White Paper

Everything as a Service

Elements of an Effective Enterprise Cloud Computing Strategy

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Across the contemporary innovation technology spectrum, four key disruptive forces continue to shape and reshape our digital world at a rapid and significant pace on a global scale: Social, Mobile, Information (analytics, big data, etc.) and Cloud Computing.

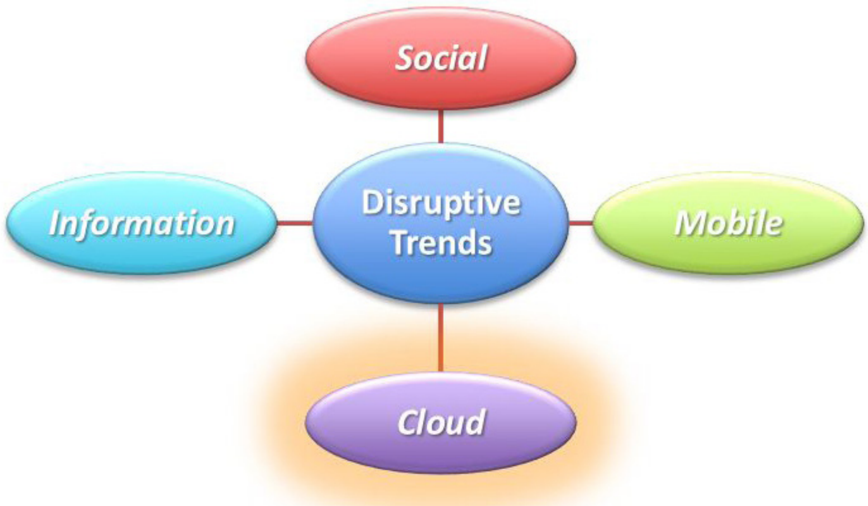


Figure 1 - Contemporary Disruptive Trends

Cloud Computing has been maturing in recent years, both from a technical capability perspective as well as from its increasing use as an enterprise platform for critical applications. Astute technologists recognize that while it still has certain limitations, Cloud Computing also has the potential to further commoditize many technical aspects of delivering solutions to end users with the timeless allure of 'cheaper, better, faster'. Through rapid provisioning and lower operating costs, Cloud Computing can free up both intellectual and fiscal capital to accelerate the introduction of innovative, market-differentiating products and services. Like all technology trends, however, Cloud Computing does not guarantee success; it is simply one more tool available to the enterprise to achieve its mission.

In this paper, we'll go through a high-level overview of some common Cloud Computing concepts without going deep into technical implementation details or making specific solution realization suggestions. Once we've established a baseline, we'll then discuss some recommended components that should be part of an effective Enterprise Cloud Computing Strategy. These components include:

- Business-Oriented Strategic Elements
- Strategic Pace of Adoption
- Cloud Implementation Patterns
- Enterprise Cloud Reference Architecture
- Information Security

Basic Cloud Computing Concepts

Before we discuss Cloud Computing from a strategic Enterprise Architecture point of view, we will first establish a baseline set of definitions to anchor our discussion to. This will include taking a high-level look at several Cloud Computing concepts, such as a conceptual reference model, service delivery models, physical deployment models and common cloud characteristics. The intent is to cover enough of the basics to facilitate the rest of our discussion without getting bogged down into more technical detail than necessary. Deeper technical information on Cloud Computing is widely available and you'll find some excellent references in the Recommended Reading section at the end of this paper.

Cloud Computing Defined

As with the other three disruptive forces (Social, Mobile, Information), Cloud Computing lacks a specific, singularly accepted definition. While they are generally similar, the four definitions below each have their own subtle nuances:

Merriam-Webster *"Cloud Computing: the practice of storing regularly used computer data on multiple servers that can be accessed through the Internet. First known use of the term Cloud Computing: 1996."* [i]	**Gartner** *"Gartner defines Cloud Computing as a style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service using Internet technologies."* [ii]
U.S. NIST *"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."* [iii]	**Forrester** *"A standardized IT capability (services, software, or infrastructure) delivered via Internet technologies in a pay-per-use, self-service way."* [iv]

Table 1 – Examples of Cloud Computing Definitions

Rather than trying to combine the definitions into a single, proprietary definition for the sake of this paper, let us instead call out some of the more common conceptual Cloud Computing elements that can be derived:

- A pool of computer, network and storage resources and services that are made available by one party for consumption by another party
- Elastic scalability is provided and driven by consumptive demand
- Rapid resource provisioning and release capabilities are required
- Resources are made available through a network-based service, typically in a provider/subscriber model over an internet-like communication channel

In some aspects, Cloud Computing doesn't appear to be much different than earlier shared computing techniques such as time-sharing or third party service provider hosting. Some of my contemporaries would argue that we are simply witnessing the natural evolution of the ability to leverage the computing capacity of others in a much more efficient and effective way than was previously possible. Regardless of how it is branded and what infrastructure complexities are abstracted away from the Cloud Service Consumer, someone somewhere has to procure the physical environments and operate them. When you start to add modern cloud capabilities such as self-service, rapid provisioning, automated demand-driven elasticity and ubiquitous connectivity, the value proposition becomes quite attractive and worthy of deeper investigation.

Conceptual Cloud Computing Reference Architecture

Several years ago the U.S. Department of Commerce's National Institute of Standards and Technology (NIST) published the NIST Cloud Computing Reference Architecture, which has become generally accepted as a baseline industry model for Cloud Computing. While there have been nominal variations and extensions derived over time, the fundamental principles still apply today; as such we'll rely on the NIST point of view as the baseline for our discussion.

Figure 2 shows the NIST Cloud Conceptual Reference Model, which identifies primary actors in the cloud ecosystem, along with their various services and areas of concern. Note that this model does not designate whether these different roles are to be fulfilled by intra-affiliates (internal to the organization), inter-affiliates (external to the organization) or a combination of both; the reference model holds true in each case.

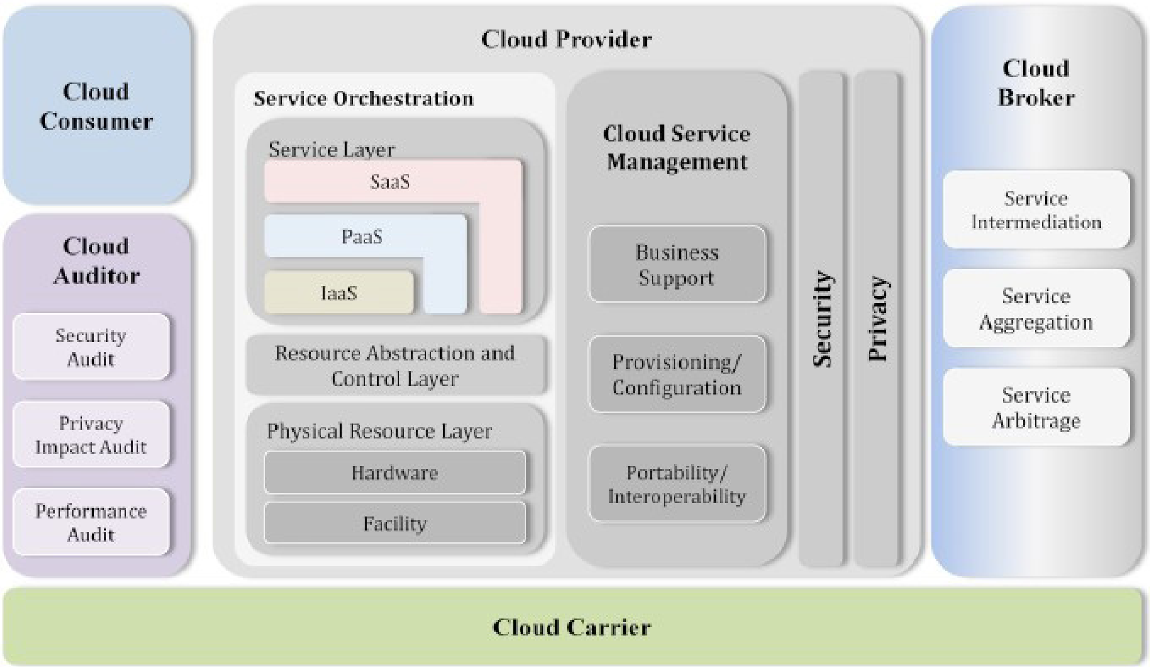


Figure 2 - NIST Cloud Conceptual Reference Model [v]

Let's take a moment to discuss each of the primary actors and their role in the Cloud Conceptual Reference Model.

