is one such domain that is based on cloud and evolved because of the availability of mobile devices and intelligent medical devices. Telemedicine technologies remotely provide service like tele-consultations, tele-surgeries, tele-radiology, video conferencing and home monitoring.

Because of the telemedicine services, a patient not only gets the healthcare services without leaving their place but the physicians can also share records in case of complex decision making. Cloud based telemedicine services could also be developed to improve the doctor to doctor interaction and build a community of doctors that can provide these services online anytime from any place. The benefits of using cloud based telemedicine services are:

1. It's a flexible model and a technology of future where patients don't actually need to visit a consultant for any medical advice. The consultants can access the EHRs anytime from any location.
2. It offers treatment across the geographical boundaries and in a more cost efficient way.
3. Patients can save their travelling time and money.
4. Consultants can use this model to reduce the unnecessary visits of patients and can save in their time.
5. Several consultants can access records remotely and jointly give an advice or perform a tele-operation.

D. Clinical Research

Due to the explosion of data, the pharmaceuticals companies these days have started using the cloud and its services to improve on research and development. Currently, the pharmaceuticals companies do not have enough computing resources to run large data sets and with cloud, they can easily work on DNA sequencing and next generation sequencing. The cloud has become an important aspect of R&D because of the growing importance of biologics in the

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research process. Certain cloud service providers are also giving pharma-based cloud offering or solutions tailored to their needs in a very cost efficient way [4].

E. Drug Discovery

Drug discovery is the process of discovering new drugs for medical diseases that are efficient and effective. The process involves processing and analyzing potentials compounds having trillions of different chemical structures. The organizations lack such high computing resources and hence, cloud is the best way to accelerate the process of drug discovery in a more time efficient and cost efficient manner. Example – Molplex, Newcastle University and Microsoft Research has jointly developed an IAAS, named "clouds against disease" to provide organizations with computing resources to analyze huge biological structures.

F. Analytics

Cloud computing facilitates the scaling of information and insights are available in real time. The availability of such data ensures that all clinical knowledge is available to physicians and consultants which can enhance the decision making process. The focus here is on value creation rather than just consumption. The data gathered can be analyzed and tracked in a better way so as to provide treatments efficiently. The data can be stored for future medical research purposes [4].

G. Health Information Exchange

Cloud computing has greatly affected the way data is being stored. The data stored in cloud is not only available for fast retrieval but can also be managed and shared effectively and in a secured way. Cloud promotes the sharing of health information records stored in the form of EHRs. The data shared can only be accessed by authorized personnel thus providing an additional layer of security. The exchange of health information has affected the cures being found and treatments being given to the patients. Health information exchange promotes a more healthy society but sharing data between different medical units nationwide.

H. Medical Imaging

The cloud has not penetrated this domain much and is still in its infancy. But the situation may change in near future. The topics of great research in this domain are medical image reconstruction and medical image processing.

Medical image reconstruction requires accurate quantitative analysis of reconstructed images. The quantitative imaging requires heavy computational workload for reconstruction process and associated correction algorithms leading to long execution times. Example – Monte Carlo modeling. Cloud infrastructure can address this problem as these algorithms can be executed in a multi-threaded fashion with parallelization [6].

Medical image processing is another domain that benefit from cloud. Research in this domain has led to algorithmic improvements. Any new algorithm that is developed needs to be compared with current algorithms to check if it provides improved image processing. Cloud can provide benchmarks for such comparisons by creating and making them available for widespread use. Such datasets combines information from different databases related to image processing algorithms such as segmentation, denoising and fusion. Again, cloud can work as an infrastructure to run such algorithms [6].

I. Digital Libraries

The prime source of knowledge among medical students, researchers and practitioners are libraries. However, the paper based libraries cannot meet the current requirements due to their limited availability, geographical boundaries and financial barriers. Digital libraries are being developed to serve the research requirements of the medical community so that the access to the manuscripts and works of literature can be made easily available. Cloud based libraries offers services like on-demand, indexing, query services and library management systems. The benefits of cloud driven libraries are:

1. The search process based on semantic based queries makes it hassle free.
2. Information is readily available and remotely accessible.
3. Institutions can provide access to such libraries to their students online.
4. Researchers can track the progress of current developments in medical domain.

J. Medical Education

Cloud computing has marked its presence first in the education domain. Education the current population means transferring the knowledge gained till now to the researchers of the future so that they can continue to research and builds a more human-centric society. Cloud can also be used by medical universities to provide teaching services like online lectures and online content to promote the education on healthcare.

V. OPPORTUNITIES AND CHALLENGES

Healthcare organizations are expected to provide improved healthcare services while simultaneously limiting the increase in costs. Economics, simplification and convenience of the way cloud-computing based services are delivered made cloud a great topic of interest in healthcare industry. However, despite the significant advantages of the utilization of cloud computing in healthcare information technology, security and data portability are some challenges that have hindered its growth.

As any new innovation, cloud computing should also be evaluated before its adoption. This section presents a 4-aspect model which shows the opportunities and challenges from the aspects of management, technology, security and legal.

