Analysis of On-premise to Cloud Computing Migration Strategies for Enterprises

By

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Abstract

In recent years offering and maturity in Cloud Computing space has gained significant momentum. CIOs are looking at Cloud seriously because of bottom line savings and scalability advantages. According to Gartner's survey in early 2010 of 1600 CIOs around the world, Cloud computing and virtualization were on top of their list. This interest has also resulted in slew of products and services from existing IT players as well as new comers which promise to offer many solutions to pave the path towards Cloud computing adoption by enterprises.

As organizations get on to the Cloud computing bandwagon they are looking at their current IT setup and looking at the best way they can take advantage of what Cloud has to offer. For a given enterprises, getting on to Cloud might be a complete new start from scratch, a limited deployment of new applications or migration of part of existing applications integrating backwards with on-premise applications. To take advantage of the Cloud, enterprise will need to define their short and long term Cloud strategy. They will need to consider factors specific to their businesses and determine their requirements, risks and benefits. Proper investigation by the enterprise will give them insight in to the benefits and specific strategy they need to follow to gain the said benefits from Cloud.

This Thesis analyzes specific strategies which enterprises can adopt, both from business and technology perspective to make sure the migration and integration between on-premise and Cloud happens with minimal disruption to business and results in maximum sustainable cost benefit. It presents the current state of On-Premise IT and Cloud Computing space and then compares them to come up with enterprise specific variables based on which one can make Cloud migration decisions. Finally, Thesis presents the broad frameworks for "migration to Cloud" and confirms the same by interviewing enterprise managers involved in Cloud migration. There are various ways to slice and approach the Cloud migration – but all should take in to consideration the business processes, architecture of existing systems, architecture of available Cloud services, interoperability between on-premise and Cloud applications, maturity of Cloud and standards, short and long term cost savings, sustainability, data/security/regulation, user adoption, available Service Level Agreements (SLAs) and business criticality.

Acknowledgements:

First and foremost I would like to thank Professor Michael Cusumano for his guidance and direction during the process of writing this Thesis. He has been very accommodating and always given timely feedback. Cloud computing is a complex space, his papers and guidance has given me needed direction to be able to finish this work.

I would like to express my heartfelt thanks to all who took time to interview with me and give their precious thoughts, data and vision of Cloud computing in their organizations. There would have been no way for me to verify real world Cloud computing migration strategies without the insight which I got after talking to IT leaders in two pharmaceutical and one retail giant.

I would like to thank Pat Hale, the director of Systems Design and Management Program who has always been there to answer questions and take care of any roadblocks. Thanks to Bill Foley and all the staff in SDM office who were always there to help and answer our questions. I'm grateful to be part of SDM program where I learned so much over last three years from my professors, the institute and peers.

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Finally, I dedicate this Thesis to my wife Shalini and my two beautiful kids Saachi and Daksh. They have been on a three year journey with me and have given their time, patience and help all the way. I would not be writing this if it was not for their help, love and dedication.

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Chapter 1: Introduction

Information Technology is again going through a critical shift as it has gone through in the past half century - eras of mainframes, PCs, client/server, web and now Cloud Computing. Theory around Cloud computing is pointing towards its success and most of the technological and business factors are also on its side. There has seen increased investment and shifting strategies by big players and appearance of large number of Small and Medium Businesses (SMBs) in the Cloud space. Research and market prediction indicate that Cloud computing will be a 42 billion industry by 2012 which is driving lot of attention towards it (Gens, 2008). That being said it still has lot of roadblocks to cross related to security, data ownership, privacy, standards etc. Enterprises are going through testing and assessing what Cloud services are out there which can improve their bottom line and business effectiveness. A crucial step in this Cloud journey will be the Cloud Migration which will need well drawn out strategy, detailed planning and tested migration path.

At high level enterprise will need to:

- Understand the concept of Cloud computing, its architecture, what it can offer and associated risks.
- Evaluate the models, architectures, technologies and best practices to adopt Cloud computing.
- Classify the Business processes which are good candidates for Public/Private Cloud.
- Depending on the case use Private Cloud as the stepping stone.
- Analyze how Cloud and on-premise IT mix will affect short and long term business strategy.
- Learn from implementations by other companies in similar areas of business.
- Use available decision/migration frameworks and customize them for your organization.

Motivation:

In my fifteen years of work in Information Technology space I have seen couple of technology shifts which have changed the way businesses implement and use Information technology. Namely the move from Host based systems to Client/server to Web based systems. Each of these changes have opened up the possibilities for businesses to do more but at the same time also have created challenges for their IT departments to continuously adopt and generate better value for business at lower costs. We are currently going through another such shift called Cloud computing. I got chance to be involved in two Cloud related lab projects in my previous semesters to do some in-depth reading, analysis and interviews which has rooted my interest in this topic. I see migration from on-premise to Cloud computing to be one of the next important areas, hence my interest in doing more research on it. I also see this as an opportunity for me to apply what I have learnt at MIT and at my job to create a sound base for something I see myself working on post graduation.

Thesis Statement & Primary Research Objectives:

Enterprises are standing at a juncture where soon they will have to decide which applications they want to move in to the Cloud. When enterprises are ready to move, they will have to create a roadmap of their migration strategy, and depending on the business and applications there will be various paths, challenges and risks.

Research objectives of this Thesis are:

- Research and contrast On-premise IT with Cloud Computing solutions leading to variables for business case for migration to Cloud.
- Analyze the business and technical implications, challenges and rewards of migrating from on-premise setup to Cloud computing.
- Create broad frameworks for "migration to Cloud" and confirm the same by interviewing enterprise managers involved in Cloud migration.
- Apply lenses from learning at MIT and capture industry perspective by interviewing experts.

Research Methods & Approaches

- Data Collection via online/book literature research.
- Data Collection via interviewing IT managers in enterprises.
- Analysis, Classification and documentation of findings.
- Use of personal experience, learning at MIT and inputs from professors.

Thesis Structure

This Thesis assumes that migration to Cloud computing is inevitable and sooner or later enterprises will have to go through the decision and migration frameworks to decide what to move to Cloud and when. There is substantial amount of investment and good level of confidence in current On-premise IT solutions - the business processes, partnerships, technology maturity and sense of security, all are on the side of On-premise IT. Best way then to analyze the Cloud migration strategy is to contrast current state of On-Premise IT and Cloud Computing space to get the parameters on which business decision can be made.

This Thesis starts by looking at current state of On-Premise IT, including how enterprise IT got to where it is today and what is driving the consolidation and move to the Cloud. We look at advantages and problems with On-premise IT. Then we talk about Cloud computing – the opportunities it offers, roadblocks which need to be cleared yet and its maturity. Comparing both gives us the clear picture, which forms the foundation for Cloud migration decision process. Cloud Migration chapter looks at various frameworks which can be customized for a given enterprise and used to facilitate the decision making process on what to move to Cloud and when. We also look at various options available for enterprises looking to move to Cloud – Private, Public and Hybrid Cloud.

Thesis ends with real world Cloud migration strategies adopted by two pharmaceutical giants and one retail giant. The real world scenarios confirm the migration strategies listed in this Thesis, plus present added perspectives on the role of current economic conditions, innovation, and centralization wave on Cloud migration decision. Interviews with IT leaders in these companies confirmed that migration to Cloud is happening, companies are experimenting - its matter of time when during next refresh cycle of an application, enterprise IT leadership will think, does it make sense to move this application to Cloud?

Chapter 2: State of On-Premise IT

Cloud computing is presenting enterprises with new ways to implement IT solutions allowing them to access services cost effectively and flexibly. It is a promising space but before enterprises can start taking advantage of Cloud computing they have to look at their current IT implementations and surrounding business processes to find out how they can move effectively to the Cloud computing space without compromising current investments and security. It is prudent to contrast advantages and disadvantages of On-premise IT solution with the pros and cons of Cloud computing space. This chapter looks at current state of On-premise IT including history of how we got here. We'll also look at Software Development lifecycle (SDLC) and sourcing models so that we can weigh their benefits and pain points against Cloud computing solutions later in this document.

History

Before we get to current state of On-premise computing and Cloud computing it's important to know how we got here. How has modern computing made its way to businesses over the years and evolved since its inception almost six decades back.

Looking at the history of computing there are couple of themes which are visible right away. The advances in computer technology have made new products bigger, faster, cheaper and better. Bigger in terms of computing power, storage space etc., faster in terms of bus and network I/O, cheaper in terms of cost (per given computing parameter) and better in terms of reliability and usability (Skamarock B. G.). Processing power, Network speed and Memory capacity have been rising at a steady pace resulting in better speeds and performance while their costs are steadily falling. Software programs have also become more sophisticated to make use of available expanding computing resources. Availability of computing resources at commodity prices is in fact one of the main drivers of Cloud computing advancement.

Finally there has been the theme of centralization and decentralizations. Initial mainframe systems were central with all computing and storage in a single large location. Advent of PCs and client server computing systems brought in the decentralized computing. With time the IT management vows of dispersed systems has again resulted in centralization of some of the resources. Cloud computing is yet another step towards recentralization of computing resources, brining the pendulum back.

Table in Figure 1 below shows, how computing has evolved over the past half century and which companies have led the computing evolution. The major evolution is from data center applications to today's service delivery models. The service-oriented computing is the result of fundamental paradigm shifts in all areas of technology—starting with the kind of hardware, applications, methodologies, algorithms, and the nature of applications (Nagaraju Pappu, 2007).

	1960s - 1970s	1080 - early 90s	Mid 90s - 2003	2004-now
Evolution of Computing	Mainframe based computing	Client server computing	Web based computing	Utility or grid computing
IT Companies	IBM	Database Companies	Amazon, Yahoo	Google; ??
Industry Mantra	EDP, Requirements	Computing, Algorithms	Distributed Systems	Integration
Innovations	Structured Programming	Unix, Networking, User Interfaces, APIs	Standards and Environments	Semantic Web - connecting the dots
Programming	Procedure Oriented	Problem Oriented	Object Oriented	Aspect Oriented
Software Engineering	Non-existent	Problem Solving	CMM like Processes	Agile Programming
Evolution of Applications	Electronic Data Processing; Turnkey projects	Information Management	Content Management and Delivery	Service Management - managing Quality of Service
Evolution of Users and usage	The developers were also the users	A few trained users	The customer becomes the user	Usage is from any consumer of the service a customer or even another service
Evolution of Development	Programming in the Lab	Programming in the small	Programming in the Large	Programming in the World
Nature of Applications	Backroom Apps	Desktop Apps, productivity improvement	Process Automation	Enterprise Integration

Figure 1: Evolution of Computing

On-Premise Software development and lifecycle

Software Development Life Cycle processes found way in to enterprises because of the requirement of customization of software to fulfill specific business needs in the organization; generic software from bundled sources was unable to meet specific needs unique to individual companies. "Business need" took the form of software requirements which were fed through the steps of analysis, development, testing and deployment to a working product (as shown in Figure 2 below).

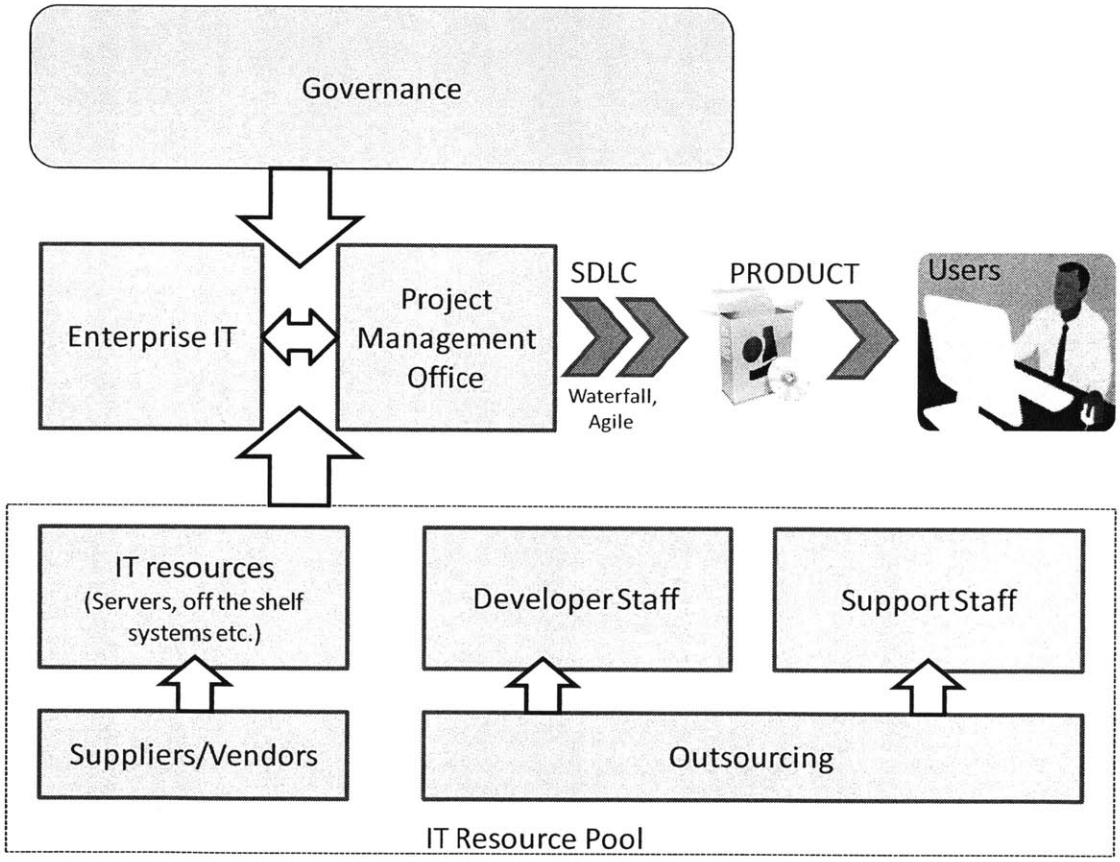


Figure 2: Software Development in Enterprise

Traditionally IT development in enterprises has happened through gathering of user requirements, making a project (or group of projects) out of it and then buying resources to accomplish the project. The result is many products with their own systems and processes adding to the existing complexity of enterprise IT.

