# ADVENT OF CLOUD COMPUTING TECHNOLOGIES IN HEALTH INFORMATICS

**Omer K. Jasim, Safia Abbas, El-Sayed M. El-Horbaty, Abdel-Badeeh M. Salem**

***Abstract***: *Cloud computing is internet based computing that allows client computers to access shared resources, software, and information from servers on the web/cloud. Health informatics technology describes the use of computer information systems to manage the patients' electronic health records based on electronic health record. The advent of cloud computing technology provides effective and dependable results to support healthcare services. The cloud technology reduces these costs for consumers and IT by improving clinical and quality outcomes for patients. This paper discusses the potential rule of the cloud technology in healthcare informatics. In addition, it presents the global challenges and technical difficulties which are facing this new technology.*

***Keywords***: *Cloud Computing, Healthcare Informatics, Cloud Challenges, Health Cloud Technology.*

## Introduction

Cloud technology is a new way of delivering computing resources and services. This technology is defined as a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services) [Alex R. et al, 2011]. In essence, cloud computing is the legal transfer of computing as a service rather than as a product where the approach of these shared resources or services is furnished as a utility over a net. Over the cloud computing, customers can utilize network-based tools or applications through a web browser just as if they were programs installed locally on their own computer [Srinivasa R. at al, 2009; Omer K. et al, 2013; NSA, 2013].

On the other side, health informatics technology (HIT) describes the use of computer information systems to manage the patients' electronic health records based on electronic health record (EHR). Precisely, EHR system allows users in healthcare governance, such as hospitals, clinic, or a doctor's to enter, store, process, access, and manage patient healthcare data [Sanjay P. et al, 2012; Ruoyu Wu. et al, 2010]. As shown in Figure 1, typical data in EHRs include hospital's information, doctor's order entries and comments, patient's identification, laboratory test results for trainer, and others. EHRs can support clinicians towards providing better healthcare by granting access to comprehensive patient data, help to reduce medical prescription errors with various alerting functions, and can help patients and doctors to oversee their treatment and charge books for insurance payments [King M. et al, 2012; Samuel, O.W. et al, 2013; Ruoyu Wu. et al, 2012].

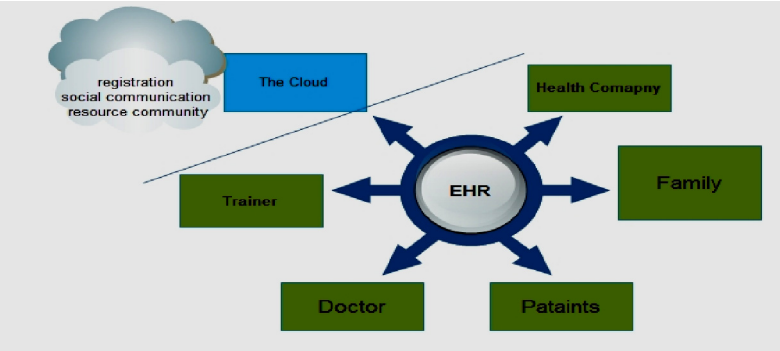


**Figure1.** Schematic of EHRs

All EHRs components are mentioned above, can easily relate to the cloud environment based on an accumulation of "www" based application or numbers of services tools [Ruoyu Wu. et al, 2012]. The cloud has an infrastructure built so consumers can deploy and run their applications [Eman AbuKhousa et al, 2012]. They also have different platforms with multiple operating systems so consumers can build, test, and deploy their applications on virtual servers. Thus, the cloud provides highly scalable environment to effectively manage the load, it provides many benefits for HIT by integration with healthcare providers, and these integration mechanisms help the HIT provider to share the data between many organizations. Data sharing serves various purposes that helping to improve the healthcare services. Moreover, many advantages are gone from this integration such dynamically updating, file storages, manageability, and fasting for health care operations [Thomas Trojer et al, 2012; Sunyaev A. et al, 2010; Buyya, Jwt al, 2011; H. Liohr et al, 2009].

This paper explains the impact of cloud technology on HIT rely on studies and discuss the healthcare systems and models in the context of this technology. Moreover, the paper discusses the proposed technical solutions for the HIT challenges. The remainder of this paper is structured as follows. Section II reviews the existing methods for healthcare in cloud computing technology, health cloud architecture and components are given in Section III. Section IV explains the global challenges and solutions for health cloud technology (HCT). Section V presents the information are enriched by this article. Section VI shows the conclusion and future works.