> ***Cloud Consumer:*** An entity (i.e. organization or individual) that acquires and consumes cloud services from a Cloud (Service) Provider through some form of a business or professional relationship. Depending on the service model, this consumption may be anywhere from using the service provider's hosted application to operating an entire systems on top of the provider's

cloud infrastructure. It is important to note that Cloud Consumers may be discrete customers as well as organizations or institutions leveraging cloud services on behalf of their own constituents (i.e. employees, customers, trading partners, suppliers, etc.).

Cloud Provider: An entity that provides cloud services to Cloud Consumers, either as a third-party service provider (i.e. for profit) or as an internal services organization (i.e. an operational cost center). Focus areas include supporting service orchestration, service management, service operations, and maintaining environmental privacy and security.

Cloud Auditor: An entity that can conduct independent assessments of the Cloud Computing ecosystem on behalf of all parties to validate that committed performance, security and privacy service levels are being met. This role may take on additional compliance-related audit functions for clouds operating in or on behalf of heavily regulated industries.

Cloud Broker: An entity that manages the relationship between the cloud provider and the cloud consumer, focusing on service intermediation, service aggregation and service arbitrage. While not common (or always needed) on every cloud implementation agreement, Cloud Brokers can be helpful in mapping out complex multi-party relationships where a third-party intermediary can be beneficial to all stakeholders and contracting parties.

Cloud Carrier: An entity that acts as the intermediary communications provider between the participating cloud parties. Given that much cloud connectivity is through the public Internet, this role is often overlooked by Cloud Consumers when mapping out a cloud service topology.

The challenge, as with any emerging technology, is to decipher how the term ‘Cloud Computing’ is being used in order to separate marketing ‘spin’ from the more defining aspects of Cloud Computing. To facilitate that distinction, we turn our focus to key cloud concepts as outlined by the NIST, namely the distinction between common cloud service characteristics, cloud service models and cloud deployment models.[vi]

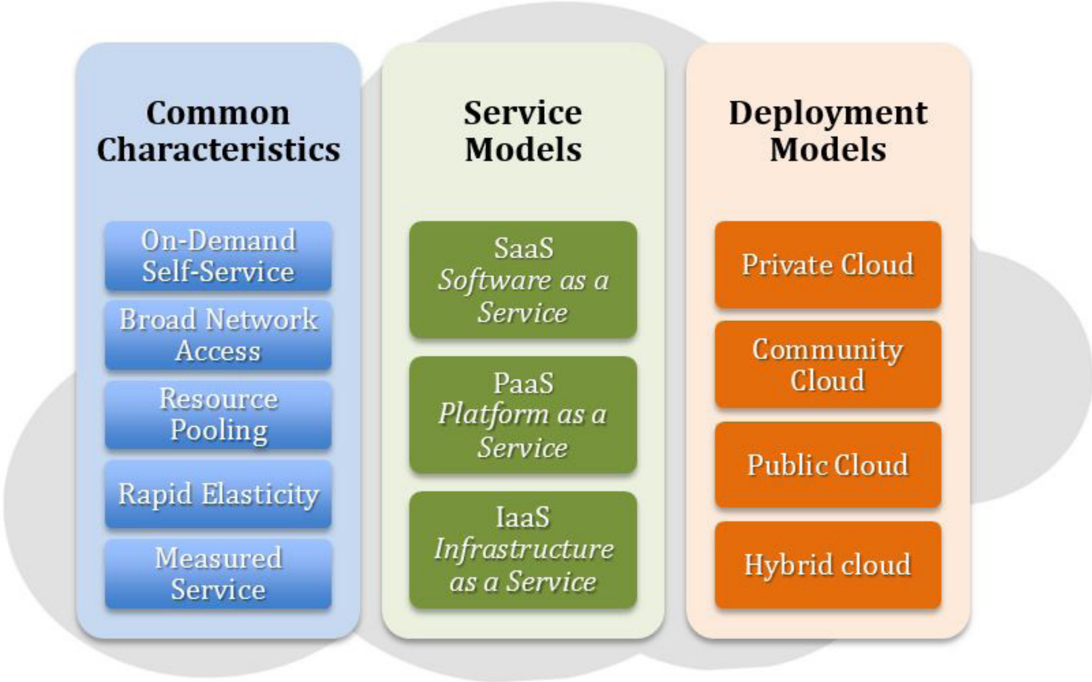


Figure 3 - NIST Key Cloud Concepts [vii]

Common Characteristics of Cloud Services

Although continuing to evolve, Cloud Computing services continue to display several common characteristics that fundamentally differentiate them from other computing service patterns. These characteristics include On-Demand Self-Service capabilities, Broad Network Access, Resource Pooling, Rapid Elasticity and Measured Service, all of which are consistent with and supportive of our previous observations on the various Cloud Computing definitions above.

On-Demand Self-Service: The ability of a Cloud Service Consumer to request services from the Cloud Service Provider as needed without requiring the participation of an intermediary party (i.e. avoiding manual requests or the need to contact a human support function to obtain cloud computing resources). This capability is often exposed through an electronic self-service catalog with predetermined (and preapproved) images and computing patterns.

Broad Network Access: The ability of a Cloud Service Consumer to reach the Cloud Computing resources of a Cloud Service Provider through widely available network solutions based on Internet connectivity. The complexity of the network is generally abstracted away from the consumer, reducing the usage of dedicated communication channels wherever possible (unless required due to specific security requirements).

Resource Pooling: The ability of a Cloud Service Provider to support the processing needs of multiple Cloud Service Consumers across the provider's collection of physical computing, storage and network resources. These resources are dynamically allocated and reallocated to various cloud consumers based on processing demands, typically in a multi-tenancy configuration where consumers are virtually isolated from each other but running on and within the same physical infrastructure.

Rapid Elasticity: The ability of a Cloud Service Provider to quickly scale Cloud Computing resources up or down to meet Cloud Service Consumers' capacity demands with minimal latency and negligible to nil manual intervention. The presumption is that the providers have over-capacitized their physical resources in anticipation of supporting consumption demands through rapid provisioning and de-provisioning of virtual environments. It is the responsibility of the Cloud Service Provider to proactively foresee and mitigate potential delays when additional physical resources must be acquired.

Measured Service: The ability of a Cloud Service Provider to maintain and produce accurate metrics regarding Cloud Service Consumer capacity utilization for the purpose of environmental control, resource optimization and accurate billing of services. Cloud services are generally charged based on (1) service capacity level subscription, such as minimum and maximum thresholds, and (2) the amount of services actually consumed, such as CPU utilization, data storage and network bandwidth consumption.

