International Journal of Information Management 43 (2018) 146–158

Contents lists available at ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt

Review

Cloud computing-enabled healthcare opportunities, issues, and applications: A systematic review

Omar Ali[a], Anup Shrestha[a,*], Jeffrey Soar[a], Samuel Fosso Wamba[b]

[a] University of Southern Queensland, West Street, Toowoomba, Queensland 4350 Australia
[b] Toulouse Business School, Department of Information, Operations and Management Sciences, Toulouse France

ARTICLE INFO

Keywords:
Cloud computing
Healthcare services
Systematic review
Classification framework

ABSTRACT

Cloud computing offers an innovative method of delivering IT services efficiently. Extant literature suggests that cloud technology can enhance the level of services in various industries, including healthcare services. As with any technological innovation, cloud computing should be rigorously evaluated before its widespread adoption. This research study presents a systematic review of scholarly articles of cloud computing in the healthcare sector. We considered 316 articles and filtered down to 88 articles to present a classification framework that has three dimensions: cloud computing-enabled healthcare opportunities, issues, and applications. Implications to future research and practice are highlighted in the areas of value-added healthcare services towards medical decision-making, data security & privacy obligations of cloud service providers, health monitoring features and innovative IT service delivery models using cloud computing.

1. Introduction

The healthcare sector is facing challenges that include financial pressures, management of multiple stakeholders for services delivery, and ageing populations (Kaur & Chana, 2014). Greater use of information and communications technology (ICT) can support in meeting these challenges for the healthcare sector (Fichman, Kohli, & Krishnan, 2011). Developments in ICT alongside the necessity to make healthcare provision more efficient have led to growing health ICT applications (Shiferaw & Zolfo, 2012). ICT has been used to support healthcare to provide better access to patient records (Lu, Xiao, Sears, & Jacko, 2005; Venkatesh, Rai, Sykes, & Aljafari, 2016) and for decision making. There is further potential for ICT to help the healthcare sector to reduce costs and improve service outcomes (Fichman et al., 2011; Venkatesh et al., 2016; Romanow, Cho, & Straub, 2012).

Cloud computing promotes IT services that are available at all times and from all locations (Ali, Soar, & Shrestha, 2018; Mell & Grance, 2010). It is a new mechanism of delivering computing resources, not a new technology (Dwivedi & Mustafee, 2010; Senyo, Addae, & Boateng, 2018). Microsoft Office 365 and Google Docs are examples of non-medical platforms in the cloud whereas Microsoft HealthVault and Google Health platform are examples of applications in medical services (Spil & Klein, 2014). There are three significant improvements offered by the cloud computing model in comparison with conventional computing: (1) powerful computing resources are accessible on demand, (2) service provision without any requirement of up-front commitment by customers, and (3) availability for short-term use (Armbrust et al., 2010; Bayramusta & Nasir, 2016). The cloud model has impacted many industries and it is projected that almost 80% of today's existing companies will have adopted cloud computing by 2020 (Kuttikrishnan, 2011). Furthermore, cloud computing can be adopted by organizations that lack resources and infrastructure to set up on-premises applications (Ahuja, Mani, & Zambrano, 2012).

Research conducted by Rosenthal et al. (2010); Ozdemir, Barron, and Bandyopadhyay, (2011) and Zhao, Ni, and Zhou, (2017) suggested that medical informatics communities can embrace the advantages of this new cloud model for data sharing and applications. Medical data administration and analysis are expensive and there is a lack of relevant application solutions (Harsha, Pussewalage, & Oleshchuk, 2016; Sultan, 2014a). Cloud computing may have the potential to overcome these issues (Agarwal, Gao, DesRoches, & Jha, 2010; Anderson et al., 2007; Kochan, Nowicki, Sauser, & Randall, 2018; Memon, Owen, Sanchez-Graillet, Upton, & Harrison, 2010).

Cloud-based applications can offer solutions to current problems within healthcare (Griebel et al., 2015; Harsha et al., 2016; Kuo, 2011). However, despite the anticipated benefits, the rate of adoption and effective use of cloud computing within the healthcare sector remains significantly low (Bannerman, 2010; Rosenthal et al., 2010). The

* Corresponding author at: School of Management & Enterprise, University of Southern Queensland, West Street, Toowoomba, Queensland 4350 Australia.
E-mail addresses: omar.ali@usq.edu.au (O. Ali), anup.shrestha@usq.edu.au (A. Shrestha), soar@usq.edu.au (J. Soar), s.fosso-wamba@tbs-education.fr (S.F. Wamba).

https://doi.org/10.1016/j.ijinfomgt.2018.07.009
Received 13 April 2018; Received in revised form 19 July 2018; Accepted 19 July 2018

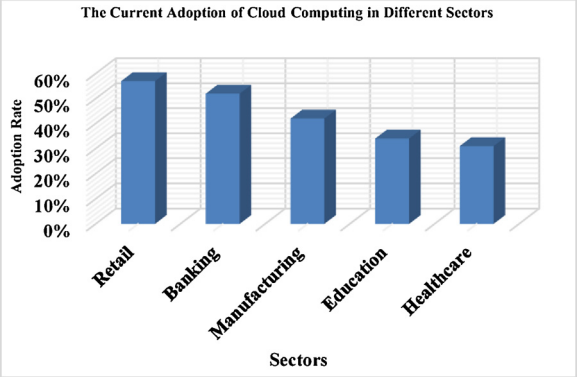

Fig. 1. The current adoption of cloud computing (The Economist Intelligence Unit, 2015).

highest adoption of cloud computing is within the retail industry at 57%, whereas the healthcare sector has been reported with 31% adoption (The Economist Intelligence Unit, 2015). Fig. 1 portrays adoption of cloud adoption across key industry sectors.

