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Architectural Strategies for Cloud Computing

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Executive Overview

Cloud computing is the convergence and evolution of several concepts from virtualization, distributed application design, grid, and enterprise IT management to enable a more flexible approach for deploying and scaling applications.

Cloud promises real costs savings and agility to customers. Through cloud computing, a company can rapidly deploy applications where the underlying technology components can expand and contract with the natural ebb and flow of the business life cycle. Traditionally, once an application was deployed it was bound to a particular infrastructure, until the infrastructure was upgraded. The result was low efficiency, utilization, and flexibility. Cloud enablers, such as virtualization and grid computing, allow applications to be dynamically deployed onto the most suitable infrastructure at run time. This elastic aspect of cloud computing allows applications to scale and grow without needing traditional 'fork-lift' upgrades.

IT departments and infrastructure providers are under increasing pressure to provide computing infrastructure at the lowest possible cost. In order to do this, the concepts of resource pooling, virtualization, dynamic provisioning, utility and commodity computing must be leveraged to create a public or private cloud that meets these needs. World-class data centers are now being formed that can provide this Infrastructure-as-a-Service (IaaS) in a very efficient manner.

Customers can then decide to develop their own applications, to run on their own internal private clouds, or leverage Software as a Service (SaaS) applications that run on public clouds. Integration and federation of services across both the public and private cloud, so-called "hybrid clouds," is an emerging area of interest. The public cloud concept allows customers to develop and deploy applications with tremendous speed without the procurement and red-tape issues of dealing with potentially slow moving and costly IT departments. This also allows customers to shift traditional Capital Expenditures (CapEx) into their Operating Expenditure (OpEx) budgets.

Driven by concerns over security, regulatory compliance, control over Quality of Service (QoS), vendor lock-in, and long-term costs, many larger customers, who have the economies of scale and strong IT competency, will build internal private clouds. These private clouds can provide the same cost and agility benefits as public clouds, while mitigating enterprise concerns about security, compliance, QoS, lock-in, and TCO.

IT Architecture Evolution

Architecture evolves over time. In the 1960s and 1970s, the first wave of computing consisted of large, expensive, labor-intensive, monolithic servers that could be considered the forefathers of the mainframe. Internal resources were pooled and heavy use was made of virtualization to ensure that the very best was made of these very expensive resources.

In the 1980s and 1990s, with the rise of PCs, the shrinking costs of networking and computing infrastructure, and a need for more agility, client/server provided the ability to split the application tier away from the server tier. This was done to support distributed clients running richer user interfaces and also to reduce costs by offloading the user handling, application workloads off monolithic servers. These larger servers remained to address massive batch processing and scientific workloads.

In the 2000's, as data centers started to fill out, and power, space and cooling became more and more expensive, concepts such as commodity grid computing and virtualization started to become established. Cloud computing takes these concepts further by allowing self-service, metered usage and more automated dynamic resource and workload management practices. As services became more and more distributed, SOA emerged as a methodology to integrate and orchestrate distributed business services. This need exists today, as customers require integration between public, private, and in-house services.

In some ways, the cloud has become the distributed virtualized mainframe of an era past! It's funny how the same concepts change their clothes but remain constant throughout the evolution of computing. In many cases, today's Cloud was based on foundational concepts that addressed an early need to best leverage computing resources almost 40 years ago. A large monolithic server was easy to secure relative to a virtualized resource on the Cloud. Security is still the number one concern of many customers who want to leverage public Cloud services today.

Primary Benefits of Cloud Computing

To deliver a future state architecture that captures the promise of Cloud Computing, architects need to understand the primary benefits of Cloud computing:

