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Cloud Computing Adoption: A Mapping Of Service Delivery And Deployment Models

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ABSTRACT

The recent upward trend in adopting cloud computing by businesses worldwide reflects the captivating opportunity of cost effective computing brought by cloud computing to replace the traditional IT computing services model. However, the decision to adopt cloud computing is somewhat complex. This paper will review the literature of cloud computing service and deployment models with the aim to determine the relevant characteristics of both service delivery and deployment models. Then, the authors will develop a mapping between the two sets of characteristics of cloud computing models. The mapping will lead to the development of a decision-making framework for managing cloud-computing adoption.

Keywords: cloud service delivery models, cloud deployment models, cloud computing adoption, characteristics of cloud computing models, managing cloud computing adoption

INTRODUCTION

The National Institute of Standards and Technology (NIST) described the cloud model as consisting of five essential characteristics of cloud computing, three service delivery models, and four deployment models [14]. Essential characteristics include on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. NIST's three service models are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). NIST's four deployment models are private cloud, public cloud, hybrid cloud, and community cloud. The recent statistics on the cloud computing technology market are surging. A recent study by Al-Jabri [2] found that more awareness about cloud computing leads to more adoption. Cloud computing has provided an attractive alternative for many businesses in terms of cost saving in establishing and maintaining IT resources [17]. Establishing an IT function, managing software licensing and up-gradation to meet ever fast growing computing demands are complex and costly as well. However, the cloud-computing industry offers businesses a number of different adoption scenarios. Therefore, businesses face a number of decision-making issues in their endeavor to adopt cloud computing to support their business processes and operations. For example, which of the cloud delivery models from available options (SaaS, PaaS, or IaaS) is best to adopt? In addition, which deployment model amongst the common models (private, community, public, or hybrid) suits their environment and fulfills their requirements? Answering these decision questions is not simple and requires the consideration of the relevant decision factors, which in turn generates multiple decision scenarios simultaneously. A review of literature revealed a lack of research work in addressing the above two questions pertaining to managerial decision making of cloud computing adoption.

This paper aims to explore existing research on cloud computing. It is theoretical in nature, as it provides a literature review that focuses on the characteristics of cloud computing service and deployment models and then highlights their inter relationships by developing a mapping between them. The paper begins by explaining cloud computing. It then defines cloud-computing technology and discusses benefits and risks of cloud computing adoption. Then, it will determine a set of characteristics of both service delivery and deployment models. Next, it will build a mapping between these characteristics with intent to propose a decision-making framework for managing cloud-computing adoption. This paper will provide new insights into the area of managing cloud-computing adoption. In addition, it will extend our understanding of the characteristics of cloud computing service and deployment models and the relationship between them.

BACKGROUND

Of the many definitions found in literature, one portrayed by the NIST has been acknowledged as the most comprehensive one and is widely accepted. NIST defines cloud computing as "A model for enabling 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" [8, p.11] [14]. Initially web-based and start-up companies started providing cloud services [11]. Then major players like Amazon and Google followed. Because of on-demand self-service, extensive network access, resource pooling, speedy elasticity, and measured service characteristics, cloud computing has been cited as 'the fifth utility' (along with water, electricity, gas, and telephone), whereby computing services are readily available on demand, like other utility services available in today's society [3]. Despite of the benefits of cloud computing, its adoption is not without challenges. Xin-ping et al [24] highlighted challenges of adopting cloud

computing in the medical industry. Among key challenges, bandwidth, security, authentication, management, resource development, and charging methods were mentioned. Cloud computing provides on-demand services over computer networks. Cloud customers do not possess, manage or maintain the applications, platforms, data, etc. but only use them as final products by accessing services with IT support. The advantage is that it reduces costs of application-based construction and maintenance. However, the risk of data leakage becomes a major issue because application and data servers are located outside company premises, unless the company uses a private cloud. Khajeh-Hosseini et al [9] posit that adoption decisions of cloud computing is not straightforward. Cost calculations are complicated; the adoption may result in a major organizational change that will affect the way employees work, and corporate governance issues are not well understood. A more recent investigation by Phaphoom et al [16] offers an extensive review of the different barriers facing cloud-computing adoption by organizations.