The first formal Software Development Life Cycles were sequential as they went from one step to next till reaching the final step, also known as "Waterfall model". It is still one of the most used methodologies of SDLC in organizations. In Waterfall model completion of each step leads to the next till end is reached. Reviews may occur before moving to the next phase which allows for checks and possible changes; the phase completion criteria are also referred to as a "gate" that the project must pass through to move to the next phase, hence the term "Phase-Gate". In true waterfall making any big change or going back the gates to prior phases is discouraged once it's complete. This "inflexibility" is inherent to the model and has given rise to other more "flexible" models discussed later. For long time waterfall methodology of SDLC was only way project managers used to develop the software systems. This did work for some but most of the projects either wasted lot of resources in terms of money and people or were delivered too late to make business impact or did not give the intended business benefit. In Waterfall Software development is tied to the project metrics more than the business benefit metrics causing conflict in the success of end product.

Soon development teams realized that to create a software product with frozen requirements does not work most of the time. This gave rose to Iterative software development methodologies which assumed that it is impossible to know all requirements for a successful application before development starts. Development is evolutionary consisting of much small, scoped, feature-based iteration that deliver a product which is closer to the customer's vision. In recent years iterative methodoligies has made great in-roads in to the software development teams in enterprises because of the cost savings and accurate product development. Iterative methodologies have taken away lot of rework and wastage of resources which were typical in waterfall. In addition the end product is more close to what customer actually desires. Iterative projects enable an organization to build a project in an incremental way while staying in the comfort zone of a sequenced method. An iterative method is a sequenced, product-based method. (Hotle, 31 March 2010)

Agile is iterative approach with collection of methodologies which include Scrum, Feature-Driven Development, Extreme Programming, Test-Driven Design etc. Agile needs tight collaboration between business and the software development teams to get product closer to the intended business need. Agile methods are very useful where the business has little to no understanding of its requirements (which is normal in new products or new business processes), or where the business process changes rapidly by nature. Iterative software development methods are base of Cloud software development.

Developing software in house let's you customize it and gives the ability to integrate it better with existing systems but it comes with following shortcomings.

- Dedicated teams: Usually enterprises keep a dedicated team of developers. Resources are retained even when project has finished, this to make sure they have needed resources in hand for possible forthcoming projects. This adds to the ongoing operations cost.

- High Cost: Apart from some small rapid delivery projects, the cost of developing systems in house is usually more than a similar off the shelf system.

- Late deliveries: Traditional in-house software development is known for either missing on scope or time leading to missed business opportunities.

- Product quality: In enterprises it's common to hear users complaining about the quality, performance and bugs in in-house built software systems. Releasing a below par product to end project within budget might lead to higher support costs later.

Cloud Computing model solves lot of the shortcomings of traditional on-premise software development methods by delivering business needs as services while hiding the systems complexities, but also comes with its own share of problems which needs mitigations, as discussed in later chapters.

Current State of On-Premise IT:

Currently enterprises are going through consolidation to reduce their operations footprint. They are becoming leaner to maintain their competitive advantage by putting more of their available resources in their core business as oppose to IT operations.

Following are some of the current trends in On-Premise Enterprise IT:

a. Application consolidation – Over the years On-Premise IT in most enterprises have been embedded with business making it easier to better understand the business requirements. This though has created overlapping systems where one or more departments in an enterprise have applications which do similar function. As part of consolidation enterprises are creating central pool of applications which can be accessed by business across organization. Consolidation of applications is driving lot of advantages namely, small footprint of applications to save on maintenance costs, more streamlined IT operations and improved support.

b. Outsourcing – Consolidation has made it easier to pick up a pool of applications and outsource them easily. In recent years boundaries of what can/should be outsourced in enterprises has been pushed further because of better performance, cost savings and improved Service Level Agreements (SLAs) with sourcing partners. This is an important point when considering Cloud computing – as enterprises have already used vendors outside their premises to maintain and support their business critical applications, the pro-Cloud group in enterprise is asking the question why can't we to the same by moving applications to Cloud.

c. Support – IT support has become more streamlined through adoption of processes like ITIL and COBIT. In-house support has taken a new role of managing the relationships while most of ground work done by outsourcing partner. This trend is because of the maturity in off-shoring support models which provide better support with round the clock options at better prices.

d. Application development – More and more organization are going towards off the shelf systems with minimal customizations. This again has happened through business process changes in the enterprises which have streamlined the systems requirements for given business process. This shift in enterprise IT is key to Cloud adoption as most of the Cloud offerings are standards with minimal front end customization.

e. Datacenter consolidation – Datacenters throughout organizations are implementing server consolidation projects by going towards blade servers. This has reduced the space and energy footprint in datacenters. Datacenter consolidation presents first wave of IT operations cost savings to enterprises, building the confidence to move infrastructure boundaries to Cloud infrastructure options.

f. Back-office –Enterprises are outsourcing non-core package back-office needs like emails and teleconferencing to vendors. Complete Email outsourcing has seen rise because it's one clearly demarcated large chunk which can be picked and outsourced.

Trend in consolidation and outsourcing of non-core business processes in enterprises will continue and will make IT departments leaner with time. On the other hand IT giants are continuing to acquire more and more service specific vendors to widen their service spectrum. Future points towards handful of large players which will offer IT services on Cloud at a price point which will push enterprises to consider moving considerable part of their IT operations to Cloud.

Case for keeping On-Premise IT

Enterprises have been moving their business processes, IT development and support outside their perimeter. Last decade saw an exponential increase in outsourcing of non-core IT services and business processes. The trend still continues with enterprises pushing boundaries of what to outsource or host external to the organization. While CIOs are making these decisions, they are presented with opportunities in Cloud computing area, they are confronted with the question like, how can they realize cost and performance benefits out of it. That being said, traditional in-house systems even with their big price tag and high ongoing expenditure seem safe because of the control they provide. These benefits and merits do come in to the decision process when IT managers think about migrating to Cloud.

Technical perspective

1. Data storage and location: Having infrastructure inside your walls gives you the control over servers and data they hold. You know where your data is.

2. Security: Having your own infrastructure within your premise gives you the sense and control of security. You can be flexible with securing your applications and data depending on the criticality.

3. Architecture: On-premise systems give applications high architectural flexibility. Having control over infrastructure, application platforms and development resources, the applications can be customized to better fit the user's needs (albeit at additional costs).

4. Hardware dependencies: Dependencies between different architecture layers can be controlled better in On-premise systems by making needed adjustments and fixes.

Business perspective

1. Ownership of data: Knowing the location and condition of your data gives businesses in enterprise the sense of confidence and control (which is lost when one moves to Cloud). In On-premise systems, enterprise owns the data and can change, use, purge it when they like – they own it.

2. Regulatory Issues: Sometimes enterprises might want to move data outside their perimeter for cost and performance benefit but regulatory requirements might not allow them to do so. For example, "electronic patient data" regulation might not allow a pharmaceutical company to host patient data in the Cloud even though technical and business perspective it might make perfect sense to host it in Cloud.

3. Privacy issues: Having your data hosted out on vendors' machine might make it open to government agencies who might be allowed access based on legislative acts. Having data on-premise gives the control in the hands of enterprise allowing them to take actions best in the interest of company and its customers.

4. Cost/Benefit: There have been various models in support of cost benefit of outsourcing, hosting and Cloud computing but depending on the utilization and scenarios there might be some cases where on-premise IT can be implemented in a way to justify its cost given other benefits it gives of data control and security.

5. Change management: Sometimes making decision to move perfectly running systems and application outside enterprise does not make sense as the move might cause change in business processes, user behavior and system integration nightmares. Change management is the key when planning for Cloud migration.

Chapter 3: State of Cloud Computing

Defined

Cloud computing is a style of computing where scalable and elastic IT-enabled capabilities are delivered "as a service" to external customers using Internet technologies (Cearley, 2010).

In Cloud computing the infrastructure and software details are abstracted behind the service interfaces. What the service does is more important than how the technology behind the scene is used to implement the solution. This is moving towards simplifying the customer facing interface and only presenting what customer needs, hiding all the complexities behind. Cloud is based on multi-tenancy which means that multiple services used by customers tap the same shared pool of resources, creating economies of scale. Another important characteristic of Cloud is Elasticity, which is ability to ramp up and down the resources assigned to a service on-demand. Services in the Cloud are delivered using internet technologies and follow the utility model where customers pay based on the usage metrics.

Brief History

Cloud computing is a progression of decade old concepts which have finally become cheap and fast enough to be bundled in to services for enterprises. Past computing trends which led to on-premise computing of today also created technologies which are now the foundations of Cloud Computing technology – namely virtualization, multiprocessing, parallel processing, abstraction, utility computing (time sharing) etc. The concept of time-sharing and virtualization has been around since the days of IBM, both of these concepts were used in early IBM machines. There were in fact companies like Tymshare which sold computer time by giving access to its mainframes via dialup lines (Krishnan, 2010). Mainframes were also one of the first systems which utilized the concept of a central,

reliable, robust computing resource used by many machines. In addition, the concept of Grid computing has been there since 90s which in many ways a precursor to Cloud computing.

Virtualization of servers in datacenters in this decade has acted as a stepping stone towards Cloud computing. The server consolidation using virtualization has given enterprises taste of how much cost savings can be done using Cloud technologies which is leading them to pilot projects in Cloud.

Amazon pioneered the infrastructure Cloud space in 2002 with introduction of Amazon Web Services (AWS) and later launched S3 (Cloud storage offering with "pay per use" model) in 2006. Same year EC2 was launched making core computing infrastructure available. Salesforce provided the other two pieces of Cloud the SaaS (Software as a Service) offering and later offering of PaaS (Platform as a Service) in the form of Force.com. Google entered in to the space in 2008 with launch of Google apps followed by Microsoft and other companies. In recent years there have been lots of big and small players offering different layers and services of Cloud spectrum.

Cloud computing has long way to go before it crosses the roadblocks around standards, security and data ownership. Till then there will be pieces of Cloud computing which will be packaged and sold by different companies to suit different enterprises. These intermediate steps will increase the knowledge and confidence of enterprises leading to increasing degree of adoption by them.

Layers of Cloud Computing Stack

At a high level, Cloud can be viewed as a combination of Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a service (IaaS). Web based service offerings have served as a prelude to current Cloud offerings and is base of Cloud services. At a high level all the current Cloud offerings can be classified in following four categories (Roehrig, 2009) :

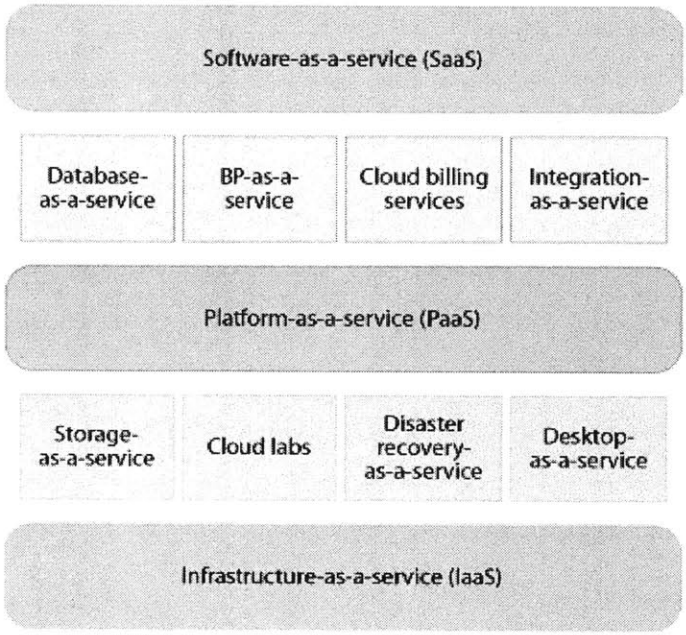
Web-based service offerings are Rich Internet Applications (RIA) which provides a specific service via the web. Examples are Facebook, Zillow, Google Apps and Flickr. Many of the IT service providers are not in the business of providing Web-based services, but they are aligning to help clients implement these offerings by taking common applications across organizations and offering them via web – Travel reservation system for enterprise travel is one example.

Software-as-a-service offerings include complete applications that can be customized by clients and delivered over the Internet. Salesforce.com is an example where a complete CRM application is offered as a service, clients do not have to worry about infrastructure and software licenses they just pay monthly usage charge to Salesforce.com depending on their agreement.

Platform-as-a-service offerings are externally hosted services providing complete platforms to create, run, and operate applications, including development tools, management tools and user-management services. These services include offerings such as Google App Engine and Force.com (for customizing salesforce.com SaaS offering). Apart from some exceptions like IBM currently most of the IT service providers don't really play in PaaS space but many firms do offer consulting and development support to help clients leverage platforms provided by other firms.

Infrastructure-as-a-service includes both full infrastructures on which clients can deploy applications as well as separate infrastructure services (e.g., virtual computing capacity, virtualized hosting, utility storage, etc.). Most of the Cloud providers currently

either have existing IaaS offerings (Amazon, Rackspace etc.) or are well on the way to developing as-a-service offerings for processing, storage, networking and so on.



54338 Source: Forrester Research, Inc.

Figure 3: Cloud computing stack

There are some services within the Cloud layers mentioned above that do not fit clearly in to one of the bins but are discrete services that can be consumed standalone, such as storage as- a-service or IT functions such as "disaster recovery" delivered as an on-demand Cloud service (see Figure 3). Similarly there are application services which are Cloud services that provide a discrete middleware function but are not complete, standalone applications. Examples include Cloud databases like Microsoft SQL Azure, billing systems like Amazon DevPay, and integration services like Boomi (Staten, TechRadar For Infrastructure Operations Professionals:Cloud Computing, 2009).

On one hand there is influx of many Cloud providers coming with innovative offerings and on the other there is huge investment from big players like IBM, Microsoft, HP, and telcos who are expanding their traditional offerings to Cloud. It's only a matter of time when Cloud services will get sophisticated and specific to industry segments, for easy adoption and migration.

Opportunities in Cloud

There are many opportunities in Cloud which makes it an attractive option for enterprises. Research indicates that roughly 5% of the sourcing budget in an enterprise is applied to transformation types of services, while efficiency and enhancement types of services command roughly 80% and 15% of the sourcing budget respectively, indicating that major portion of the budget is applied towards keeping the systems up and running as oppose to transformational undertakings. Adoption of Cloud-based solutions will increase the relative participation of transformational services because of innovative business models and transformed business processes (Dreyfuss, Feb 2010).