## Existing Methods

Cloud computing can take on a vital part in containing healthcare integration costs, optimizing resources and ushering in a new era of inventions. Current trends aim towards accessing information anytime, anywhere, which can be achieved when moving healthcare information to the cloud. This new delivery model can make healthcare more efficient and effective, and at a lower cost to technology budgets. There are several articles that introduce contributions to building the environment for HCT.

Ortho [2014], plans to implement a cloud-based practice management technology solution through a company called Care Cloud (CeC). The CeC of Soma predicts that the use of the system will eventually evolve into a more advanced form of data sharing among Soma network of clinics as well as third party institutions such as insurance companies. The platform is designed to offer greater care efficiency to both the practice and its patients by minimizing redundancy inpatient procedures, therefore, the costs associated with them are minimized.

Yu [2011] investigates utilizing a service modeling approach to model the requirements and design of different Service-Oriented Architecture (SOA) based services by using Service Oriented Modeling and Architecture (SOMA) and employing Service Oriented Modeling Framework (SOMF) modeling styles and assets. It shows how to rapidly implement and evaluate e-health applications using this approach. Generally SOA can provide a full solution for facing some of the development and performance challenges facing the HCT.

Teng et al. [2010] provided a long term off-site medical image archive solution for Digital Imaging and Communication in medicine (DICOM). One of the biggest challenges which the healthcare industry struggles with is the growing cost of managing long-term on-site medical imaging archives. The continually increasing need for high volumes of medical images is resulting in scalability and maintenance issues with picture archiving and communication systems (PACS).

Guo et al. [2010] proposed a loud-based intelligent Hospital File Management System (HFMS) that aims to improve some of the restrictions (storage capacity, low performance) which characterize the traditional hospital management systems (HMS).

Fan et al. [2011] presented the Data Capture and Auto-Identification Reference (DACAR). DACAR aims to develop, implement and disseminate a novel secure platform in the Cloud for capturing, storing and consuming

data within a healthcare domain. By using a single point of contact, the DACAR platform promises to provide solutions for the challenges of HCT services.

From above attempts and methods , the cloud computing has given opportunities for clinics, hospitals, insurance companies, pharmacies, and other healthcare companies to agree in collaborating between them and share healthcare information to offer better quality of service and reduce costs.

## Health Cloud Architecture

Recently, many medical organizations install software on their office or interconnection system. It shares with potential interruptions such as power outages, software upgrades, hardware failures and human mistake. When the software migrates to the cloud, upgrade the software to the open environment without breaking up your practice. The cloud base is built in redundancy, meaning that your system is perpetually usable, even if there is an outage on our goal. The services are designed so that outages remain transparent to the users and all services available.

### Cloud Computing Architecture

A cloud computing architecture can be basically divided into three layers the characteristics layer, the model layer, and the deployment layer [Guo L. et al, 2010]. The characteristic layer contains four phases (on demand service, broad network, resource pooling & Rapid elasticity, measured services), it aims to (i) develop and adopt the rapidly evolving of cloud technology, (ii) abstract the details of inner implementations, and (iii) facilitate the information retrieving service anywhere, anytime [Fan L. et al, 2011].

