Inf Technol Manag (2012) 13:445–454
DOI 10.1007/s10799-012-0139-4

Enterprise cloud service architectures

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Published online: 18 August 2012

Abstract As a new computing paradigm, cloud computing has received a lot of attention from enterprises and has being integrated or applied to enterprise architectures. This paper surveys the state of the art of enterprise cloud service architectures. Specifically, this paper discusses enterprise cloud service architectural requirements, design approaches, architectural styles, emerging cloud service platforms, applications and related challenges in an enterprise context. This paper also identifies research trends and opportunities for researchers and practitioners in this fast moving field.

Keywords Cloud computing · Enterprise applications · Services architecture · Architectural requirements · Enterprise clouds · Cloud computing platforms · Enterprise cloud service architectures

1 Introduction

The IT services of modern enterprises are characterized by a need for greater flexibility, scalability and cost benefits [26, 36, 42]. As an emerging new computing paradigm for delivering on-demand and scalable computing services [47, 78], cloud computing is likely to be an attractive option for enterprises at different sizes. In particular, cloud computing has become commercially viable for many small and medium enterprises (SMEs) due to its flexibility and pay-as-you-go cost structure in light of the current climate of economic difficulties [77].

In recent years, there has been a sharp rise in the number of cloud computing publications such as books, articles, white papers and technical reports. Many of these publications have discussed cloud service architectural methods, service selection, evaluation, deployment, implementation and challenges. Currently, a key challenge in cloud computing is "the lack of a de facto standard or single architectural method, which can meet the requirements of an enterprise cloud computing approach" [62]. To help readers get a systematic understanding of enterprise cloud services, we survey the state of the art of enterprise cloud service architectures and discuss architectural requirements, design approaches, architectural styles, emerging cloud service platforms, applications and related challenges in an enterprise context. We also identify research trends and opportunities for researchers and practitioners in this fast moving field.

The rest of this paper is organized as follows. Section 2 presents an in-depth review of enterprise cloud service architectures including the architectural requirements, design approaches and architectural styles. Section 3 describes emerging cloud service platforms and cloud-based enterprise applications. Section 4 describes the future research directions and challenges in this area.

2 Literature review

The literature review starts from an overview of cloud computing. Subsequently, we reviewed the architectural requirements, design approaches, and different architectural styles for enterprise cloud service architectures.

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2.1 Overview of cloud computing

There are many definitions for cloud computing. A widely accepted definition is given by Mell and Grance [47] at the National Institute of Standards and Technology who define cloud computing to be "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 supplied and released with minimal management effort or service provider interaction". In practice, cloud computing often refers to Internet-based development and use of computing technology.

The cloud computing architecture is composed of three layers: resource, platform and application. The resource layer is the infrastructure layer which includes physical and virtualized computing, storage and networking resources [58]. The platform layer includes components such as web server, application server, and enterprise service bus [58]. The application layer serves the user and is mainly used for transaction processing and interaction [58].

According to Mell and Grance [47], cloud computing includes three major delivery models: (1) Software as a Service (SaaS). The consumer is able to use an application to meet his or her specific needs. However, the consumer does not have control over the operating system, hardware, or network infrastructure on which the application is running [47]. Salesforce.com and Google Apps are well-known examples of SaaS; (2) Platform as a Service (PaaS). The consumer uses a hosting environment for application development. The consumer has control over the applications and possibly partial control over the hosting environment [47, 93]. But the consumer does not have control over the operating system, hardware, or the network infrastructure. An example of PaaS is Microsoft Azure; (3) Infrastructure as a Service (IaaS). The consumer has greater access to computing resources including processing power, storage, networking components and middleware. In general, the consumer has control over the operating system, storage, deployed applications, and possibly networking components [25, 47]. However, the consumer cannot control the underlying cloud infrastructure [10, 25, 47].