MANAGEMENT OF CLOUD COMPUTING ADOPTION

Organizations desire to have in cloud computing some attributes that are important for adoption. They have the desire for a service that is easy to understand and use, that helps users to be more economically efficient, that is more flexible, and that aids innovation and creativity in business processes [22]. Firms will definitely wish to possess high performing, secured cloud platform, with reliable service, and an accountable provider, a highly available service (minimum cuts or disruption), and greater client control of data and applications. They also wish to have scalable cloud services [1] [10]. Attaining the benefits cloud computing is not simple and not without risk. Major risk factors include security and privacy of service and data, end user or client loss of control of service and data [7]. In general, the decision making process involved in the planning and management for adopting any new technology is complex. The reason is that a number of organizational, technical, and environmental factors can affect successful decision making for cloud computing adoption [18, 21]. As for the managerial decision for adopting cloud computing, a detailed understanding of organizational characteristics and their business requirements for IT services, the features of cloud computing capabilities, and associated risks are all essential. Sun et al [20] classified existing approaches for cloud service selection from five perspectives: decision-making techniques, data representation models, parameters and characteristics of cloud services, contexts, and purposes. Sun et al [20] summarized nine dimensions, which represent cloud characteristics (parameters or factors) considered by cloud service selection approaches. These characteristics include security, performance, accessibility, usability, scalability, resource allocation, payment, reputation, and functionality. Our study focuses on identifying the relevant characteristics for deciding on the best combination of cloud delivery service (SaaS, PaaS, or IaaS) and deployment models (public, private, hybrid, and community) that fits the organizational requirements. To reach this objective, we classified the relevant cloud characteristics into three categories: (1) services delivery characteristics, (2) deployment characteristics, and (3) service and provider selection characteristics. The following three sections describe these three categories of characteristics.

KEY CHARACTERISTICS FOR SELECTING CLOUD SERVICE DELIVERY MODLES

For an organization to decide what type of cloud service delivery to adopt, it needs to be aware of the relevant characteristics of service delivery models. In Table 1, we defined four key characteristics that we believe are very relevant to the selection of a delivery service model among the three alternative cloud service models.

Table 1. Characteristics relevant to selecting cloud service delivery models

Service model characteristic	Description	Reference
Cost of service	Service price and payment terms	[5] [6]
Service adaptability to business needs	The degree of flexibility the firm will have with changing the cloud service workflow to suit a firm innovated business process	[19]
Service complexity	Complexity describes the degree to which the innovation is perceived as difficult to understand and complex to use. In other words, how easy to understand, learn, and use the cloud service.	[18] [21]
Service setup time	Setup/installation time taken for the client to start using service	[19]

KEY CHARACTERISTICS FOR SELECTING CLOUD DEPLOYMENT MODELS

Adopting organizations of cloud computing deploy one or more of the above-mentioned three cloud service models in different ways in accordance with their needs. The most common models of cloud deployment as defined by the NIST are Private, Community, Public cloud, and Hybrid cloud [14] [23]. These deployment models represent alternative options for deploying the selected cloud service model. For an organization to decide what type of cloud deployment model to adopt, it needs to be aware of the relevant characteristics of cloud deployment models. In Table 2, we defined four key characteristics that we believe are relevant to the selection of a cloud deployment model among the four alternative cloud deployment models.

Table 2. Characteristics relevant to selecting cloud deployment models

Deployment model characteristic	Description	Reference
Cost of cloud deployment	a. Initial capital cost plus b. Additional operating cost	[19]
Security of data	Security level of the used service and client data maintained by the cloud deployment model. This includes: a. Data integrity (data accuracy and recovery) b. Level of audibility c. Access control	[5] [7] [15] [20]
Privacy of data	a. Degree of confidentiality of data maintained by the cloud deployment model	[7]
Control of service and/or data	a. Location of Client's data storage (client's local server or cloud server) b. Manageability i. Ease of monitoring the service ii. Autonomy (degree of political control or ownership the firm will exercise on the cloud service)	[7] [15]

MAPPING OF THE CHARACTERISTICS OF SERVICE DELIVERY AND DEPLOYMENT MODELS

Next, we map the service delivery characteristics with the deployment characteristics in order to reach a decision on the combination of service delivery and deployment models that match or qualify certain organizational requirements and characteristics. Assuming that an organization has already determined to switch to or adopt cloud computing, then it needs to make two more decisions. (1) What service delivery model and what deployment model to choose or adopt (for example, public SaaS, public PaaS, private SaaS, hybrid SaaS, etc.). (2) To select the right service and provider from a set of alternative services and their providers. We believe that two logical steps are involved in making such decisions. First, an organization will need to determine the delivery model and deployment model to adopt. Second, it will then need to select the best service from the alternative cloud services and providers. This study focuses on developing a framework, which assists management to make the first decision. To be able to choose the right combination of the service delivery model and the deployment model, we construct a mapping between the characteristics that are relevant to selecting a service model against the characteristics relevant to selecting the deployment model. This mapping will produce 12 cells representing 12 combinations of service delivery and deployment models. Each of these combinations will imply the conditions that fits certain types of organizational requirements for cloud computing. Thus, an organization can choose the right combination cell that best matches their requirements.

