Implications of Integration and Interoperability for Enterprise Cloud-based Applications

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Abstract. Enterprise's adoption of cloud-based solutions is often hindered by problems associated with the integration of the cloud environment with on-premise systems. Currently, each cloud provider creates its proprietary application programing interfaces (APIs), which will complicate integration efforts for companies as they struggle to understand and manage these unique application interfaces in an interoperable way. This paper aims to address this challenge by providing recommendations to enterprises. The presented work is based on a quantitative study of 114 companies, which discuss current issues and future trends of integration and interoperability requirements for enterprise cloud application adoption and migration. The outcome of the discussion provides a guideline applicable to support decision makers, software architects and developers when considering to design and develop interoperable applications in order to avoid lock-in and integrate seamlessly into other cloud and on-premise systems.

Keywords: enterprise cloud, integration, cloud-to-cloud integration, SaaS integration, distributed applications, business process transformation.

1 Introduction

Cloud computing has emerged as a strong factor driving companies to remarkable business success [1]. The cloud paradigm is an attractive deployment option for many enterprises as they continuously strive to reduce business complexity and improve user productivity through process standardization [2]. The scalability, multitenancy, elasticity and on-demand access of the cloud, etc. removes many barriers to enterprise deployment. While cloud applications offer outstanding value in terms of multitenant features and functionalities, they introduce several integration and interoperability challenges that hinder enterprises' decisions for or against cloud adoption. The first challenge is that, many organisations have different systems and applications that might use different technologies, protocols, applications and devices distributed across a network [2] [3]. In such heterogeneous environments, information can come from many places — such as transactions, operational, document repositories and

external information sources in many formats, including data, content and streaming information [3]. In this aspect, lost, inaccurate or incomplete information also can generate high costs and lose of productivity when having to search for information or synchronize data. Moreover, poor data quality can lead to failure of business processes and erroneous decision-making. The second challenge is that most core enterprise applications (such as Customer Relationship Management or CRM, Supply Chain Management or SCM and Enterprise Resource Planning or ERP systems) are being packaged to the cloud in a Software-as-a-Service (SaaS) model, and delivered to companies as point solutions that service only one Line of Business (LoB). As a result, organisations without a means of synchronizing data between multiple LoBs are at a serious disadvantage in terms of maintaining accurate data, inability to make real-time and information-backed decisions, and difficulty in realizing complete business process automation. Real-time sharing of data and functionality becomes difficult in such distributed computing environment. Finally, since each vendor that provides a cloud solution creates its own application programming interfaces (APIs) to the application, this will complicate integration efforts for companies of all sizes (small or large) and locations as they struggle to understand and then manage these unique application interfaces in an interoperable way, and integrate applications from cloud to cloud and cloud to on-premise systems.

Therefore, as enterprise environments are becoming increasingly distributed and heterogeneous, there is a need to integrate between disparate systems to satisfy business requirements and needs. In this paper, we argue that interoperability is one of the means by which enterprises can achieve such integration. Interoperability enables the exchange of data between two or more systems by adhering to common standards, protocols, contends with the software and implementation details for interoperations. This includes exchange of data via interface standards, the use of middleware, mapping to common information exchange models etc. [4]. Integration on the contrary deals with technical connections between systems. In the absence of shared standards between systems, enabling seamless interaction between business processes in a heterogeneous environment becomes intricate. Since integration and interoperability both build upon standards, standardization should be considered as the key to achieve them in a distributed cloud environment. This argument is further substantiated with our survey findings reported at a later point in this paper.

The rest of the paper is structured as follows. Section 2 provides an overview of integration, evolving enterprise concerns and challenges, key survey findings and analysis, and the cloud integration imperatives. Current methods for enabling cloud integration are also discussed herein. Section 3 describes interoperability, highlights core enterprise requirements, and discusses how standards can be used to enable interoperability and seamless integration. Finally section 4 presents conclusion and future research direction.

2 Cloud Integration

In the past, enterprise applications and data were linked within corporate Intranet through one or more standards-compliant integration platforms, brokers, and

backbones such as Enterprise Architecture Integration (EAI), Enterprise Service Bus (ESB), and Enterprise Information Integration (EII). Over the past few decades, there has been an evolution in integration architecture across the industry, with progressively greater degrees of exposure for a business function. In the current era, enterprises require capabilities that can be more easily sourced from cloud-based providers.