According to Mell and Grance [47], cloud-based services can be deployed via four methods: (1) Public Cloud. A public cloud is characterized as being available to the general public from a third-party cloud service provider such as Google, Amazon, Microsoft, and others who run public clouds. For example, Google has more than 450,000 servers in its data centers and has infrastructure in place to supports public clouds [3]. A public cloud does not mean that a user's data is publically visible or not secure; public cloud vendors typically provide an access control or security mechanism for their users; (2) Private cloud. Cloud services can be offered on private networks. Private clouds are typically designed and managed by an IT department within an organization. In a private cloud service, data and processes are managed within the organization without the restrictions of network bandwidth or security exposures, or without the legal requirements that using the public cloud services might entail; (3) Community Cloud. Using a community cloud, the cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., missions, security requirements, policies, and/or compliance considerations). It may be managed by the organization or by a third party, and it may exist either on-premises or off-premises; (4) Hybrid Cloud. A hybrid cloud is a combination of a public, private, and/or community cloud that interoperates. In this model, users typically outsource non-business-critical information and processing to the public cloud, while keeping business-critical services and data in the private cloud [25].

Cloud Computing are commonly associated with characteristics such as high scalability, agility, high availability, high reliability, security, virtualization technology, multi-sharing, services in the pay-per-use mode (utility computing), automated resource management (e.g., automated backup), support for all service oriented applications [70, 78]. As a new IT paradigm for user services, cloud computing provides a powerful way to transform the way that IT resources are utilized [10, 25]. Cloud computing offers many potential benefits such as cost saving, rapid elasticity and scalability [39, 47] to enterprises by making IT applications and services available to enterprise users anytime and anywhere on the internet.

2.2 Architectural requirements for enterprise cloud service architectures

Identifying architectural requirements is the first step in the process of creating enterprise cloud service architectures. According to Rimal et al. [62], the architectural requirements can be classified according to the requirements of cloud providers, the enterprises that use the cloud, and end-users. Our review in this paper is focused on the enterprise requirements for the cloud service architectures.

To identify and understand the requirements, each enterprise needs to conduct need assessment and requirement analysis as indicated by the system development life cycle or software engineering literature. That means each enterprise needs to gather information from cloud vendors and related stakeholders such as technology consultants, employees and cloud computing experts. Collectively, they would work together to figure out what services the enterprise needs and about the details of each service. Esteves [16] recommends enterprises to identify requirements from cloud computing building blocks including essential characteristics, service delivery models (IaaS, PaaS and SaaS), deployment models, and enabling technologies (virtual machines, cloud storage, etc.). Rimal et al. [62] summarize a list of enterprise requirements for enterprise cloud deployment including security, cloudonomics, data governance, data migration, business process management requirements, third-party engagement requirements, and transferable skills requirements. Quartel et al. [60] and Engelsman et al. [14] suggest business requirements modeling as an approach to analyze the goals and requirements that can be realized by enterprise architecture elements.

On the other hand, enterprises can also get insights by reviewing the requirements of their enterprise service-oriented architectures (ESOA) if they have one available. Many enterprises have implemented systems based on the service-oriented architecture in the past few years [37, 68]. In general, enterprise cloud service architectures are typically grounded in previous work on enterprise service-oriented architecture, which was designed to address the complexity and to build better architectures and solutions for enterprise [73, 87]. A traditional ESOA is typically built on three-layer infrastructures which are "Web server, enterprise application server and service infrastructure, and enterprise information storage and business service infrastructure" [73].

Shifting to cloud computing has brought new type of requirements to ESOA and requires ESOA to expand its uses from on-premise to off-premise [11, 20, 23, 73]. Researchers [22, 39, 51, 93] suggest that the design of the cloud service architecture should meet the following requirements: uniform high capacity, free virtual machine migration, resiliency [15, 44, 91], scalability, backward compatibility. For example, Guo et al. [22] specify scalability, fault tolerance and high network capacity as three important requirements when they design a network structure for a large data center. As errors in business processes result in poor data accuracy, Närman et al. [52] advocate interviews as a primary data collection technique to do architecture requirement analysis and increase data accuracy.

2.3 Design approaches for enterprise cloud service architectures

So far there is no widely accepted guideline for designing enterprise cloud service architectures. In general, the design approaches have to depend on the detailed requirements that enterprises developed in the above step. As each enterprise has its own characteristics and requirements, it is hard to make one design approach that fits all enterprises.