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Aspect	Opportunities	Challenges
Management	Low Cost Resource availability Pay per use	Lack of trust Cultural resistance Loss of governance
Technology	Low maintenance Scalability Flexibility Green computing	Resource exhaustion Data lock-in Transfer bottlenecks Bugs
Security	Replication Defensive resources	Separation failure Poor encryption
Legal	Commitment Policies development Regulations	Jurisdiction Privacy Intellectual Property

Table 1. Overview of Opportunities & Challenges

1) Management Aspect

- Opportunities

The biggest advantage of cloud computing is its low cost. Example – Amazon charges only USD 0.1 per hour for 1.0 GHz x 86 instructions set architecture [29]. Any organization can get a cost –effective and in house IT infrastructure through cloud computing without the need of purchasing the internal hardware [29].

Also, cloud computing has this feature of rapid elasticity which makes deployment easy. Healthcare industry now can manage pica bytes of data over the cloud hassle free. This also reduces the cost of IT staffing and training and have increased their capabilities. Cloud is like a new way for Management information systems (MIS). MIS being used in healthcare industry streamlines the information flow within and outside the organization. Physicians can user this system to provide better care, customers use it for querying services and administrators use it to manage human resources.

- Challenges

Healthcare organizations have mission critical data such as patient records and medical research and lack of trust in data security is the main reason that resists many organizations to move to cloud [30]. Concerns arise when the mission critical application moves to such cloud computing paradigm or platform where the service provider cannot guarantee effectiveness in data security [31]. Another concern regarding the privacy of users arises when a user does not want to share their data and moving on cloud changes the mission of such applications.

Loss of governance arises when the service level agreements (SLAs) may not offer complete commitment to the client. Cultural resistance i.e. organization's inertia to share data and change the traditional ways is another challenge when it comes to adoption of cloud [5]. These issues may put the organization's investment at risk and hence stops the management from moving to cloud.

2) Technology Aspect

- Opportunities

The small and medium level healthcare organizations (SMEs) usually do not have enough IT staff and resources to maintain and serve the mission critical applications such as EHRs and using the cloud based EHR services eliminates the need of staffing and setting up the infrastructure [32]. The bigger organizations can move their mission critical applications to the cloud which provided them flexibility.

Using cloud has another technological benefit i.e. green computing. Green computing is using the available resources more efficiently so as to promote environment and energy saving. Using resources tailored to the needs of the organization reduces the electricity expenses and emission of dangerous materials into the environment [33].

- Challenges

Some of the main technological challenges are unpredictability of performance, interoperability of data, data transfer bottlenecks and bugs in large-scale distributed cloud systems.

Low cost and flexibility are the key concepts of cloud and due to the competitive market cloud service providers may overcommit the computing resources like CPU and storage to attract the customers. In order to maintain the profit, they may limit the access or use outdated hardware. A customer does have knowledge about their internal architecture and this may lead to unpredictable performance [34].

Interoperability is one of the main issues that arise when moving healthcare application to the cloud. A key component in healthcare information technology is the reliable sharing of data to between the consultants, physicians and patients to improve healthcare services. But due to the vast existence of different protocols, OS, programming languages, platforms, database models and approaches that cloud providers and healthcare organizations are using, interoperability has turned out the biggest issue when moving from one cloud to other.

Healthcare systems are not currently designed using common data modeling constructs resulting in different database designs and incompatible systems. Most of the cloud providers also use proprietary APIs for application development and data storage. Such reasons hinder the migration of data from vendor to another which is needed for scalability and to take advantage of other lower-cost services when one specific provider stops offering the required services.

Data integration, the most important pre-requisite of systems integration is another issue in interoperability that arises when there is a need to integrate systems that are based on different database models. For example – something as innocuous as a phone number may be formatted in one system as 9999999999 whereas another system will read it as (999) 999 9999.

Interoperability must occur at different levels: provider, software and healthcare systems. The provider level needs the standardization of APIs which would permit development of applications compatible with different cloud service providers and in-house cloud. The software level

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needs software developers to share some common data model and design products or healthcare systems that can interact with each other.

To help facilitate these issues, healthcare organizations have some standard development organizations (SDOs) like HealthLevel 7 (HL7) to standardize the specifications in healthcare informatics [4]. A new approach to design healthcare systems is required to develop more interoperable systems. Such change will result in substantial benefits to healthcare community.

Data transfer bottlenecks arises when medical based organizations require downloading or uploading huge amounts of data to the cloud which may be limited because of the physical networking bandwidth [5].

Another technical issue is bugs in cloud systems because it's usually difficult to mage large-scale distributed systems [5].

3) Security Aspect

- Opportunities

The prime resistance when it comes to adoption of cloud in healthcare is data security [35]. But that does not necessarily mean that cloud is less secure than in-house infrastructure. For example – once a 9.0 magnitude earthquake in Japan destroyed all medical and legal documents. The service providers like Amazon, Google have invested huge resources to improve security issues which customers can't afford. All kinds of security measures like hardware, software are cheaper when implemented on large scale.

Another benefit is that cloud replicates data in multiple locations which provides data redundancy and independence from system failure. Cloud systems can scale defensive resources dynamically which it more robust against attacks such as denial of service (DOS).