Cloud Service Models

A large portion of the dialog around Cloud Computing tends to focus on the Cloud Service Models contained within the Cloud Service Provider's Service Orchestration Layer, specifically directed at the Service Layer where the level of services provided is distinguished. One of the advantages of leveraging a Cloud Service Provider's offerings is their ability to abstract the rest of the layers and components away from the Cloud Service Consumer's area of concern, allowing them instead to focus on the inherent capabilities of the services being provided. Although recent use of the term '... as a Service' has become quite liberal (and questionable), we will limit our discussion to the three fundamental cloud service models: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS), often referred to as the SPI model.

Figure 4 demonstrates that the resource layers do not materially change across the different Cloud Computing service models. Cloud Computing architectural layers typically include Network, Storage, Server, Virtualization, Operating System, Middleware, Runtime, Data and Application strata, each providing a specific functional set of shared-pool resources. What varies in the different service models is determining 'who' will be responsible for providing and managing 'what' layer, as shown in the Cloud Service Model Responsible Party Matrix. Each service model has its share of benefits, drawbacks and applicable use cases; no single model should be considered superior or mutually exclusive to the others. Selection of the appropriate service model really should come down to fit-for-purpose validation, given the processing requirements of the service consumer.

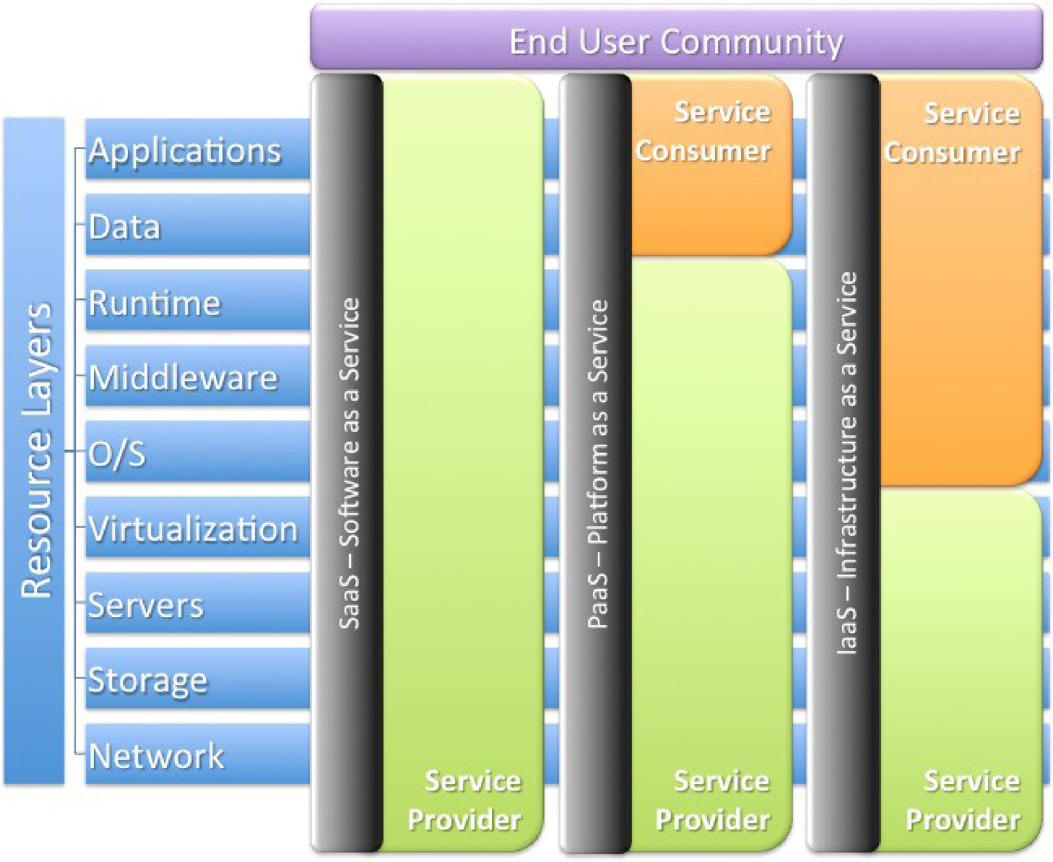


Figure 4 - Cloud Service Model Responsible Party Matrix

SaaS - Software as a Service: The Cloud Service Provider manages all layers of the cloud environment, allowing the Cloud Service Consumer the ability to use fully hosted software solutions, including application functionality, data entry/storage/retrieval and basic account management functions. Typical applications include sales force automation, personal records management (i.e. financials, health, etc.), personal email and social networks.

PaaS - Platform as a Service: The Cloud Service Provider offers an environment where the Cloud Service Consumers can build and deploy applications for their end-user community. The provisioned PaaS environment is typically pre-configured with the appropriate run time images (i.e. Java, MySQL, etc.) as required by the cloud service consumer and their solution delivery team. PaaS environments are typically used for software product development, testing and deployment, as well as hosting database and data analytic solutions.

IaaS - Infrastructure as a Service: The Cloud Service Provider is responsible for supporting the four lower resource layers only, including Network, Storage, Server and Virtualization capabilities. Cloud Service

Consumers mange the rest of the stack, from the Operating System layer all the way up through the Application layer – essentially leasing infrastructure upon which to operate their systems. Typical usage of the IaaS model includes storage, platform hosting and operation, backup and recovery and core business processing.

Cloud Deployment Models

In the next aspect of Cloud Computing we'll look at is deployment; specifically the four commonly accepted cloud deployment models, which include Public, Private, Hybrid and Community Clouds.
Each deployment model has its proper set of use cases and most organizations wind up utilizing a combination of the models to meet their unique environmental needs. The different models distinguish themselves in how the cloud services are reached (i.e. public versus private network connectivity) and how exclusive the user community is (i.e. non-restrictive versus highly restrictive).

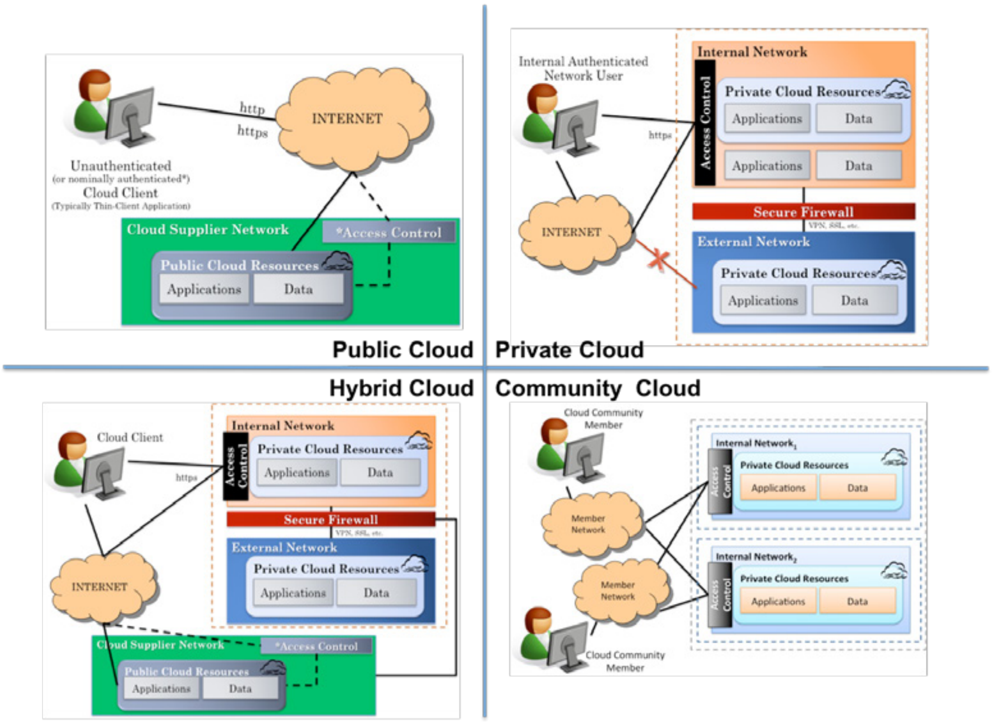


Figure 5 - Leading Cloud Deployment Models [viii]

Public Cloud: The Cloud Service Provider makes cloud resources available to the general public through public network access (e.g. over the Internet), typically providing services to a diverse population of end users.