Currently, the most common design approach for designing enterprise cloud service architectures we found is based on the layered approach used in ESOA [93]. The service management, application management, identity management, network monitoring and governance used in ESOA have been reused in the design of new enterprise cloud service architectures [93]. However, enterprise cloud service architectures have made many improvements by enhancing existing ESOA services and adding new specific services for clouds. For example, enterprise cloud service architectures provide more dynamic, real-time and automatic runtime governance to services and elastic infrastructure and add new cloud provisioning service and cloud subscription service [43, 73]. Based on the layered approach, enterprises can eventually develop or customize an enterprise cloud service architecture that works for them by continuous refinement and tweaking. As network structure is important to the performance of the enterprise cloud service architecture, researchers have also come up with different ways to design the underlying network structure. The main network structure used in data centers is based on the fat tree topology which relies on a switch-based tree structure to interconnect the increasing number of servers using various core and rack switches [51]. An alternative network structure is using DCell-based DCN solution which uses servers equipped with multiple network ports and mini-switches to construct its recursively defined architecture [22]. Furthermore, some researchers focus on extending existing software to manage cloud-based services instead of designing new software from scratch. Song et al. [69] have extended IBM data centre management software to manage cloud-scale data centers by using a hierarchical set up of management servers. They chose a hierarchical distribution of management components to balance the management workload for a large number of servers.

2.4 Different enterprise cloud service architecture styles

An enterprise architecture style such as client–server style is an abstraction of a family of enterprise-level software systems and is important for achieving quality enterprise architecture design [67, 72, 74]. Due to different requirements and design approaches, researchers and cloud vendors proposed different enterprise cloud service architecture styles. Samimi et al. [64] proposed a service clouds architecture which uses a distributed infrastructure to facilitate rapid prototyping and deployment of adaptive communication services. Their proposed infrastructure "combines adaptive middleware functionality with an overlay network substrate in order to support dynamic instantiation and reconfiguration of services" [64]. Zhang and Zhou [92] proposed a cloud computing open architecture (CCOA). The CCOA is a cloud computing centric service-oriented architecture framework which bridges the power of SOA and virtualization in the context of cloud computing ecosystem. Tang et al. [73] further proposed a way to extend the ESOA style to a new hybrid architectural style based on a specific cloud service-oriented formula that combines both ESOA style and cloud computing style. They indicated that the hybrid architectural style is "an abstraction of concrete enterprise service-orientated architectures, which includes SOA architectural elements, service design patterns as well as principles, and SOA quality attributes" [73].

In addition, many cloud vendors such as Amazon, Google, IBM, Oracle and Microsoft also propose their own architectural styles to combine ESOA and the power of cloud computing powers. For example, Amazon cloud architecture is an instance of the combined architecture styles of ESOA and cloud computing [72]. All these architectural styles are kind of hybrid in nature and extend the scope of ESOA to the cloud by adding new services and improving some existing SOA services [63, 73].

3 Emerging cloud computing platforms and enterprise applications

As a result of different requirements, design approaches, and architectural styles, researcher and cloud vendors have proposed and developed cloud computing platforms which combine the ESOA and the power of cloud computing. As consumers and enterprises gradually realize the potential benefits of on-demand "Software as a Service (SaaS)", "Platform as a Service (PaaS)", and "Infrastructure as a Service (PaaS)", we have seen a substantial increase in the number of cloud computing platforms on the market recently [6, 8, 27, 56]. In general, each cloud computing platform on the market has its own characteristics, strengths and weaknesses [56]. The following are some emerging cloud computing platforms:

- Abiquo enterprise cloud is designed to build, integrate and manage public, private and hybrid cloud [1]. Abiquo provides powerful features to give users full control over server, storage and network resources and also allow enterprises to deploy and manage cloud resources using an industry-standard API [1, 56].
- Aneka is a market oriented cloud development and management platform with rapid application development and workload distribution capabilities [6, 8, 62, 91]. As a .NET-based service-oriented resource management platform, Aneka is designed to support multiple application models, persistence and security solutions, and communication protocols in private and public network environments [6, 8].
- Amazon Elastic Compute Cloud [2] provides users a virtual environment to run Linux-based applications. The user needs to create a new Amazon machine image (AMI) or use an existing AMI from a global library [6, 8]. Then the user can submit his or her AMIs to Amazon simple storage service. Afterwards, the user can "start, stop, and monitor instances of the uploaded AMIs" [6].
- Eucalyptus is a leading cloud computing software platform for on-premise (private) Infrastructure as a service clouds [17]. It is an open-source implementation of Amazon EC2 and is fully compatible with the popular Amazon web services including Amazon Elastic Compute Cloud and Amazon simple storage service [56].
- Google App Engine [19] allows people to run web-based applications written using the Python programming language. Google App Engine supports "application programming interfaces (APIs) for the datastore, Google Accounts, URL fetch, image manipulation, and email services" [6]. A web-based Administration Console is offered to the user to manage web applications too.
- Microsoft Azure [48] is designed to allow software developers to easily create, host, manage, and scale both Web and non-web applications through Microsoft data centers. Microsoft Azure supports many proprietary development tools and protocols [8].
- Nimbus Platform [53] is a cloud computing platform for science and provides an integrated set of tools that deliver the power and versatility of infrastructure clouds to scientific users [53]. Nimbus is also compatible with Amazon Elastic Compute Cloud and Amazon simple storage service. Nimbus allows users to lease remote resources and build the required computing environment by deploying virtual machines [56].
- OpenNebula [54] is an open-source cloud computing product for data center virtualization. OpenNebula provides customizable solutions for users to build virtualized enterprise data centers and private cloud infrastructures [54] and allows user to deploy and manage virtual machines on physical resources [56].