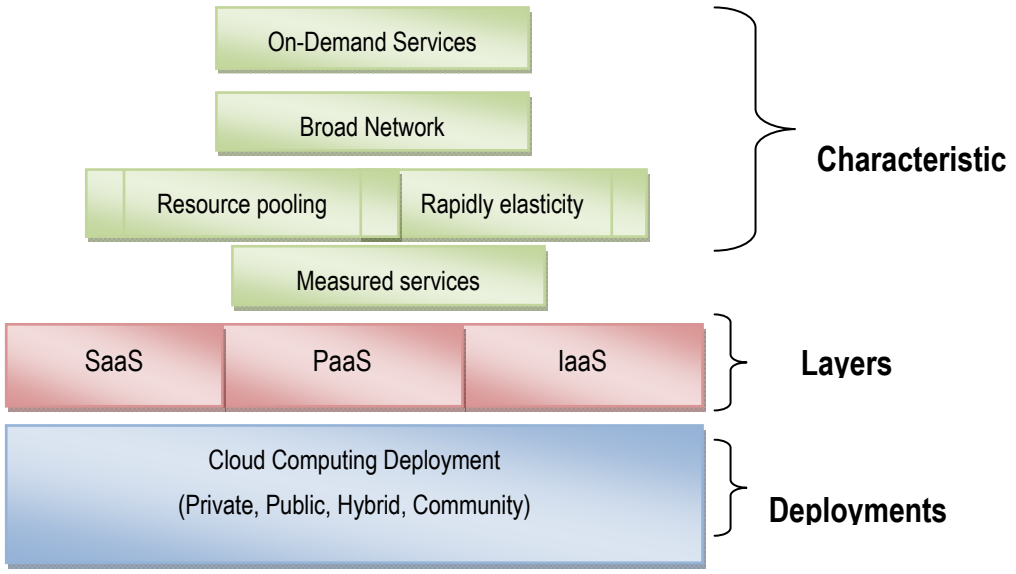


**Figure 2.** Cloud Environment Architecture

Generally, the model layer consists of three models arranged as follows (see Figure 2):

1. **Infrastructure as a Service** (IaaS): this is a providing service in which the provider is responsible for providing housing, running and maintaining the equipment used to support operations including storage, hardware, servers and networking components. The Amazon web service (S3) [Ruoy Wu. et al, 2012] is an example for IaaS.

2. **Platform as a Service** (PaaS): this service enables the users to use virtualizes servers and associated services for running existing applications or developing and testing new ones, Google Apps are an example for the PaaS [Matt Matlock , 2013; Eman AbuKhousa et al, 2012].
3. **Software as a Service** (SaaS): this service aims to run software on the provider's infrastructure and provide licensed applications to enable users to use the services. Moreover, SaaS offers more transparent to the end user. An example of SaaS is the Salesforce.com CRM application [Pearson S. et al, 2009; Hosseini, 2012].

**Health Cloud Technology (HCT)**

Over the HIT system will grow largely due to the increasing amount of patient data and additional improvements in the application software that may require more computing power. This will require additional computing resources in order to keep performing efficiently. On the cloud can add more servers with the push of a button and will be transparent to HIT providers. This eliminates the need to buy additional hardware and perform ground-up configuration and disruption that would be required with an in-office solution to keep your system running [Rosado D. et al, 2012].

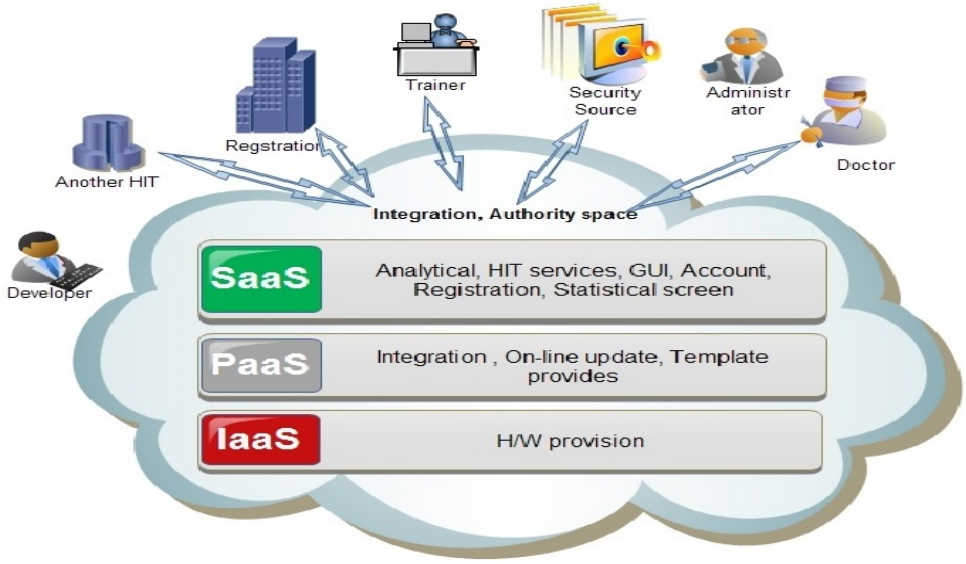


**Figure 3.** HCT architecture (adopted from [Eman AbuKhousa et al, 2012])

As shown in Figure 3, upgrade the standard cloud architecture to HCT architecture, the HCT consists of an integration area and the three basic layers of cloud. The integration and authority area contribute to achieve following objectives:

I. Accomplish the cloud authority access such as (registration, portal web, connects to another communication system);
II. EHR verification: checking the authority of EHR after migration to the cloud;
III. Integration between traditional EHR files with the Cloudy EHR for HCT;
IV. Determined the type of cloud deployment is used to share the health company files.