- Challenges

The information technology is prone to many security risks such as hacker attacks, network breaks, natural disasters, poor encryption key management and privilege abuse. Risks that are more specific to cloud computing also include separation failure. The resources on cloud can be accessible to anyone from anywhere and if the provider fails to separate these resources, it can cause severe security risks. For example – if a user deletes some data, it may not be deleted permanently from the disk but just not accessible to it. When another user accesses the same resource in a multi-tenant environment, it would get access to another user's deleted data [35]. This presents a higher risk in cloud computing.

The ENISA's summary on risks in cloud computing says that – "*The customer management interfaces of public cloud providers are Internet accessible and mediate access to larger sets of resources (than traditional hosting providers) and therefore pose an increased risk especially when combined with remote access and Web browser vulnerabilities*".

The need of the hour is to develop strong key based encryption mechanisms to prevent data loss, theft and security breaches so that the trust of the customer can be preserved and more applications can integrate with cloud to provide enhanced and more secure services.

4) Legal Aspect

- Opportunities

For the full utilization of cloud computing, customers trust should be built in terms of data security and privacy. This can be done by adoption of clear policies and practices to reduce the risks. Cloud service providers have started building policies and practices to protect customer data [36-38]. There are many government and non-profit organizations which are working on to suggest development strategies for trusted platforms [39-42]. For example – trusted computing group (http://www.trustedcomputinggroup.org/), a not-for-profit organization, suggests a set of hardware and software technologies to enable the construction of trusted systems [5].

- Challenges

Legal issues such as contract law, intellectual property rights, data jurisdiction and privacy are the major concerns related to the use of cloud computing in healthcare [43-47]. The data in cloud could be stored over multiple jurisdictions which may have different laws related to data security and privacy [46, 47]. For example- the US Health Insurance Portability and Accountability Act (HIPAA) restricts providers from disclosing personal health records to non-authorized third parties whereas the Providing Appropriate Tools Required to Intercept and Obstruct Terrorism (PATRIOT) Act [48] gives the US government the right to access data in case of an emergency situation or if a situation is necessary to homeland security. Intellectual property rights consider the individual users to be the sole owners of their data. Such differences in laws create security issues as providers may have to share data without the authorization of users and it turns against intellectual property rights.

As cloud is a distributed and multi-tenant model, the failure in separation of resources would result in centralized storage which would put the user sensitive data such as EHRs at a high risk of disclosure by other parties [35].

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Poor breach notification is also a privacy issue as it does not really protects user's data [5]. A recent survey shows that those users who have been breached in the past year are at a greater risk for fraud than typical user [49].

VI. STRATEGIC PLANNING FOR MOVING TO CLOUD

As any new technology or innovation, cloud needs to be evaluated completely before making a decision on whether to move on cloud or not. Whenever a healthcare organization considers moving to cloud, it needs strategic planning to identify new cloud's benefits and risks, evaluate its capabilities through which the mission critical goal can be achieved and finally decide on the model to implement. Many studies are done in the past for the planning part and some of them are mentioned below.

- In [50], Marks and Lozano described an adoption life cycle model to initiate a cloud project which involves 9 stages as pilot/concept, strategy and roadmap, modeling and architecture, implementation planning, implementation, expansion, integration, collaboration, and maturity.
- In [51], the Project Management Institute published a white paper that mentions 8 stages to implement cloud project and 2 sample case studies.
- In [52], Stanoevska-Slabeva et al provides guidelines to move from traditional IT infrastructure to cloud. The guidelines include steps as initial analysis, pilot project, internal interconnection, monitoring and evaluation.
- In [53], the US Federal Health released an IT strategic Plan which can be used by government organizations to implement healthcare related cloud projects. The plan has two goals: patient-focused healthcare and population health. The plan also has 4 objectives: privacy, security, interoperability, adoption and collaborative governance.
- In [54], a 4-stage model named "HC2SP" is proposed as shown in figure that can be used by healthcare organization to determine the strategy while moving from traditional IT to cloud.

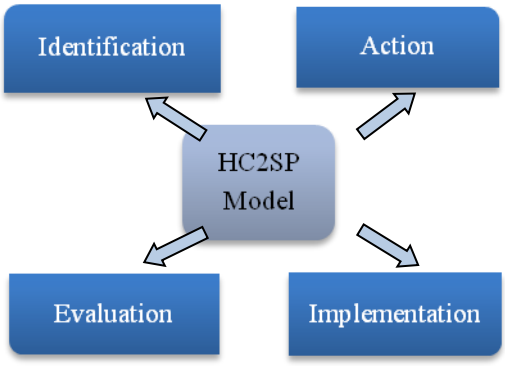

Fig. 8. Strategic Planning model

1) Stage 1: Identification

The first stage involves the analysis of current infrastructure that is being used in the organization and identification of the objectives or new services that needs to be achieved. The best way to do this would be to hear the voice of the patients or customers. A root cause analysis method can be applied to this problem which includes causes such as the process of admission or discharge, duplicate charting, paper based systems, automated systems such as EHRs [56].

The objective of this step is to address the current problems and clarify what patients are expecting in order to build patient-centered services more effectively and efficiently.

