Costs of Migration and Operation in the Cloud

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1. Introduction

At one level cloud computing is just Internet enabled time sharing. Instead of organizations investing in all the Information Technology (IT) assets such as hardware, software and infrastructure they need to meet business needs; cloud computing technology makes these resources available through the Internet. Cloud computing allows an organization to adopt a different economic model for meeting IT needs by reducing capital investments and increasing operational investments. Gartner has predicted that "2016 will be defining year for cloud as private cloud begins to give way to hybrid cloud, and nearly half of large enterprises will have hybrid cloud deployments by the end of 2017" [1]. McKinsey and Company predict that the total economic impact of cloud technology could be $1.7 trillion to $6.2 trillion by 2025[2].

"Cloud computing embraces cyber-infrastructure and builds upon decades of research in virtualization, distributed computing, grid computing and more recently networking, web, and software services".[3] In other words, although the term cloud computing is relatively new, the concepts and technologies behind cloud computing have been emerging and evolving for some time. Consumers of cloud computing access hardware, software, and networking capabilities from third party providers in much the same way they get electricity or water from their utility companies.

The utility computing model offered in the cloud clearly brings benefits – especially to small and medium sized enterprises and any sort of startup business. In addition to the cost savings from not having to purchase all the hardware, software and infrastructure associated with running a business, cloud solutions bring agility, scalability, portability and on-demand availability as well. So what's the downside?

While the potential for cost savings is real, as with all things – getting there is not free. A company with firmly entrenched legacy systems needs to think about the trade-offs of migrating from the status quo into the cloud. Migration into the cloud could spur a host of activities. These include issues of installation and configuration, possible changes to code to adapt to the cloud hosts operational environment, possible changes to data base queries and schemas, changes to the Graphical User Interface (GUI), as well as adaption for changes in the way applications interface with legacy applications or other applications in the cloud. They also need to identify the cloud solution providers, understand their pricing models and determine a strategy to wisely and affordably move to the cloud.

This paper reports on on-going research into the costs and benefits of cloud computing. Section 2 discusses cloud computing – what it is, what are the different types of cloud computing and how it is being used by businesses and the government. Section 3 presents an overview of the risks and benefits of cloud computing. Section 4 delves into the potential issues associated with migration of legacy capabilities into the cloud. Section 5 contains a discussion of costs of operations in the cloud, detailing

the various pricing models and options currently offered by cloud providers. Section 6 presents guidance for using this information to understand the total cost of moving capabilities into the cloud.

2. Cloud Computing

According to the National Institute of Standards and Technology (NIST) cloud computing delivers five key features [4]:

- On demand self-service – required IT resources are available when they are needed and where they are needed
- Ubiquitous and broad network access – all one needs is an Internet browser and a network connection to get to their applications and data.
- Location independent resource pooling – the location of data centers is irrelevant allowing cloud providers to pick locations where real estate and power are affordable.
- Rapid elasticity – through virtualization and distributed processing the offerings expand and collapse based on user requirements
- Measured service – the utility model requires that there be infrastructure in place to measure the amount of cloud services delivered to consumers. Systems automatically control and optimize resource utilization through this metering capability

Chances are good that you are a consumer of cloud computing in some form or fashion. If you have a webmail account such as gmail or Hotmail, you are using a browser based system to access the mail applications hosted on the Internet and your messages are being stored in a server in a data center somewhere in the world. The pictures, messages and videos you post to Facebook, YouTube, Twitter, etc. also reside in the cloud.

There are four types of clouds discussed in the literature:

- **Public Cloud** – available to any user of the Internet willing to meet the terms and conditions of the cloud service provider.
- **Private Cloud** – cloud computing infrastructure and technologies are maintained and operated for a specific organization, department or agency. The private cloud is owned by the organization, department or agency that utilizes it. Private clouds are created when an organization wishes to take advantage of cloud computing technology but does not wish to have their data or applications on the Internet.
- **Community Cloud** – Cloud infrastructure that is established and maintained where several organizations, departments or agencies have similar needs and requirements - such as to support an academic collaboration.
- **Hybrid Cloud** - This implies an intermingling of two or more of the types of clouds in a way that they are sensibly integrated into an organization's way of doing business.