Table 3 depicts a mapping between the three service delivery models against the four standard deployment models. As mentioned above, after having decided which service delivery and deployment models to adopt, the second step of our approach is to search for alternatives of the selected service and deployment models from the available cloud providers. Then, once we have found a set of alternatives, we can apply the multi-criteria decision making approach to select the best service and service provider. The multi-criteria decision-making approach and methods handle this kind of decision problem well [19] [20]. The key factors and their sub factors that are relevant for the selection of the service and service provider depends on the service and the provider. Examples of these characteristics include cost, suitability of service to organization IS needs, agility (adaptability, compatibility, scalability, and setup time), reliability (uptime, disaster recovery, compliance, stability, and reputation), usability (setup complexity, ease of learning and use), performance (response time, user support, and network bandwidth), and accountability (provider auditability, data ownership, provider ethicality, and sustainability) [12] [13] [18]. The case of independent software vendors offering their software as a service from a Cisco private cloud infrastructure [4] illustrates the applicability of such mapping in helping managers to decide on the combination of service delivery and deployment models to adopt.

IMPLICATIONS AND CONCLUSIONS

This paper identifies the characteristics/factors that are useful for the evaluation and selection of the type of service delivery model and deployment model an organization will adopt. We developed a mapping between the identified characteristics of cloud computing service and deployment models. Based on the mapping, we will identify a set of conditions that qualify an organization for the adoption of the correct combination of the cloud service delivery and deployment models. The literature review undertaken in this paper is a part of a larger study, which establishes a starting point for an investigation for the validation of the proposed mapping and associated conditions as a mechanism to assist management to determine the correct service delivery model and its deployment. We believe this decision is critical for the adopting organization and should take place before selecting the desired service and service provider. Thus, the outcome of this paper provides a platform, which will lead for the development of a multi-criteria decision making method to assist in selecting the service and service provider, which will be the next phase of the study.

Table 3. A mapping between cloud computing service delivery models and deployment models

Service Model / Deployment	SAAS	PAAS	IAAS
PRIVATE CLOUD	1. Service is ready made software 2. Cost is medium as private cloud costs more than public 3. Adaptability is limited since flexibility with changes of IS needs is limited (application belongs to provider and under his control) 4. Complexity is low as the SaaS service is easy to install and use 5. Setup time is moderate 6. Service is under the control of the provider as it is managed by the cloud provider 7. Data security is high since client data is stored on a private cloud 8. Data privacy is high since client data is stored on a private cloud	1. Service is platform for developing, hosting, and running applications by the client 2. Cost is high as private cloud costs more than public and PaaS costs more than SaaS 3. Adaptability is high since flexibility with changes of IS needs is not limited as the application is under control of client 4. Complexity is high as the PaaS service requires IT technical, functional, and development skills to use 5. Setup time is high 6. Service is under the control of the provider, as the provider owns it, but the developed applications are under the control of the client 7. Data security is high since client data is stored on a private cloud	1. Service is infrastructure for developing, hosting, and running applications by the client 2. Cost is medium to high as private cloud costs more than public and IaaS costs more than SaaS 3. Adaptability is high since flexibility with changes of IS needs is not limited as needed resources are easy to scale up or down by the provider to fulfil client needs 4. Complexity is medium as the IaaS does not require much IT skills to use 5. Setup time is moderate 6. Service is under the control of the provider, as the provider owns it 7. Data security is high since client data is stored on a private cloud 8. Data privacy is high since client data is stored on a private cloud
PUBLIC CLOUD	1. Service is ready made software 2. Cost is low as public cloud is shared by multiple clients 3. Adaptability is limited since flexibility with changes of IS needs is limited (application belongs to provider and under his control) 4. Complexity is low as the SaaS service is easy to install and use 5. Setup time is minimal 6. Service is under the control of the provider as it is managed by the cloud provider 7. Data security is low since client data is stored on a public cloud 8. Data privacy is low since client data is stored	1. Service is platform for developing, hosting, and running applications by the client 2. Cost is medium as PaaS costs more than SaaS 3. Adaptability is high since flexibility with changes of IS needs is not limited as the application is under control of client 4. Complexity is high as the PaaS service requires IT technical, functional, and development skills to use 5. Setup time is moderate 6. Service is under the control of the provider, as the provider owns it, but the developed applications are under the control of the client 7. Data security is low since client data is stored on a public cloud	1. Service is infrastructure for developing, hosting, and running applications by the client 2. Cost is medium as public cloud is shared by multiple clients 3. Adaptability is high since flexibility with changes of IS needs is not limited as needed resources are easy to scale up or down by the provider to fulfil client needs 4. Complexity is medium as the IaaS does not require much IT skills to use 5. Setup time is minimal 6. Service is under the control of the provider, as the provider owns it 7. Data security is low since client data is stored on a public cloud 8. Data privacy is low since client data is stored on a public cloud