2) Stage 2: Evaluation

This stage involves the evaluation of opportunities and challenges in a clod based approach. The best way for a potential organization is to do a strengths, weaknesses, opportunities and threats (SWOT) analysis to evaluate its feasibility [57]. Moreover, the organization needs to develop solutions to solve the identified issues. In [58], Buyya and Ranjan discuss solutions to handle cloud-federated management issues such as data transfer bottlenecks. In [59], Kuo proposed an XML-based mediator to handle data-lock in interoperability problems. There are many more organizations which descried possible ways to handle problems that can arise in moving from traditional IT to cloud. The objective of this step is to develop a solution to solve organization specific problems so as to move forward in the development process.

3) Stage 3: Action

After evaluation, if an organization wants to move forward to build a cloud based system it needs to work on an implementation plan as follows:

- *Step 1*: This step involves determining the cloud service (SaaS, PaaS or IaaS) and deployment model (public, private, community or hybrid) for the solution. Each service or solution has its own benefits and risks and selection totally depends on the specific requirements of the organization.
- *Step 2*: This step involves the comparison of different service providers so as to analyze which provider would be able to satisfy all the requirements. The provider's reputation and performance also needs to be evaluated before finalizing anything.
- *Step 3*: This step involves finalizing the service provider and assure all the security, privacy and legal aspects with the provider. The assurances covers aspects such as policies and regulations, privacy laws, data backup, pay per use before moving on towards service level agreements (SLAs).
- *Step 4*: This step involves addressing issues related to data interoperability as it would be required in future when moving from traditional IT to cloud or moving from one provider to another.
- *Step 5*: This step involves implementation of a pilot project just as a proof to see how the proposed solution would provide enhanced services.

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4) Stage 4: Final Implementation

This stage involves the final shift and deployment of cloud infrastructure as proposed. It also involves planning on how to evaluate the implemented system and provide enhanced services. Some targets or goals should be established beforehand so as to compare the progress and performance. If the healthcare organization is not satisfied, it needs to check what factors influences the achievement and if there is some unsatisfied service on the side of cloud provider, it needs to make a shift.

VII. CONCLUSION

Cloud or utility computing is a new paradigm for providing the information technology services and is highly appreciated and used due to its features such as pay as you go model, elasticity and broad network access. The organizations are now able to build systems and provide services in a more cost efficient way as it obviates the need to setup own hardware infrastructure by making all the computing resources available on-demand over the web. Cloud computing has marked its presence in all domains such as social media, education and healthcare. Cloud computing is growing its roots in the healthcare industry. Cloud computing is creating a kind of network between the patients, physicians and institutions. Using cloud, medical industry can improve the access to information as it offers scalability and flexibility. This paper shed light on its evolution which briefly mentions the initiatives taken by big names like Amazon, Google and IBM to build and enhance cloud based healthcare services and mentions the various services that are being provided these days. The services include Data Management, Electronic Medical Records (EHRs), Telemedicine, Clinical Research, Drug discovery, Analytics, Health Information Exchange, Education, Medical Imaging and Digital libraries. However, still there are many challenges that hinder the growth of cloud computing in healthcare such as data security, vendor lock-in, interoperability, legal issues, cultural resistance and difference in legal jurisdictions over data. Fortunately, some organizations such as HIPAA and PIPEDA are working on to build standards in order to protect user data and other NGOs like Trusted Computing Group and Cloud Security Alliance are working to setup guidelines to setup trustworthy cloud applications.

When a healthcare organization needs to make a shift from traditional IT to cloud, it needs a strategic plan which is demonstrated in this paper as a 4-stage model as identification, evaluation, action and final implementation. These stages overall starts with identifying the services that needs to be provided, then moves to address the different challenges of cloud, then moves on to finalize the service providers and build a pilot project and finally moves towards implementation of proposed solution.

Despite of the various challenges, cloud has taken its place in healthcare industry and is moving forward to provide enhanced patient-centric healthcare services that are beneficial to patients, professionals and researchers and is promoting a healthy environment.

VIII. FUTURE

The potential of cloud computing in providing 21st century healthcare has many possibilities for professionals and researchers working in this domain. Cloud is transforming the healthcare services by converting them into virtual private service. It is a sign of industry maturation just like electrical power generation moved from small private units to larger providers. Implementing best practices of design, deployment and use is generating a new future of cloud computing based healthcare applications. In a research done by Gartner, cloud computing was ranked as the top priority among CEOs and CTOs [61].

As said by a CEO of a cloud based IT company:
"If you woke up this morning and read in The Wall Street Journal that, say, Overstock.com has stopped using UPS and FedEx and the U.S. mail, and had bought fleets of trucks and started leasing airport hubs and delivering products themselves, you would say they were out of their minds. Why is that much more insane than a health care company spending $2 billion a year on (traditional) information technology?"

Cloud computing presents a great opportunity for information technology users and service providers [62, 63]. The advantages of cloud computing has undoubtedly increased its adoption and its use in healthcare to provide patient-centric services is inevitable.