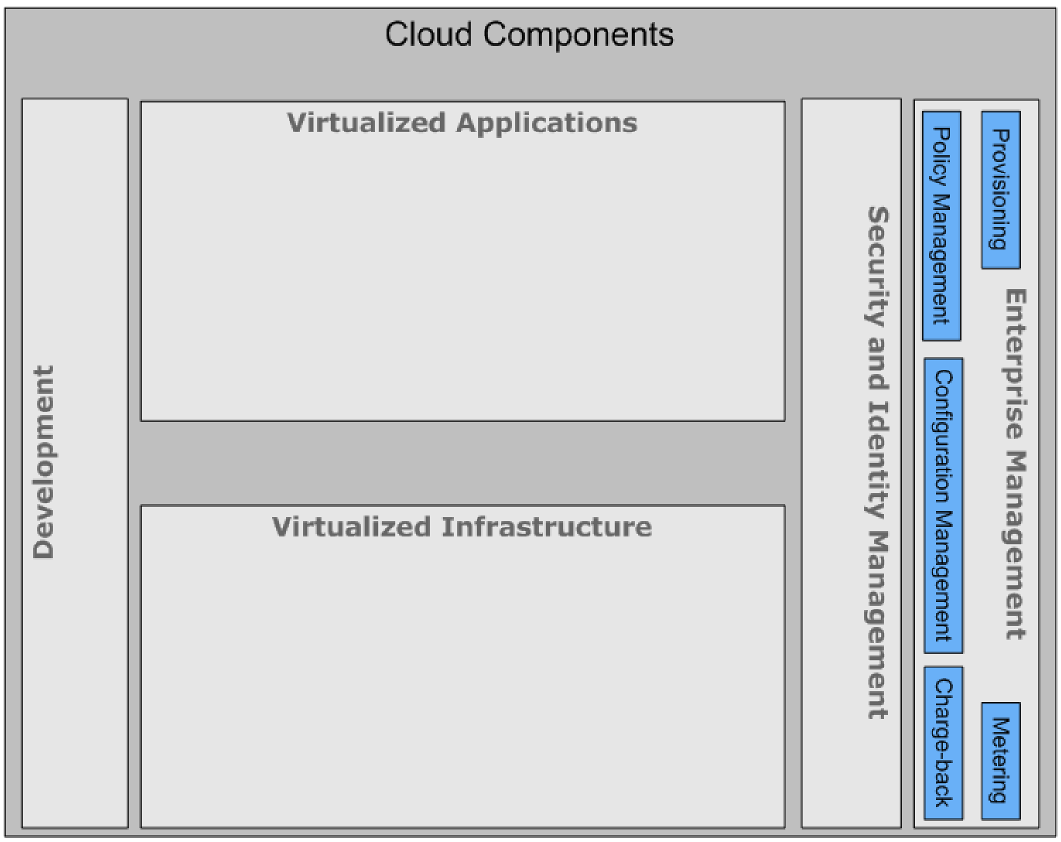
- Decoupling and separation of the business service from the infrastructure needed to run it (virtualization)
- Flexibility to choose multiple vendors that provide reliable and scalable business services, development environments, and infrastructure that can be leveraged out of the box and billed on a metered basis—with no long term contracts
- Elastic nature of the infrastructure to rapidly allocate and de-allocate massively scalable resources to business services on a demand basis
- Cost allocation flexibility for customers wanting to move CapEx into OpEx
- Reduced costs due to operational efficiencies, and more rapid deployment of new business services

Cloud Building Blocks

The building blocks of cloud computing are rooted in hardware and software architectures that enable innovative infrastructure scaling and virtualization. Many data centers deploy these capabilities today. However, the next infrastructure innovations are around more dynamic provisioning and management in larger clusters both within and external to the conventional corporate data center.

There are also implications for next generation application design to make optimum use of massively parallel processing and fault tolerance.

The diagram below illustrates some common architectural components:



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Virtualized Infrastructure

Virtualized Infrastructure provides the abstraction necessary to ensure that an application or business service is not directly tied to the underlying hardware infrastructure such as servers, storage, or networks. This allows business services to move dynamically across virtualized infrastructure resources in a very efficient manner, based upon predefined policies that ensure specific service level objectives are met for these business services.

Virtualized Applications

Virtualized applications decouple the application from the underlying hardware, operating system, storage, and network to enable flexibility in deployment. Virtualized Application servers that can take advantage of grid execution coupled with Service Oriented Architectures and enable the greatest degree of scalability to meet the business requirements.