Economics: Cloud services offer reduced entry and exit barriers, allowing enterprises to react quickly to business changes. The IT spending pattern with Cloud is very predictable as enterprise cash-out for services. Cloud also reduces unnecessary cost arising due to unused licenses and features, as you only pay for what you use. Appendix A shows price comparisons of computing resources of some of the current Cloud players in the market.

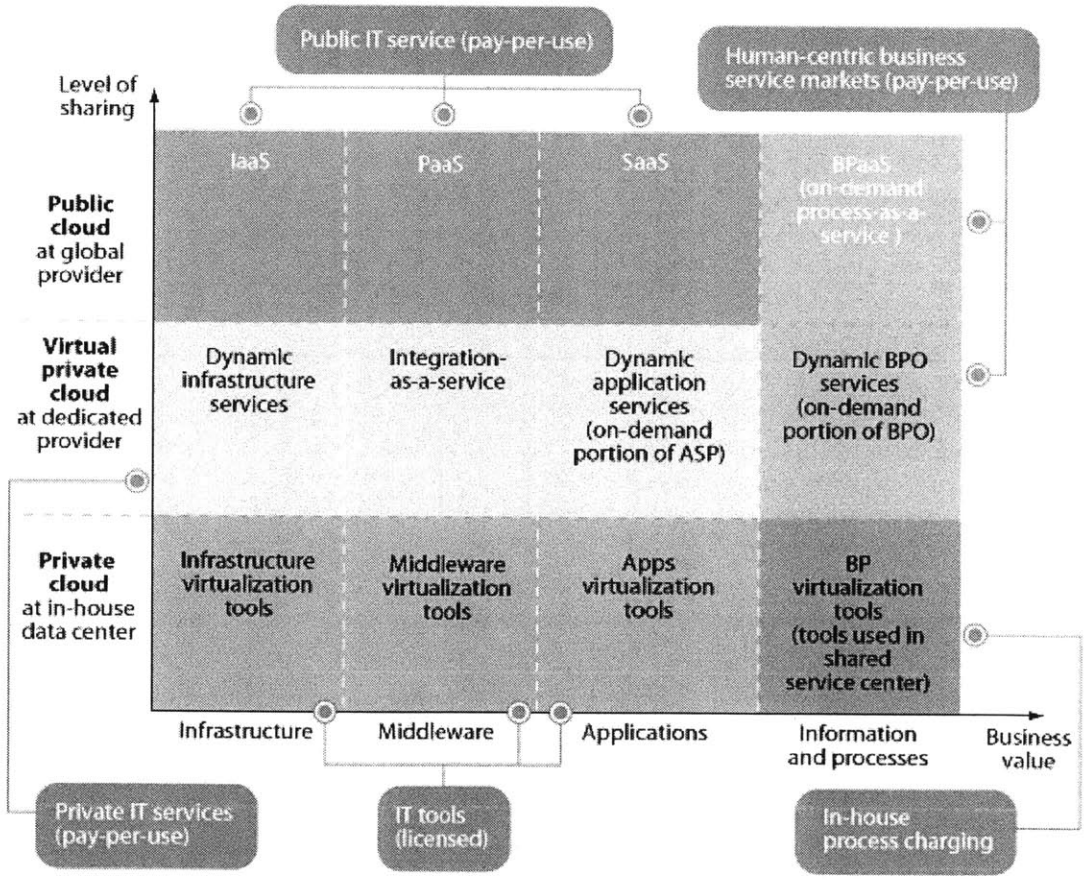
Agility: Cloud enables organizations to be agile with their IT infrastructure and software needs by adding, removing IT resources on-demand due to elasticity and use of shared resources inherent in the Cloud implementations. In Cloud, scalability, flexibility and elasticity are service attributes that positively contribute to business process value by reducing cycle times and accommodating volume fluctuations.

Simplicity: The whole process of infrastructure provisioning and running applications is simple in Cloud space. Cloud offers simple provisioning, ramp-up and decommissioning which makes it easier for businesses to get better turnaround and test their ideas at a much cheaper and faster pace.

Composite applications: In Cloud users can leverage the flexibility of dynamically accessing anything, and the diversity of available functionalities arising from composite applications. These new applications promise to provide users with simpler interfaces with better business integration and simpler support models.

Application development: Cloud platforms fixes lot of constraints inherit in the traditional software development. Cloud will move most of the responsibility of creating services with desired functions to providers making it easier and less expensive for enterprises to consume them.

Apart from visible opportunities Cloud computing also brings capabilities to enterprise at each layer. Cloud computing spans a wide range of IT-enabled capabilities, from low-level infrastructures to high-level business processes. As seen in the diagram below more discrete categories appear as we go deeper including sub divisions of the high level classification of Infrastructure, Platform and Software including additional services used to manage and monitor the overall Cloud environment (David W. Cearley, March 2009):



Source: July 6, 2010, "The Evolution Of Cloud Computing Markets" Forrester report

56885

Source: Forrester Research, Inc.

Figure 4: Cloud markets and capabilities

Cloud Computing Concerns and Roadblocks

Cloud brings lot of opportunities and capabilities to the table but it does come with its share of concerns around data security, data ownership, reliability and lack of standards. These roadblocks will inhibit the adoption of Cloud till they have been cleared through technology or business process re-engineering. At a high level these inhibitors can be divided in to two - the internal factors which are related to technology and business process (within a given enterprise) and the external ones which are due to the factors external to the enterprise like regulatory, privacy and legal concerns. To carve a way towards smooth Cloud adoption, both the internal and external inhibitors will need to be tackled in parallel.

Security: Security and Privacy are current top reasons for not adopting Cloud. Most concerns center around data protection, system integrity (access controls and vulnerabilities), and availability, but privacy is of course also a key concern. There is also notion that business-critical data is outside the perimeter of enterprise, creating perception of unmanageable business risk. This definitely comes in CIO discussions and draws comparisons with security comfort with data on on-premise systems (EUROPE, 2009).

Reliability and Performance: Performance and availability of the applications are important criteria for enterprises. With On-Premise systems there is sense of control on which is lost when their applications are hosted on the infrastructure of Cloud provider. Systems uptime with Cloud providers is not as robust as with on-premise vendors. SLAs with most of the current Cloud vendors are generic with little room for customization which creates anxiety in the IT group. Additionally for applications which have part of the system in Cloud and part in-house face integration and performance issues.

Lock-in: There are no Cloud computing standards today to promote a common way of developing and migrating applications to Cloud. Enterprises have to adapt the standard offered by their vendors and get in to the risk of lock-in with a specific vendor thus

giving away economies of multi-vendor models. In addition, there are very few vendors who offer full range of Cloud computing capabilities pushing enterprises to adopt different Cloud services from different vendors each using different standards. Level of lock-in might differ depending on what slice of Cloud computing paradigm an enterprise is getting in to - Infrastructure-as-a-service providers like Amazon have low lock-in because of well defined infrastructure standards and pretty common implementation by other IaaS providers, but platform and application providers like salesforce.com have high lock-in.

Change in existing Business processes: Cloud space provides wide range of capabilities from agility, flexibility to economies but to take true advantage of these opportunities it demands more-responsive organizational and change management processes. This creates need for enterprises to re-engineer their business processes in order to take advantage of all what Cloud has to offer.

Legacy applications: A big challenge for large enterprises planning to move their applications to Cloud is the fact that their business processes are aligned with legacy systems which are decades behind in terms or technology and performance. Linking legacy systems with related applications in Cloud pose integration and performance challenges. To take true advantage of Cloud, legacy applications need to be rewritten. For most enterprises rewriting the legacy applications will be a multi-year long process which will result in parallel systems and business processes between traditional and Cloud platforms, and that can become very problematic.

Losing existing investments in on-premise IT: Large enterprises have already invested in their own data centers. Their current business processes can leverage existing investments in datacenter better. Hence it's important for organizations to see when they want to move to Cloud – if current investment in datacenter is already done then it might make sense to use that computing power for near future and develop a Cloud computing strategy for the right time in future.

Regulatory/Legal issues: Regulatory and legal concerns are external factors which might hinder the Cloud adoption by a given organization. For example it is technically feasible and also might make business sense to host patient data in the Cloud but the regulatory authorities (like FDA) might not allow the same due to privacy and security concerns.

Compliance: Lack of control over where that data may be physically located in Cloud is a nonstarter for some enterprises. Cloud services scenarios get complicated and worrisome when you consider the legal implications of data that's not locked down into a specific physical space. Some governments also impose limits on what kinds of data can cross national boundaries, and this will further inhibit the economies of scale that enable the Cloud services model to be commercially viable (Roehrig, 2009).

Maturity: There is lack of maturity on two sides of the line, lack of maturity of enterprises prevents them from incorporating more Web-based solutions in their IT application portfolios, and the lack of maturity of Cloud solution providers which prevents them from appropriately defining the exact features they want to provide in a given service at a given price point (Dreyfuss, Feb 2010).

Lack of Standardization in Cloud space: Cloud computing standards are yet far from reality. This creates multi vendor solutions with proprietary implementations causing some enterprises to only do a limited move to Cloud and wait for their bigger move till standards are in place. Lack of standards feed in to vendor lock-in and complexity.

Lack of transparency: Many of the Cloud solutions currently available are often provided as "plug-and-play" offerings that apparently need little or no attention and can be implemented immediately. Such products still are essentially "black boxes" that remain poorly understood by buyers and users. There is lack of transparency with this new business model which means new business risks that must be assessed and properly managed (Dreyfuss, Feb 2010).

Licensing approaches: License models in the "pay as you model" of Cloud computing are totally different than the traditional licensing models. One major challenge for organizations looking for Cloud computing will be adapting new licensing structures in Cloud and look-out for the possibility of variable charges. Perhaps licensing based on the concurrent users will prevail but there are still lot of variables like software usage based on CPU, Bandwidth and time which can complicate the licensing approaches. Appendix-B shows where various licensing model falls in the spectrum of type of software packaging and various software pricing models.

Service Level Agreements (SLAs): With new tools, standards, and continuing provider maturity, IT service management practices have advanced significantly over recent years. But existing service-level agreements (SLAs) and delivery processes for Cloud services lack the detail and maturity of traditional SLAs in large enterprises. Current Cloud vendors only provide standard SLAs with no customization. SLAs are critical to the success of Cloud computing and it's expected that in future through technology advances and competition SLAs will evolve to ensure higher confidence level of quality of service.

Fog in Cloud value proposition: Cost savings in Cloud has been put out there as one of the main attractions of Cloud computing. There are lots of questions though around whether savings claims are valid. One of the reports published by McKinsey in mid 2009 (McKinsey & Co. Report: Clearing the Air on Cloud Computing) asserts that, "Current Cloud computing offerings are not cost-effective compared to large enterprise data centers." Even though providers are claiming savings of 20% to 50% beyond traditional delivery methods for Cloud-enabled delivery, enterprise ROI models break down often because they either don't know true current costs or don't have models in place to assess true value of moving to Cloud. Enterprise will only be able to understand the economics of Cloud computing by modeling their specific scenarios and cost points in detail.

Development lifecycle in Cloud

Cloud computing represents parallel paths of evolutions at different levels of the technology stacks (Infrastructure, Platform and Application). Many of these offerings are modular by design and enable developers to pick and choose which services to incorporate when building a solution and to combine these with on-premises based functions and subsystems (Valdes, November 2008).

Application development lifecycle in Cloud is little different than the traditional one. The release cycles tend to be small in Cloud because of the need of feature addition in shorter intervals. Development methodologies like Agile cater themselves nicely to the frequent feature development and release model and are being used in Cloud Application development. Cloud Software development Platforms are used for developing, deploying, hosting, and maintaining Cloud-based Web services and applications. The platform offerings typically include development tools, management tools, and a runtime environment within which custom applications execute in the Cloud. Applications created for Cloud take advantage of available elasticity and processing resources to be more productive. Cloud Application Development platforms also provide high degree of infrastructure abstraction than traditional web development, thus easing developer concern of resource scalability and component distribution (Eric Knipp, September 2009). Due to the need to move towards creating apps providing standard services, the service providers will take ownership of a larger part of the software development life cycle than they have taken in traditional on-premises hosted models.

Enterprises are observing if some of the existing on-premises platforms can be extended to add the support for Cloud computing. Most of the near term software development lifecycle will be associated with moving, integrating on-premise applications in Cloud. This will cause current on-premise software development methodologies to continue till the time when enterprise decide to subscribe to a replacement service from Cloud or decide to rewrite the on-premise application to take advantage of scale and performance of Cloud. A dramatic shift is under way in the

enterprise-software industry as established vendors embrace services in the wake of declining product revenues. It remains to be seen whether life-cycle dynamics or business-model choices are behind the long-term trend (Cusumano M. A., 2008).

Below is an example of steps involved in a typical Web browser-based, integrated Cloud environment for rapid Cloud Application Development (Kumar, 2009):

1. Create Forms: The Composer enables users to create rich Web UI forms (web pages) by dragging and dropping from a wide variety of UI widgets such as text, date, currency, number, check boxes, picture fields etc.

2. Create Application Objects (Tables): When a user creates a form, optionally, application objects can be created by the system automatically to persist the information entered in the forms.

3. Create Business Process Models (BPM): System enables users to create business process models through modeling.

4. Consume Web Services: It is easy to consume third party Web services such as those exposed by Google, Sales Force, other applications, etc.

5. Build Reports and Charts: Ability to enable end-users to create reports and charts instantly in various formats.

Modular development examples like these are typical of development models in Cloud. Enterprise can start integrating some of business benefits of what Cloud has to offer with on-premise applications and then with time assess if it makes sense to move other applications to the Cloud.

Maturity and Horizon

Cloud computing package standardized IT services into optimized and automated solutions enabling economies of scale that most on-premise IT operations envy. Enterprise need to research, test and decide which services to pick, customize, and implement to most cost-effectively leverage the benefits of Cloud. While most Cloud services are immature today and thus really only best applied to new applications and services, as they mature, their applicability to existing applications and equipment will increase. Enterprise also need to understand that not every application, middleware, or infrastructure can (or should) be delivered as a Cloud service, and some areas of service are simply too new to categorize. Diagram below from research shows the current maturity and trajectory of Cloud computing components (Staten, TechRadar For Infrastructure Operations Professionals:Cloud Computing, 2009).