- Cloud infrastructure is provisioned for open use by the general public
- Typically located on the cloud provider's premises
- Access is open or registered with limited credential validation

Private Cloud: The Cloud Service Provider makes cloud resources available exclusively to members within the cloud service consumer's organization.

- Cloud infrastructure is provisioned for private use by a single organization or entity
- May be hosted either on premise (consumer's facilities) or off premise (providers facilities)
- Access is controlled within the organization entity

Hybrid Cloud: The Cloud Service Provider employs two or more cloud deployment models on behalf of the cloud service consumer. The benefit of this model is that it allows for deployment optimization, harnessing the best attributes of the different deployment models without sacrificing capabilities or over-engineering solutions that are not warranted.

- Cloud infrastructure is a composition of two or more distinct cloud deployment models (private, community, or public), which may be implemented on premise, off premise or both.
- Maintain unique entities and boundaries, bound together to enable data and application portability
- 'Cloud Bursting' quality of service metrics may be used for load balancing between cloud components
- Access is dependent on the types of Cloud Deployment Models Integrated

Community Cloud: The Cloud Service Provider grants access to a collection of private clouds to a select group of members from the cloud service consuming organizations. These discrete organizations may be truly separate or they may be divisions or lines of business within the same institution. The community member organizations typically share a common objective or set of concerns that is not intended for others, such as members of a purchasing cooperative or a proprietary supply chain needing to collaborate in real time to maintain competitive advantages in the marketplace.

- Cloud infrastructure is provisioned for exclusive use by a specific community of organizations with shared concerns
- Resources may be located either on or off premise, and likely both
- Access is controlled but spans multiple entities or organizations

Enterprise Cloud Computing Strategy

There are several key considerations for Enterprise Architects when it comes to establishing an effective enterprise-wide Cloud Computing strategy. Many organizations typically have a combination of formal and informal technical guiding principles, but fail to establish and publish a comprehensive cloud computing strategy that fully addresses both technical and non-technical aspects in a strategic manner. As part of the organization's broader enterprise strategy, it is recommended that it formulate a holistic Enterprise Cloud Computing Strategy. Even if an organization doesn't believe that Cloud Computing is currently the right approach for them, having an articulated strategy will help support that position (i.e. memorialize what that position is based on and why), as well as provide decision criteria as to when and if that position should be revisited in the future.

Accenture recommends a series of introspective questions an organization should ask itself in the formulation of its Enterprise Cloud Strategy. Although the list appears to be presented from the assumption that Cloud Computing is a foregone conclusion within the organization, it does raise some useful topical aspects that a good strategy should address:

- How do I separate the realities of the cloud from the hype?
- What are my options for adopting Cloud Computing?
- What steps should I take to get started in the cloud?
- The cloud seems very tactical – why do I need such a broad strategy?
- How concerned should I be about privacy and regulation?
- Which of my mission-critical applications are candidates for cloud?
- How does my operating model need to evolve to support a cloud strategy?
- How do I procure for the cloud?
- How does the cloud change my strategic investments, now and in the future?

Table 3 - Accenture's Key Cloud Strategy Questions [ix]

Common features of an effective Enterprise Cloud Computing Strategy include the incorporation of strategic business-oriented elements, identification of key security considerations, declaration of intentional adoption pace, definition of the enterprise-level Cloud Computing reference architecture, and an alignment to relevant industry cloud patterns. Please note this does not constitute the full outline of the strategy, but rather points out a few specific topics for consideration.

Business-Oriented Strategic Elements

In Cloudonomics, Weinman raises the point that while Cloud Computing can be a very valuable and useful technology:

> *"Information technology is the embodiment of a firm's ability to exploit information, and the cloud can offer unique implementations of such technology that otherwise would be difficult if not impossible.*
>
> *However, the important lesson for CIOs is that IT, or the cloud, by itself, may not accomplish very much. It is important to determine how cloud adoption aligns with the strategy of the business and its Web of relationships and complements other changes to products, process, people, and partners"* [x]

While often presented as a business imperative, cutting costs is not really a strong strategic business strategy per se, unless the intent is to improve margins in order to free up capital for specific investment in strategic initiatives. While Cloud Computing typically does offer significant cost benefits over infrastructure models, those benefits should be considered as an aspect of the Cloud Computing Strategy, but not necessarily the only aspect. As Kavis points out, there are often misperceptions that may lead a team towards Cloud Computing solutions, when in reality their problems or issues may be better served through other means:

> *"One of the biggest misguided perceptions of Cloud Computing is that cloud initiatives will greatly reduce the cost of doing business. That may be true for some initiatives, but not for all of them; after all, cost is not the only reason to leverage the cloud...Not every problem is one that needs to be solved by Cloud Computing"* [xi]

Unless the organization is pursuing new cloud-centric revenue streams or perhaps optimizing supply-chain integrations, the net impact to the broader organization from harvesting cloud-based cost savings may be impressive in light of the discrete IT budget, but may still have only a nominal impact on the firms' overall bottom line:

> *"Different firms will find different opportunities to leverage the cloud...reducing costs within the IT function via the cloud is beneficial but not [necessarily] strategic. After all, if IT costs are an average of 4% of revenues, and the cloud could [hypothetically] reduce IT costs by 25%, the net impact to the corporation is only 1%, or perhaps a few percent of its cost structure, [which is] hardly compelling for a cost-leadership strategy. However, in such a company, to the extent that cloud-based services can optimize supply chains or operations logistics, the impact could be substantial"* [xii]

Many organizations jump into Cloud Computing without fully understanding the net economic and operational implications or determining what an acceptable outcome or rate of return from the investment should be. Several years ago The Open Group published a white paper on building a Cloud Computing Return on Investment (ROI) model as part of their Cloud Business Artifacts Project. As the figure below demonstrates, both Cloud Computing ROI models and Cloud Computing Key Performance Indicators (KPIs) can be aligned to four common dimensions: Time, Cost, Quality and Margin.

