Cloud Service Brokers

An emerging trend in cloud adoption and migration

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***Abstract*—With the advent of cloud, a large number of cloud providers have surfaced in the market. Cloud Consumers are rapidly using cloud services(IaaS, PaaS, and SaaS) to meet their business needs while cloud providers are rapidly developing much needed tools and environments. This rapid growth however is creating a significant need to develop fast and controlled mechanisms for managing costs, capacity and resources at agreed service levels in order to have a smooth adoption, management and maintenance of cloud for both consumers and providers. Cloud Services Brokerages (CSBs), an intermediary between the consumer and providers, emerges as a solution to address above need. In this paper we focus on reviewing the significance, role and services of a CSB, followed by a categorization of CSBs on the basis of the services they provide, and a method to select a CSB from a pool of CSBs.**

Keywords- CSB,cloud broker,utility, Aggregation, Migration, Integration

I. INTRODUCTION

The concept of cloud has finally emerged as a popular concept from its nascent stages. Cloud currently represents 8% of office systems and 50 million users worldwide, excluding India and China [24]. Gartner suggests that by 2017, cloud shall account for a third (33%) of office systems. This figure should reach to something as high as 60% by 2022 [24]. "Cloud services won't reach their full potential until we can automate how we buy and sell them", says Peter Judge [25].In this context, Cloud Services Brokerages(CSBs) have emerged as a solution. These CSBs provide services encompassing pillars of consultancy, management and technology so that companies function with an operational ease. Not only do they help companies in adopting the cloud, but also help them in managing and maintaining it [5]. They will help in migrating the company's data to the provider that suits the needs better, in the due course of maintenance [22] [28].

The contribution of this paper can be summarized as follows:

1. Classification of CSBs
2. Analysis that defines a CSB, its roles, functions, and benefits
3. A method for selecting a CSB

The rest of the paper is organized as follows: Section II outlines related work in this area. Section III provides a classification of CSBs and studies the functionality and utility of a CSB. Section IV demonstrates a mechanism to select a CSB from a pool prevailing in the market.

II. RELATED WORK

There is a growing interest in both, the Technical and business aspects of a CSB[51]. NIST (National Institute of Standards and Technology) anticipates a need of intermediaries between consumers and providers. Liu et al [26] defines a cloud broker, and describes its role in NIST Cloud Computing reference architecture. Somashekar, Sam [27] explains how a cloud broker surveys cloud providers to estimate and compare their capabilities, liabilities, business models and costs. Buyya et al[1] provides a high level architecture of a Cloud Broker Service encompassing the various services it provides in a hypothetical federated Cloud Computing environment. Pawluk et al[2] gives the design and implementation of a cloud broker service for cooperative cross cloud usage, and puts the implementation to test. [3,9] published by CSBs give an overview of the logical model, core concepts, communication architecture, and common broker patterns. Past research works have also explored the utilities that a CSB can provide. Somashekar, Sam [27] has defined a cloud broker as a special instance of a service procurer, which creates and maintains relationships with multiple cloud providers. Some obvious functionalities of a cloud broker include consolidated billing, seamless switching between providers and monitoring. Liu et al[26] defines a cloud broker as an entity that manages the use, performance and delivery of cloud services, and negotiates relationships between Cloud Providers and Cloud Consumer. It categorizes the services of a cloud broker as service intermediation, aggregation and arbitrage. By service intermediation, a cloud broker enhances a given service by improving some specific capability and providing some value added services to the consumer. By service aggregation, a cloud broker combines and integrates multiple services into one or more services. By service arbitrage it integrates services that are not fixed, and allows flexibility to choose from multiple providers.

Pawluk, et al [2] enumerates various approaches by means of which a cloud broker can ensure interoperability between multiple providers. Grivas et al[6] focuses cloud broker's role in handling the change management of business processes. Nair et al[7] proposes how a cloud broker ensures data security . Buyya et al[8] describes the role of a cloud broker in creation and maintenance of an SLA (Service Level Agreement). We observe that various business and technical issues of CSBs are being addressed through such research works. However, we don't find any consolidated view of CSB's role or a method that facilitates the selection of a CSB. In this paper, we attempt to fill these gaps.