REFERENCES

[1] Nabil Sultan, Making use of cloud computing for healthcare provision: Opportunities and challenges, http://www.sciencedirect.com/science/article/pii/S0268401213001680

[2] Oana-Sorina Lupse, Vasile Stoicu-Tivadar, Lacramioara Vida, Marcella Mihaela, Cloud Computing and Interoperability in Healthcare Information Systems, https://www.researchgate.net/profile/Vasile_Stoicu-Tivadar/publication/267781309_Cloud_Computing_and_Interoperability_in_Healthcare_Information_Systems/links/54bcb6200cf253b50e2d5380.pdf

[3] Neha Dubey, Sangeeta Vishwakarma, Cloud Computing in Healthcare , http://www.ijcter.com/papers/volume-2/issue-5/cloud-computing-in-healthcare.pdf

[4] Cloud Standards Customer Council, Impact of Cloud Computing on Healthcare, http://www.cloud-council.org/deliverables/CSCC-Impact-of-Cloud-Computing-on-Healthcare.pdf

[5] Alex Mu-Hsing Kuo, Opportunities and Challenges of Cloud Computing to Improve Health Care Services, http://www.jmir.org/article/viewFile/jmir_v13i3e67/2

[6] George C. Kagadis, Christos Kloukinas, Kevin Moore, Jim Philbin, Panagiotis Papadimitroulas, Christos Alexakos, Paul G. Nagy, Dimitris Visvikis and William R. Hendee, Cloud computing in medical imaging, http://scitation.aip.org/content/aapm/journal/medphys/40/7/10.1118/1.4811272

[7] Brooks, C. (2010). Medical management firm turns to cloud computing. Search Cloud Computing, http://searchcloudcomputing.techtarget.com/news/1508378/Medical-management-firm-turns-to-cloud-computing.

[8] Narcisi, G. (2012). Cloud outage fears slow global cloud adoption, survey says. http://searchcloudprovider.techtarget.com/news/2240158428/Cloud-outagefears-slow-global-cloud-adoption-survey-says.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

[9] Kolakowski, N. (2010). Dell, practice fusion to offer medical records system. http://www.eweek.com/c/a/Health-Care-IT/Dell-Practice-Fusion-to-Offer-Medical-Records-System-805388/#sthash.MKmsNz0g.dpuf.

[10] Rolim CO, Koch FL, Westphall CB, Werner J, Fracalossi A, Salvador GS. A cloud computing solution for patient's data collection in health care institutions. 2010 Feb 10 Presented at: In: Proceedings of the 2nd International Conference on eHealth, Telemedicine, and Social Medicine; February 10-16, 2010; New York, NY: IEEE. [doi:10.1109/eTELEMED.2010.19]

[11] Nkosi MT, Mekuria F. Cloud computing for enhanced mobile health applications. In: Proceedings of the 2010 IEEE 2nd International Conference on Cloud Computing Technology and Science (CloudCom). New York, NY: IEEE; 2010 Presented at: The 2nd IEEE International Conference on Cloud Computing Technology and Science; Nov 30- Dec 3, 2010; Indianapolis, USA. [doi: 10.1109/CloudCom.2010.31]

[12] Rao GSVRK, Sundararaman K, Parthasarathi J. Dhatri: a pervasive cloud initiative for primary healthcare services. In: Proceedings of the 2010 14th International Conference on Intelligence in Next Generation Networks (ICIN). New York, NY: IEEE; 2010 Presented at: The 14th IEEE International Conference on Intelligence in Next Generation Networks (ICIN); October 11-14, 2010; Berlin, Germany. [doi: 10.1109/ICIN.2010.5640918]

[13] Koufi V, Malamateniou F, Vassilacopoulos G. Ubiquitous access to cloud emergency medical services. In: Proceedings of the 2010 10th IEEE International Conference on Information Technology and Applications in Biomedicine (ITAB). New York, NY: IEEE; 2010 Presented at: The 10th IEEE International Conference on Information Technology and Applications in Biomedicine (ITAB); November 3-5, 2010; Corfu, Greece. [doi: 10.1109/ITAB.2010.5687702]

[14] Avila-Garcia MS, Trefethen AE, Brady M, Gleeson F, Goodman D. Lowering the barriers to cancer imaging. In: eScience 2008: IEEE 4th International Conference on eScience. New York, NY: IEEE; 2008 Presented at: The 4th IEEE International Conference on eScience; December 8-12, 2008; Indiana, USA. [doi: 10.1109/eScience.2008.33]

[15] Bateman A, Wood M. Cloud computing. Bioinformatics 2009 Jun 15;25(12):1475 [FREE Full text] [doi:10.1093/bioinformatics/btp274] [Medline: 19435745]

[16] Kudtarkar P, Deluca TF, Fusaro VA, Tonellato PJ, Wall DP. Cost-effective cloud computing: a case study using the comparative genomics tool, roundup. Evol Bioinform Online 2010;6:197-203 [FREE Full text] [doi: 10.4137/EBO.S6259] [Medline: 21258651]

[17] Memon FN, Owen AM, Sanchez-Graillet O, Upton GJ, Harrison AP. Identifying the impact of G-quadruplexes on Affymetrix 3' arrays using cloud computing. J Integr Bioinform 2010;7(2):111. [doi: 10.2390/biecoll-jib-2010-111] [Medline: 20134078]