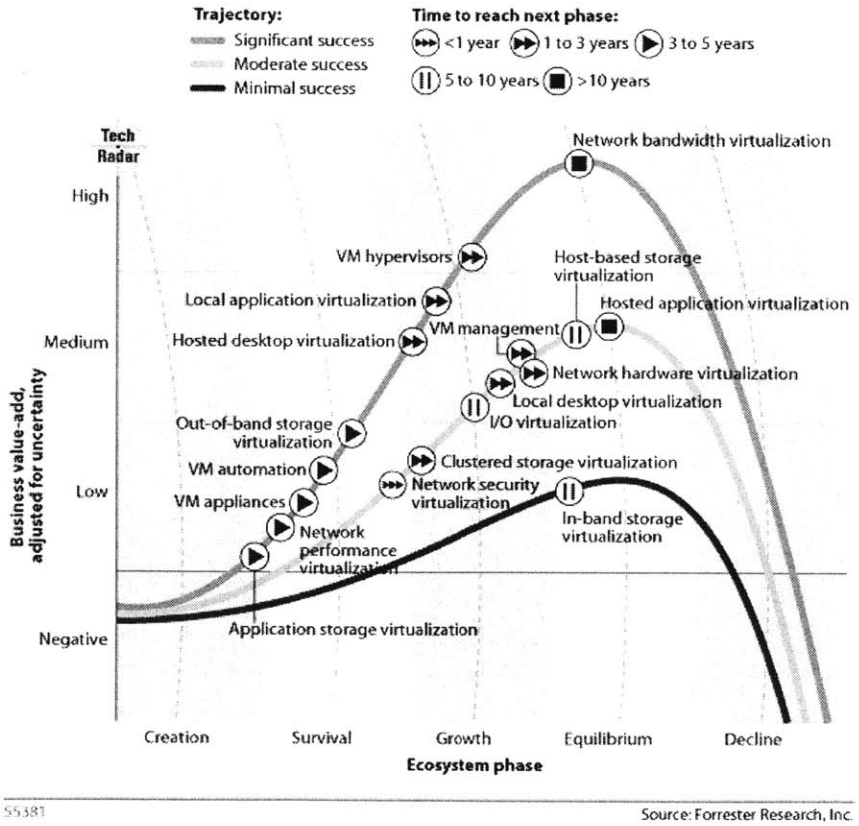


Figure 5: Relative maturity of various Cloud computing layers

It's clear from the graph in Figure 5 that that there is still lot of maturity road to travel as most of the current offerings are very limited in their function. Only IaaS and SaaS offerings have seen significant success but they are early on their growth trajectory and so will take another 5 years to get to a substantial acceptance from enterprises. Important services for enterprises like Integration as a Service and Business Process as a Service have only seen moderate adoption and even they have lot of catching up to do before any serious adoption by the customers.

Additional visible points about Cloud maturity are:

a. Enterprise Confidence Lags: Capabilities of Cloud computing are clear but due to lack of experience in Cloud implementations and lack of greater success data, it makes enterprises nervous to move anything business critical to Cloud.

b. Application immaturity: Many applications and service offerings cannot be moved today to Cloud due to risk of lock-in stemming from lack of standardization or just the fact the some of the services cannot be effectively coded for Cloud given the immaturity of the Cloud development platforms.

c. Players in Cloud: Cloud offerings are littered with small vendors which might not be too attractive to enterprises given most of their on-premise applications are on major vendors like Microsoft, IBM and Oracle. Enterprises are awaiting Cloud maturity from major IT vendors to see if their offerings will make it easier for them to port their existing on-premise applications to Cloud.

Let's look at adoption of one of the accepted Cloud layers, Infrastructure as a Service (Staten, TechRadar For Infrastructure Operations Professionals:Cloud Computing, 2009).

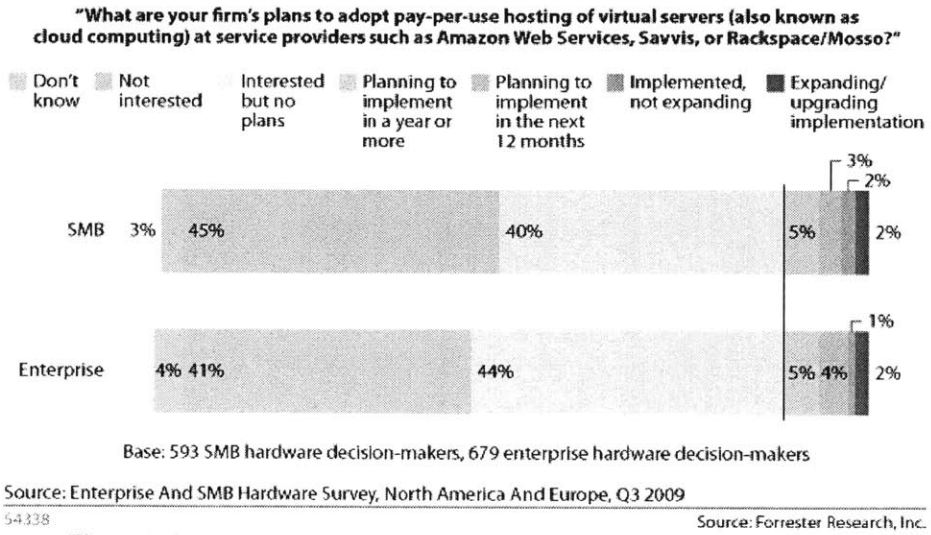


Figure 6: Current adoption and horizon of Cloud IaaS in enterprises and SMBs

As seen from in Figure 6 most of the firms are either waiting on the side or have no immediate plans (85-90%) to implement Cloud infrastructure offering. Only 10% are either planning or have implemented IaaS offering. This again points to the lack of maturity of Cloud offerings and cautious adoption from enterprise.

As seen in the Figure 7 below, Software as a Service has been more accepted in certain segments but still seeking broader acceptance and maturity in wider application categories. While it is relatively easy for a software product company to create a hosted version of its products, delivering these products over a SaaS platform (like Amazon, Google, Microsoft Azure) requires rewriting of major portion of code to user interfaces and available services (Cusumano M. , 2010).

Software-as-a-service	
Why the Growth phase?	SaaS, now 10 years old, has become an established software delivery model for certain segments of the market. Forrester survey data shows that fully 20% of enterprises and SMBs have implemented or are piloting at least one SaaS solution. All major enterprise ISVs have SaaS offerings, and all major SIs are building large SaaS practices.
Business value-add, adjusted for uncertainty	**Medium.** Not all applications are suited to SaaS delivery, and not even all implementations of SaaS-suited software are appropriate for a SaaS delivery.
Time to reach next phase	**5 to 10 years.** SaaS maturity varies widely across application categories, which suggests a long simmer before SaaS reaches equilibrium. Plus, wholly half of Forrester survey respondents in 2008 showed no interest in deploying SaaS or were unaware of it.
Trajectory (known or prospective)	**Significant success.** SaaS has the potential to significantly reduce operational and maintenance costs for customers, has dramatically faster time to deployment, and can deliver richer functionality to the customer at a much faster rate. Where suitable, SaaS holds significant potential for improving corporate productivity and efficiency.

54328 Source: Forrester Research, Inc.

Figure 7: Maturity of Software-as-a-Service

Figure 8 below shows how Cloud service model compares to the traditional on-premise IT service model. Most of the services in Cloud service model might not cater for an easy transition from conventional service models due to difference in the development models and architectures.

Conventional computing model	Cloud service model
Applications • Client-side apps • Client/server apps • Web interface to local server app • Data and process resides on PC or on local server	**End user cloud services** • Rich Internet applications • Web 2.0 technologies • Software-as-a-service • Data and process resides at service provider
Developer tools and techniques • Client-side development tool • Service-oriented architecture (SOA) • Composite applications • Proprietary APIs, such as Win32	**App-components-as-a-service** • Internet-hosted software services that enable mashups • Web-hosted development tools • Community development tools for shared templates and code • Proprietary service provider APIs and schema
Middleware • App server • File and object stores • Database • Integration server	**Software-platform-as-a-service** • Hosted app platform • Hosted data, file, and object stores • Hosted database • Software-integration-as-a-service
Physical infrastructure • Servers • Disks • Networks • Systems management	**Virtual-infrastructure-as-a-service** • Virtual servers • Storage shares • Virtual LAN configurations • Management-as-a-service

45073 Source: Forrester Research, Inc.

Figure 8: Comparison between Cloud Service and the Conventional Computing Models

Technical case for Cloud

Traditional IT is under pressure of delivering more with same or less resources in an ever changing computing landscape. In most of the enterprises, IT operations take 70% of the IT budget, leaving very little for any technological innovation implementation within organization. IT departments are trying hard to keep up with fulfilling their business demands with the resources they have in hand. Traditional IT systems implementations have not been scalable and only stand for 3-5 years for a given requirement before they are upgraded or replaced with something new. This all creates spaghetti of overlapping systems which do not deliver needed business benefits and require constant maintenance and upgrade. Following are some of the technical vows of IT departments in enterprises which keep them awake at night:

a. Low business demand response time: IT departments today cannot keep up with the new business systems demand. Current processes and implementations are resource heavy and costly; yet do not deliver the needed requirements in time to the business. This is a strategic disadvantage as competitors who are able to tap in to cheap and better computing alternatives get advantage over time to market and processes efficiencies.

b. Procurement/Provision Process overload: Traditional IT work on "Procurement and Provisioning" models which are dreaded with long approvals and actions causing delays in a simple request like getting a server to test a new business idea.

c. Capacity Planning problems: Business needs in an enterprise are complex and dynamic. It's an uphill battle for most enterprise IT to keep their capacity in sync with the business demands and deliver needed services in time.

d. Complex Business needs: Business needs in enterprises are not clearly prioritized. This makes it difficult for IT to manage assignment of resources to business which needs them most. IT asset utilization with true business need has always been a challenge in enterprise IT.

e. Adhoc needs: There are large numbers of business requests which are mainly proof of concept and these requests do not come from traditional provisioning process creating a tension between IT and business. IT wants to make sure their resources are used for prioritized business need and business wants to test something new which might give them an edge over competitor.

f. High Performance Computing (HPC) needs: Last five years have seen a huge amount of unstructured data piling within various business areas of enterprises which can be mined to get useful information leading to strategic advantage. Systems required to mine through large amount of unstructured data can be costly affair if done on-premise – Cloud presents an attractive alternative. Like unstructured data mining there are other applications in various organizations which need HPC and it's very difficult for on-premise IT to compete with Cloud on price, performance and time.

Cloud computing implementation either using public, private or hybrid could be the answer. Following are some of the opportunities in Cloud space which might make some of the problems listed above disappear easing some of the pain which IT organizations and their business have been going through till now.

a. Better way to provision Infrastructure: Infrastructure services in Cloud are standardized that allow on the fly elastic scaling of services. IT departments can take advantage of Infrastructure service through private or public Cloud and ease some of their pain points related to ad-hoc business demand or seasonal requirements which cannot be dealt with agility by on-premise IT.

b. Application deployment and management: Most Cloud infrastructure software allows you to easily add, move, or change an application with very little, if any, intervention by Cloud provider personnel. This makes it attractive for IT managers to look at Cloud for the options where they can move some of their IT processes (disaster recovery) and applications (using non sensitive data).

c. Project funding and resourcing: Because of pay as you model of Cloud the upfront IT costs are less, which speeds innovation and increases the number of projects that can be funded. Resourcing of needed skill sets for a given project is not an issue in Cloud as Cloud providers do most of the weight lifting leaving only customization to the enterprise project team. Diagram below in Figure 9 shows various IT models and how economies of scale and skill in Cloud Computing will drive its adoption compared to other computing services (James Staten, 2009).

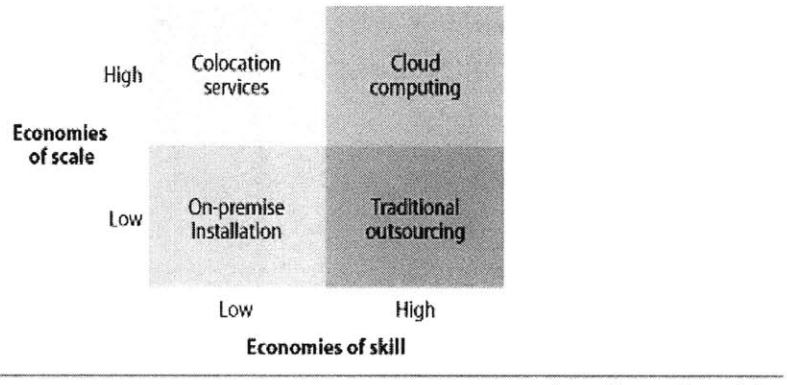


Figure 9: Economies of scale and skill matrix

d. Architecture simplicity: As most of the Cloud offerings are services as oppose to systems, the IT architects need not worry about the systems behind the abstraction, they can just represent that as a box with business inputs and service outputs. This model works best for applications/services which need no or little customization. In most implementations there are no software or hardware requirements at the customer end or specialized tools needed to deploy the application.

e. Speed: Cloud gives enterprise IT the leverage to take on business requests (or give them direct access to provider through in-houses processes) as they come and thus be more agile in fulfilling business demands. The speed to conceive, test and deploy business solutions in Cloud is fast because Cloud-based solutions start with a prebuilt foundation.

Business case for Cloud

Apart from the technical benefits listed above, main reason why Cloud space has gotten traction is because of the business benefits it provides to an enterprise. Following points makes the business case for moving to Cloud computing:

No contracts: Most Cloud vendors do not require any long term contracts allowing enterprise IT to choose from various offerings in the market which best suits their business needs. This also reduces the financial risk of tied in a long term contract for IT development or deployment. Flexibility like these in Cloud makes them ideal to prototype a new service, conduct test and development, or run a limited-time campaign without any commitments.

Pay by use model: Pay by usage model is attractive to organizations that do cross charging; instead now business can work directly with Cloud providers to get their resources and only use internal IT for any configuration, customization or training. This on one hand gives control to the business and on the other hand allows IT to be leaner saving operational costs. According to Michael Crandell, CEO of RightScale, a company that helps customers get their applications up on Amazon EC2, "Amazon is $70 to $150 per month fully burdened for a server versus an average of $400 per month for an enterprise." (Staten, Is Cloud Computing Ready For The Enterprise?, March 2008)

Better IT spending visibility: A Cloud-based service provider can give an idea on how much it will cost to provide a given service to a group of users or to provide a given amount of storage for a given time. This gives financial transparency and is comforting to IT managers and CFOs who must keep track of where the money is going.