Enterprise Management

Enterprise management provides top-down, end-to-end management of the virtualized infrastructure and applications for business solutions. The enterprise management layer handles the full lifecycle of virtualized resources and provides additional common infrastructure elements for service level management, metered usage, policy management, license management, and disaster recovery. Mature cloud service management software allows dynamic provisioning and resource allocation to allow applications to scale on demand and minimize the waste associated with underutilized and static computing resources.

Security and Identity Management

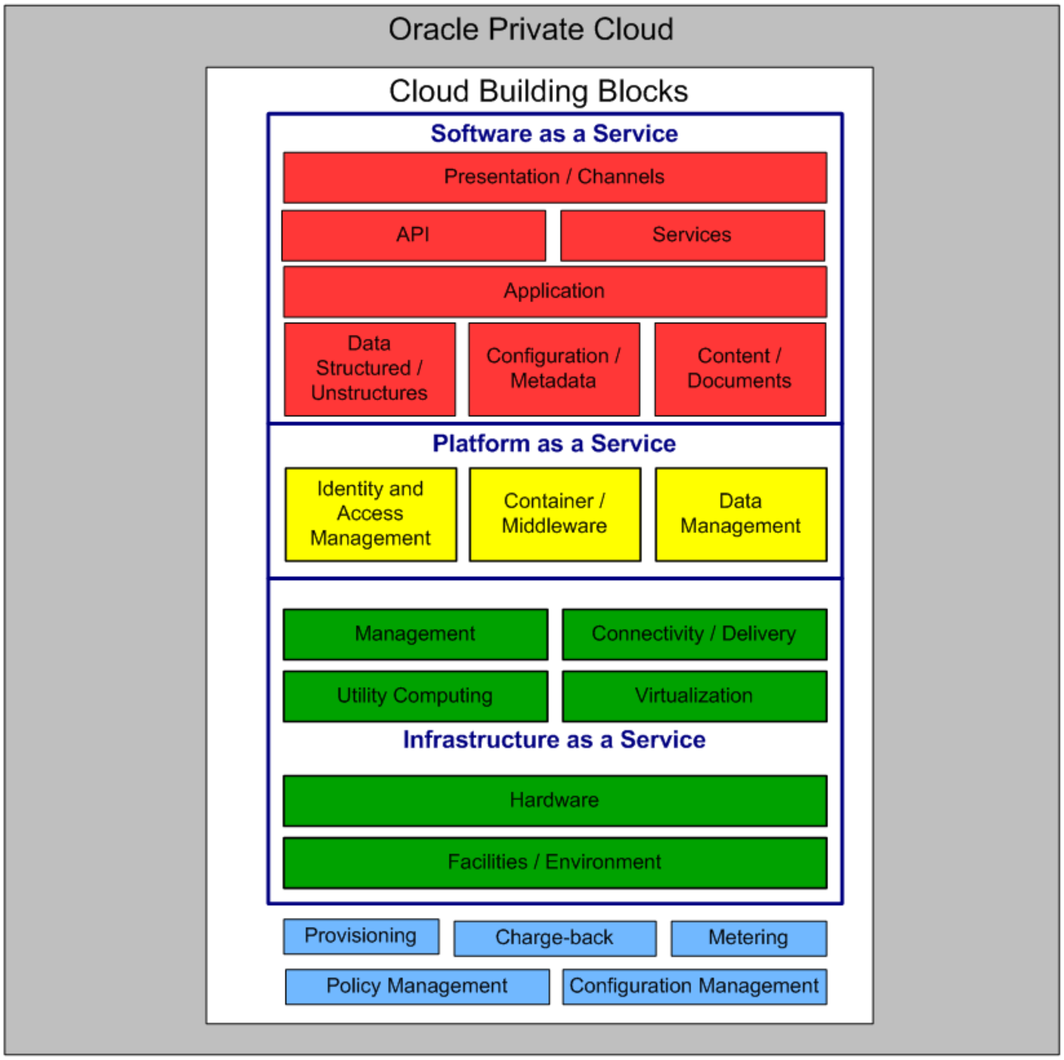
Clouds must leverage a unified identity and security infrastructure to enable flexible provisioning, yet enforce security policies throughout the cloud. As clouds provision resources outside the enterprise's legal boundaries, it becomes essential to implement an Information Asset Management system to provide the necessary controls to ensure sensitive information is protected and meets compliance requirements.