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TABLE I. PRIMARY ROLES, CLOUD SERVICE BROKERS

Aggregator	BlueWolf, Ingram Micro Cloud, SynnexCloudSolv, Tech Data TDCloud, HP- Aggregation Platform for SaaS, ComputeNext, Infogain, CloudCompare, Cloud Nation, CompatibleOne, Appirio, CloudSherpas, NephosTechnologies, Rackspace Cloud Tools Marketplace*, AWS Marketplace*, ComcastUpware*,SaaSMax*
Integrator	Appirio, Dell Boomi, CloudSherpas, Liason Technologies, Cordys, Gravitant, GXS Trading Grid, Cloud Ecosystem Hub
Governance	Gravitant, Vordel, Infosys Cloud Services, SinglePoint
Customiser	Appirio, CloudSherpas, Infosys Cloud Services, Compatibleone

* Essentially an online store that provides background information about third party cloud services and links to pertinent third party websites for potential purchasing opportunities

III. ROLES AND CLASSIFICATION OF A CSB

A CSB not only assists in cloud adoption and management, but also helps in cost saving and in providing faster agility along with more flexible IT capability [5]. Figure 1 shows it as an intermediary between consumers(C1, C2, ..Cn)and providers illustrating interaction between the consumer and the CSB, the CSB and the cloud provider, the consumer and the cloud provider. The direct shell interaction between consumer and provider is further elaborated in this section. Gartner [29] suggests that by 2014, IT organizations in 30% of the 1000 Global companies will broker (aggregate, integrate and customize) two or more cloud services for internal and external users, up from 5% today.

In this section, we have enumerated services that a CSB can provide, and classified them based on different parameters that are:

i. Business service versus Technical service
ii. Consumer specific versus provider specific utilities

In Table 1, we have classified CSBs based on their primary roles. Following definitions in [52] and the primary services listed for various CSBs, we have also categorized some of the popular CSBs in 4 different categories based on the type of services they provide in Table 1.

There are four distinct roles of Cloud Services Brokers

1) Aggregator- is a broker that takes multiple cloud services encompassing different providers and funnels them to clients through a channel. The client uses the services proportionate to one's needs and pays one's bill to the broker. The broker "owns" the relationship on behalf of the client. The broker might manage service-level agreements (SLAs) for the customer. It can offer extra services on top of the cloud, ranging from extra security services to business continuity, and anything in between [23]

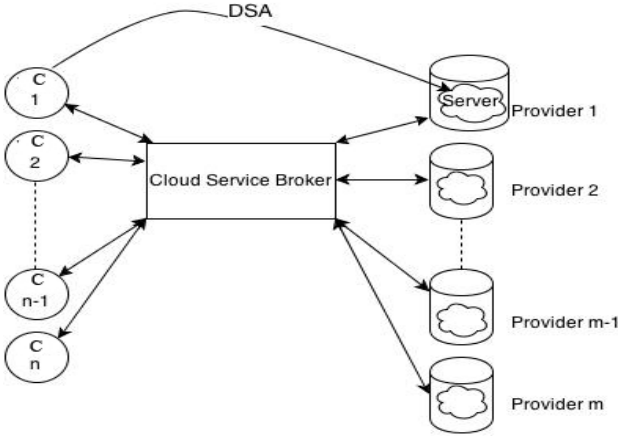

Figure 1. Interaction between Consumers, CSBs and Cloud Providers

2) Integrator- Technically skilled, this type of provider merges services from an assortment of cloud providers to create a net new business process [23].

3) Governance Services- This is especially important in highly regulated industries such as healthcare and financial services, where protection of consumer data is essential. Here, the broker ensures that the cloud service provider treats the data in accordance with the regulations and policies, and that security practices are adhered to [23].It will handle the basic administrative tasks of the system.

4) Customizer- As the name suggests, customizers will create extensions to existing cloud services for a specific functionality and then ensure that the extensions work properly [23]. It will alter its functionality to the needs of the consumer.

In Table 2, we have classified each utility as Business and/or Technical utility. In Table 3, we have classified CSB based on each of the above roles. A CSB provides utilities both for the consumer and the provider, where ES stands for Extra Service, while NS stands for Not Specified.

Let, Set A= {Un|1<=n<=18}

Set A includes Consumer specific utilities that help make the task of the consumer easier.

Set B= {U1, U3, U4, U8, U9, U13, U16}

Similarly Set B includes Provider specific utilities. We have also summarized to which set (A or B) each utility belongs to. The utilities (U1 to U18) that are expected of a Cloud Service Broker are elaborated below.