In addition to there being several types of clouds, there are also several types of cloud computing offerings:

- Software as a Service (SaaS) – Applications that are accessed via the cloud. End users access commercially available software applications remotely through the Internet. Typical examples include project management, document management, customer relationship management, and social networking applications
- Infrastructure as a Service (IaaS) - Computer infrastructure is accessed via the cloud. Rather than purchasing, provisioning and maintaining servers, data centers, and networking equipment, end users utilize computer infrastructure, generally through a platform virtualization environment, through the Internet. Iaas is usually purchased on a utility computing model basis where the user only pays for the resources that they utilize. Typical examples include backup and recovery, storage, service management, and computation power.
- Platform as a Service (PaaS) – Development platform is accessed via the cloud. The end user has access to the hardware, software and infrastructure necessary to develop or test applications. Typical examples include database, development and testing, and business intelligence environments.

3. Benefits and Risks of cloud computing

One could easily see the value cloud computing might bring to an organization – particularly small to medium enterprises (SMEs) that may not have the capital to invest in the IT infrastructure that might take their business to the next level. It is quite clear that for many organizations, turning to cloud services would result in cost savings. Instead of having to buy and maintain hardware and software they can simply access it through the Internet. They could also reduce their IT footprint resulting in potential cost savings on real estate and power consumption.

Cloud computing certainly offers potential benefits for organizations that experience peaks and valleys in their requirements for IT resources (if you think about it – that pretty much means any organization that doesn't have round the clock operations). According to James Staten of Forrester "Most enterprise data centers are using less than 50 percent of the total capacity of their resources." [5]. Organizations using cloud services need not resource for their peak needs but rather take advantage of on demand scalable services as they are needed.

As cloud services are adopted in an organization, freeing IT personnel from running backups and installing patches, the IT group has more time to devote to aligning IT services with business needs, creating opportunities for more organizational agility. Because cloud providers are in the business of delivering IT services around the clock, they have a great deal of redundancy built into their offerings. Cloud consumers can expect excellent levels of reliability and availability.

While it is true there are many potential benefits of cloud computing, not all clouds are the white and fluffy kind; there are also potential risks associated with an organization moving some or all of their IT services into the cloud. Two of the most frequently cited concerns are security and maturity. Security concerns seem obvious; organizations have sensitive data that they don't want to fall into the wrong hands. Concerns over maturity relate to the fact that there aren't consistent standards across the industry so there exist potential portability issues associated with moving from one cloud provider to

another. The good news is that both of these concerns are being proactively addressed by the federal government. In 2009 GSA's cloud office established working groups on both security and standards and in 2013 NIST published Version 2 of the "NIST Cloud Computing Standards Roadmap".[18]

There are also data governance, privacy and legal issues that may be associated with ventures into the cloud. Who owns the data and how do they assure that the data is not made available to nascent third parties who have no business accessing it? If a particular consumer's data resides in a foreign country, what set of laws apply if the data is lost or a contract is breached? These are issues that need to be understood and addressed as organizations move important business processes into the cloud. Another challenge is the fact that progress into the cloud leads to loss of control on the ground. IT groups need to relinquish control to an outside source and are often not able to create custom solutions to meet unique business needs.

A final risky area has to do with the fact that for some businesses the cloud does not prove to be an economically sound decision. There are several reasons why this might occur. The cost for migration to import business applications may exceed the post migration cost savings to the extent that a return on investment is not realized in a reasonable time. It could also be that due to a nature of the business, the business consumes resources in such a way that the cost of operating in the cloud exceeds the cost of operating in a more traditional environment. For this reason, it is important for a business to understand that the actual costs of migration, the various pricing options of cloud services, and the ultimate cost for them to operate in the cloud.

4. Cloud migration cost drivers

When thinking about cloud migration costs, one important factor to consider is whether the cloud capability is software as a service (SaaS), platform as a service (PaaS), or infrastructure as a service (IaaS). For software as a service usually the end users have little or no control over the deployment so the only potential migration issue would involve importing of data from legacy systems. When using platform as a service, the users have limited control but there are quite a few configuration issues that might have to be dealt with. While with infrastructure as a service, the end user has a lot of control over configuration but still needs to deal with compatibility and overhead.

In order to understand the costs of migration, one must first understand the activities that go on during a typical migration. According to [6], the steps of migration include:

- Discovery and analytics – this step includes analysis of the existing applications with the eye towards determination of whether or not they are suitable for migration to the cloud. It is not necessarily feasible that all of the organization's applications be moved into a cloud environment. Once feasibility has been established, a profile needs to be created of the source environment of the application or applications whose migration seems feasible.
- Map – this step includes creating a plan for what the software stack and applications will look like in the target (cloud) environment.