Currently, with the advent of cloud computing, enterprise IT service delivery has moved from a single provider mode. This shift is increasingly based on the composition of multiple other services and assets (technological, human, or process) that may be supplied by one or more service providers distributed across the enterprise network in the cloud [5]. A consequence of this development is that consumers (i.e. enterprises and end-users) now have more choices of service provider that they can choose from. But as pointed out by [6], service consumers with global operations require faster response time, and thus save time by distributing workload requests to multiple clouds at the same time. Often, the onus is on the consumer to procure these web services individually and then integrate them per requirement [7]. To further complicate the situation, many companies are not (only) building on public clouds for their cloud computing needs, but combining public offerings with their own on-premise (private) IT infrastructure, leading to so-called hybrid cloud setups [8]. Management challenges also arise, due to privacy and compliance issues around data and existing investments in IT infrastructure, middleware, and business applications, which tend to provide opposing forces to hosting with the cloud. However, considering distributed cloud-based applications may be developed or provided by different vendors with varying programming languages, data formats and protocols, a significant integration effort is required to enhance and increase interoperability of these applications.

In such scenarios, the challenging question for enterprises' now is how to create seamless data flow between disparate applications hosted in the cloud environment so that they work together with other cloud products or with their on-premise counterparts. While a new generation of cloud-based integration tools has made this process less complex and expensive, contending with the explosive growth in APIs, software as a service (SaaS) applications etc. exponentially compounds the integration challenge. The required integration mechanism must federate between existing on-premise systems and new cloud applications, platform, and infrastructure, providing a rapid and easy-to-use method of setting up integrations [9]. The promise of cloud-based services is to reduce cost, simplify IT management, and improve productivity via automation and standardization [10]. However, the reality for consumers and IT managers is that to benefit from current cloud offerings, often they must adopt to cloud service provider specific interfaces that are incompatible with one another and with on-premise management services. Due to this beneficial extension, integration tasks have increased the complexity of decision-making in respect of enterprise cloud migration. The more enterprises adopt the cloud to host their business processes, equally there is a stronger need of a powerful tool to integrate their on-premise systems to the cloud. Therefore, as organisations struggle with the complexities of integrating cloud services with other critical systems residing on-premise, the ability to share data across these hybrid environments is critical.

2.1 Survey Findings and Analysis

This study seeks to identify interoperability requirements and integration implications for enterprise cloud-based application adoption. The research method used is based on Survey Monkey, a quantitative online survey questionnaire tool [11]. A total of 200 companies were invited to participate in the survey. Overall, 114 participants completed the online survey, which constituted an acceptable total response rate of 63%. Participants in the survey varied between IT professionals, managers and decision-makers within their respective business enterprise. Prior to discussing the key findings, it should be pointed out that the questionnaire comprised of several questions, however only those which revealed crucial issues of integration and interoperability are presented and discussed in context.

The research reported in this paper reveals that over 50% of businesses are already using cloud services, while a greater majority (69%) utilise a combination of cloud services and internally owned applications (hybrid IT) for organisation needs. To explore the business rationale for migrating on-premise IT services to the cloud, this study raised the question "are you considering moving business critical systems (or applications) to the cloud?" The findings reveals that about 54% of organisations have planned to move one or more business critical systems, while 20% have expected to host critical systems in the cloud. However, only 10% of organisations have actually implemented critical systems in the cloud environment.

Underestimating the difficulty associated with integrating between cloud and on-premise is a common pitfall with migrating enterprise systems to the cloud. Cloud adoption will be hampered if there is not a good way to integrate data and applications across clouds [12]. Moreover in [13], it is argued that the cost and complexity of developing and maintaining integrations between heterogeneous platforms with disparate interfaces and protocols can easily erase the economic and efficiency gains the cloud delivers. In agreement with the aforesaid, the survey by [14] of business managers around the world on their experiences with cloud-based applications, revealed that companies have abandoned the use of roughly one departmental cloud application a year due to integration problems. In the same study, 54% of respondents acknowledge they have experienced staff downtime due to integration problems, and 75% have had their ability to innovate impaired by poor integration of their cloud applications. This is further sustained with a more recent study by [15], which shows that 43% of companies, with revenues greater than $500 million, noted integration challenges as primary barrier to enterprise cloud application adoption in 2015. Nevertheless, the survey conducted in this paper paints a clear picture on the importance of integrating cloud solutions with on-premise systems. As illustrated in Fig. 2, a vast majority (56%) of respondents indicated that it is very important for their organisations to integrate on-premise IT assets with cloud-based services. This finding suggests organisations with a unique portfolio of IT investments migrating to cloud-based solutions require a mechanism that can easily, quickly and efficiently connect their critical systems to the cloud. It is anticipated that standardization of APIs will significantly help resolve this integration imperative, because it will facilitate development as well as the deployment process – eliminating the necessity of factoring applications to comply with other cloud providers APIs (as discussed further in Section 3). In fact, this means the integration solution must intersect