A. U1: Facilitating Cloud Adoption

Cloud adoption can be defined as moving the existing data or applications to the cloud. IT product giants like Google, Amazon, and Microsoft provide public clouds loaded with a myriad of features. This makes the process of choosing and adopting the cloud challenging. The following points explain the different aspects where a CSB should help:

1) A CSB should help weigh the advantages and disadvantages of adopting the cloud, pertaining to technology[10][31]

2) A CSB should help choose among different cloud service providers

3) A CSB should help decide whether moving to the cloud is commercially viable [32]

4) A CSB should engage with and manage Cloud Providers

5) A CSB should help adoption of cloud by cloud engineering guidance

B. U2: Scalability

The consumer's requirement of cloud resources can change over time [12]. This might include increasing or decreasing the processing speed, memory, storage, bandwidth and price. The answer to this is scalability. Mei et al[33] defines it w.r.t. two dimensions - horizontal and vertical. Horizontal cloud scalability is the capacity to connect and integrate multiple clouds to function as one logical cloud unit. Vertical cloud scalability encompasses the

ability to improve cloud capacity by enhancing individual nodes or improving their bandwidth. Chieu et al[34] brings into light the dynamic aspect of scalability in a cloud computing environment .This overhead of scalability should rest with the CSB. The CSB should ensure that the consumer is provided cloud resources in proportion to its needs. Also, the cloud infrastructure provided should be enhanced or reduced after negotiating with the cloud providers.

C. U3: Solutions Provided and Implementation Services

Automation of services helps improve efficiency and reduces manpower requirement. A CSB should provide automated software or products to help the consumer in cloud adoption cloud-sourced development, estimating cloud metrics, data security and cloud integration [13] [35]. Appirio, for example, provides software products like Cloud Metrics, CloudFactor and CloudSync [13]. Cloud Metrics helps in identifying and reducing drivers of complexity and cost. CloudFactor connects a cloud provider salesforce.com with Google Apps to boost productivity of the consumer. CloudSync helps keep customer contacts in salesforce.com in sync with Google calendar and contacts. Cloud Sherpas, provides software solutions for data security, single sign-on and identity management, virtualized desktops, data integration and collaboration. Single sign-on enables one password to unlock infinite applications. Virtualized desktop helps the consumer in accessing the applications from multiple places and on multiple devices [35].

TABLE II. CLASSIFICATION OF CSB UTILITIES

	Title	Business/ Technical Service	Set A/B
U1	Facilitating Cloud Adoption	Business	A,B
U2	Scalability	Technical	A
U3	Solutions provided and Implementation Services	Technical	A,B
U4	Customer Support and Guidance	Technical	A,B
U5	Updating with time and business change	Business	A
U6	Integration Services	Technical	A
U7	Handle enhancements on cloud	Technical	A
U8	System Administration	Technical	A,B
U9	Data Security	Technical	A,B
U10	Customization	Business	A
U11	Multiple Cloud Provider support	Business	A
U12	Interoperability between providers and Aggregation	Business	A
U13	Cloud Monitoring	Business	A,B
U14	Direct shell access to user	Technical	A
U15	Avoiding Vendor lock-in	Business	A
U16	Cost usage analysis	Business	A,B
U17	Continuous improvement in the cloud	Technical	A
U18	Migration-Brokerage	Business	A

TABLE III. CLASSIFICATION OF UTILITIES BASED ON ROLES

	Aggregator	Integrator	Governance	Customiser
U1	NS	NS	NS	NS
U2	✓	✓		
U3	✓			✓
U4	NS	NS	NS	NS
U5	✓ (ES)			
U6		✓		
U7	✓ (ES)		✓	
U8	✓ (ES)		✓	
U9	✓ (ES)		✓	
U10	✓ (ES)			✓
U11	✓	✓		
U12	✓			
U13			✓	
U14			✓	
U15	✓ (ES)		✓	
U16	✓ (ES)		✓	
U17	✓ (ES)		✓	
U18			✓	

D. U4: Customer Support and Guidance

To help consumers with cloud management and maintenance, interaction with the consumers to strategize and plan is important. Cloud Sherpas, for example, offers consultative workshops for consumers, which help develop strategies for cloud technology in data security implementations, social business strategic initiatives and custom mobile development projects [36]. A CSB should provide continuous support and guidance to the consumer's executives, and also suggest them more viable alternatives both in terms of usage and selection of providers [14]. Also, it should mediate in case of complaints and grievances and ensure that the customer is satisfied.

E. U5: Updating with time and business change

Handling changes of consumer's business processes and ensuring that the systems are running with minimum downtime is something that needs to be taken care of [6]. Under such circumstances, a CSB should accordingly alter the cloud strategy of the consumer and help consumer re-adopt the cloud by leveraging existing data or scaling it.