These emerging cloud computing platforms provide a way to efficiently deploy and provide cloud services and applications to enterprises at different sizes. Please be noted that each cloud computing platform has certain unsolved issues [56]. Enterprises need to be aware of their characteristics, features, underlying technologies, and individual strengths and weaknesses before they select a cloud computing platform for enterprise deployment and implementation. So far, many enterprises have built successful applications such as business applications and manufacturing applications on top of cloud computing platforms [36, 59]. For example, New York Times used

Amazon EC2 to process scanned images from their newspaper archives [79]. Instead of making an investment in a large cluster that is needed only for a short period of time, New York Times rent needed resources to complete this task which won't repeat for a long while. In addition, there are also many cloud-based enterprise applications that are related to emails, storage (dropbox or similar applications), desktop applications (e.g., office applications), etc. Vrable et al. [80] developed an enterprise storage application named Cumulus, which implements file system backup to a remote cloud storage provider. Subsequently, Vrable [79] developed another more advanced enterprise storage application named BlueSky, which is a shared network file server backed by cloud storage. BlueSky relies on cloud storage for data durability, but provides good performance by caching data locally. We will see more and more enterprise applications that are moved to the cloud as more enterprises adopt cloud solutions. In the meantime, enterprise cloud applications will become more scalable, multi-tenant aware and configurable as more researchers are using multi-tenancy patterns to design, develop and deploy service-oriented enterprise cloud applications [49].

4 Future perspectives

The increasing adoption of cloud computing has emerged as an inevitable trend. Nonetheless, as more and more enterprises with different needs and idiosyncratic natures jump on the band wagon, we observed several key developments and critical challenges. In particular, small and medium enterprises (SMEs) conventionally are short of their own resources to embrace emerging technologies. A resource sharing platform with common architectures for cloud-based services to reduce operating costs and increase business efficiency of SME is in urgent need. Enterprises need to diligently examine the design requirements and approaches in order to create a new ECSA or incorporate the emerging cloud-oriented services into their enterprise architectures.

4.1 Research trends

We identified a few research trends associated with enterprise cloud service architectures (ECSA) and their adoption as follows.