HYBRID CLOUD	1. Service is ready made software 2. Cost is low to medium as cost will include hiring private cloud 3. Adaptability is limited since flexibility with changes of IS needs is limited (application belongs to provider and under his control) 4. Complexity is low as the SaaS service is easy to install and use 5. Setup time is moderate 6. Service is under the control of the provider as it is managed by the cloud provider 7. Data security is moderate since client sensitive data will be stored on a private cloud 8. Data privacy is moderate since client sensitive data will be stored on a private	1. Service is platform for developing, hosting, and running applications by the client 2. Cost is medium to high as private cloud will be used in addition to the public cloud plus PaaS costs more than SaaS 3. Adaptability is high since flexibility with changes of IS needs is not limited as the application is under control of client 4. Complexity is high as the PaaS service requires IT technical, functional, and development skills to use 5. Setup time is high 6. Service is under the control of the provider, as the provider owns it, but the developed applications are under the control of the client 7. Data security is moderate since client sensitive data will be stored on a private	1. Service is infrastructure for developing, hosting, and running applications by the client 2. Cost is medium to high as private cloud will be used in addition to the public cloud 3. Adaptability is high since flexibility with changes of IS needs is not limited as needed resources are easy to scale up or down by the provider to fulfil client needs 4. Complexity is medium as the IaaS does not require much IT skills to use 5. Setup time is moderate 6. Service is under the control of the provider, as the provider owns it 7. Data security is moderate since client sensitive data will be stored on a private cloud 8. Data privacy is moderate since client sensitive data will be stored on a private
COMMUNITY CLOUD	1. Service is ready made software 2. Cost is low to medium as cost of hiring community cloud will be divided by a group of clients 3. Adaptability is limited since flexibility with changes of IS needs is limited (application belongs to provider and under his control) 4. Complexity is low as the SaaS service is easy to install and use 5. Setup time is moderate 6. Service is under the control of the provider as it is managed by the cloud provider 7. Data security is low since client data is stored on shared community cloud 8. Data privacy is low since client data is stored on shared community cloud	1. Service is platform for developing, hosting, and running applications by the client 2. Cost is medium as PaaS costs more than SaaS 3. Adaptability is high since flexibility with changes of IS needs is not limited as the application is under control of client 4. Complexity is high as the PaaS service requires IT technical, functional, and development skills to use 5. Setup time is high 6. Service is under the control of the provider, as the provider owns it, but the developed applications are under the control of the client 7. Data security is low since client data is stored on shared community cloud	1. Service is infrastructure for developing, hosting, and running applications by the client 2. Cost is medium as community cloud will be shared by multiple clients 3. Adaptability is high since flexibility with changes of IS needs is not limited as needed resources are easy to scale up or down by the provider to fulfil client needs 4. Complexity is medium as the IaaS does not require much IT skills to use 5. Setup time is moderate 6. Service is under the control of the provider, as the provider owns it 7. Data security is low since client data is stored on shared community cloud 8. Data privacy is low since client data is stored on shared community cloud

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REFERENCES

[1] Aljabre, A. (2012) 'Cloud computing for increased business value', *International journal of business and social science*, Vol. 3, No. 1, pp. 234-239.

[2] Al-Jabri, I. M. (2015) 'The perceptions of adopters and non-adopters of cloud computing: application of technology-organization-environment framework', *The Fourteenth International Conference on Electronic Business*, ICEB2014, pp. 250-257. Taipei, December 8-12, 2014.

[3] Buyyaa, R., Yeoa, C. S., Venugopala, S., Broberg, J., & Brandic, I. (2009) 'Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility', *Future Generation Computer Systems*, Vol. 25, No. 6, pp.599–616.