Consequently, the other components are classified into three layers same as the basic layers in cloud architecture, firstly, SaaS responsible for the clinical system services, healthcare provider, and system login page, secondly, PaaS utilizes the report testing, updating system, and integration with the other environment, finally, IaaS provides a physical processing and storage requirements.

## HCT Challenges and Solutions

The slow adoption of the cloud computing model in the health informatics field is mostly due to two important concerns can be summarized into (i) security and data privacy, (ii) Data probability and Integrity. Those issues need to be fixed in order to overcome obstacles when moving to the cloud environment.

### Privacy Concerns

Originally, the exchange of the files and data between traditional HIT systems is not an easy task from the security point view, due to unsecure communication between these companies. Therefore, the Migration of data or file storages to a third party organization is more complex to do, especially when moving sensitive information such as healthcare data. Hence, more robust security should be assured to avoid all concerns to adopt HCT such as access controls, audit controls, authentication, authorization, transmission security and storage security in order to avoid exposing the information to unauthorized entities [He C. et al, 2010; Grobauer, B. et al, 2010].

These issues are an obstacle that has slowed the cloud adoption and should be addressed in order to enable the trustworthiness of cloud systems [Nguyen D. et al, 2012]. Fortunately, many of the biggest cloud providers in the market such as Microsoft, Google, and Amazon have commitments to develop the best policies and practices to secure a customer's data and privacy, also, many researchers and research centers were focusing on privacy point (see Table 1).

Moreover, the data of HIT's unlike other kind of data has strict confidentiality, privacy and security concerns [Soma A., 2011]. The Health Insurance Portability & Accountability Act (HIPAA) compliance is the most fundamental requirement when moving medical records to the cloud as a solution for this challenge. The aims of this system are:

- Reducing costs and enhances the overall efficiency;
- Effectiveness of health care delivery and insurance industry;
- Enhancing the ability of various entities in the healthcare industry to exchange information via standardization;
- Ensure the confidentiality and security of personal health information;
- Ensure portability and continuity of health insurance coverage.

**Table 1.** Privacy research areas in HCT

| Author (s) | Privacy Research Areas | Articles Info |
|---|---|---|
| Samuel, O.W. et al., 2013 | HIT challenges for secure delivery | **Enhanced Cloud based Model for Healthcare Delivery Organizations in Developing Countries** |
| Soman A. K., 2011 | HIPAA implementation on cloud | **Cloud-based Solutions for Healthcare IT** |
| Ruoyu Wu et al.,2012 | Regulatory level privacy protection | **Towards HIPAA-compliant Healthcare Systems in Cloud Computing** |
| Jason King et al., 2012 | Organizational/System level privacy protection | **Audit Mechanisms in Electronic Health Record Systems: Protected Health Information May Remain Vulnerable to Undetected Misuse** |
| Thomas Trojer et al, 2012 | Personal level privacy protection | **Managing Privacy and Effectiveness of Patient-administered Authorization Policies** |
| Matt Matlock et al., 2013 | Data level privacy protection | **Systematic Redaction for Neuroimaging Data** |

### Interoperability

Interoperability (Data probability and integrity in some references) is one of the biggest challenges when moving healthcare systems to the cloud, the concern regarding the ability to transition to another cloud vendor or back to the healthcare organization without disrupting operations or introducing conflicting claims to the data [Li M., 2010].

With traditional IT, the healthcare organization has physical control of systems, services and data. The concern is that if a provider were to suspend its services or refuse access to data, a healthcare organization may suddenly be unable to service its patients or customers [H. Liohr, A.et al, 2009; Ortho predict web site, 2014].

The lack of probability and integrity across cloud systems could make it very challenging to migrate to a new cloud service provider. This risk highlights the need for provider agreements that address termination rights, rights to access and retrieve data at any time, termination assistance in moving to another provider to allow a breach of contract to be remedied before the provider terminates or suspends services [Yu W., 2011; Teng C. et al, 2010]. Therefore, a new approach to developing health care systems should be taken in order to design more interoperable systems. This change will result in numerous and substantial benefits to the health community. Table 2 summarizes the studies about data probability constrains and solutions in HCT.