- Provision – this step provides for actual creation of the environment in which the migrated application or applications will operate. This could include activities such as creating virtual machines and setting up those machines with the proper supporting software for the applications.
- Migrate –this step involves the actual movement of the applications, software stack configurations, and the associated data bases. The actual migration includes the following activities:
    - Database changes – making necessary changes to queries and schemas
    - Code changes – changes for new programming models in the cloud, changes for database access layer, changes to create functionality that might not exist in a cloud environment, etc.
    - Connection changes – it going from an LAN to a WAN may require modifications in the connection logic
- Remediate and test – once the application has been migrated, it is important to verify not only that it continues to function as expected but also to ensure that performance is acceptable.

While at some level, all of these steps need to be carried out for successful migration, the implications with respect to cost and effort will be different depending on the cloud model selected.

As mentioned earlier, migration to software as a service could be a completely trivial exercise, such as signing up for Facebook, Twitter, or Pinterest. If for example you are launching an instance of salesforce.com to replace a similar legacy capability, there will be some effort associated with database migration.

Migration of applications to an infrastructure as a service cloud platform should not be too complicated since users have full privileges on the virtual machines, with the ability to install required operating systems and other software necessary for successfully accomplishing the workload of the application. The cost of migration could be trivial if the amount of resources that the application requires is stable and satisfied by available service plans. If however, there are resource requirements that vary significantly over time, it may be necessary to implement resource management capability for the application. In this case the cost of migration will literally be the cost of implementation of the resource management component.

Another thing to consider when migrating to an infrastructure as a service platform, are what [7] refers to as the hidden management costs; users of IaaS are required to understand the virtual servers, operating systems, middleware stacks and other software required to support their applications. Depending on the in house talent, costs of training, installation, and administration may be non trivial. Basically, costs of migration of legacy application to an IaaS are low in that the only development or customization required centers on the resource management components, when necessary. However, users of IaaS need to be aware of the activities they will be responsible for with respect to making the migration successful.

Conversely, there are very few "hidden management costs" involved in the migration to a PaaS because the environment is much more tightly controlled. There are, however, potentially much greater actual migration costs because of this tight control on the environment. Users of PaaS require a fair amount of information about the specific environment in the target cloud environment before they can make a reasonable assessment of the costs of migration.

The items that need to be considered for this type of migration include [7]:

- Programming language compatibility – may seem like this would be a no brainer, anyone considering migration to PaaS would certainly ensure that the target platform supported the language or languages of the application to migrate. But it's also important to ensure that the specific version of SQL or Python is supported. If not, one should expect to incur costs associated with modifications to accommodate different versions.
- Database compatibility –it's not uncommon at all for the databases supported by the PaaS provider to be different from the database your legacy application uses even if they are the same "database". It's quite likely that some of the supported features are not available through the PaaS or that some of the features behave somewhat differently.
- Third party and other supporting components – depending on whether or not your application depends on capabilities delivered from components from outside libraries, it should be assumed that your migration will include some code development to replicate some of these capabilities
- Graphical user interface (GUI) – if you are migrating a desktop application, with a desktop based user interface, it's likely that significant modifications will be required to create a cloud appropriate GUI.

In addition to the fact that code may need to be developed or modified to accommodate for one or more of the above configuration issues, there may also be a need to migrate databases to the cloud environment. Clearly, the data will need to be imported from the legacy database. The size and complexity of the database will determine the effort associated with this import. There could also be other issues. If the PaaS doesn't support standard SQL, it's possible that query statements will require rewriting. Since PaaS generally supports fairly light weight database functionality, there may also be the need to develop code to handle predefined functions and other capabilities currently available through your legacy database. There also may be issues around unsupported data types.

5. **Cloud provider pricing plans**

According to [8] the lack of standardization has led to a wide variety of pricing models offering varying levels of performance; this has resulted in a great deal of confusion as users try to compare services from various providers. Cloud pricing models can be characterized as follows [9]:

- Consumption based - One simply pays for the resources they use such as disk space, CPU time, network traffic, etc.
- Subscription based – The user pays for access, typically, unlimited, or a specific period of time.