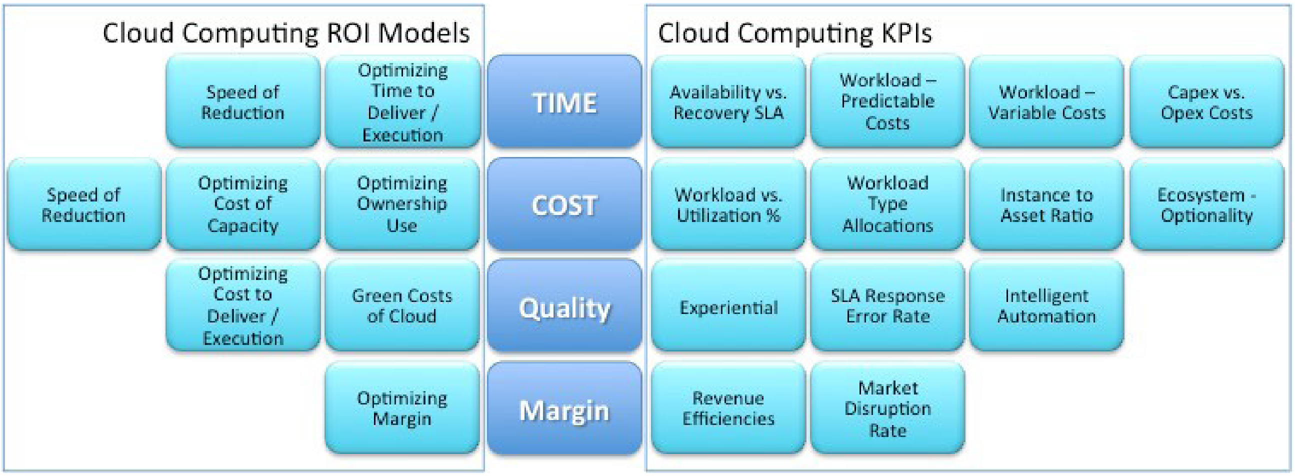


Figure 6 - Cloud Computing ROI Models and KPIs [xiii]

The Time dimension recognizes the advantages and metrics related to the anticipated acceleration of solution delivery in a Cloud Computing environment. The Cost dimension identifies the more common financial impacts resulting from Cloud Computing and the means to assess the net operating cost benefits being received. The Quality dimension focuses on the potential experiential improvements (or degradation) over the current computing model. The Margin dimension drives awareness of how Cloud Computing solutions impact the financial bottom line of the organization to gauge and assess investment effectiveness. Impact on the firm's margin, generally an amalgamation of changes to the other dimensions, is often overlooked even though it can potentially have the most dramatic impact on the organization's overall financial performance.

As each of these dimensions reflect business-centric considerations, you'll quickly (and correctly) surmise that these aspects are not unique to Cloud Computing and could be adapted to the organization's current technology ROI evaluation models and KPIs. The benefit of this approach is that it takes some of the 'mystique' out of Cloud Computing and provides a more objective means of assessing its nearness of fit to the organization's economic objectives. It is beneficial to incorporate these aspects and dimensions into the Enterprise Cloud Computing Strategy ahead of time, rather than trying to 'back into' benefit justification at a later date. This doesn't have to be a heavyweight or sluggish process – apply enough energy and rigor to match the potential level of investment over an anticipated timeline, such as the next 12 to 18 months.

Strategic Pace of Adoption

Given the relative ease of implementing an off-premise public offering by existing cloud service providers (i.e. Amazon Web Services/Elastic Compute Cloud, salesforce.com, etc.), the 'grassroots' introduction of Cloud Computing into many companies is likely erupting both within and outside the purview of the formal technology organization. Many firms are using their own resources to set up and establish internal private cloud services to better meet the needs of their development and product delivery activities. Rapid environmental and solution deployment, however, doesn't always equate to an equal capacity for the rapid expansion of requisite operational capabilities. An effective Enterprise Cloud Computing Strategy needs to outline the firm's position on how quickly and to what extent Cloud Computing will be adopted across the enterprise; the objective is intentional control without unintended constriction.

It is important to recognize that while many robust offerings are available, Cloud Computing is still maturing – short of SaaS offerings, not all products are enterprise grade, all-encompassing solutions and often require taking a heterogeneous integrated product solution approach. Based on their most recent hype cycle for Emerging Technologies, at the time of this writing Gartner still sees Cloud Computing as being 2 to 5 years away from reaching the 'Plateau of Productivity'. If we look at the corresponding Hype Cycle for Cloud Computing, it is no surprise that the SPI Model components (SaaS, PaaS and IaaS) are progressing at different paces, with SaaS out ahead of both IaaS and PaaS respectively. Despite all of the progress and market accolades for Cloud Computing as a universal solution, only one of the three Cloud Computing service models (SaaS) has moved out of the 'Trough of Disillusionment' and onto the 'Slope of Enlightenment'.

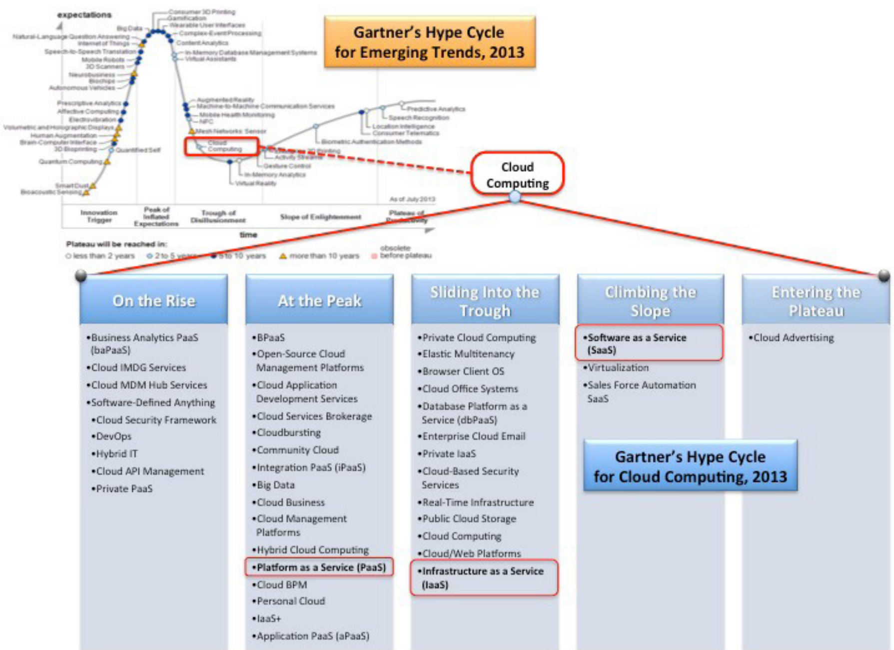


Figure 7 - Gartner Hype Cycles for Emerging Technology and Cloud Computing [xiv,xv]

In Figure 8, we see the Gartner Hype Cycle for Cloud Computing mapped against their corresponding Adopter Categories as defined by Everett Rogers in Diffusion of Innovation. [xvi] These Adopter Categories include:

- Innovators – Venturesome
- Early Adopters – Respectful
- Early Majority – Deliberate
- Late Majority – Skeptical
- Laggards – Traditional