**Table 2**. Interoperability research areas in HCT

| Author (s) | Interoperability Research Areas | Articles Info |
|---|---|---|
| Alex Mu. et al., 2011 | **Data Migration probability** | Opportunities and Challenges of Cloud Computing to Improve Health Care Services |
| Sanjay P. Ahuja et al., 2012 | **Present a complete survey on moving challenges** | A Survey of the State of Cloud Computing in Healthcare |
| Ruoyu Wu, et al , 2012 | Error rate of data transmission | Secure Sharing of Electronic Health Records in Clouds |
| Eman AbuKhousa et al., 2012 | Interoperability and security challenges in Healthy cloud computing | e-Health Cloud: Opportunities and Challenges |

As a solution for this challenge, utilize the concept of Service-Oriented Architecture for implementing the HCT. SOA aims to make services available and easily accessible through standardized models and protocols without having to worry about the underlying infrastructures, development models or implementation details. This helps achieve interoperability and loose coupling among HCT components and also among HCT users [AbuKhousa E. et al, 2012; healthcare site, 2014].

## Results and Discussions

Despite of the same challenges have contributed to the slow adoption of the cloud, there are equally as many benefits for providers to embrace this new technology across the enterprise. Based on this study a lot of benefits encompass both business and clinical areas as the following:

1. **Cost**: The cloud allows for health IT managers to avoid the costs of extra on site storage and network infrastructure. In addition, it also allows for greater financial flexibility in health IT because the cloud model is based on a scalable, on demand system.

2. **Reliability:** The central storage of data allows for increased IT responsiveness and efficiency. Disaster recovery is noted as being one of the key benefits of storing information in the cloud.
3. **Portability:** The centralized platform in the cloud allows for health care providers to access vital patient data regardless of the original geographic location that their records were generated remotely from a cloud provider.

Moreover, according to this study, many challenges associated with HCT such as privacy, data probability, integration, and data migration. Figure 4 illustrates these challenges and we noticed through four years from 2010-2013, the privacy and security challenges are taking the bulk from the authors, these solicitudes due to many reasons:

- The open environment for cloud computing technology;
- Lack of security restrictions at the SaaS layer;
- Unsecure communication between cloud providers and clients;
- The weakness associated with the hypervisor layer in most cloud providers acts the cavity for the attacker.

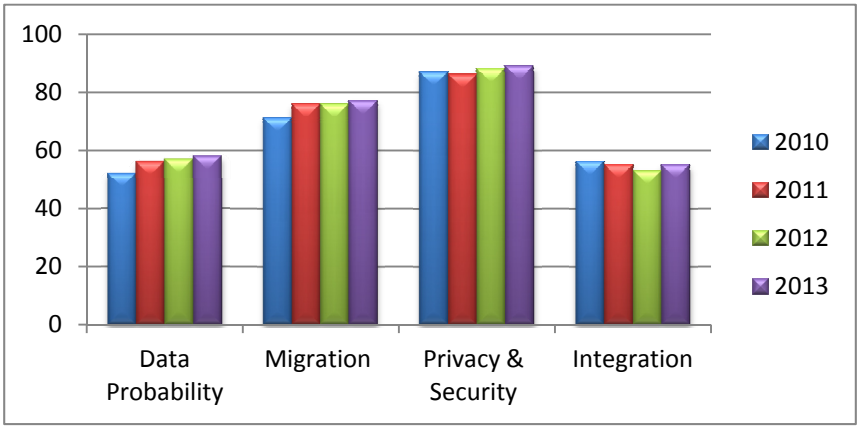


**Figure 4.** Statistical analysis for HCT challenges

So, a collection of precautions must be followed to overcome the privacy challenge such providing a private IP network isolation for each client, supplying a modern encryption algorithms to guarantee secure communication , and periodically, execute the server load balancing features and automated backups.

## Conclusion and Future Work

The current tendency of adopting cloud computing in the medical field can improve and solve several collaborative information issues in healthcare organizations as well as cost optimizations. Standardized cloud-based applications will bring obvious advantages to patients, doctors, insurance companies, pharmacies, imaging centers, etc. when sharing data across medical organizations yielding better outcomes. Challenges such as privacy concerns and Interoperability will rise due to the cloud-computing model and deployment. Thus, the adoption of the cloud is progressing slowly. Through this survey we conclude the HCT will hopefully engender a future development of the cloud-based systems adoption, despite all of the obstructions.