[18] D. Papakonstantinou, M. Poulymenopoulou, F. Malamateniou, and G. Vassilacopoulos, "A cloud-based semantic wiki for user training in healthcare process management," XXIII Conference of the European Federation for Medical Informatics (MIE 2011), August 2011, vol.169, pp. 93-97, doi: 10.3233/978-1-60750-806-9-93

[19] B. Pardamean, and R. R. Rumanda. „Integrated Model of Cloud-Based E-Medical Record for Health Care Organizations," 10th WSEAS International Conference on E-Activities, December 2011, pp. 157-162

[20] Amazon Web Services. 2011. AWS Case Study: Harvard Medical School URL: http://aws.amazon.com/solutions/case-studies/harvard/

[21] Business Wire. The Free Library. 2008. DiskAgent Launches New Remote Backup and Loss Protection Software as a Service Offering URL: http://www.thefreelibrary.com/DiskAgent(TM)+Launches+New+Remote+Backup+and+Loss+Protection+Software...-a0182194404

[22] Strukhoff R, O'Gara M, Moon N, Romanski P, White E. SYS-CON Media, Inc. 2009 Mar 20. Cloud Expo: Healthcare Clients Adopt Electronic Health Records with Cloud-Based Services URL: http://cloudcomputing.sys-con.com/node/886530

[23] Editorial Staff. HealthImaging.com. 2010 Feb 16. Acumen Nabs ONC Cloud Computing Contract URL: http://www.healthimaging.com/index.php?option=com_articles&view=article&id=20648:acumen-nabs-onc-cloud-computing-contract&division=hiit

[24] Korea IT Times. IT Times. 2010 Jul 20. Telstra Plans Launch of E-Health Cloud Services, Tip of the Iceberg for Opportunity URL: http://www.koreaittimes.com/story/9826/telstra-plans-launch-e-health-cloud-services-tip-iceberg-opportunity

[25] IBM Press Room. IBM. 2010 Nov 22. European Union Consortium Launches Advanced Cloud Computing Project With Hospital and Smart Power Grid Provider URL: http://www-03.ibm.com/press/us/en/pressrelease/33067.wss

[26] Danek J. Public Works Government Services Canada. 2009 Oct 6. Cloud Computing and the Canadian Environment URL: http://www.scribd.com/doc/20818613/Cloud-Computing-and-the-Canadian-Environment

[27] Avery P. IT Business Edge. 2009 Aug 26. Research Indicates Increase in Cloud Computing URL: http://www.itbusinessedge.com/cm/community/kn/blog/research-indicates-increase-in-cloud-computing/?cs=35256

[28] Bannerman PL. Cloud Computing Adoption Risks: State of Play. In: Proceedings of the 17th Asia Pacific Software Engineering Conference Cloud Workshop. New York, NY: IEEE; 2010:10-16.

[29] Armbrust M, Fox A, Griffith R, Joseph AD, Katz RH, Konwinski A, et al. EECS Department, UC Berkeley. 2009. Above the Clouds: A Berkeley View of Cloud Computing. Technical Report URL: http://www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-28.pdf

[30] Everett C. Cloud computing: a question of trust. Comput Fraud Secur 2009 Jun 10(6):5-7. [doi: 10.1016/S1361-3723(09)70071-5]

[31] Jansen W, Grance T. National Institute of Standards and Technology, US Department of Commerce. 2011 Jan. Guidelines on Security and Privacy in Public Cloud Computing URL: http://csrc.nist.gov/publications/drafts/800-144/

[32] Zhang R, Liu L. Security models and requirements for healthcare application clouds. In: Proceedings of the 2010 IEEE 3rd International Conference on Cloud Computing (CLOUD). New York, NY: IEEE; 2010 Presented at: The 3rd IEEE International Conference on Cloud; July 5-10, 2010; Miami, FL, USA. [doi: 10.1109/CLOUD.2010.62]

[33] Baliga J, Ayre RWA, Hinton K, Tucker RS. Green cloud computing: balancing energy in processing, storage, and transport. Proc IEEE 2011;99(1):149-167. [doi: 10.1109/JPROC.2010.2060451]

[34] Durkee D. Why cloud computing will never be free. Commun ACM 2010;53(5):70-69. [doi: 10.1145/1735223.1735243]

[35] European Network and Information Security Agency. ENISA. 2009 Nov. An SME Perspective on Cloud Computing: Survey URL: http://www.enisa.europa.eu/act/rm/files/deliverables/cloud-computing-sme-survey/

[36] Microscoft Corp. 2010 Nov. Privacy in the Cloud: A Microsoft Perspective URL: http://www.microsoft.com/privacy/cloudcomputing.aspx

[37] Google Privacy Center. Google. 2010 Oct 3. Privacy Policy URL: http://www.google.com/google-d-s/intl/en/privacy.html

[38] Amazon Web Services. 2008 Oct 01. AWS Privacy Notice URL: http://aws.amazon.com/privacy/

[39] US Department of Health & Human Services. 1996. The Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy and Security Rules URL: http://www.hhs.gov/ocr/privacy/