somewhere between the corporate firewall. To look further at the figure below, the result also suggests most organisations are unlikely to have in place the in-house skills to support a major organization change in the near future. In this case, cloud providers are better placed to assist enterprises for their integration implementation, business process transformation, and strategic guidance.

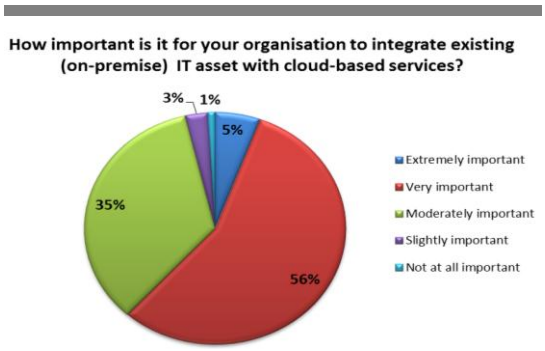

Fig. 1. Integration is the key to enterprise cloud adoption and migration

2.2 Cloud Integration Imperative

In today's contemporary business environment, immediate access to timely information is essential to quickly respond to changing customer needs, widening competitive threats, and new market openings. A major challenge in this aspect is the ability to capture the data being generated in this rapidly evolving environment and synchronize the data to optimize business operations while capitalizing on new market opportunities. This integration imperative is briefly discussed below to illustrate the emerging data and application challenges associated with utilizing proprietary cloud-based solutions.

Data Management: With the proliferation of cloud-based applications, platforms and infrastructure, the potential for data fragmentation and disconnected data silos has grown exponentially [16]. Only a decade ago, five million records would have been considered a large volume of data. However, at present, the volume of data stored by enterprises is often in the Petabyte, or even Exabyte [3]. Consequently, as the volume of data increases at a faster rate than the ability to absorb and manage, it creates a data management problem for both consumers and businesses. This situation raises issues related with data portability, interoperability, and inability to ensure enterprise data privacy and security – considering information multiplies and is shared even more widely in the cloud. Moreover, if data is properly managed and maintained, data integration and data quality can actually become critical enablers (and not inhibitors) for successfully deploying enterprise cloud computing services.

Application Management: Enterprise applications are progressively becoming more decoupled, service-oriented and composed of multiple layers [17]. However, their composition and integration is hindered by the fact that legacy code needs to be re-written to take advantage of elasticity [18]. In consequence, cloud computing has been fast adopted by start-ups developing from scratch new applications and less by

large organisations owning legacy systems [ibid]. Therefore, when selecting the right integration approach to connect cloud applications (i.e. SaaS) to on-premise systems, it is critical that the solution is able to seamlessly bridge the source and target systems within the enterprise network. This means that cloud integration solution will share a common codebase, runtime engine and overall architectural integrity with the on-premise data integration platform. Understanding this relationship early in the integration process will offer immediate insight into interoperability, security, scalability and performance concerns [16].

2.3 Approaches for Cloud Integration

A report published by [19] suggests that businesses currently have the following four primary choices for integrating cloud-based applications with on-premise systems: (a) building a custom-based solution based on the cloud vendor's API, (b) purchasing integration software, (c) subscribing to an integration-as-a-service (IaaS) solution, and (d) engaging professional services or a system integrator. Once a choice has been made, the integration process can be instantiated and implemented in four prominent layers and levels as briefly discussed below.

Data Integration: Data integration deals with moving or federating data between different type of data sources [20] [21]. The main drawback of data integration between cloud and on-premise environment is that the developer will have to understand and maintain the underlying schemas regularly to address any changes [16]. This approach is complex for SaaS applications since the consumers neither have access rights nor control to manipulate the underlying database. The data formats and contents are handled by the service provider, so major data portability considerations are needed. Further, as communication between clouds and on-premise typically has a high latency, this makes synchronization difficult. Also, the two environments may have different access control regimes, complicating the task of moving and integrating data between them. Therefore it is critical that organisations ensure the chosen integration solution is able to synchronize data bidirectional from SaaS to on-premise systems securely without opening the firewalls.