So, in the future we will recommend to design a new healthcare cloud system which able to overcome all challenges. For protection, provide a novel security scheme based on quantum encryption model, and for data, probability, utilize the waterfall model to insure the life cycle of the file migration and consolidation.

## Bibliography

[AbuKhousa, E.; Najati, H.A. UAE-IHC, 2012] "Steps towards Integrated E-Health Environment in UAE". In Proceedings of the 4th e-Health and Environment Conference in the Middle East, Dubai, UAE, 30 January 2012–2 February 2012.

[Buyya, J. Broberg, and A. Goscinski, 2011] "Cloud computing Principles and Paradigms," New York, USA, Wiley Press. pp. 1–44.

[Dark Government, 2014] "NSA-Embraces Cloud computing, URL: http://www.darkgovernment.com/news/nsa-embraces-cloud-computing,5:00 pm.

[Eman AbuKhousa, Nader Mohamed and Jameela Al-Jaroodi, 2012] "e-Health Cloud: Opportunities and Challenges", Future Internet 2012, 4, 621-645; doi:10.3390/fi4030621.

[Fan, L.; Buchanan, W.; Thummler, C.; Lo, O.; Khedim, A.; Uthmani, O.; Lawson, A.; Bell, D. DACAR, 2011] "Platform for eHealth Services Cloud". In Proceedings of the 4th International Conference on Cloud Computing, Miami, FL, USA, July 2011; pp. 219–226.

[Grobauer, B.; Walloschek, T.; Stocker, E., 2011] "Understanding cloud computing vulnerabilities. IEEE secures. Privacy Mag. 2011, 9, 50–57.

[Guo, L.; Chen, F.; Chen, L.; Tang, X., 2010] "The building of cloud computing environment for e-health". In Proceedings of the International Conference on e-Health Networking, Digital Ecosystems and Tech. (EDT), Shenzhen, China, 17–18 April 2010; pp. 89–92.

[H. Liohr, A. R. Sadeghi, C. Vishik, and M. Winandy, 2009] "Trusted privacy domains challenges for trusted computing in privacy-protecting information sharing". In Information Security Practice and Experience, 5th International Conference, (ISPEC'09), volume 5451 of Lecture Notes in Computer Science, pages 396 - 400.

[He, C.; Jin, X.; Zhao, Z.; Xiang, T. A ,2010] "Cloud Computing Solution for Hospital Information System". In Proceedings of the Intelligent Computing and Intelligent Systems (ICIS), Xiamen, China, 29–31 October 2010; pp. 517–520.

[Hosseini, A.; Sommerville, I.; Sriram, I., 2012] "Research Challenges for Enterprise Cloud Computing". Available online: http://arxiv.org/abs/1001.3257 (accessed on 28 June 2012).

[King M. Janson, Ben Smith, and Laurie Williams, 2012] "Audit Mechanisms in Electronic Health Record Systems: Protected Health Information May Remain Vulnerable to Undetected Misuse", International Journal of Computational Models and Algorithms in Medicine, 3(2).

[Li, M.; Yu, S.; Ren, K.; Lou, W., 2011] "Securing Personal Health Records in Cloud Computing: Patient-centric and Fine-grained Data Access Control in Multi-owner Settings". In Proceedings of the 6th International ICST Conference on Security and Privacy in Communication Networks (SecureComm 2010), Singapore, 7–9 September 2010; pp. 89–106.

[Matt Matlock, Nakeisha Schimke, Liang Kong, Stephen Macke, and John Hale, 2013] "Systematic Redaction for Neuroimage Data", IJCA,Vol.5, No. 2.

[Nguyen, D.K.; Lelli, F.; Papazoglou, M.P.; van den Heuvel, W.-J., 2012] "Blueprinting Approach in Support of Cloud Computing. Future Internet ,PP 322–346.

[Omer K., Safia M., El-Sayed M., and Abed-Albadaa S., 2013] "Cloud Computing Cryptography: state of the art", International Journal of Computer, Information Science and Engineering Vol:7 No:8, 2013

[online available] http://www.healthcare-informatics.com/article/orthopedic-care-clinic-franchise-launched\

[Online available] http://www.fiercehealthit.com/story/cloud-computing-healthcare-question-not-ifwhen/2012-01-0.