Development tools

Next generation development tools can leverage cloud's distributed computing capabilities. These tools not only facilitate service orchestration that can leverage dynamic provisioning, but also enable business processes to be developed that can harness the parallel processing capabilities available to clouds. The development tools must support dynamic provisioning and not rely on hard coded dependencies such as servers and network resources.

Different Levels of Cloud Computing

Cloud computing is typically divided into three levels of service offerings: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a service (IaaS). These levels support virtualization and management of differing levels of the solution stack.



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Software as a Service

A SaaS provider typically hosts and manages a given application in their own data center and makes it available to multiple tenants and users over the Web. Some SaaS providers run on another cloud provider's PaaS or IaaS service offerings. Oracle CRM On Demand, Salesforce.com, and Netsuite are some of the well known SaaS examples.

Platform as a Service

Platform as a Service (PaaS) is an application development and deployment platform delivered as a service to developers over the Web. It facilitates development and deployment of applications without the cost and complexity of buying and managing the underlying infrastructure, providing all of the facilities required to support the complete life cycle of building and delivering web applications and services entirely available from the Internet. This platform consists of infrastructure software, and typically includes a database, middleware and development tools. A virtualized and clustered grid computing architecture is often the basis for this infrastructure software. Some PaaS offerings have a specific programming language or API. For example, Google AppEngine is a PaaS offering where developers write in Python or Java. EngineYard is Ruby on Rails. Sometimes PaaS providers have proprietary languages like force.com from Salesforce.com and Coghead, now owned by SAP.

Infrastructure as a Service

Infrastructure as a Service (IaaS) is the delivery of hardware (server, storage and network), and associated software (operating systems virtualization technology, file system), as a service. It is an evolution of traditional hosting that does not require any long term commitment and allows users to provision resources on demand. Unlike PaaS services, the IaaS provider does very little management other than keep the data center operational and users must deploy and manage the software services themselves--just the way they would in their own data center. Amazon Web Services Elastic Compute Cloud (EC2) and Secure Storage Service (S3) are examples of IaaS offerings.

Architecture Implications and Principles

To take full advantage of the benefits of Cloud computing, there are a number of architectural implications that should be observed.

Business Architecture

Cloud offers unprecedented control in allocating resources dynamically to meet the changing needs of a business. This is only effective when the businesses service level objectives have been clearly articulated and guide the cloud's enterprise management layer. Application performance metrics and SLAs must be carefully documented and monitored for an effective cloud deployment.

To maximize the distributed capabilities afforded by clouds, business processes should identify areas where asynchronous or parallel processes can be used.

Key Business Architectural Principles

- Business Alignment, Cost Optimization
- Compliance with Laws and Regulations
- Business Agility
- Minimize Cost

Application Architecture

Application services should abstract resource allocation and avoid the tight binding of its resources to invokers of the service. Dependencies on static references to infrastructure (for example, storage, servers, network resources), as well as tightly coupled interfaces to dedicated systems, should be avoided.

To take advantage of the cloud's scalability capabilities, applications should take advantage of distributed application design and utilize multi-threading wherever possible. Applications should leverage distributed locking, GUID generation, and integration layers to provide the greatest flexibility in deploying on a cloud.

Key Application Architectural Principles

- Technology Independence, Adherence to Standards
- Common Development Methodology
- Loosely coupled Interfaces.

Information Architecture

Cloud computing offers the potential to utilize information anywhere in the cloud. This increases the complexity associated with meeting legal and regulatory requirements for sensitive information. Employing an Information Asset Management system provides the necessary controls to ensure sensitive information is protected and meets compliance requirements. This is essential when considering public or hybrid clouds as information may leave the confines of the data center, which may violate certain legal and regulatory requirements for some organizations.