[40] Minister of Justice, Canada. 2011 Jan 1. Personal Information Protection and Electronic Documents Act (PIPEDA) URL: http://laws.justice.gc.ca/PDF/Readability/P-8.6.pdf

[41] European Commission. EuroPriSe: The European Privacy Seal for IT Products and IT-Based Services URL: https://www.european-privacy-seal.eu/

[42] United Nations. United Nations Commission on International Trade Law. 2010. UNCITRAL Legislative Guide on Secured Transactions URL: http://www.uncitral.org/pdf/english/texts/security-lg/e/09-82670_Ebook-Guide_09-04-10English.pdf

[43] Pearson S. Taking account of privacy when designing cloud computing services. In: Proceedings of the ICSE Workshop on Software Engineering Challenges of Cloud Computing (CLOUD'09). New York, NY: IEEE; 2009 Presented at: the IEEE First international workshop on software engineering challenges for Cloud Computing (ICSE); May 16-24, 2009; Vancouver, BC, Canada. [doi: 10.1109/CLOUD.2009.5071532]

[44] Svantesson D, Clarke R. Privacy and consumer risks in cloud computing. Comput Law Secur Rev 2010;26(4):391-397. [doi: 10.1016/j.clsr.2010.05.005]

[45] Mather T, Kumaraswamy S, Latif S. Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance (Theory in Practice). Sebastopol, CA: O'Reilly Media, Inc.; 2009.

[46] Kuner C. Data protection law and international jurisdiction on the Internet (part 1). Int J Law Inf Technol 2010;18(2):176-201. [doi: 10.1093/ijlit/eaq002]

[47] Ward BT, Sipior JC. The Internet jurisdiction risk of cloud computing. Inf Syst Manag 2010;27(4):334-339. [doi: 10.1080/10580530.2010.514248]

[48] Financial Crimes Enforcement Network, US Department of Treasury. FinCEN. Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism (USA PATRIOT) Act of 2001. no date URL: http://www.fincen.gov/statutes_regs/patriot/index.html

[49] Javelin Strategy & Research. 2011. Data Breach Notifications: Victims Face Four Times Higher Risk of Fraud URL: https://www.javelinstrategy.com/brochure-158

[50] Marks EA, Lozano B. Executive's Guide to Cloud Computing. Hoboken, NJ: Wiley; 2010.

[51] White Paper. Project Management Institute (PMI). 2011. Cloud Computing: The New Strategic Weapon URL: http://www.pmi.org/~/media/PDF/Home/CloudComputing_FINAL.ashx

[52] Stanoevska-Slabeva K, Wozniak T, Hoyer V. Practical guidelines for evolving IT infrastructure towards grids and clouds. In: Stanoevska-Slabeva K, Wozniak T, Ristol S, editors. Stanoevska- Slabeva K, Wozniak T, Ristol S. editors. Grid and Cloud Computing: A Business Perspective on Technology and Applications. Berlin: Springer; 2010:225-243.

[53] US Department of Health & Human Services, Office of the National Coordinator for Health Information Technology. The ONC-Coordinated Federal Health IT Strategic Plan: 2008-2012. Washington, DC: ONC-HIT; 2008.

[54] Kuo AM, Borycki E, Kushniruk A, Lee TS. A healthcare Lean Six Sigma System for postanesthesia care unit workflow improvement. Qual Manag Health Care 2011;20(1):4-14. [doi: 10.1097/QMH.0b013e3182033791] [Medline: 21192203]

[55] Lee TS, Kuo MH. Toyota A3 report: a tool for process improvement in healthcare. Stud Health Technol Inform 2009;143:235-240. [Medline: 19380942]

[56] Lee TS, Kuo MH. Toyota A3 report: a tool for process improvement in healthcare. Stud Health Technol Inform 2009;143:235-240. [Medline: 19380942]

[57] Marston S, Li Z, Bandyopadhyay S, Zhang J, Ghalsasi A. Cloud computing: the business perspective. Decis Support Syst 2011;51(1):176-189. [doi: 10.1016/j.dss.2010.12.006]

[58] Buyya R, Ranjan R. Special section: Federated resource management in grid and cloud computing systems. Future Generation Comput Syst 2010;26(8):1189-1191. [doi: 10.1016/j.future.2010.06.003]

[59] Kuo MH, Kushniruk AW, Borycki EM. Design and implementation of a health data interoperability mediator. Stud Health Technol Inform 2010;155:101-107. [Medline: 20543316]

[60] Cloud Computing in Health Care to Reach $5.4 Billion by 2017: http://www.eweek.com/c/a/Health-Care-IT/Cloud-Computing-in-Health-Care-to-Reach-54-Billion-by-2017-Report-512295/

[61] Gartner Newsroom. Gartner, Inc. 2011 Jan 21. Gartner Executive Programs Worldwide Survey of More Than 2,000 CIOs Identifies Cloud Computing as Top Technology Priority for CIOs in 2011 URL: http://www.gartner.com/it/page.jsp?id=1526414

[62] Creeger M. CTO roundtable: cloud computing. Commun ACM 2009;52(8):50-56. [doi: 10.1145/1536616.1536633]