The main objective of this research study is to evaluate the extant literature on the adoption and use of cloud computing in the healthcare sector that have been published in IS and healthcare journals with the aim of highlighting the contributions from current research and discussing future research directions.

An overview on the current cloud adoption in the healthcare sector is presented next. This is followed by the research methodology explaining our systematic review mapping process and presenting research results based on a classification framework. This is followed by a discussion of current literature in terms of opportunities, issues and applications of cloud computing for the healthcare industry. Finally, implications to future research and practice are highlighted.

2. Adoption of cloud computing in the healthcare sector

Cloud computing is altering healthcare IT, particularly within the Electronic Health Records (EHRs) domain (Chatman, 2010; Kuo, 2011). Cost minimization in IT investments can have subsequent benefits towards better healthcare services (Lian, Yen, & Wang, 2014; Lisa, 2011; Ramachandran, 2016). Strukhoff, O'Gara, Moon, Romanski, and White, (2009) reported that prescription expenses can be decreased by 80% and billing for patients and insurance businesses can be completed within 2 h as opposed to up to 7 days with an introduction of cloud-enabled health information systems.

A cloud-based system has been proposed to automatically compile patient data involving sensors that are linked to medical devices to process data for storage, accessibility and sharing (Rolim et al., 2010). This system can minimize typed mistakes or errors from gathering of data manually, not only making the process simpler but also allowing better access to quality data (Venkatesh et al., 2016). Nkosi and Mekuria (2010) proposed a cloud computing system that supplies not only multimedia sensor signal processing. Rao, Sundararaman, and Parthasarathi, (2010) reported on a pervasive cloud initiative called 'Dhatri' which leveraged the power of cloud computing and wireless technologies to enable physicians to access patient medical information at any time. The Greek National Health Service trialed an emergency medical system in the cloud by combining the emergency system with patient data ensuring immediate access for doctors by being able to utilize all devices yet maintain low expenses at the same time (Koufi, Malamateniou, & Vassilacopoulos, 2010).

In Australia, an e-Health cloud has been proposed as a collaboration between Telstra and the Royal Australian College of General Practitioners (RACGP). This collaboration aims to produce applications related to diagnosis and control, medical software, prescriptions, education and referral appliances (Korea IT Times, 2010). Bioinformatics research in the medical field has been successfully powered by the cloud computing technology (Arrais & Oliveira, 2010; Avila-Garcia, Trefethen, Brady, Gleeson, & Goodman, 2008; Kudtarkar, Deluca, Fusaro, & Tonellato, 2010; Memon et al., 2010). Although there are several value propositions of cloud computing promoted by a unique IT service delivery model over the Internet, business cost savings appear to be the most critical factor for its popularity and wide adoption.

3. Research methodology

Given the large numbers and frequently updating healthcare publications, it is practically impossible for health practitioners to study relevant articles for evidence-based practice (Bastian, Glasziou, & Chalmers, 2010). Moreover, healthcare professionals should not depend on the results of a single study to make decisions as such studies may have certain biases and the results may be inconclusive (Abbas, Raza, & Ejaz, 2008). In order to adopt evidence-based practice, healthcare professionals must sought strong evidence of research that informs practice. The hierarchy of evidence that ranks evidence for healthcare interventions promote systematic reviews as one of the strongest evidence for evidence-based health practice (Evans, 2003). Therefore, studies from systematic reviews are relevant as they provide summarised research implications to practice on a given topic that is considered rigorous and trustworthy in comparison to controlled trials or case studies.

Systematic reviews promote a method of identifying, evaluating, interpreting, and synthesising all the available research relevant to a particular research topic area, or phenomenon of interest (Dikert, Paasivaara, & Lassenius, 2016; Victor, 2008). A major aim of the systematic review is to provide evidence in a transparent and rigorous way to enhance the validity and reliability of the research findings (Coren & Fisher, 2006; Kitchenham & Charters, 2007). Systematic reviews are undertaken through a staged process covering: definition of the review scope, search questions and protocol; selection of evidence; quality appraisal of evidence; data extraction and synthesis; and reporting and dissemination (Petticrew & Roberts, 2008).

The guidelines for systematic literature reviews are very important to support researchers while conducting systematic literature (Kitchenham & Charters, 2007). The systematic review that is presented in this research study follows the procedures and guidelines that are described in Tranfield, Denyer, and Smart, (2003); Kitchenham (2004), and Kitchenham and Charters (2007). Our research study has three phases: planning, execution, and summarizing or reporting. The steps followed during each phase are shown in Fig. 2 (each column of the figure corresponds to the related phase).

3.1. Planning phase

The first step of the planning phase referred to the *identification* of the need for a systematic review. As described in the previous section, although there is active research towards the adoption of cloud computing in the healthcare sector, there is no systematic review that summarizes all research findings and offers a deeper insight into the implications to research and practice in this research area.

The second step of the planning phase is the *development* of the research review protocol. This systematic review protocol provides a base to understand current cloud computing-enabled healthcare research. A review protocol was developed to define a research classification framework originally developed by Ngai and Wat (2002) to conduct a systematic review within the relevant journal articles dealing with cloud computing technology in the healthcare sector. A similar classification framework on a literature review study on e-commerce adoption conducted by Van Oranje et al. (2009) has been adapted in this study. The classification framework has three dimensions: opportunities, issues, and applications. We amend this framework by adding