Key Information Architectural Principles

- Implement Information Lifecycle Management
- Regulatory and Legal Compliance
- Enforce Data Privacy.

Technology Architecture

Implementing Service Oriented Architectures (SOA) provides the most effective means of leveraging the capabilities of cloud computing. SOAs distributed nature, service encapsulation; defined service level objectives, virtualized interfaces, and adherence to open standards align with Cloud's architectural requirements.

Cloud's highly distributed nature requires a more robust security management infrastructure. Implementing federated identity hubs and defined communication zones are typically required for cloud deployments to control access across multiple cloud nodes--especially when those nodes exist outside the organization.

Cloud infrastructures simplify the deployment of grid application servers which offer improved scalability and disaster recovery.

Key Technology Architectural Principles

- Control Technical Diversity
- Adherence to Standards
- Scale Capacity and availability to satisfy Business Objectives
- Virtualize dependencies to hardware and software
- Unified Security Infrastructure.

Organizational Considerations

The successful deployment of clouds within organizations depends on a number of factors--some technical and others organizational. These include:

- The extent of infrastructure standardization among the existing application silos of the current state architecture
- The complexity and degree of customization and integration of the current state architecture.
- The willingness of lines-of-business to share infrastructure instead of "owning their own"
- The extent to which the current state architecture must accommodate legacy systems
- Past experience of the IT department in deploying technologies and concepts critical for clouds, such as standardization, consolidation, virtualization, clustering, and more
- An effective governance structure is required to guide the cloud implementation to meet the business objectives of the organization.

System Architecture Design Considerations

Performance Considerations

- Cloud infrastructures have the potential to introduce unpredictable performance behaviors. While sharing a large infrastructure can average out the variability of individual workloads, it is difficult to predict the exact performance characteristics of your application at any particular time. Like any shared infrastructure, varying individual workloads can impact available CPU, Network and Disk I/O resources resulting in unpredictable performance behavior of the combined applications.
- Public cloud infrastructures by the nature that they are outside the enterprise data center must leverage wide area network which can introduce bandwidth and latency issues. Multi-peered networks, encryption offloading, and compression are necessary design considerations.
- In addition, many Public Cloud providers have multiple storage offerings with varying performance characteristics. Typically, write performance is typically impacted to a much larger degree than read performance, especially with non-block oriented storage.
- Variability in network resources can significantly impact write operations with clustered application servers. Applications should categorize information that has lower availability requirements to identify candidates for asynchronous writes or replication.
- To overcome many of these challenges, Cloud can leverage proactive scaling of resources to increase capacity in anticipation of loads. For example, if you have implemented a web site that has heavy loads from 9:00 am to 3:00 pm, you can dynamically increase capacity for that period of time. To take advantage of this, your application must be architected to leverage distributed application design.

Clustering Options

- Shared Cluster – A cluster of servers/blades that is shared by many applications or database tenants. However, database or application server instances are dedicated to their application.
- Shared Instance – A single database instance across a cluster that runs multiple database schemas on behalf of multiple application tenants. This is an efficient design (for example, one database upgrade services many applications), but also highly restrictive (all applications must be upgraded at the same time).
- Dedicated cluster – Some applications will be large enough to merit a dedicated portion of the hardware environment. This does not increase their cost to support since they share the same inexpensive components with the rest of the cloud and capacity can be assigned to them or reassigned to other purposes as needed.

Implementing Cloud Computing

All of the architectural and organizational considerations mentioned thus far generally apply to all implementations of a cloud infrastructure. As we focus on building the cloud, a number of models have been developed for deploying a cloud infrastructure.

Private Clouds

In a private cloud, the infrastructure for implementing the cloud is controlled completely by the enterprise. Typically, private clouds are implemented in the enterprise's data center and managed by internal resources.