- Developing SLA-aware ECSA. To achieve high quality assurance in enterprise cloud services, SLA-aware ECSA are increasingly being adopted in enterprise service computing [72]. The methodology and design principles of service level agreement (SLA) and quality of service (QoS) will be increasingly emphasized, modeled and monitored in the design of enterprise cloud service architectures [5, 68, 72, 73]. Further research will be needed to develop mechanisms for automated service level management, automated SLA monitoring, adaptive resource management based on SLA and demand, and adaptive SLA-Aware service execution [72].
- Developing SME-specific ECSA. There is a need for creating cloud-based service architectures for SMEs in order to encourage and support their cloud adoption. Researchers have started to conduct research for SME-specific cloud-based information services architectures by combining the characteristics of cloud computing with the actual needs and requirements of SMEs. Wang [81] proposes a cloud-based information services architecture for SMEs by adapting a high-level market-oriented cloud architecture developed by Buyya et al. [8]. This cloud-based information services architecture includes four main components: (1) Users/SMEs, who can submit their service requests to a selected cloud computing platform for processing; (2) Service level agreements (SLA) Resource Allocator, which is used as the interface between external users and SMEs [8]; (3) Virtual machines (VMs), which provide users with remote access to a pool of physical computers via the Internet and allow users to reserve a "virtual computer" with the desired operating system and applications; (4) Physical Machines, which are used to build a data center with numerous computing resources to meet specific needs and requirements of SMEs. This ECSA is scalable and can be dynamically available to meet the SMEs' needs on a pay per use basis. It has the potential to provide SMEs with many information system services at a lower cost.
- Increased effort in developing generic cloud service interfaces for ECSA. As different cloud vendors provide different interfaces to their cloud-based services which were enabled using varied enterprise architectures and enabling technologies, Dodda et al. [13] defined an architecture for cross-cloud system management and proposed a generic interface to facilitate the management of compute resources from different cloud providers in an homogenous manner. Harmer et al. [24] developed a cloud resource interface to hide the details of individual APIs in order to support the development of provider neutral applications. To increase the widespread adoption of ECSA, developing a more generic interface is being increasingly accepted by the cloud computing researchers.
- Increased effort in the development of evaluation criteria and decision support tools for decision making, risk assessment and evaluation of enterprise cloud adoption. The literature has shown that more efforts are being

conducted to help enterprises (1) understand the benefits and risks of cloud adoption and (2) evaluate the cloud-based services from cloud vendors. Thethi [75] proposes four criteria for evaluating cloud vendors: cloud platform maturity, technology alignment, operational alignment, and geographic alignment. Leong [34] suggests that while cost, operational stability, and the ability to scale are important when choosing a cloud service provider, each organization also needs to consider how well the cloud solution suits its organization's application architecture, how well it provides the level of customer support needed by the organization, and how well it meets the organization's service level, security, privacy, and compliance needs [25, 55]. Later, Leong and Chamberlin [35] further proposed weightings for specific evaluation criteria, including ability to execute and completeness of vision. Khajeh-Hosseini et al. [30] developed two decision support tools to aid enterprises for decision making during the migration of IT systems to cloud computing. The first tool is a modeling tool that produces cost estimates of using public IaaS clouds and was used to compare the cost of different cloud providers, deployment options and usage scenarios. The second tool which they developed outlines the benefits and risks of using IaaS clouds from an enterprise perspective and can be used for risk assessment. Wang et al. [85] developed a trust-based service selection model to estimate the degree of user trust in a particular service based on past experience and indirect recommendation of the service for web service selection. Their model can be useful to evaluate the cloud service experience over time and determine future cloud service selection.

- Increased efforts in investigating the factors involved in enterprise cloud migration. The literature also has shown that increased efforts in investigating the factors involved in cloud migration. A few case studies in enterprises at different sizes have been conducted to identify and prioritize these factors. Many factors have been identified to have an effect on the migration of enterprise applications to cloud platforms and will determine when and how enterprises will migrate applications to the cloud [32, 63]. These factors include [30, 62]:
  - Mechanism of enterprise applications migration to the cloud,
  - Procedures to extend enterprises policies and governance to cloud deployments,
  - Design of public clouds to meet enterprise systems scope,
  - Enterprise managers' attitude and perception of possible impacts and changes induced by cloud migration in the existing it environment,
  - Implementation techniques, domain knowledge and cost concerns,
  - Organization's characteristics and competitive strategies, and
  - Influences of internal and external parties on the adoption decision process and organizational readiness

4.2 Challenges

Enterprises at different levels face many common challenges such as control, vendor lock-in, performance, latency, security, privacy and reliability [7, 93]. For example, enterprise managers are concerned with factors that may negatively affect the quality of cloud-based services such as Internet problems, service disruption and software bugs. Some enterprises are also concerned with issues and possible consequences such as cloud service provider dependency, or changes due to bankruptcies, shutdowns and acquisitions. Some enterprises have trust-related concerns with the reliability and security of cloud storage. In addition, currently no regularity organizations have reached the agreement on how to standardize the external interfaces of cloud-based systems [58, 93]. Oftentimes, cloud service providers have their own definitions of the interfaces and APIs. As a result, once an enterprise started to use the services of a cloud service provider, the enterprise is most likely to be locked by the provider and will have a hard time to switch to other cloud service providers. Enterprises are increasingly concerned about how hard it would be to move applications and data from one cloud service provider to another when they are selecting cloud service providers [25]. Regardless of these common concerns, large enterprises and SMEs have unique concerns and face different challenges in terms of the migration, adoption, and deployment of cloud-based applications and services. Below we discuss the ECSA challenges and specific challenges from the point of view of large enterprises (LE), and small and medium enterprises (SMEs).