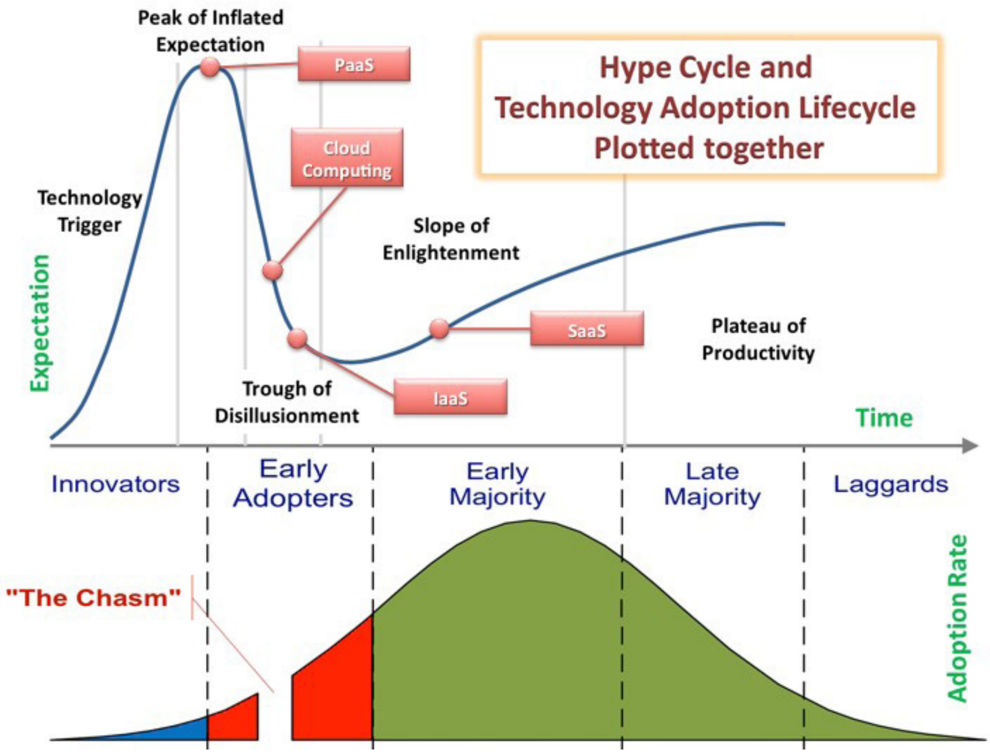


Figure 8 - Gartner Hype Cycle + Rogers Innovation Adoption Model [xvii]

While we could debate the precise alignment of the adoption times against the relative maturing of available Cloud Computing service models, the key message is that each organization will have to weigh the risk/reward factors, institutional appetite for change and ability to execute against the evolving Cloud Computing landscape as it continues to mature. This self-awareness should then influence and define how rapidly the organization will intentionally adopt, migrate, expand and/or contract Cloud Computing capabilities, either holistically across the enterprise or on a divisional scale, matrixed to Cloud Service/Deployment model pairs (i.e. join the Early Majority for Public Cloud SaaS, but perhaps wait for Private Cloud PaaS to mature). An effective Enterprise Cloud Computing Strategy will outline and clarify how aggressively the organization will be planning to utilize Cloud Computing capabilities and under what conditions.

Cloud Implementation Patterns

Identifying and incorporating available cloud implementation patterns into the Enterprise Cloud Computing Strategy provides high-level topology guidance and an architectural approach for solution architects and design engineers to follow. CloudPatterns.org is a community site that, by way of example, provides a Cloud Computing taxonomy and set of patterns as described below. Their inclusion here demonstrates the types of vendor-agnostic resources available to provide architects with independent tools to help assess, evaluate and influence the organization's strategic cloud architecture. Three baseline concepts from their model include:

> ***Mechanisms:*** *Technology mechanisms represent well-defined IT artifacts that are established within an IT industry and commonly distinct to a certain computing model or platform. The technology-centric nature of cloud computing requires the establishment of a formal level of mechanisms to be able to explore how a given pattern can be applied differently via alternative combinations of mechanism implementations.* [xviii]
>
> ***Design Patterns:*** *The simplest way to describe a [design] pattern is that it provides a proven solution to a common problem individually documented in a consistent format and usually as part of a larger collection.* [xix]
>
> ***Compound Patterns:*** *A compound pattern is a coarse-grained pattern comprised of a set of finer-grained patterns. Singled out in this catalog are some of the more common and important combinations of the patterns, each of which is classified as a compound design pattern.* [xx]

Each of the Mechanisms has a full description, relational pattern mapping information and one or more generalized diagrams. Each of the Design Patterns has a user story in the form of a question, a problem statement, a corresponding solution statement, applicability details, relationship mapping and generalized schematics. Each Compound Pattern describes and outlines the intersection and interaction of multiple Design Patterns and their corresponding complex, coarse-grained usage.

	Cloud Patterns																																							
Cloud Computing Mechanisms	Automated Administration	Bare-Metal Provisioning	Broad Access	Centralized Remote Administration	Cross-Hypervisor Workload Mobility	Cross-Storage Device Vertical Tiering	Direct I/O Access	Direct LUN Access	Dynamic Data Normalization	Dynamic Failure Detection and Recovery	Dynamic Scalability	Elastic Disk Provisioning	Elastic Network Capacity	Elastic Resource Capacity	Hypervisor Clustering	Intra-Storage Device Vertical Data Tiering	Load Balanced Virtual Server Instances	Load Balanced Virtual Switches	Multipath Resource Access	Non-Disruptive Service Relocation	Pay-as-You-Go	Persistent Virtual Network Configuration	Platform Provisioning	Rapid Provisioning	Realtime Resource Availability	Redundant Physical Connection for Virtual Servers	Redundant Storage	Resource Management	Resource Pooling	Resource Reservation	Self-Provisioning	Service Load Balancing	Service State Management	Shared Resources	Storage Maintenance Window	Storage Workload Management	Synchronized Operating State	Usage Monitoring	Workload Distribution	Zero Downtime
Audit Monitor				X		X				X															X			X	X	X	X			X		X		X	X	X
Automated Scaling Listener	X					X					X		X	X		X	X																			X		X		
Billing Management System				X																	X																			
Cloud Storage Device	X	X				X		X	X		X	X				X			X	X				X			X		X	X			X	X	X	X	X		X	X
Cloud Usage Monitor	X			X		X	X	X		X	X	X	X	X		X	X	X		X	X				X			X	X	X	X	X	X	X		X		X	X	X
Failover System										X																X	X								X		X			
Hypervisor	X	X					X	X			X	X	X	X	X		X	X	X	X		X	X	X		X			X	X			X	X			X		X	X
Load Balancer																	X	X														X				X		X	X	X
Logical Network Perimeter		X		X			X						X		X		X	X	X			X				X		X	X	X	X			X		X			X	X
Multi-Device Broker			X	X																											X									
Pay-Per-Use Monitor				X		X	X	X			X	X	X	X						X	X								X				X					X		
Ready-Made Environment																							X																	
Remote Administration System				X																								X	X	X	X									
Resource Cluster															X		X															X							X	X
Resource Management System		X		X																			X					X	X	X										
Resource Replication	X	X					X	X			X	X	X	X	X		X	X	X	X		X	X	X		X	X		X	X		X	X	X	X		X		X	X
SLA Management System		X		X						X										X					X															
SLA Monitor				X						X										X					X													X		
State Management Database																																	X				X			
Virtual Server	X						X	X			X	X	X	X	X		X	X	X	X		X	X	X		X			X	X			X	X			X		X	X

Figure 9 - Cloud Computing Design Patterns / Mechanism Matrix

Assembling this information into a simple matrix like the one shown in Figure 9 can help identify dependencies between the desired Design Patterns and their required Mechanisms. It can also point out potential gaps or suboptimal designs under consideration or already in place. This information can also be used to validate that designs account for proper resiliency of highly leveraged Mechanisms that supporting multiple Design Patterns.

Taking the mapping a step further, we constructed the matrix shown in Figure 10, which demonstrates how thirty-nine of the Cloud Patterns can be assembled into thirteen discrete Compound Patterns. Note that nine of the Compound Patterns actually leverage seven of the other Compound Patterns as well, as identified on the far right side of the matrix.