Better cash flow: The major financial benefit of Cloud computing especially in these economic times is avoiding taking on debt and keeping cash in the company longer. If a project uses a Cloud-based service provider, then enterprise is saved of making huge upfront investment. Instead, payments are made at regular intervals as agreed with provider, which is more aligned with the return from investment.

Better return on assets (RoI): Assuming similar IT asset returns on both Cloud and on-premise IT, it makes sense to go with Cloud's pay-as-you-go model where cost is incurred in the same period that the value is delivered (James Staten, 2009).

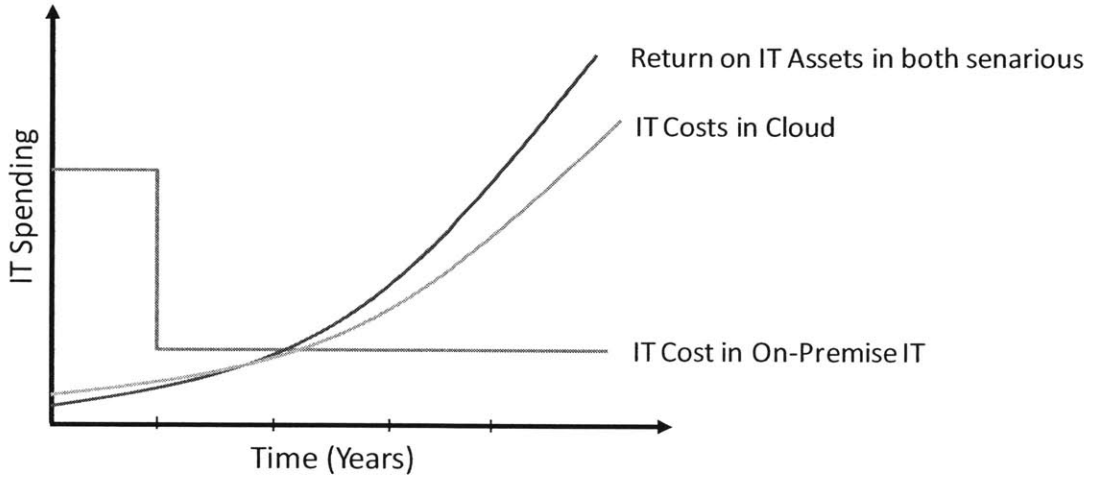


Figure 10: Comparison of Return on IT assets between Traditional IT and Cloud

Both from technical and business perspective, Cloud space offers lot of opportunities which makes it an easier, efficient and cost effective alternative to traditional IT models. As the Cloud standards emerge in coming years and enterprises gain better understanding of what they can move to Cloud, the adoption will rise and it's not far when a major part of enterprise IT will happen in Cloud.

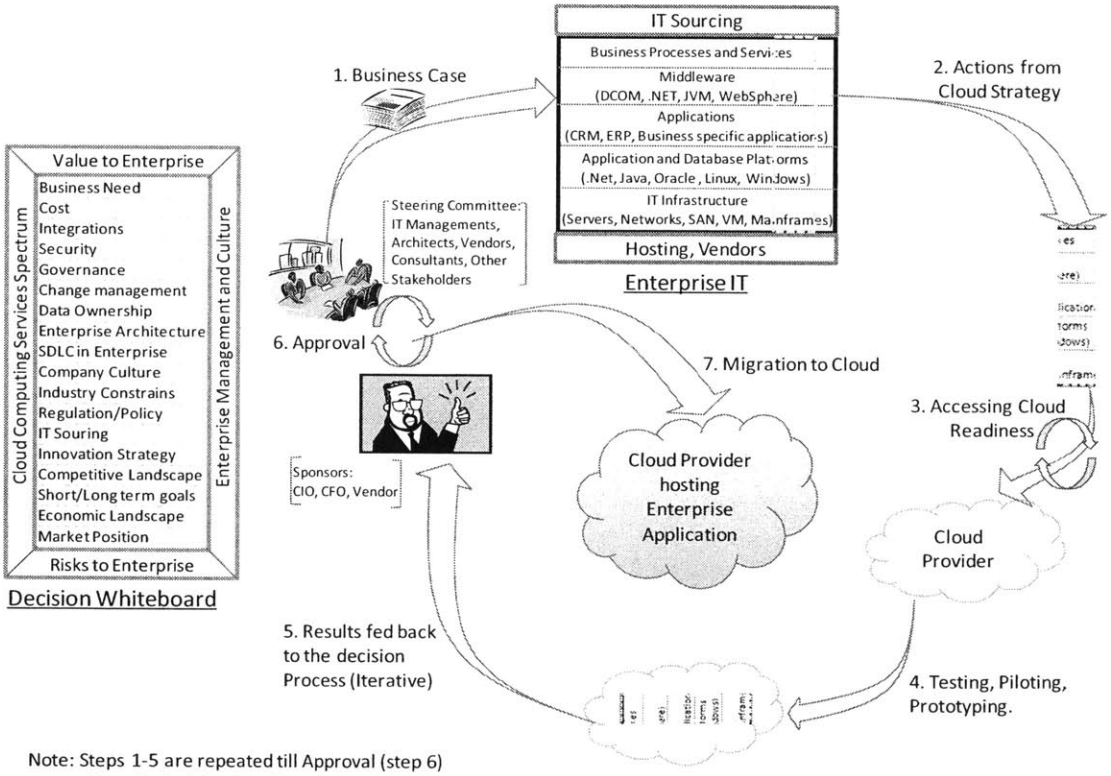
Chapter 4: Migration to Cloud

Once an enterprise has made decision to allocate part of its budget to explore the Cloud space or bring in a brand new service from Cloud to the enterprise, what are the frameworks they should follow? What qualifications criteria they should look for Cloud adoption, what applications or areas of their business they should move to Cloud, what areas they should leave on-premise for now and how they should define their short and long term Cloud strategy. Cloud space brings lot of opportunities but different enterprises and industry domains will have their unique drivers and constrains for Cloud computing adoption. To answer these questions and many others we look at the processes and frameworks that enterprises can adopt to make a smooth transition to Cloud.

In this chapter we look at the generic decision and migration frameworks which can be adopted and customized by enterprises to make a case for or against Cloud computing. Listed frameworks are basic representation and can be peeled down further for specific scenarios or industry requirements. The outcomes of "decision framework" are - should we move to Cloud or not, what should we move, when should we move. Given that enterprise has made the decision to move to Cloud, "migration framework" guides on how to move to Cloud – what are the current opportunities in Cloud, what Cloud computing architectures are available, which applications are good candidates for which Cloud architecture? We also explore frameworks and migrations path and then compare them with real world examples on how enterprises are exploring and moving to Cloud later in this Thesis.

Decision Framework

Decision frameworks adopted by various enterprises will depend on hard factors like cost savings, performance benefit etc and soft factors like agility in the enterprise IT, culture of the company, competitive landscape etc. At a high level there will be some sort of steering committee which will comprise of key stakeholders in the organizations, they will work on the business case of going to Cloud. Once the Cloud migration strategy is in place the readiness of organization and its applications to move to Cloud will be assessed through pilots and prototypes. The results of pilots and readiness testing will drive the approval from sponsors of the Cloud migration initiative. A Cloud migration decision framework might look like the one in Figure 11, although it might differ in approach by IT departments in different enterprises. This generic Cloud Migration decision Framework consists of following steps from creation of Business Case to Approval:



Note: Steps 1-5 are repeated till Approval (step 6) or an alternate decision is achieved.

Figure 11: Cloud Migration Decision Framework

In a given enterprise the Cloud migration initiative is likely to come from a set of sponsors in senior management. They might either form a loosely managed group of folks from different areas to assess readiness or may create a more formal group like steering committee which will work with business and sponsors to drive the Cloud migration strategy.

1. Creation of Business Case: The very first step before big initiative like moving on-premise applications to Cloud would be the creation of business case. Business case will include the metrics indicating financial, performance and key business benefit which will give clear reason to move (or not) to Cloud. An important part of business case will be setting of a baseline for assessing the impact of the investigation and estimating high level costs and resource requirements.

2. Cloud Migration Strategy: Once the business case is in place the next steps would be to come up with an Cloud computing migration strategy by aligning the investigation with the business strategy, and show how it can deliver business value. Show how the investigation might lead to changes that will affect business and the IT architecture environment. An important part of the Strategy will be to work with key stakeholders to identify business needs.

3. Assessing Cloud readiness: Next, evaluate which Cloud computing models, architectures, technologies and best practices will make sense to implement (e.g., Private, Public or Hybrid Cloud) in your enterprise setting. Also assess the budgetary, resource and technical requirements necessary to prepare the business for pilot/testing phase of investigation. From financial perspective develop a total cost of ownership analysis and review established policies for assessing risks and change management. There are many tools available which one can use to get to numbers quickly, like ROI calculator at http://www.getapp.com/Cloud-computing-roi-calculator which allows you to calculate costs for IT infrastructure, development costs, projects, IT services costs on-premise and see, with average % reduction how much an organization can save in Cloud.

4. Testing, Piloting and Prototyping: Identify the application/business processes within enterprise which will be good candidates for testing/piloting in Cloud. For most organizations these will be non mission critical applications yet important ones to be able to show the performance and cost benefits.

5. Results/ Observations: Develop and implement the pilot/prototype and communicate the results. Note down any specific observations which might be of interest to the iterative decision making process.

6. Feedback to Decision process: Steering committee will analyze the findings of readiness assessment and pilot/prototype effort. Depending on the results they might revise the strategy and business case creating subsequent iterations in the decision process. Results and findings are also presented to senior management, key stakeholders and business leaders to get their inputs and direction.

7. Decision: Depending on the assessment outcome steering committee might work with sponsors to make a decision for or against Cloud computing migration. Decision might include the parameters like choice of Cloud architectures, applications to migrate, change in business process and their management etc...

Decision making process will also include factors such as:

- Sourcing Strategy.
- Enterprise Architecture.
- Relationships with vendors and business partners.
- Company culture pertaining to IT innovation and adoption by business.

Decision process is a required step to customize the Cloud adoption to a given enterprise - Understand the Cloud-computing trends and assess what are their possible impacts on business objectives, strategies and processes. Assessment will indicate what should change — and what needs do not change — and a tentative time frame for those changes (Dreyfuss, Feb 2010)

Migration Framework

Once the decision has been made to move to Cloud, there are still important steps which should be followed to achieve a smooth transition. Enterprise needs to come up with migration strategy and plan before they can actually implement the business process in Cloud. Also important is feeding back the learning from implementation for future migration decision and is essential to the whole migration framework.

Migration Strategy

Migration Strategy involves finding and understanding various Cloud migration options available to an enterprise. Look at the business priorities and work on a strategy that offers a balance between the migration costs and getting needed business benefits in time. This also involves looking at all the internal and external technology and business dependencies and deriving the most optimal way from the available options. Migration strategy should include discussion on data integration, change management of business processes, outsourcing, user training, documentation and architectural implication.

Cloud Migration Strategy should be in place even if there is no immediate need for Cloud migration, this will help enterprises to get on quickly with migration plans if the need is identified in the future decision processes.

Systems Dynamics depiction in Figure 12 below shows how various parameters influence each other, decision framework and the migration strategy. For example, the need for customization of a Cloud offering, which will replace on-premise application might affect the costs as well as Cloud migration options, which in-turn affects the migration framework and strategy. The parameters might differ depending on the IT implementation of a given enterprise but this gives a sense of how various parameters interact with each other to influence the migration strategy.

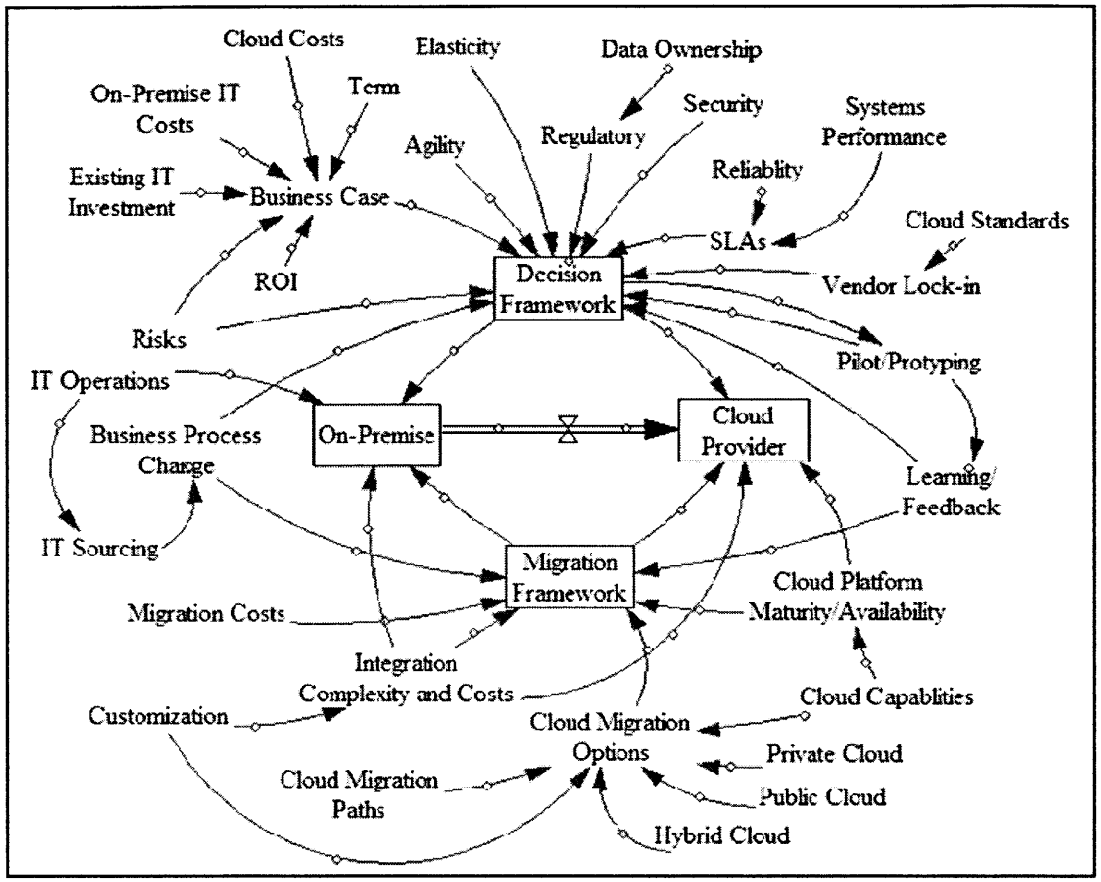


Figure 12: Systems Dynamics depiction of various parameters influencing Cloud decision framework and the Cloud migration strategy

Migration Path

Depending on the Migration strategy enterprises have following three options with a Cloud infrastructure – private, public and hybrid. Within each of these options they have the migration paths of - IaaS, SaaS or PaaS (see Figure 13 below). The choice is driven by business priorities such as economics, scalability, on-demand provisioning, and pay-as-you go model and constrained by factors such as security, migration costs, existing IT investments etc. Enterprises also have option to leverage a hybrid approach in which they can mix and match migration paths depending on business criticality and security concerns of a given application or business process.