- Market based – pricing for service me is based on supply and demand. The user can even choose to pay the market price or can make a bid to use it at a lower price and when the market price reaches that price their workload is activated.
- Advertising based – service is delivered at low or no cost, but service is periodically interrupted by advertisements

Software as a service is generally priced using either a subscription based model or an advertising based model. Pricing models for PaaS and Iaas tend to be significantly more complicated, because different providers use different models. Some examples of pricing models include [12]:

- Price per hour determined on memory in GB, processing units, storage space in GB, and platform
- Price per transferred data in GB (either outbound, inbound, or both)
- Price per quantity of queries
- Price per TB of data stored
- Network price per GB stored including inbound and outbound
- Bandwidth charged per GB transferred

Most providers use some combination of the above pricing models to determine costs of their services. ([12] outlines specific models for many of the popular providers). Service Level Agreements (SLAs) are also a potential cost factor. Most of the more popular cloud service providers offer calculators to help users determine what their per month charged would be based on the resources that they require. Examples of this can be found at [13],[14],[15],[16].

6.0 Cost Estimation Considerations

There are several dimensions involved when formulating an assessment of costs associated with migration and operation in the cloud. An organization first needs to do an assessment of which applications should be migrated to the cloud. There are several reasons why certain applications might not be suitable for cloud migration. They may deal with sensitive data, may require special hardware devices, may require special physical configurations difficult to replicate in the cloud, or may have a requirement for large bandwidth or intense computations which make the cost of cloud computing economically unattractive. Once applications for migration have been identified, the next step is to decide on the cloud platform and chose a provider.

The organization needs to do an assessment of existing configurations and the talents and experience of its IT staff. Coupling this information with knowledge of the applications and their supporting infrastructure targeted for migration should make it clear whether SaaS, PaaS, or IaaS is the best choice. Once this decision has been made, the organization is now in the position to determine which providers are most likely to meet their needs, and can use tools such as those cited above to determine the best financial solution for their workload needs.

The next step is to consider application migration costs. The following is a checklist for the estimator to guide their thought process during this estimation process:

- Does this migration include any SaaS solutions? If so…
  - Are there data migration issues? If so ……
    - Is the target platform database compatible with source database? If not…
      - Determine the extent to which queries require modification and or rewriting, treat this like a software estimation exercise
    - Assess the size and complexity of the data to determine the amount of time and effort required for the physical transfer of data
    - Alternatively, the work cited in[17] has developed a measure, cloud migration points (CMP) using a format similar to that developed by the international function point users group (IFPUG) to help size migration projects in the cloud. In their work they found CMP to trend nicely with effort on a small set of cloud migration projects. One of the component of this measure, creates a CMP value for the database migration as a function of the amount of query modification necessary and an assessment of the data population size .
- Does this migration include any IaaS solutions? If so…
  - Are resource requirements stable and well within the provisions of cloud provider selected? If not….
    - Determine requirements for resource management component, treat this as a software estimation exercise
  - Is the migration staff experienced with the technologies available on the cloud platform? If not…
    - Determine the amount of training, installation and administration that will need to be performed to get the staff and the platform ready for migrated applications(s)
- Does the migration include any PaaS solutions? If so….
  - Is the programming language compatible with the language for the source application? If not…
    - Assess the amount of code that will require modification, treat this as a software estimation exercise
  - Are there database compatibility or migration issues? If so….
    - Same considerations as with the SaaS as detailed above
  - Are there third party components or other supporting components that are not compatible with the selected platform? If so….
    - Assess the amount of capability that will have to be modified or created, treat this as a software estimation exercise
  - Is the GUI suitable for a cloud implementation? If not……
    - Assess the amount of software that will be needed to create a suitable GUI, treat this as a software estimation exercise.

7. **Conclusions**

Cloud computing can definitely be a cost savings alternative, particularly for small to medium businesses or businesses that have significant peaks and valleys in their resource requirements. This cost savings does not come without risks and challenges. Security continues to be a concern and most likely there will never be a cloud secure enough for the most sensitive pieces of data. Most businesses will likely settle for a hybrid solution where they connect legacy or private cloud solutions with public could hosting of applications not requiring high levels of security or protection. Lack of standardization in interoperations and pricing also presents challenges to those moving to or living in the cloud.

The effort associated with migrating to a cloud solution ranges from trivial to significant depending on the application(s) being ported and the flexibility with such applications. Those willing to accept a different implication of a legacy capability can migrate directly to a SaaS solution with little or no effort. Those wishing to operate their specific systems an a cloud environment need to do their homework to find the most practical and cost effective cloud provider for their particular requirements (technology, processing, storage, Service Level Agreements, etc.). They need to know the potential roadblock, make choices to avoid them as much as possible, and plan for enough time and effort to address those that can't be avoided.

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