4.2.1 Challenges for enterprise cloud service architecture

ECSA requires a careful combination of cloud computing and service-oriented computing. To design a useful enterprise architecture that comprises complex business processes, certain desirable performance goals and quality of service (QoS) properties need to be achieved in ECSA and enterprise applications deployed on ECSA [76, 88]. Tang [72] indicates that "the existing technology for modeling and analyzing enterprise cloud service architecture is still immature and cloud computing is very complicated as well as dynamic with many issues, such as performance, security, and availability.” Thus, it is very challenging to build an ECSA that meets QoS requirements and SLA contacts. So far, there is a lack of accepted SLA-aware theoretical framework and standards that can guide the modeling, analyzing and implementing enterprise cloud service architecture. There is also a lack of practical applications and cases of implementing SLA-aware ECSA [72].

4.2.2 Challenges for large enterprises

In general, large enterprises have developed a variety of information systems and applications over a long period of time [4, 37, 38, 45, 66, 71, 83, 84, 86, 90]. Many of their enterprise systems and applications offer an extensive range of capabilities and are integrated with other systems and applications both inside and beyond the enterprise. In particular, they spend a great deal of time and money on integrating distributed information from various sources into a unified format and on building an enterprise architecture that supports interoperability between different systems and applications. Their enterprise architectures are often complex and are composed of different technologies, techniques, and tools that make up the enterprise computing environments in which various applications such as manufacturing applications are delivered and used [9]. In many cases, large enterprises have “different ‘owners’ within the enterprise and have complex dependencies among the systems themselves, the data that they process, the middleware used, and the platforms on which they run” [28]. For multinational enterprises (MNEs), their information systems are even more complicated because their information systems are often developed and supported by people in different regions and countries. Studies indicate that the implementation and use of information systems within MNEs have been influenced by national differences including political and economic factors, infrastructure capabilities, physical environments, and cultural issues [33, 65]. Typically, it is almost impossible to find an individual within the enterprise who knows about all of the systems that are being used. The dependencies and internal relationships among different systems would not be realized until accidents happen when something simply stops working after a change has been made [28].

A recent survey [18] examined the adoption of cloud computing by enterprise IT managers and revealed that more than 80 % of respondents from large enterprises were interested in cloud computing deployments. However, many of them were struggling with the question “Do the cost savings, fast implementation, and other benefits outweigh the risks?” Some managers were also concerned about the lack of standardization of application program interfaces, standardized APIs and interoperability among different cloud platforms [11, 20, 21]. Another major concern is about the reliability of cloud services. For large enterprises, loss of service could results in substantial loss of business opportunities and customer dissatisfaction [32, 36, 78]. The main challenge for adopting cloud solutions in large enterprises is that there is a lack of guidelines, standardized cloud service architectures, business models, and sufficient examples of successful cloud adoption to reduce managers’ uncertainty and fear in making such an expensive decision and investment [32]. As a result, many large enterprises would not adopt cloud computing until issues such as privacy, legal compliance, and security have been solved and more sustainable business models of cloud adoption have emerged [55]. We suggest that further research on large enterprises’ cloud adoption can focus on (1) the complexity and dependency issues associated with architectural change, technology change and migration, such as data and information integration, management and governance, service monitoring, and integration of legacy applications with cloud applications [89]. To address the complexity issues effectively, a methodology that incorporates simulation, data mining and multidisciplinary design of complex products is recommended [45, 61]; (2) the financial transaction and other costs, risks such as security, privacy, legal, compliance, etc.), and benefits of adopting cloud solutions and services; (3) the effects of cloud-based solutions on the work of IT departments and other parts of the enterprises such as the impact and compatibility of cloud-based technology with organizational policy, regulation, structure, value, products and services [28, 29].