In the spectrum of Cloud offerings the relative standardization and cost effectiveness increases as you go from Private to Hybrid to Public option. So a Private option can give you benefits like ownership of data and perceived security but it might cost you more than a public Cloud option. In current environment even though the benefits of moving to Cloud computing are clear, the security and data ownership fears are keeping enterprise to make a full hearted move – Private Clouds fill this gap by providing the economics and giving control of data and security to enterprise IT.

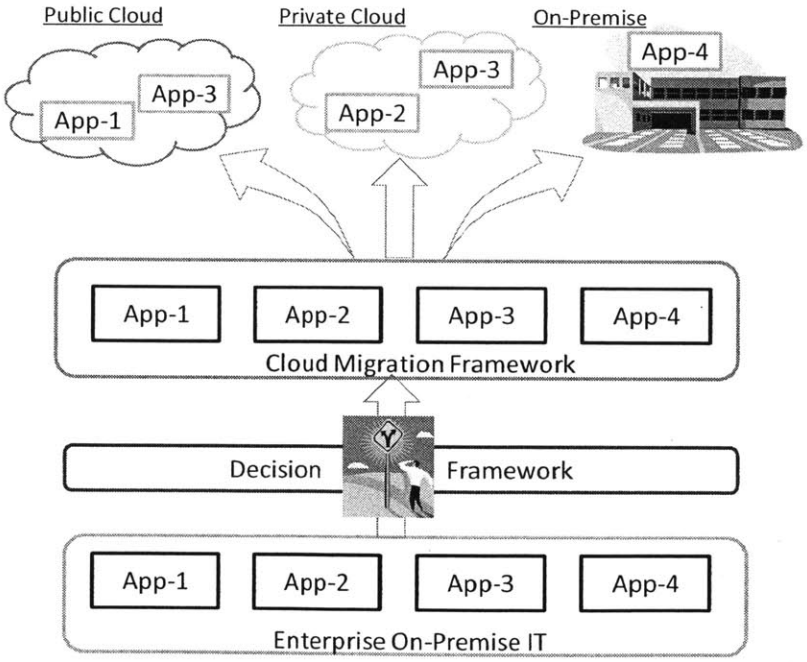


Figure 13: Cloud Migration paths for Enterprises

Figure 14 below shows more detail about Private, Public and Cloud implementations and their comparison. Cost savings and degree of "standardized applications and services" increases as you go from Private Clouds to Public Cloud. The degree of sharing between Cloud tenants increases as you go from Private to Public Cloud. Private Cloud (Internal Cloud) is ideal for organizations that are risk averse and have sensitive data which they do not want to see outside their enterprise perimeter. Hosted Clouds (Hybrid) is good first step for non critical applications or good second step for critical applications after an organization has gained enough experience and confidence from Cloud to take it to next level. Pubic Cloud offers maximum cost savings and performance benefits and might be only type of Cloud in future but till it matures to that extent the enterprise will use Private and Hybrid as part of their Cloud migration strategy.

	Public cloud	Hosted cloud	Internal cloud
Where it resides	Internet-connected data centers	Internet-connected data centers	Corporate data center
Tenancy model	Multiple clients	Multiple clients	Single company
VMs reside on	Shared infrastructure	Dedicated but hosted infrastructure*	Dedicated infrastructure
Security model is	Common across all customers, with limited configurability	Common across all customers, with greater configurability	Unique to the customer
Cloud managed by	Provider	Provider or IT ops	IT ops
Infrastructure managed by	Provider	Provider	IT ops
Billed by	Consumption	Monthly for dedicated infrastructure, excess billed by consumption	Consumption-based metering for BU chargeback or allocation

*Infrastructure may be fully dedicated or partially shared.

54043 Source: Forrester Research, Inc.

Figure 14: Cloud Migration paths for Enterprises

Planning and Implementation

Once a migration strategy is in place it should drive the planning and implementation phase of Cloud migration. During migration planning, understand the variables and their affect on the business process. Categorize and prioritize the variables in the bins which will make it easier to deal with them during implementation. At the enterprise level, make sure to involve the stakeholders early in the process so that they have vested interest in the success of Cloud migration. Identify the dependent upstream/downstream applications and processes and facilitate clear communication through a well documented communication plan. Buy in support of stakeholders outside the organization (vendors and business partners), they should see benefit in Cloud migration as oppose to challenges. In large enterprises with complex weave of systems and processes its critical to involve enterprise architecture group and make sure they are onboard with moving applications/business processes to the Cloud. Enterprise architects will also highlight any integration or architectural implications which might be costly in long run.

IT services and operations should also be involved from early on, to get their input on any support implications and anything additional they might have to support during the transition period. Early involvement will give IT operations the window to hire needed resources to support the migration of application(s). In addition there might be changes needed on the support process (helpdesk calls, SLAs, Knowledge base etc...) to make sure users continue to get the service during migration phase. In new support model of Cloud computing, IT operations will also need to make sure Cloud providers are delivering what is agreed in SLAs.

Finally, during implementation make sure the testing, qualification/validation and back-out plans are in place. There might be challenges around moving and securing large amount of data to Cloud. Check for up/down stream dependencies and performance pitfalls. Make a preferred Cloud provider list in place for various services needed by the enterprise and select providers that have already achieved success in the technologies and business processes your applications will use.

It's always recommended to take small group of applications and move them in a phased approach for better understanding and risk mitigation. During testing phase make sure proper impact analysis (technical as well as business) is done. Depending on the success of testing, customize or package the application/service for easy consumption by enterprise users. All affected users should be communicated about the change and any training they need to go through. (Chetan Kothari, 2010)

IT Operations Strategy

In the new world of Cloud computing, IT support will have to consider Cloud as an extension of their on-premise capabilities and make sure they are onboard with new requirements to deliver required support and make sure Cloud providers deliver (through SLAs) same or better quality of service to business. Cloud gives instant access to computing resources for innovation in business but it can easily create nightmare for the IT operations. The fact that it's so easy to provision computing resources and integrate them with on-premise IT, users might add to the complexity of the systems used by enterprises. IT Operations and enterprise architecture groups should be involved during these decisions to make sure the enterprise standards are followed and that applications are supported. For example, IT operations group and Enterprise architect can agree on a limited agreed stack of technologies which can solve the enterprise's range of business needs (Golden, 2010). They can have mechanisms in place which let the stakeholders know easily the impact of new application and business process migration to Cloud on up/down stream applications and business processes.

Feedback loop - Once the application(s) has been migrated to Cloud there are opportunities to learn from the implementation, user experience, vendor experience, performance metrics, cost savings and ROI. Feedback new found problems, new discovered risks and success stories to the Migration strategy so that future Cloud adoption can be adjusted accordingly.

Cloud Architectures

Traditional software used in enterprises is meant to be used only by the organization and its divisions; some might have links to their business partners for small number of shared applications. The prevailing application platforms, such as .NET Framework, Java and others, have been designed to meet single enterprise organization use model. An application deployed on-premise relies on an underlying application platform built around an application server, such as WebSphere, JBoss or .NET Framework. The application platform also uses a data platform, typically built around a database management system. Both data and application platforms, in turn, work over the underlying infrastructure built around an operating system, such as Linux or Windows. The entire stack serves one user organization as shown in Figure 15 below.

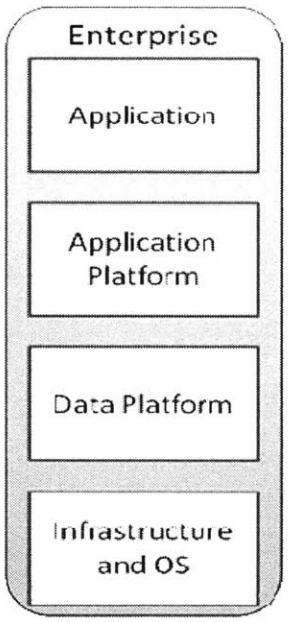
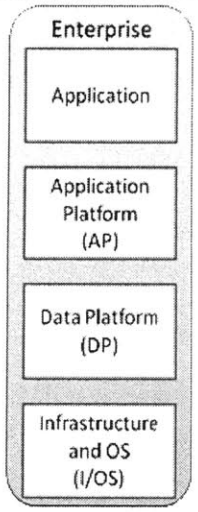
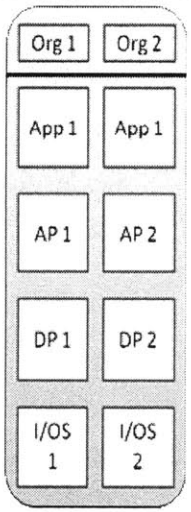
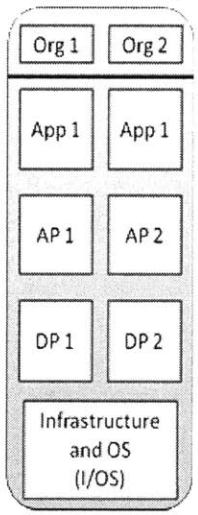
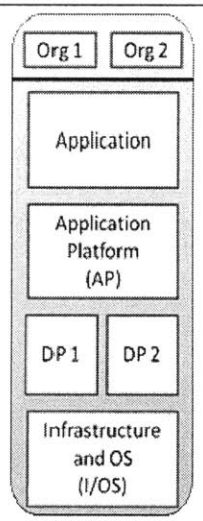
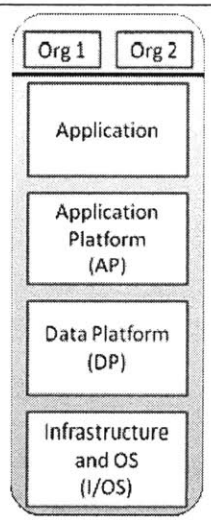


Figure 15: Layered architecture in a typical enterprise IT application

This layered technology architecture, well-established in enterprise computing also applies to Cloud computing. As the computing resources that underlie the business application are layered, the application's multi-tenancy can be implemented at any of the underlying layers (Natis, 2008).

Table below compares existing enterprise architectures to variations of Cloud architectures, based on sharing the computing resources (layers) that underlie the application (Natis, 2008):

Enterprise	Shared Nothing	Shared Infrastructure	Shared Process	Shared Everything
				
Application is deployed On-premise for use by one organization. Resources acquired based on maximum forecast use. The entire stack serves one user organization.	Each organization has its own stack of resources very much like traditional hosting. Cloud provider provides the same application to all organizations with limited customization.	Each organization has dedicated stacks of technology but infrastructure resources are allocated from a shared pool (virtualization).	Each organizations share all the layers except the data platform. The reason for data platform isolation is to ensure the integrity of data of a given organization.	In this architecture everything is shared. Data isolation and integrity is taken care are the application level.

Enterprise	Shared Nothing	Shared Infrastructure	Shared Process	Shared Everything
New group of users and enhancements needs more resources which are fulfilled by buying dedicated computing resources for the application.	Easy to transfer on-premise applications to off-premise because full stack can is hosted off-premise.	Shared computing resources are allocated to applications as needed. Applications are charged in proportion to the use of the resources	Shared computing resources are allocated to standard applications keeping data control and ownership with organizations.	All stacks are shared allowing all benefits of economies of scale and use of standard applications.
Becomes complex and costly with time and does not provide the solutions needed business in time and at the desired cost.	Might provide some operational costs savings but not to the scale expected from true Cloud implementation sharing layers below application with other tenants.	Redesign of application might be needed to take full benefit of resource virtualization and elasticity.	Needs coding to effectively manage the allocation of resources among organizations using the stack and data transactions isolation.	Tenant isolation, customizations and organizational specifics are handled at the application level.
Complete control of the application and its resources down to the hardware level.	Complete isolation of multiple organizations hosted at Provider, down to the hardware level.	Easy entry option to Cloud computing space resulting in immediate cost savings	Possible hesitation to allow business data to be handled outside premise for security reasons.	Security, Data ownership and privacy concerns might be there.
Examples: On Premise Microsoft Exchange, Enterprise SAP implementation.	Examples: Microsoft Exchange Dedicated Edition; SAP CRM On-Demand; Oracle CRM On-Demand.	Examples: Amazon EC2, Microsoft's Windows Azure Services Platform and IBM's Blue Cloud.	Examples: Cordys' platform, Magic Software Enterprises' uniPaaS, Relationals' LongJump.	Examples: Google App Engine, RollBase Platform as a Service, Salesforce's Force.com

Table 1: Available variations of Cloud architectures

Chapter 5: Case studies

While doing my thesis I got opportunity to work on many mini projects which helped me research and gather knowledge about the Cloud computing space. In addition to that I was able to interview industry experts who gave me their views and key insights in the Cloud computing. This section lists the real world examples of enterprises on the path to migrating some their on-premise IT services to Cloud. I wanted to find what business and technical thought process they went through, how did they choose which application to move to Cloud first, what process they followed to choose the vendor, what has been their experience so far, what are their concerns and finally what are their short term and long term Cloud migration plans.

In the process of interviewing I collected lot of data which I have filtered and picked only the portion which is relevant to the topic of Cloud adoption and migration strategies. I was able to interview two IT leaders involved in Cloud computing in pharmaceutical firms and one retail giant. I have changed the names of the companies on their request and also changed name of the applications they moved to Cloud. Rest of the data is accurate and helps us understand how some of the current enterprises are approaching to Cloud computing space.

Following are the three real world scenarios which are covered in this section:

a. Cloud migration of a major US based pharmaceutical giant – Saachi Pharmaceutical.
b. Major retail S-Mart's move to Cloud infrastructure.
c. Email migration to Cloud of a big UK based Pharmaceutical enterprise – Remedy Pharmaceutical.