[63] Fox A. Computer science. Cloud computing: what's in it for me as a scientist? Science 2011 Jan 28;331(6016):406-407. [doi: 10.1126/science.1198981] [Medline: 21273473]

[64] Brown A, Weihl B. Official Google Blog. 2011 Jun 24. An Update on Google Health and Google PowerMeter URL: http://googleblog.blogspot.com/2011/06/update-on-google-health-and-google.html

[65] Guide to examples of cloud computing in healthcare, http://searchhealthit.techtarget.com/essentialguide/Guide-to-examples-of-cloud-in-healthcare

[66] Vladimir Stantchev, Ricardo Colomo-Palacios and Michael Niedermayer, Cloud Computing Based Systems for Healthcare, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4032744/

[67] Brown A, Weihl B. Official Google Blog. 2011 Jun 24. An Update on Google Health and Google PowerMeter URL: http://googleblog.blogspot.com/2011/06/update-on-google-health-and-google.html

[68] Benjamin Harris, 5 ways cloud computing will transform healthcare, http://www.healthcareitnews.com/news/5-ways-cloud-computing-will-transform-healthcare

[69] Peter Mell, Timothy Grance, The NIST definition of Cloud Computing, http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf

[70] HIMSS Analytics, The Cloud Evolution in Healthcare, http://www.level3.com/~/media/files/ebooks/en_cloud_eb_healthcare.pdf

[71] "HL7 version 3 Interoperability Standards Normative Edition 2009, Based on HL7 v3 Data Types," Release 1, Disk 1 – Standards Publication

[72] B. Pardamean, and R. R. Rumanda. „Integrated Model of Cloud-Based E-Medical Record for Health Care Organizations," 10th WSEAS International Conference on E-Activities, December 2011, pp. 157-162

[73] J. M. Ferranti, R. C. Musser, K. Kawamoto, and W. E. Hammond, "The Clinical Document Architecture and the Continuity of Care Record: A Critical Analysis," Journal of the American Medical Informatics Association, vol. 13, pp. 245-252, February 2006

[74] M. Vida, and L. Stoicu-Tivadar, "Measuring medical informatics systems interoperability using the LISI model," 9th IEEE International Symposium on Intelligent Systems and Informatics (SISY 2010), September 2010, pp. 33-36, doi: 10.1109/SISY.2010.5647396

[75] Alagoz, F., Valdez, A. C., Wilkowska, W., Ziefle, M., Dorner, S., & Holzinger, A.(2010). From cloud computing to mobile internet from user focus to culture andhedonism the crucible of mobile health care and wellness applications. In 5thinternational conference on pervasive computing and applications (ICPCA), 2010.

[76] Wall Street Journal. (2011). More predictions on the huge growth of "cloud comput-ing". http://blogs.wsj.com/digits/2011/04/21/more-predictions-on-the-huge-growth-of-cloud-computing/

[77] Warman, M. (2011). Patient records go online in data 'cloud'. The Telegraph, http://www.telegraph.co.uk/health/healthnews/8600080/Patient-records-go-online-in-data-cloud.html

[78] The Open Group. (2011). Cloud computing survey. https://www.opengroup.org/cloudcomputing/uploads/40/24144/Open Group Cloud Computing SurveyFINAL.pdf.

[79] Lewis, N. (2010). Microsoft aims to alleviate health IT cloud concerns. http://www.informationweek.com/news/healthcare/security-privacy/225702414.

[80] Scott Good "Why Healthcare Must Embrace Cloud Computing" Forbes May 2013.

[81] Chatman C. How cloud computing is changing the face of health care information technology. J Health Care Compliance 2010 Jun;12(3):37-70.

[82] Schweitzer EJ. Reconciliation of the cloud computing model with US federal electronic health record regulations. J Am Med Inform Assoc 2011 Jul 4. [doi: 10.1136/amiajnl-2011-000162] [Medline: 21727204]

[83] Rosenthal A, Mork P, Li MH, Stanford J, Koester D, Reynolds P. Cloud computing: a new business paradigm for biomedical information sharing. J Biomed Inform 2010 Apr;43(2):342-353. [doi: 10.1016/j.jbi.2009.08.014] [Medline: 19715773]

[84] Wall DP, Kudtarkar P, Fusaro VA, Pivovarov R, Patil P, Tonellato PJ. Cloud computing for comparative genomics. BMC Bioinformatics 2010;11:259 [FREE Full text] [doi: 10.1186/1471-2105-11-259] [Medline: 20482786]

[85] Horowitz, B. (2011). Cloud Computing Brings Challenges for Health Care Data Storage, Privacy, http://www.eweek.com/c/a/Health-Care-IT/Cloud-Computing-Brings-Challenges-for-Health-Care-Data-Storage-Privacy-851608/

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[86] C. Vecchiola, S. Pandey, and R. Buyya, ―High-Performance Cloud Computing: A View of Scientific Applications,‖ in 10th International Symposium on Pervasive Systems, Algorithms, and Networks (ISPAN), (IEEE, Kaohsiung, 2009), pp. 4–16.http://dx.doi.org/10.1109/I-SPAN.2009.150

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