Business Logic Integration: To facilitate integration at this level, the development of a middleware technology is required. Middleware technologies help developers by making the design of distributed cloud solutions less challenging [22] [23]. As an important integration technology, middleware is often used by enterprises to integrate new applications, emerging technologies, and legacy applications. In order for cloud applications to offer the maximum value to users they must provide simple mechanism to import or load external data, export or replicate data for reporting or analysis purposes, and also keep enterprise data synchronized with on-premise applications [20].

Communication Layer Integration: This layer connects the service requestor to the service provider and its underlying solutions platforms realizing the requested service [24]. For example, an enterprise procures a cloud-based application (e.g. CRM) and need to synchronize their master list of customers and other business critical data with their on-premise ERP (e.g. SAP) system in order to meet certain business objectives. Typically, protocols such as HTTP and Internet Inter-ORB

Protocol (IIOP) are used to facilitate information exchange among different distributed applications [25].

Presentation Layer Integration: The integration in this layer mainly focuses on user interface (UI) integration [26]. Further work on effective standardization at the presentation layer is required for effective user interface integration to take place. Furthermore, as cloud computing enables new technologies and devices to be introduced into enterprise systems, UI integration poses new challenges associated with various interface types, standards, definitions, and service interfaces. All of these mean that presentation layer integration requires a good understanding of various applications, devices, and enterprise-wide integration requirements

3 Interoperability Considerations

Interoperability is a critical enabler for broad adoption of cloud computing by enterprises [27]. Lack of interoperability makes it difficult to consolidate enterprise IT systems in the cloud. The term interoperability has many definitions from different viewpoints, and is often misused to include the term portability. A single comprehensive definition of interoperability would not provide much information. Instead, independent groups such as NIST [28] and Open Group [24] consortium have provided definitions for interoperability in three different cloud domains: (a) service interoperability, (b) application interoperability and (c) platform interoperability. Service interoperability is defined as the ability of customers to use services across multiple cloud platforms through a unified management interface. Application interoperability is the ability of cloud-enabled applications to collaborate, across different platforms, in order to deliver their functionalities or create new ones. In contrast, platform interoperability is the ability of platform components to interoperate. Generally, both service and platform interoperability is required to enable application interoperability.

Due to a number of variables that come into play in a complex cloud solution that involves interoperability capabilities, several case scenarios have been discussed by [5]. In a scenario selected, enterprise links in-house capabilities with cloud services. This is done in an effort to highlight key aspects of cloud computing interoperability and current methods for enabling seamless interoperation. This scenario is motivated by the case of a hybrid cloud solution in which the business processes are offered by a public cloud, while other business critical components, and are internally managed by the organization following a private cloud model. In such hybrid environments, enterprises are susceptible to challenges such as maintaining uniform control and transparency over all resources in the distributed environment, whether they are part of public or private cloud resources. However, in spite of how similar a public and private cloud is built, design and implementation differences will inevitably exist, thus triggering interoperability issues which further complicate the initial integration task.

In the scenarios above, the main obstacle to achieving a seamless integration is the poor interoperability, since several application components need to interoperate to achieve the business goal. Interoperability challenges come into play when such

application components are distributed among clouds. To avoid rewriting the entire application, the cloud services hosting the components must share a compatible API. In this connection, a proper analysis of available APIs of both the in-house system and cloud services is highly required to clearly understand how the integrated system will function and perform during execution. An important aspect to also consider is the migration to and portability among clouds. Suppose an application of an enterprise is built in a particular cloud service or an in-house system, and for cost, performance or security reasons, the enterprise decides to shift the application and data to a new provider. The question is what happens if the new provider does not support the same export and import formats? An even more, there is no guarantee that the initial provider will offer an export mechanism, considering presently there is no legal provision that mandates cloud providers to provide data export functionality, in the first place. Assuming that portability among clouds is feasible and that the application is distributed among several clouds, there is still no guarantee that various parts of the application are able to interoperate due to lack of shared data formats, communication interface, security requirements etc. In a fully interoperable heterogeneous environment, the application can access data from both in-house and cloud databases through a common API thereby simplifying the overall integration tasks. In reality, current differences in cloud providers API, data, and message formats or communication protocols represent a major obstacle to the ubiquitous cloud realization. Tackling is often dependent on the usage of one or more business standards.