Saachi Pharmaceutical's Cloud Strategy

Saachi Pharmaceutical (name changed upon request) is one of the top five pharmaceutical companies in the world. Headquartered in US, it has also grown like other pharmaceuticals through years of mergers and acquisitions. Saachi has a decentralized organization structure with each of the business units having their own IT departments. Central IT is only responsible for back-office services. There are advantages to on-premise IT aligned closely to business namely, good turnaround, better understanding of business needs, and opportunity of high customization of applications. This though comes at a price, which is driving organizations including Saachi Pharmaceutical to move towards centralized IT. Apart from centralizing its IT operations Saachi is looking at Cloud to save costs and fulfill their High Performance Computing (HPC) needs.

I got opportunity to talk to one of the IT managers in Cloud computing group in Saachi Pharmaceutical. Here is how Sponsors and IT managers in Saachi are taking advantage of Cloud and still keeping the risks associated with Cloud in check:

Governance:

Saachi's senior management and CIO are on-board with the idea of trying Cloud space. Their first attempt to move data collaboration application to Cloud was sponsored by CIO. Central IT is also on-board with the idea of Cloud and they are part of Cloud migration initiative. They also discussed with the enterprise architecture and legal team to make sure there are no other implications of putting data out on Cloud.

Migration Strategy:

Saachi started with simple use cases on public Cloud, creating Proof of Concepts (POCs) and pilots. They used "Setup-Test-Repeat" model to play with various "computing configurations" and fine the one which suits their need. Pilots were used to demonstrate the business value to stakeholders. Soon after PoCs and pilots they picked a "data collaboration application" where data was not bound by regulation and moved that to Amazon Elastic Cloud. They were able to show phenomenal cost and performance

advantage. With success of data collaboration application they are now looking at Cloud as primary means for their High performance Computing needs. Saachi has done data classification (public, private, confidential) which gives them visibility of possible applications and associated data which are good candidates for Cloud. They choose applications based on criticality (for now they are only picking non business critical apps), potential savings and performance gains and then make decision on migrating it to Cloud. Saachi has also successfully piloted and adopted other layers of Cloud - SaaS in the form of HR application which is fully hosted in Cloud. They are also using Cloud as secondary computing resource when their on-premise computing resources are peaking (Cloud Bursting).

Cloud computing use cases executed by Saachi Pharmaceutical (Data from the slide-deck provided by company):

- Public data/applications –Public Cloud.
- Elasticity (peak demand problem).
- Private External data –Private Public Cloud (Collaboration or B2B or Enterprise Data bus integration).
- Scratch storage (temp space).
- Backup & Archiving.
- Disaster recovery.
- Development and Testing.
- CapEx to OpEx transfer.

User Experience:

Users of Cloud and business units see following benefits due to Cloud migration:

- Elasticity - Business likes that they can scale up and down as needed an only pay for what they use.
- Provisioning time – Provisioning time is one-tenth of usual On-premise provisioning at Saachi Pharmaceutical.
- Cost – Cloud implementations costs far less than on-premise. They were able to implement data collaboration application in Cloud at 10%-20% of the estimated cost if they would have done it in-house.
- Reliability – In their implementations so far users are happy with the availability of the applications which are migrated to Cloud.
- Utility model – Business likes the pay as you go model.

Risks and Mitigation:

IT Manager at Saachi said, the value in Cloud model is visible its matter of selling it to the business and IT and making them comfortable with risks through PoCs and Pilots. To make sure they do not run in to patient data and privacy landmines, Saachi has done clear data classification which helps them find what not to move to Cloud. Data owners and legal teams are involved in data classification. In addition they have implemented encryption to make sure data is not easily readable even if its seen by someone. Only machines on Saachi's network can access the Cloud application (through IP filtering).

They have concerns around data ownership – what happens to data after decommissioning; there is no way to confirm the purge of data. SLAs are standards and cannot be customized (at least with the vendors Saachi was working). The reliability has been good so far but it's still a concern that vendors do not have any incentive for customers when there is a major outage causing business implications. SLAs might be standard but as visible with Saachi's experience there is lot of redundancy build in Cloud and customers can build additional layers of redundancy for critical applications in Cloud at modest cost. Saachi is also looking at how to utilize Cloud for their Disaster recovery process.

Data Classification model used by Saachi Pharmaceutical (Data from the slide-deck provided by company):

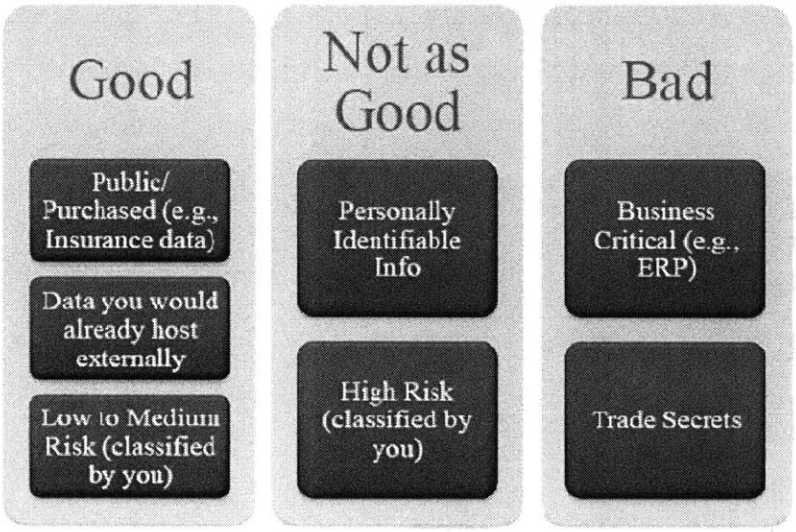


Figure 16: Data classification at Saachi Pharmaceutical

Sourcing:

Saachi used third party vendor to do the migration of their initial Cloud application from hosting to creation of periphery modules and integration with on-premise systems. Their data collaboration application mostly used open source elements. The business partner they used for Cloud is someone who has done the migration and new Cloud application projects for scientific community (this shows the availability of vendors specializing in particular areas of business). They have also involved their outsourcing partner for ongoing support and development for Cloud applications. There is a dedicated group in Saachi which makes sure the Cloud initiatives are driven seamlessly with collaboration from stakeholders within and outside Saachi Pharmaceutical.

Benefits achieved by Saachi's by their Cloud move (Data from the slide-deck provided by company):

- Reach final drug clinical dosing models in a matter of days using Cloud technology vs. months using internally dedicated hardware.
- Shorten response time for FDA inquiries from 10 to 2 days.
- Reconstruct a 100 CT Scan image study in 2 days vs. 92 days.
- Process a 100,000 molecule file in 45 minutes using Cloud vs. 7 hours on a Scientist's local machine.
- In only 4 months, implement an informatics data warehouse enabling scientists and investigators to research drug and clinical trial information in one location (would have taken 9-12 months internally).
- Reliable storage and rapid retrieval times (currently storing ~20 TB).
- For every drug clinical dosing model we can execute ourselves using Cloud technology, we save $350k by not outsourcing to a 3rdparty.

Saachi is looking at global applications accessed by their offices throughout the world to assess if they can be moved to Cloud – This might give them a great potential for cost savings and performance benefits. They are expanding the use of Cloud to archiving, storage and also looking at PaaS in the form of Microsoft Azure.

Suggestions from Saachi based on their experience with Cloud (Data from the slide-deck provided by company):

- Be wary of SLAs because the impact to your business will likely be much greater than your credit.
- Valuate multiple providers and vendors to avoid lock-in.
- Educate your Legal staff.
- Partner with Corporate I/T.

S-Mart's move to Cloud infrastructure

S-Mart (name changed on request) is one of the top 10 retailers in USA. They went through a merger in last five years and are in the process of IT systems and business process consolidation. I got opportunity to visit their data center and talk to their Vice President, Data Center Operations & IT Governance.

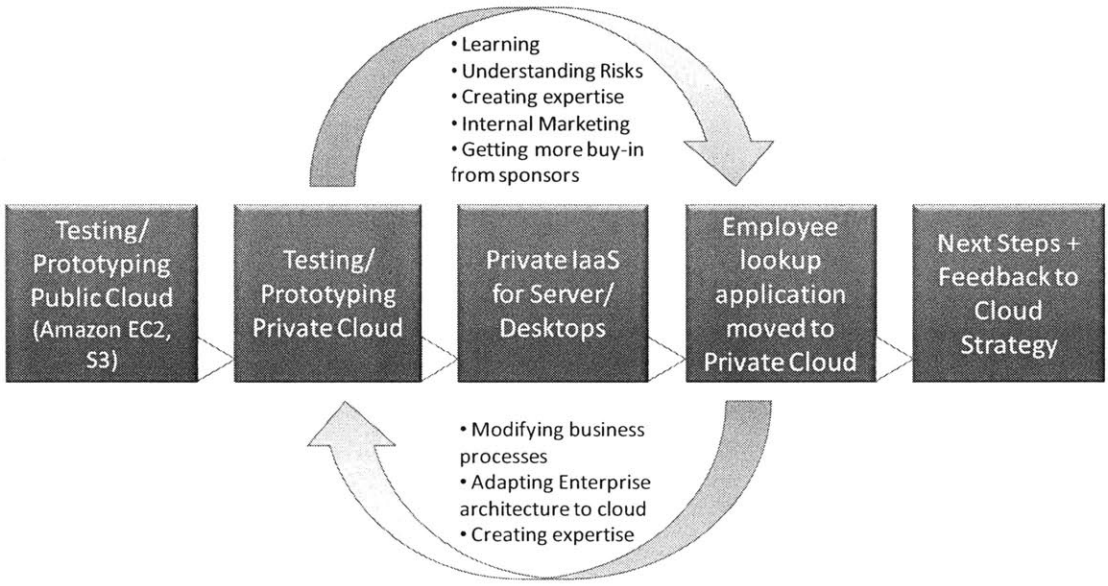


Figure 17: Cloud Infrastructure migration process adopted at S-Mart

S-Mart went through the cycle of testing and prototyping on public Cloud but then moved to Private Cloud for IaaS (see Figure 17 above). They have a mix of Public and Private Cloud initiatives now, but are concentrating on Private more for now.

Testing and Prototyping: S-Mart started their Cloud move by testing the process on Amazon's EC2 Cloud. In addition they also tested Amazon's S3 storage service. Idea of this exercise was to understand firsthand what a Cloud infrastructure can offer, what are the limitations and what can be learnt for it to make a serious move towards Cloud.

Private Cloud: Gaining from the understanding from Amazon Cloud, S-Mart has started on their Private Cloud prototype, starting with infrastructure as a service within S-Mart.

They are using POD architecture where each POD is a bundle of high performance computing resource which can be cloned to create more PODS. An application can span single POD or more and many applications can run on single POD. PODs can scale up and down thus providing the Cloud functionality in the security of data center. S-Mart has used these initial POD architected Private Cloud to create 550 virtualized servers and 330 virtual desktops. Idea here is to monitor, learn, adopt and see if there is opportunity to move more of the conventional infrastructure in to PODs architecture.

Using available standards: To avoid reinventing the wheel, S-Mart is using what has already been done by others in the Infrastructure as a Service space. They are using Zen, UNIX and Websphere to create other layers in their Private Cloud.

IT operations: Till now S-Mart is able to use their current support staff by upgrading their skills but have plans to use their outsourcing partners for support once the adoption increases. This shows on-boarding of stakeholders to create internal skill set and also reduce ongoing operation costs.

Business processes: Their plan is to offer virtual servers and desktops to the organization and cross charge based on the usage like you would do in a public Cloud. This is enabling them to sell cheaper infrastructure to business and avoiding the discussions of security in public Cloud.

SaaS: Most of S-Mart's initial move to Cloud is in IaaS space but they are able to move their "employee lookup application" to private Cloud. They are using this as a showcase to get more buy-in from management and users.

Key Performance Indicators: S-Mart has found that they can provide infrastructure services using Private Cloud 40-60% cheaper than the traditional on-premise solutions. Their main Key Performance Indicator (KPI) has been cost avoidance – they have averted lot of their server/desktop purchased to private Cloud avoiding potential costs.

Next steps: S-Mart is happy with their current success in using and learning public and private Clouds. Their next steps include expanding on Private Cloud and do following in short term:

- Establish Storage Cloud in-house.
- Move Disaster Recovery processes to Cloud.
- Continue the phased/staged approach assessing/correcting the move towards Cloud computing.
- Work on business processes to make sure any inherent risks in the Private Cloud implementation are mitigated.
- Looking at non-core applications which will be good candidates to move to Cloud.

S-Mart has been successful in learning through prototyping and POCs. They have used their available IT resources to create Private Cloud (using POD architecture) and also saved costs by using existing operations staff. They have achieved effective utilization and are able to avoid cost of new IT infrastructure purchases.

Remedy pharmaceutical's move to Cloud based email

Remedy Pharmaceutical (name changed on request) is one of the largest pharmaceutical companies in the world. Headquartered in UK, it has grown to be one of the top five pharmaceuticals through years of growth, mergers and acquisitions. Remedy decided to move its email and collaboration services to Cloud - moving approximately 90,000 email users from Lotus Notes to Microsoft's Exchange Online, a Cloud delivered service. What made Remedy to go through the move, why now, what was the decision process and what were the economics of the move (Schadler, Should Your Email Live In The Cloud? A Comparative Cost Analysis, Jan 2009).

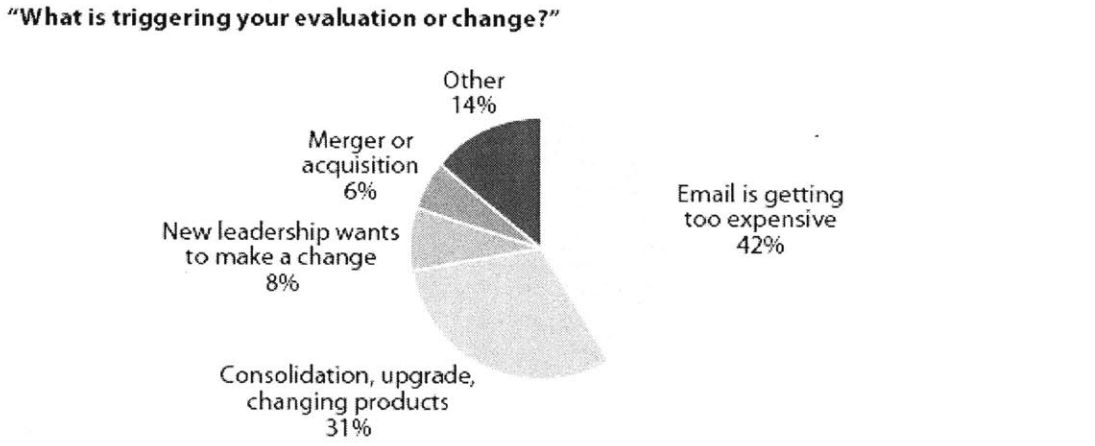


Figure 18: What's triggering moving email applications to Cloud

Major reasons triggering an evaluation or change of an enterprises email systems are: Costs issues, Consolidation movement, merger/acquisition or senior management's bias. Remedy went through a merger back in 2001 when there was opportunity to choose either Lotus Notes or Exchange and they decided on former for reasons surrounding better collaboration tools in Lotus Notes compared to MS Exchange then.