4.2.3 Challenges for small and medium enterprises

Different from large enterprises, SMEs are less likely to have dedicated in-house servers & IT staff and thus are more likely to “outsource” computing to the cloud. As the complexity of new technologies and applications continues to rise, it becomes harder for SMEs to install, configure, secure, and upgrade to the latest technologies. For example, SMEs are less likely to have in-house security experts available to address potential security issues [25, 50]. SMEs are also less likely to have dedicated, scalable and state-of-the-art in-house computing resources such as high performance servers and storage devices to support application development. Due to limited financial resources, infrastructure and IT staff, many SMEs often struggle to get up to speed with information technology and to align technology with the changing customer demands and business needs in an efficient and effective manner. The flexibility and pay-as-you-go cost structure of cloud computing provides a big advantage over an in-house IT team in terms of cost saving, scalability and flexibility for SMEs.

Cloud-based services also allow SMEs to focus on their core business, react more quickly to changes and to scale up and down as needed [25]. New applications or services can be quickly added by cloud providers with much lower up-front costs to SMEs. Thus, adopting cloud-based services is becoming an attractive and commercially viable technology solution for many SMEs (especially for newly established SMEs). In the past several years, we have witnessed that SMEs are increasingly adopting cloud-based technology to improve their productivity, reduce the cost, and increase their competitiveness [46, 57]. However, SMEs still face some unique challenges in cloud adoption. As many SMEs do not have dedicated IT staff, implementing cloud computing can be technically challenging for SMEs. Many SMEs also lack the expertise to evaluate different cloud vendors, negotiate the cloud service level agreements and contracts, and choose one vendor that really meets their specific needs and requirements. Compared to large enterprises, SMEs lack the bargaining power to get special pricing plan or discounts from cloud vendors. Due to limited financial resources, SMEs have to consider a tradeoff between performance and costs when they select cloud vendors [93]. Along the same line, many SMEs lack staff members who have expertise to monitor the billing and payment associated with the usage of cloud services and resources such as amount of data transfer and actual computing resources consumed. To encourage cloud adoption of SMEs, we suggest that future work should focus on providing SMEs the support for evaluating and selecting cloud vendors, monitoring level of service, and billing and payment. Further work also can develop decision support tools that help SMEs compare the cost of different cloud providers, deployment options and usage scenarios. Cloud vendors also need to enhance their support for SMEs' needs in learning cloud-based techniques in order to reduce their fear, uncertainties and concerns for cloud adoption.

5 Conclusion

Enterprises need an enterprise architecture that can reduce IT complexity and costs while increasing capacity, flexibility and agility [72, 76]. Thus, cloud computing is gaining momentum from enterprises at different sizes because it eliminates the requirement for enterprises to provide large up-front investment in provisioning, and allows enterprises to increase investment only when there is a rise in service demand [58, 93]. Cloud computing is changing the way that IT resources are utilized and consumed [25, 50]. To help enterprises better understand cloud-based services in an enterprise context, we survey the state of the art of enterprise cloud service architectures and discuss architectural requirements, design approaches, architectural styles, emerging cloud-based service platforms, applications and related challenges in an enterprise context. We also identify research trends and opportunities for researchers and practitioners in this fast moving field.

Currently, there are still many research challenges such as compatibility and interoperability issues with different cloud computing platforms [12], application integration [40, 41, 82], lack of a widely accepted and used standard [47], monitoring of quality of services [8] in the cloud environment, and the security of cloud platform and data in transmission [56]. To encourage wide adoption of cloud solutions, these challenges will have to be addressed to reduce enterprise managers' fears, uncertainties and concerns [93]. Further research is needed to develop a widely accepted standard for cloud service architectures and to develop guidelines and criteria to help enterprises understand their architectural requirements, select cloud service architectures, platforms, evaluate the cloud-based information services from cloud vendors, and monitoring service quality, billing and payment by considering the characteristics of enterprises at different sizes. Future research will also benefit from exploring the impact of cloud computing implementation and migration on the organization structure, IT deployment strategy, operation and performance of enterprises [29]. Decision support tools that aid decision making for the migration of IT systems to the cloud are also needed. In addition, an economic model including the accumulated saving and cost-benefit analysis of cloud computing for enterprises is very helpful for future research. On the other hand, enterprises need to "remodel and restructure their existing processes to orchestrate the cloud-enabled requirements" [31] in order to achieve maximum benefits of cloud computing.

Acknowledgments This research was supported by Social Science Foundation for the Youth Scholars of Ministry of Education of China, Grant No. 10YJC630236. The authors appreciate the valuable comments from the anonymous reviewers.

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