	Cloud Patterns																																							Compond						
Compund Cloud Patterns	Automated Administration	Bare-Metal Provisioning	Broad Access	Centralized Remote Administration	Cross-Storage Device Vertical Tiering	Direct I/O Access	Direct LUN Access	Dynamic Data Normalization	Dynamic Failure Detection and Recovery	Dynamic Scalability	Elastic Disk Provisioning	Elastic Network Capacity	Elastic Resource Capacity	External Virtual Server Accessibility	Hypervisor Clustering	Intra-Storage Device Vertical Data Tiering	Load Balanced Virtual Server Instances	Multipath Resource Access	Non-Disruptive Service Relocation	Pay-as-You-Go	Persistent Virtual Network Configuration	Platform Provisioning	Rapid Provisioning	Realtime Resource Availability	Redundant Physical Connection for Virtual Servers	Redundant Storage	Resource Management	Resource Pooling	Resource Reservation	Self-Provisioning	Service Load Balancing	Service State Management	Shared Resources	Storage Maintenance Window	Storage Workload Management	Synchronized Operating State	Usage Monitoring	Workload Distribution	Zero Downtime	Multitenant Environment	Burst In	Burst Out Private Cloud	Burst Out Public Cloud	Isolated Trust Environment	Resiliant Environment	Elastic Environment
Burst In	R				O																							R									R									
Burst Out to Private Cloud	R				O					R			R								R		R			R		O	O		O						R	R		X						
Burst Out to Public Cloud	R				O					R			R								R		R			R		R	R		O						R	R		X						
Cloud Balancing	R												R		R		R				R		R		R	R					R				R			R								
Cloud Bursting																																									X	X	X			
Elastic Environment	R				R	O	O	O		R	R	R	R			R							R			O		R			O				R		R	R								
Infrastructure-as-a-Service (IaaS)	R	O	R	R						R								R		R			R	R			R	R		R			R				R	R		X						
Multitenant Environment																												R	O				R											X		
Platform-as-a-Service (PaaS)	R		R	R						R									O	R		R	R	R			R	R	O	R		R	R				R	R		X				X		
Private Cloud	R	O	R	R															O	O			R	R			R	R		R			R				R	R		X					X	X
Public Cloud	R	O	R	R															O	R			R	R			R	R	O	R			R				R	R		X				X	X	X
Resilient Environment									R						R		R						R		R	R					R			O		R	R	R	O							
Software-as-a-Service (SaaS)	R		R	R						R									O	R			R	R			R		O	R		O	R				R	R		X						

Figure 11 - Compound Cloud Pattern Mapping: R = Required, O = Optional, X = Compound of Compounds

The benefit for Enterprise Architects in leveraging available cloud design patterns is that they can serve as a template to help them accelerate through the pattern evaluation, selection and adaptation process for the appropriate context within their organization. This level of detail may seem to be a bit excessive as part of a strategic position on Cloud Computing, particularly if the organization is simply planning to sign up with a Cloud Solution Provider and consume their services 'as offered'. In some cases that may be true and it may perfectly acceptable to not delve this far into the details, such as the implementation of low-risk third-party SaaS solutions that can depend on sufficient protection through the contractual service level agreement with the provider.

However, the organization may be pursuing an on-premise cloud strategy in which they are creating their own cloud services infrastructure, or depending on an external Cloud Solution Provider to handle high-risk/ high-value transactional processing. In these instances, ensuring the soundness and robustness of the underlying technology architecture is just as important as that of any other mission-critical solution the organization operates on, be it cloud-based or not. The level of technical validation of the Cloud Service Provider's solution must be consummate with the level of operational criticality of that solution, subsequently reflected as evaluation guidelines and implementation standards within the Enterprise Cloud Computing Strategy.

Cloud Reference Architecture

Taking both the NIST Cloud Reference Architecture model and available Cloud Patterns similar to the ones shared in the previous section a means to establish the appropriate high-level component model of a comprehensive cloud ecosystem, the Enterprise Cloud Computing Strategy would benefit by taking these conceptual architectural layers to the next step by establishing the entity's Enterprise Cloud Reference Architecture. At this point the Enterprise Architect would work with their architectural and engineering counterparts to establish the baseline set of strategic go-to cloud technologies for the organization. For example, establish guidelines on whether the hypervisor is to be native or hosted for internal cloud solutions and which ones are acceptable (i.e. KVM, Hyper-V, vCloud, OpenVZ, vServer, etc.) or not allowed.

The same rigor already applied to other reference architecture definitions within the firm should be equally applied to Cloud Computing technologies, including clarification on the use of Open Source components. Different firms have different levels of specificity in their reference architecture practices, and it is beyond our scope here to debate what the right level should be. The purpose of the Enterprise Cloud Reference Architecture is to outline strategic Cloud Computing implementation patterns and provide solution delivery teams with clear guidelines from a deployment governance perspective.

The more specific suggestion here is to identify and define what Cloud Computing should look like structurally, when it is appropriate from a contextual perspective, and how it should be implemented in terms of approved tools, vendors, protocols and patterns. By way of example, the following diagram takes a look at a sample PaaS reference architecture from IBM. While not presented here as a prescriptive recommendation, it provides us with an illustration of a potential starting point to identify the key components an inclusive PaaS Cloud Computing reference architecture might contain.

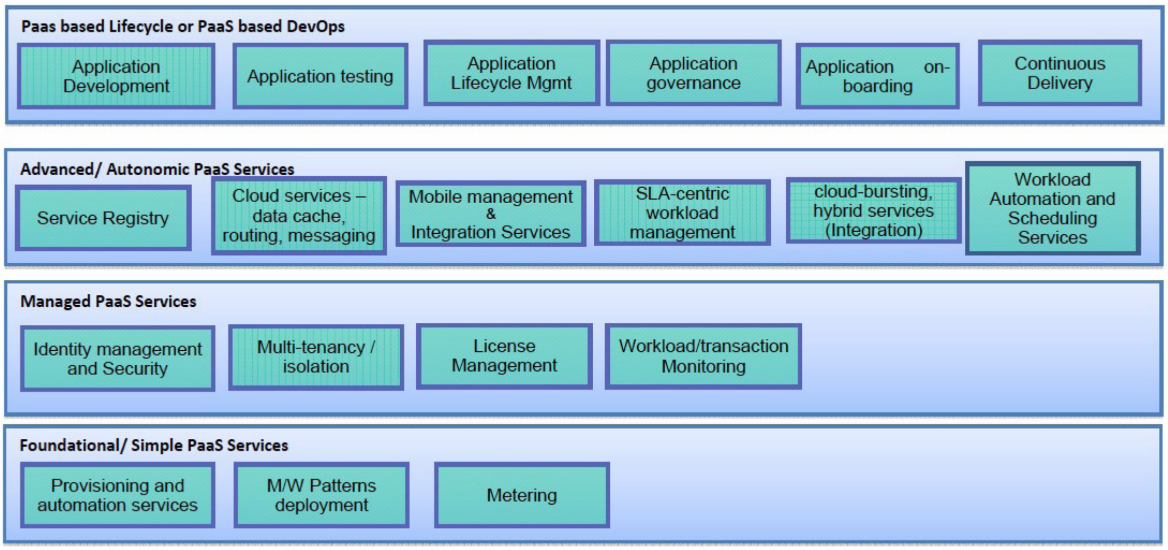


Figure 12 - Sample Cloud Reference Architecture for PaaS Solution [xxi]

Taking this sample model as a relative starting point, an organization would refactor it to meet their own needs, validating, adding, modifying and removing items as required. The next step would be to break each 'box' down into a discrete deployment model, listing strategic targeted solution components (including vendors, products, channels, etc.), complete with an operational view and integrated support model (i.e. clarification of roles, process steps, etc.). Cloud solutions that have gotten out ahead of the reference architecture process and are currently not aligned to the strategic direction would simply be 'road mapped' to conformance over time, just like any other technology realignment effort within the enterprise.