F. U6: Integration Services

Integration involves exchange information among systems in order to achieve a specific business objective [37]. These systems could be on premise or on different clouds. Further there could be application integration [38] or data integration [37][39]. As consumers adopt more and more cloud applications, integrating SaaS (Software as a Service) applications with existing on premise applications or other cloud applications becomes a huge concern [15]. A CSB should help in identifying this need and strategizing the process of integration. It can develop tools that aid

integration and manage and maintain the integrations over time [9] [41].

Appirio, a CSB provides a comprehensive set of services for cloud integration. These services include: a) Integration assessment and strategy. b) Integration Development including testing c) Cloud Integration Management [40]. Informatica, a data integration solution by Cloud Sherpas delivers data integration cloud applications that permit business consumers to integrate data both across cloud-based applications and on premise systems and databases [41].

G. U7: Handle enhancements in the cloud

The version of the cloud might change over time, especially if it is a public cloud. As in Appirio, a CSB, the broker should ensure the compatibility of consumer's applications, if and when the cloud is enhanced [11][30].

H. U8: System administration

System Administration entails tasks like defining monitoring settings, compliance standards and cloud policies [43]. It also involves features such as extending the pricing model, creating back-ups of data in the cloud and cloud recovery [43]. It includes writing and maintaining the Service Level Agreement (SLA), an agreement between the provider and the consumer [8]. This document should include every service that is expected from the provider in complete details. The administration of the system should be taken care of by the CSB [16].

I. U9: Data Security

Data Security includes facets like physical security at data center, application level security, and policies and procedures to ensure data security [44]. It is one of the most essential prerequisite of moving the data on to the cloud. CSB must make the provider to list the security measures and systems it uses at all levels in a well drafted and complete SLA [7]. Also, it should ensure that the SLA is concrete and not vague so that it can be used at the time of litigation. Appirio, a CSB, fully encrypts each piece of data before passing it on to the Amazon S3 cloud. Security standards of the Amazon S3 cloud are also ensured [45].

J. U10: Customization

Customization involves tailoring the services in accordance to the need. A CSB should do the needful [17]. Customization helps in saving cost as the consumer pays only for what it demands and nothing extra. CSB must ensure that the choices are made at an optimum cost.

K. U11: Aggregation & Multiple Cloud Provider Support

Cloud aggregation, by which a cloud broker combines and integrates multiple services into one or more new services, also involves data integration and ensures secure data movement between the cloud consumer and multiple cloud providers [26]. This is essential if the consumer wants different services from different service providers. A CSB should help aggregate cloud services from different cloud providers (private or public cloud) into one or more services [7][18]. The entire process of aggregation should be transparent for the consumer.

L. U12: Interoperability between providers & aggregation

Interoperability can be defined in two different ways [46]. One way refers to the ability of applications to move from one cloud provider to the other, and the other refers to the applications running in different clouds being able to share information, which might require having a shared set of interfaces. Every cloud provider implements the cloud in a different way, with different operating systems, storage models, APIs etc. Also, they may enforce their own set of rules and policies. It makes interoperability between providers a challenging task [46]. A CSB should ensure interoperability between the providers it supports [4]. It should ensure that a consumer is able to deploy its interconnected applications with multiple providers at the same time. It should help enforce cloud interoperability standards, and ensure that the cloud providers adhere to these standards.

M. U13: Cloud Monitoring

Cloud Monitoring is essential for activities such as Capacity and Resource Planning, Capacity and Resource Management, Data Center Management, Billing, SLA management, Troubleshooting, Performance Management and Security Management [48]. For the cloud provider, it generates workload information, while for the consumer it generates information bearing QoS (Quality of Service) [48]. A CSB should monitor the servers of the cloud provider and give the consumer an overview of their use of CPU, memory, storage and network usage in clearly arranged diagrams [19]. Rackspace, for example, helps monitor websites that are hosted on its own public cloud, its own dedicated servers and on other servers' data center. It also generates graphs and patterns for the same [47].

N. U14: Direct shell access to the Consumer

Sometimes, a consumer may want to handle the administrative tasks on its own. In that case, it might require accessing the cloud servers directly. A CSB should provide the consumer direct shell access to the servers, so that it can handle its own data whenever required [19]. It would aid consumers in performing administrative tasks through their web browsers comfortably.

O. U15: Avoiding Vendor Lock-In

The increasing number of cloud providers, their heterogeneous interfaces and lack of interoperability may bind a consumer to a particular cloud provider [49]. So it becomes nearly impossible for the consumer to exit and switch its cloud provider. This process is called as a Vendor Lock-in. A CSB should help avoid vendor lock-in, so that the consumer can easily move its data from one provider to another [20]. This can be ensured by including standardization clauses in the SLA fine print.