[Pearson, S., 2009] "Taking Account of Privacy when Designing Cloud Computing Services". In Proceedings of the ICSE Workshop on Software Engineering Challenges of Cloud Computing at CLOUD'09, Washington, DC, USA, 23 May 2009; pp. 44–52.

[R. Alex Mu, Hsing Kuo, 2011] "Opportunities and Challenges of Cloud Computing to Improve Health Care Services" International Journalof information sciences, No 22, Vol 3.

[Rosado, D.G.; Gómez, R.; Mellado, D.; Fernández-Medina, E.2012] "Security analysis in the migration to cloud environments". Future Internet 2012, 4, 469–487.

[Ruoyu Wu, Gail-Joon Ahn and Hongxin Hu, 2010] "Secure Sharing of Electronic Health Records in Clouds", Proceedings of the 1st ACM International Health Informatics Symposium.

[Ruoyu Wu, Gail-Joon Ahn and Hongxin Hu, 2012] "Towards HIPAA-compliant Healthcare Systems in Cloud Computing", International Journal for Computing and Algorithms, Vol. 3, No. 20.

[Samuel, O.W., Omisore, M.O., Ojokoh, B.A., and Atajeromavwo, E.J., 2013] "Enhanced Cloud based Model for Healthcare Delivery Organizations in Developing Countries", International Journal of Computer Applications (0975 – 8887) Volume 74– No.2.

[Sanjay P. Ahuja, Sindhu Mani and Jesus Zambrano, 2012] "A Survey of the State of Cloud Computing in Healthcare", Network and Communication Technologies; Vol. 1, No. 2.

[Soma A. K., 2011] "Cloud-based Solutions for Healthcare IT", Published by Science Publishers, P.O. Box 699, Enfi eld, NH 03748, USA An imprint of Edenbridge Ltd., British Channel Islands, Copyright reserved- 2011 ISBN 978-1-57808-702-0

[Srinivasa, R., Nageswara, R., and Ekusuma, K., 2009] "Cloud computing: An overview", Journal of Theoretical and Applied Information Technology (JATIT), pp. 71-76, 2009.

[Sunyaev J., Leimeister H., and Krcmar H., 2010] "Open security issues in German healthcare telematics". In HEALTHINF 2010 - Proceedings of the 3rd International Conference on Health Informatics, pages187-194.

[Teng C.C.; Mitchell, J.; Walker, C. A, 2010] "Medical Image Archive Solution in the Cloud." In Proceedings of the 2010 IEEE International Conference on Software Engineering and Service Sciences (ICSESS), Beijing, China, 16–18 July 2010; pp. 431–434.

[Thomas Trojer, Basel Katt, Ruth Breu, Thomas Schabetsberger, and Richard Mair, 2012] "Managing Privacy and Effectiveness of Patient-admin¬istered Authorization Policies", International Journal of Computational Models and Algorithms in Medicine, 3(2), 43-62.

[Yu, W.D. A, 2011] "Service Modeling Approach to Service Requirements in SOA and Cloud Computing—Using a U-Healthcare System Case". In Proceedings of the IEEE 13th International Conference on e-Health Networking, Applications and Services, Columbia, MO, USA, 13–15 June 2011; pp. 233–236.

## Authors' Information

***Omer K. Jasim*** *- Ph.D. student at faculty of computer and information sciences, Ain Shams University, ZIP (+2), Cell phone: 01154567015; e-mail: omarkj@auc-edu.org*

*Iraq nationality*

***Safia Abbas*** *- she is lecturer at faculty of computer and information sciences, Ain Shams University, Cairo-Egypt; e-mail: safia_abbas@cis.asu.edu.eg*

***El-Sayed M. El-Horbaty*** *- he is professor in faculty of computer and Information sciences, Head of Computer Science department, Ain Shams University, Abbasia, Cairo-Egypt; e-mail: Shorbaty@cis.asu.edu.org*

***Abdel-Badeeh M. Salem*** *- he is professor in faculty of computer and information sciences, Head of BioMedical Informatics and Knowledge Engineering Research Lab, Ain Shams University, Abbasia, Cairo-Egypt; e-mail: absalem@cis.asu.edu.eg*