Standard initiatives have emerged as the most proposed method to tackle the interoperability challenge in cloud computing. Standardization strives to support applications by different service vendors to interoperate with one another, exchange traffic, and cooperatively interact with data as well as protocols for joint coordination and control [3]. However, cloud computing still suffers from widely accepted standards. In the absence of widely accepted standards for cloud APIs and data models, organisations willing to outsource and combine range of services from different providers and on-premise systems (Hybrid IT) to achieve maximum operational efficiency will experience technical difficulties when trying to get their in-house systems to interact with cloud services. Likewise the lack of standards brings disadvantages when migration, integration, or exchange of resources is required [27]. As cloud systems are typically external components to the enterprises' overall IT system, the need to have seamless security integration calls for interoperable standard interfaces for authentication, authorization, and communication protections [7]. An identity and access management standard to support secure integration of cloud systems into existing enterprise security infrastructure is also required.

The more cloud computing evolves, the more complex will the integration of cloud services will become for cloud consumers to manage. Interoperability between clouds is vital for the further development of the cloud ecosystem and market. Interoperability challenges caused by lack of widely accepted standards are what enterprises should wary about when considering cloud integration. Architecting systems to be interoperable and integratable requires one to consider a wide set of standards to implement the solution. To this end, it is therefore important that organisations become aware of appropriate standards and protocols used by cloud providers to support data/application movability, as well as to ease the task of

integration. In the light of the advantages of standards in increasing interoperation between cloud and on-premise systems, unfortunately the survey conducted in this paper suggests most enterprises lack a comprehensive understanding in this respect. As can be drawn from **Fig. 3**, a significant majority (76.6%) of businesses were unsure of relevant standards to support interoperable cloud implementations. Standards are key to ensure requirements for interoperability, portability, and security, are fully met in the cloud environment. It is therefore important for organisations using cloud computing as an essential part of their business operations, to adopt standards-based products, processes and services. In summary, since integration and interoperability both build upon standards, standardization should be considered as the key to achieve seamless integration and interoperability in a distributed cloud environment.

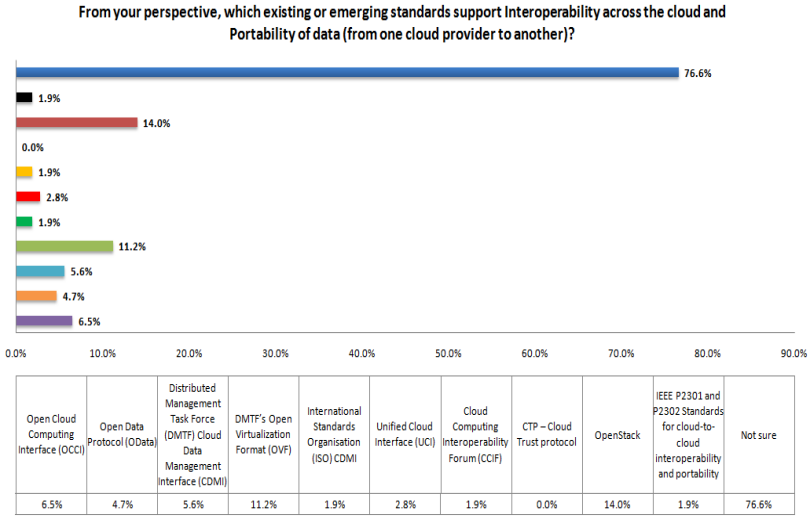

Fig. 1. Enterprises are unaware of interoperable standards

4 Conclusion

In this paper, we have discussed current issues and future trends of integrating with cloud-based services in respect of enterprise IT environments. We have also shown from an enterprise purview that integration and interoperability are seen the means of securing an enduring and compatible solution, while avoiding the pitfalls of multiple clouds. This is critical, as it guides software developers and architects to understand key barriers preventing companies from successfully combining cloud services with their on-premise IT infrastructure.

Today's dynamic business environment has made organisations to rely on the cloud for at least some of their capabilities. Unfortunately, the use of proprietary cloud-based, complicate and make integration critical. To tackle this issue, having a clear understanding of the commonalities among provider standard interfaces can help

organisations identify the key interoperability requirements and features to effectively manage the integration process.

As a future work, we would like to develop a proof-of-concept (PoC) application, paying close attention to the use of open standards technologies, and test for integration between cloud-to-cloud and cloud-to-on-premise systems.

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