P. U16: Costs-Usage Analysis

Costs are a prime consideration of consumers that opt for the cloud. Data that provides costs in accordance to usage shall help a consumer make better decisions, and manage the cloud in a better way. A CSB should provide a cloud-cost calculator that helps the consumer in knowing the costs to be incurred [21]. Moreover, it should provide visualization of costs and usage to further aid in better decision making.

Q. U17: Continuous Improvement in the cloud

A CSB should also ensure that the cloud providers improve upon their technology and infrastructure with time [16]. Also, it should provide for enhancement to the base services, providing better security or creating a completely novel set of services [42].

R. U18: Migration-Brokerage

With time the needs of a consumer as well as services the providers change. A switch from one to another provider is a very likely scenario. A CSB can help in this process known as Migration-Brokerage. It can also help in migrating an application from one cloud provider to another, which is better suited to the needs of the consumer. [22] [28]

IV. MECHANISM TO CHOOSE A CSB

A. Identifying a CSB

The consumer should start by deciding what type of CSB is required as mentioned in Section III, and get a detailed list of CSBs that fall under that category after referring to the Service Registry. A Service Registry, to which CSBs should register, is similar to an Enterprise Service Registry[50] which essentially would organize the service information and would assist the consumers in finding the CSBs that provide required services. The consumer could use utilities, from set A as mentioned in Section III, as a checklist to identify suitable CSBs.

B. Creation of a Priority utility matrix

After surveying for the suitable CSBs, the consumer should fill in a priority utility matrix as shown in Table 4.
Here B_1, B_2, B_3….,B_n are a set of 'n' CSBs, and U_1, U_2, U_3,…U_{18} are a set of utilities.

1) Each column U_k that is a utility not needed by the consumer should be filled with zero (k ranges from 1 to 18).

2) Also each cell in the above table (B_r,Us) where Us (1<=s<=18) is a utility not provided by CSB namely B_r (1<=r<=n)should be filled with zero. Every other cell (B_r,Us) should be filled with a priority value between 1 to 5, where 5 means maximum priority and 1 means minimum priority.

3) Each row should be summed up

4) The obtained summation shall give a value that we call UPM (B_i) that is User preference Metric for i^{th} CSB. It should be then filled in the matrix.

$$UPM(B_i)=\sum (B_i,U_k) \quad (1)$$

where k goes from 1 to 18.

C. Calculation of metrics to compare across CSBs

Now compare the values of UPM(B_i) in Table 4. These values will give an indication of the preference of consumers. A greater value of UPM(B_i) will mean that more requirements of the consumer are met if it opts for Broker Bi. It can be used to choose among CSBs if cost is not a consideration. Then a CSB Usability Metric, which we have called CUM is calculated as follows:

TABLE IV. PRIORITY UTILITY MATRIX

	U1	U2	U3	U4	U5	U6	…	U18	UPM(B_i)
B1									
B2									
…									
Bn									

$$CUM(Bi)=UPM(Bi)/MC(Bi) \quad (2)$$

where MC(B_i) is the monthly cost of services calculated according to the consumer's needs.

A greater CUM will mean greater satisfiability of requirements for a given cost. It can be then used as a parameter to choose between a set of CSBs. Let's say the CUM values of two CSBs B_1 and B_2 are 0.4 and 0.02 respectively. It will mean that CSB B_1 satisfies the requirement of the client in a better, efficient and cost effective way.

D. Make an inference

If requirements satisfiability and not the cost is primarily the concern, then the consumer can use the CSB with the highest value of UPM. Otherwise, the consumer can choose the CSB with the highest value of CUM, as the CSB satisfies the requirements of the consumer at an optimum cost.

V. CONCLUSION AND FUTURE SCOPE

A large pool of CSBs has surfaced in the market, with the growing popularity of cloud. In this paper, we analyzed the different aspects of CSB i.e. Cloud Service Brokers. Initially, we categorized the CSBs based on the data available on their websites. Then, we enumerated all the utilities a CSB should provide, which enlisted all the benefits of opting for a CSB, for both the consumer and the provider. Furthermore, we used these categories as an input to a four stage technique that shall help compare CSBs on preference and usability parameters.

Now is an exciting time. We propose that Cloud consumers, providers, developers and governments should work together, openly and cooperatively, to standardize the CSBs fundamental role, ensuring that the technological protocols and social conventions we set up respect professional values. The goal of the CSB is to serve by bridging the gap between consumer and provider. We build it now so that cloud adoption and maintenance becomes a breeze for all.

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