An important aspect of a successful Enterprise Cloud Computing Reference Architecture is the identification of targeted design/deployment patterns, sometimes referred to as Prescriptive Architecture. Some application solutions are clearly a natural fit for a particular model, such as using an off-premise SaaS deployment model to leverage a vendor package for non-proprietary business capabilities. Other applications, in contrast, may not be as easy to determine and require a more detailed and rigorous assessment. Linear, stateful legacy applications that are tightly coupled to themselves and the resources they consume, for example, will likely pose significant conversion challenges and correspondingly high retrofit costs in order to fully leverage the advantages of a PaaS or IaaS solution beyond simple re-hosting or re-platform efforts. A firm may decide that all net-new development should follow a 'design-for-cloud-first' approach to ensure that the fundamental architectural underpinnings for all new applications are appropriately optimized for Cloud Computing from the start.

Another consideration for cloud suitability lies in the nature of the application's transactional patterns and scalar volume fluctuation requirements. For example, communication services such as email or social collaboration events via crowdsourcing lend themselves well to cloud solutions where dynamic elasticity is beneficial. In contrast, steady state environments with flat demand curves over time or highly customized solutions may benefit more from traditional hosting solutions if properly capacitized and meeting production service level agreements. The key is that the reference architecture should not only identify the targeted Cloud Computing technology stack components, but should also identify when cloud solutions are not the preferred target environment.

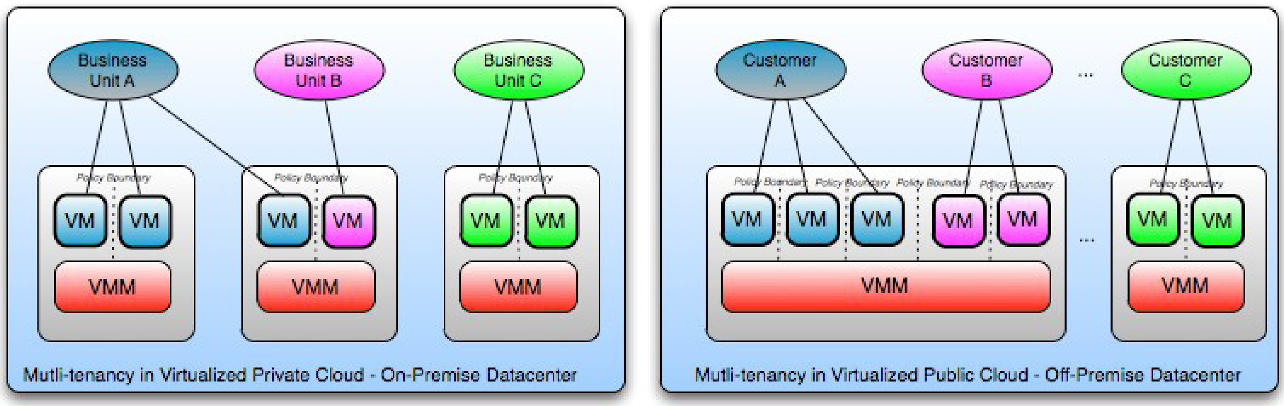
Information Security

Rapid globalization of technology and the ever-expanding interconnectedness of the 'Internet of Things' will continue to demand our constant attention to considerations around information security; all channels, all devices, all the time. Cloud Computing introduces a host of potential threat opportunities by virtually extending our computing network perimeter, typically beyond our tacit control perimeter (i.e. Intranet users on our internal secure network may consume SaaS capabilities that are running off-premise on a public cloud). It is critical that the Enterprise Cloud Computing Strategy clearly articulates how it aligns to and is compatible with the organization's information security standards.

Cloud Computing security considerations span a wide array of concerns; resource connectivity, user entitlements, data loss prevention, transitory/stationary data handling and encryption policies, data security classification restrictions, cross-border information flow...the list goes on. It is not uncommon for information security considerations to run counter to preconceived or preferred cloud solution patterns by various constituents within the organization. Without clear and congruent information security guidelines articulated in the Enterprise Cloud Computing Strategy, it is unlikely that the organization will be automatically protected from security risks in the cloud.

For example, multi-tenant public cloud solutions are typically fastest to deploy for Cloud Solution Providers and least expensive to consume by Cloud Service Consumers, making them quite popular (and typically less expensive), regardless of the elevated level of potential risk. In contrast, however, the Cloud Security Alliance (CSA) provides the following observation:

> *"Multi-tenancy in cloud service models implies a need for policy-driven enforcement, segmentation, isolation, governance, service levels, and chargeback/billing models for different consumer constituencies. Consumers might utilize a public cloud provider's service offerings or actually be from the same organization, such as different business units rather than distinct organizational entities, but would still share infrastructure."* [xxii]



Private Cloud of Company XYZ with 3 business units, each with different security, SLA, governance and chargeback policies on shared infrastructure

Public Cloud Provider with 3 business customers, each with different security, SLA, governance and billing policies on shared infrastructure

Figure 13 - CSA Multi-Tenancy Example Patterns

Enterprise Architects will find the CSA's Cloud Control Matrix to be a valuable planning tool, as it provides a series of guiding security principles and nearly 100 recommended considerations across the following areas:

Compliance	Information Security	Release Management
Data Governance	Legal	Resiliency
Facility Security	Operations Management	Security Architecture
Human Resource Security	Risk Management	

Source: https://cloudsecurityalliance.org

It is important to note that Cloud Computing solution providers have varying levels of information security performance agreements built into their solutions and services. While offerings have been improving as Cloud Computing capabilities and services continue to mature, some providers are still so bold as to say that security is completely the remit of the cloud consumers, thereby ascribing no liability for themselves. Enterprise Architects need to be extremely diligent in ensuring that a rush to implement 'fast and ready' computing resources in the cloud doesn't carry with it excessive risk and unintended vulnerability exposure that might result in a perimeter breach or loss of sensitive data.

Conclusion

In this paper we've reviewed basic Cloud Computing principles and identified several elements that effective Enterprise Cloud Computing Strategies should contain. These elements are not exhaustive, but can strengthen and enhance the impact the strategy can have on the organization. Benefits of developing and executing an intentionally articulated enterprise-level Cloud Computing strategy include:

- Opportunity to align (or realign) Cloud Computing with the broader Enterprise Architecture definition and strategy
- Clear guidance to solution engineering and delivery teams on when and how Cloud Computing capabilities should be utilized
- A means to assess, challenge and evaluate Cloud Service Provider offerings in the context of the needs of the organization
- Availability of Reference Architecture definitions and images designed to support rapid provisioning of consistent, standardized cloud environments
- A baseline set of Cloud Computing guidelines that can be used to establish convergence roadmaps to redirect non-strategic implementations over time

Recommended Reading

Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, and IaaS)

Kavis (2014)

Cloud Computing: Concepts, Technology & Architecture

Erl, Puttini and Mahmood (2013)

Cloud Computing Patterns: Fundamentals to Design, Build, and Manage Cloud Applications

Fehling, Leymann, Retter, Schupeck and Arbitter (2014)

Cloudonomics: The Business Value of Cloud Computing

Weinman (2012)

OpenStack Cloud Computing: Architecture Guide

Rhoton, De Clercq and Novak (2014)

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