In 2008 Remedy went through decision process to decide if they want to keep the existing Lotus notes infrastructure or find something else which might save company money.

Following had changed since merger, which resulted in Remedy to re-think about its email hosting strategy:

- Microsoft offering has matured enough to compete with Lotus Notes and in addition offered good cost advantage with their Cloud offering.
- Lotus notes email infrastructure was towards end of life which triggered the discussion.
- Remedy is going through consolidation of IT operations to save cost like many other firms in Pharmaceutical domain. Idea is to spend more IT resources in core business activities and leave rest to the pros who can do it better and at a lower cost.
- Years of Lotus Notes in the organization had led to heavy customization of collaborative tools. This on one hand gave the employees the freedom to better utilize the Notes environment but on the other hand created integration nightmare for Remedy's business partners who were on different email platforms. The need to go on a more accepted and standard platform was also one of the key inputs in Remedy's decision making.

Cloud Migration framework adopted by Remedy:

- **Capability matching:** Remedy analyzed the usage patterns of employees and different segments of users. This was to find if a dedicated client makes sense for a given group of users or web client will suffice. Segmentation of users helped Remedy to match the user base with the capabilities in decided solution.

- **Cost Comparison:** Remedy calculated the end-to-end cost of their on-premise email systems including servers, clients, licenses, support and maintenance costs. Remedy also did user segment based cost analysis to understand how much it costs to provide email to a given user base – much like the one listed below

(Schadler, Should Your Email Live In The Cloud? A Comparative Cost Analysis, 2009). Cost scenario below is for 15,000 employees and shows the cost advantage to move to Microsoft Cloud.

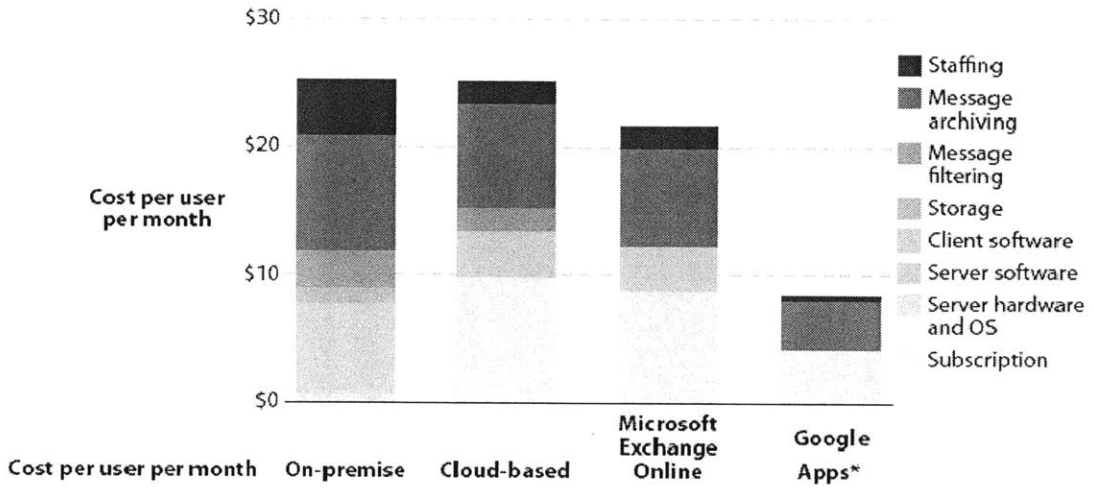


Figure 19: Cost comparison of hosting emails in different models

- **Transition Plan:** Remedy made sure they do not plug the switch off on Lotus Notes on a given weekend but made a transition plan to make sure users get enough time to move their collaboration data to new environment and get needed training to use the new environment to achieve same or better productivity than the one it's replacing.

Remedy has been successful in achieving its metrics surrounding email transition to Cloud. They have hit some roadblocks with migration of their collaboration tools but are on their way to complete that. Even with the challenges around communication, costing, and training the email move to Cloud has resulted in cost savings and strategic advantage of moving away from supporting non-core applications like email and concentrating their IT resources on core business initiatives.

Summary and Conclusion

Currently enterprises are going through consolidation to reduce their IT operations footprint. They are becoming leaner to maintain their competitive advantage by putting more of their available resources in to the core businesses as oppose to IT operations.

Traditional IT systems implementations have become more complex and costly to maintain. They are not able to deliver needed business benefits in desired time and cost. Cloud Computing solves lot of the shortcomings of traditional on-premise systems by delivering services for business needs while hiding the systems complexities. Enterprises can start taking advantage of Cloud computing by looking at their current IT implementations and surrounding business processes and by analyzing how they can move them effectively to the Cloud computing space without compromising current IT investments and security.

Cloud computing has long way to go before it can cross the roadblocks around standards, security and data ownership. Till then there will be flavors of Cloud computing, packaged and sold by different vendors to suit specific business needs. Private and Hybrid Clouds are important steps which will increase the knowledge and confidence of enterprises leading to increased adoption in coming years. Enterprises are already trying to gain better understanding by moving their non-core business applications to Cloud. This is evident in the three interviews I took where all three enterprises are on path to test available Cloud options and choose the ones which makes most business sense for their environment.

Enterprise need to research, test and decide which Cloud services to pick, customize, and implement to make most of the available Cloud opportunities. While most Cloud services are immature today and thus really only best applied to new applications and services, as they mature, their applicability to existing applications will increase. Enterprise will have to define their Cloud decision and migration frameworks and use it to understand current Cloud-computing trends. They will need to analyze the impact of

moving to Cloud on business processes, come up with decision on what should be moved and when and what should not be moved to Cloud. There is no standard template on migrating on-premise applications to Cloud but each organization can do some kind of classification of key business parameters (like Saachi pharmaceutical did with data classification as base of deciding what can and cannot be moved to Cloud) and prioritize applications/business processes which are possible candidates for migration.

Cloud migration strategies should be looked with the lens of companies' current state in terms of culture, politics, sponsorship and future IT goals. In the interviews Saachi's migration to Cloud were more service based - they took applications providing a certain set of service and moved whole service to the Cloud. Saachi has clear "data classification" which makes it easier for them to find which applications are good candidates for moving and which are not. S-Mart on the other hand is more cautious, hence taking private Cloud route. Remedy pharmaceutical is moving away from supporting noncore IT services like email and has moved all of it to Cloud saving costs and increasing productivity by using available IT resources on core business functions. The trends discovered in these interviews are not uncommon and are seen in the strategies of other enterprises.

Looking at current trends, future seems to be on the side of broader Cloud computing adoption. Investments from big IT players will push enterprises to Cloud adoption due to the fact that their existing on-premise platforms will be better compatible with their Cloud offerings. IT giants continue to acquire more and more service specific vendors to widen their service spectrum. Future points towards handful of large Cloud players that will offer IT services with better performance indicators than on-premise. When that time comes, enterprises should be ready with their business case, decision framework and Cloud migration strategy.

Appendix A

Table below shows the price comparison of the Cloud infrastructure services available from some of the Cloud players in the market.

	CPU Time (CPU hour)	Storage (GB/month)	In Bandwidth GB	Out Bandwidth GB	Comment	Function
Google App Engine	$0.10	$0.15	$0.10	$0.12		Hosted database, on-demand storage and utility computing platform. It has created a Web application platform (PaaS) that includes bandwidth and storage scalability, too.
Amazon EC2	$0.13	$0.15	$0.10	$0.17		IaaS offerings. It has done a very good job of making raw compute power and storage available.
Microsoft Azure	$0.12	$0.15	$0.10	$0.15		Azure Platform is Microsoft's cloud platform which leverages existing Microsoft Services as a bundle.
Rackspace	$0.12	$0.15	$0.08	$0.22	Storage price is 15cents for 5GB	Managed hosting provider, a prominent presence in the cloud space.
GoGrid	$0.19	$0.15	$0.00	$0.29		Cloud Hosting, Cloud Computing & Hybrid Infrastructure
ATT	N/A	$0.10	Included in per GB Cost		Storage price is for 1GB in or out.	Enterprise Hosting Services
Savvis	$499 per month for a single core, 4GB RAM 32 GB Disk Space					Managed IT infrastructure services.
IBM	$5,700 annual membership, plus per-CPU pricing					(IaaS)Blue Cloud as a series of offerings aimed at linking computers together to deliver Web 2.0 capabilities, enabling corporate datacenters to operate more like the Internet.
Verizon	$250 per month plus daily use					CaaS, IaaS, Storage.

Table 2: Price comparison of the Cloud infrastructure services available from major Cloud players

Data taken from:
Google App Engine: http://code.google.com/appengine/docs/billing.html
Amazon EC2: http://calculator.s3.amazonaws.com/calc5.html#
Microsoft Azure: http://www.microsoft.com/windowsazure/pricing/
RackSpace: http://www.rackspaceCloud.com/Cloud_hosting_products/servers/pricing
GoFrid: http://www.gogrid.com/Cloud-hosting/pricing.php
AT&T: https://www.synaptic.att.com/
IBM, Savvis, Verizon: What's In The Public Cloud - By Andrew Conry-Murray

Appendix B

Licensing Models:

Graph below shows where various licensing model falls in the spectrum of type of software packaging and various software pricing models. In Cloud space the new models like "usage-metered services" and "services with usage quotas" have emerged in recent past (Charlton, 2009).

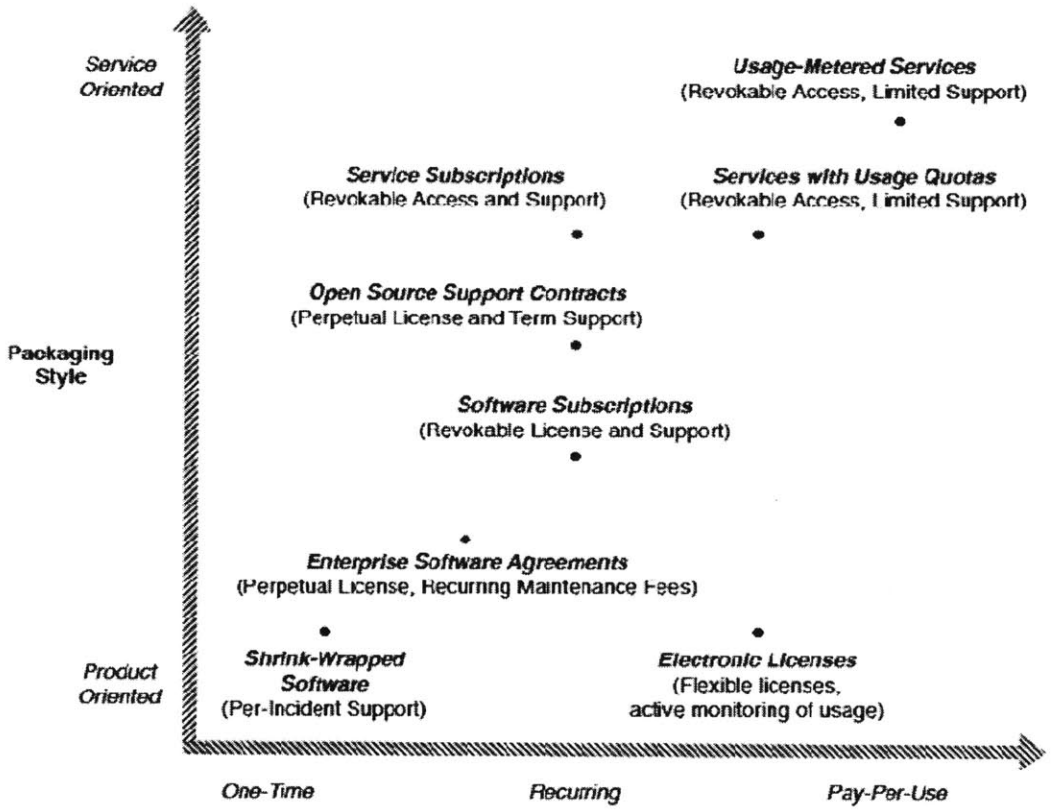


Figure 20: Licensing models based on software packaging and software pricing models

Glossary

On-Premise Systems
Systems deployed within enterprise perimeter which can be well controlled and secured as desired. Traditional Information Technology deployments in Enterprises are on-premise. Enterprise Data center is an example of on-premise system.

Cloud Provider
A service provider that offers customers Cloud services of software, infrastructure or platforms via private (private Cloud) or public network (Cloud) delivery models.

Software Development Life Cycle (SDLC)
SDLC is a structured methodology used in the development of software products and packages through investigation, analysis, design, implementation and maintenance.

Service Oriented Architecture
An application architecture in which defined functions are called to perform specific business processes in isolation with other function. Client from any device using any operating system in any language can use the service as interfaces in SOA are platform-independent.

Web Oriented Architecture
WOA describes a core set of Web protocols like HTTP and plain XML in dynamic, scalable, and interoperable Web service approach.

Virtualization
Virtualization is a process of creation of usable virtual computing bundles/chunks from a set of physical computing resources through abstraction.

High Performance Computing
High Performance Computing is use of parallel processing for running advanced programs efficiently, reliably and quickly. Encompasses advanced software, including scientific workstations, supercomputer systems and high speed networks.

Service Level Agreements
SLA is a part of a service contract where the levels of service on parameters like delivery time (of the service) or performance are formally defined.

Information Technology Infrastructure Library (ITIL)
Information Technology Infrastructure Library (ITIL) is a set of concepts, frameworks and practices for managing Information Technology (IT) and services (ITSM),

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