[4] Cisco. (2014) 'Independent software vendors: Deploy software as a service on cisco infrastructure', available at https://www.cisco.com/web/partners/partner_with_cisco/files/saas_on_cisco_infrastructure.pdf (accessed October 2015).

[5] Garg S K, Versteeg S, Buyya R. (2011) 'SMICloud: a framework for comparing and ranking cloud services', In *Proceedings of the 4th IEEE/ACM international conference on utility and Cloud computing (UCC)*, Melbourne, Australia; 2011.

[6] Godse, M. & Mulik, S. (2009) 'An approach for selecting software-as-a-service (SaaS) product', In 2009 IEEE International Conference on Cloud Computing.

[7] Güner, E. O. & Sneiders, E. (2014) 'Cloud computing adoption factors in turkish large scale enterprises', Pacis 2014, available at http://www.pacis-net.org/file/2014/1845.pdf (accessed August 2015).

[8] Jansen, W. & Grance, T. (2011) 'Guidelines on security and privacy in public cloud computing', NIST Special Publication 800-144, Gaithersburg, MD: NIST.

[9] Khajeh-hosseini, A., Greenwood, D., Smith, J. W., & Somervillie, I. (2011) 'The cloud adoption toolkit: Addressing the challenges of cloud adoption in Enterprise', Library, 42 (April 2011), pp.447–465, Available at: http://arxiv.org/abs/1003.3866 (accessed 15 May 2015).

[10] Kim, W., S. D., Lee, E., & Lee, S. (2009) 'Adoption issues for cloud computing', In *Proceedings of 11th International conferernce on information systems and Web-based Applications & Services*, iiWas 09, Kuala Lumpure, Malaysia: ACM 2009, pp. 3-6.

[11] Leavitt, N. (2009) 'Is cloud computing really ready for prime time', *IEEE Computer Society*, January 2009, pp. 16-21.

[12] Loukis, E. & Kyriakou, N. (2015) 'Organizational factors affecting propensity to adopt cloud computing', In *(HICSS), 2015 48th Hawaii International Conference on*, IEEE.

[13] Low, C., Chen, Y., & Wu, M. (2011) 'Understanding the determinants of cloud computing adoption', *Industrial Management & Data Systems*, Vol. 111, No. 7, pp.1006–1023.

[14] Mell, P. & Grance, T. (2011) 'The NIST definition of cloud computing', available at http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf (accessed 23 April 2015).

[15] Morgan, L. & Conboy, K. (2013) 'Factors affecting the adoption of cloud computing: An exploratory study', In *Proceedings of the 21st European Conference on Information Systems (ECIS2013)*.

[16] Phaphoom, N., Wang, X., Samuel, S., Helmer, S., & Abrahamsson, P. (2015) 'A survey study on major technical barriers affecting the decision to adopt cloud services', *The Journal of Systems and Software*, Vol. 103, No. 1, pp. 167-181.

[17] Preston, R. (2011) 'Top 10 CIO priorities', Information Week, available at http://www.informationweek.com/news/globalcio/interviews/231901248 (accessed 25 August 2015).

[18] Rogers, E. M. (2003). *Diffusion of Innovations*, Fifth ed. NY: New York, Free Press.

[19] Saripalli, P. & Pingali, G. (2011) 'MADMAC: Multiple attribute decision methodology for adoption of clouds', The IEEE 4th International Conference on Cloud Computing 2011.

[20] Sun, L., Dong, H., Hussain, F. K., Hussain, O. K., & Chang, E. (2014) 'Cloud service selection: State-of-the-art and future research directions', *Journal of Network and Computer Applications*, Vol. 45, No. 1, pp. 134-150.

[21] Tan, M. & Lin, C. T. (2012) 'Exploring organizational adoption of cloud computing in Singapore', The *19th ITS Biennial Conference 2012*, In moving forward with future technologies: Opening a platform for all.

[22] Venters, W. & Whitley, E. A. (2012) 'A critical review of cloud computing: Researching desires and realities', *Journal of Information Technology*, Vol. 27, No. 3, pp. 179–197.

[23] Williams, B. (2012) *The economics of cloud computing: An overview for decision makers*, Cisco Press.

[24] Xin-ping, H., Zhi-mei, Z., & Jian, D. (2010) 'Medical informatization based on cloud computing concepts and techniques', *Journal of Medical Informatics*, Vol. 31, No. 3, pp. 6-9.