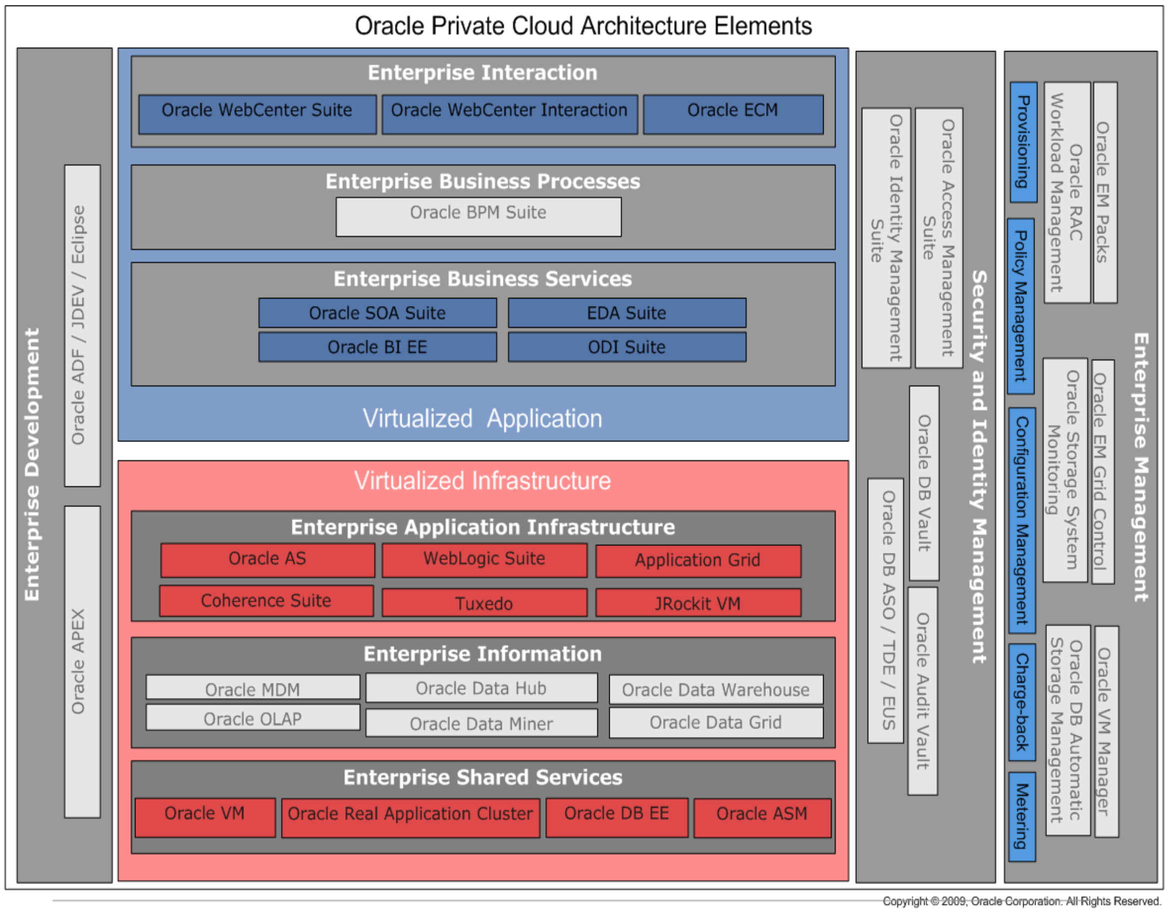
A private cloud maintains all corporate data in resources under the control of the legal and contractual umbrella of the organization. This eliminates the regulatory, legal and security concerns associated with information being processed on third party computing resources.

Currently, private clouds require Capital Expenditure and Operational Expenditure as well as highly skilled labor to ensure that business services can be met.

Larger enterprises may find it more economical to develop future state architectures internally to deliver the benefits of cloud computing to internal "subscribers." This model is ideal for enterprises that are organized with a shared services IT infrastructure. This is generally preferred among C level executives who require that the corporate crown jewels are securely located in known locations and by trusted staff.

The private cloud can also be used by existing legacy IT departments to dramatically reduce their costs and as an opportunity to shift from a cost center to a value center in the eyes of the business.

As an example, the following diagram depicts the key architectural elements of a private cloud utilizing Oracle's capabilities:



Public Clouds

In a public cloud, external organizations provide the infrastructure and management required to implement the cloud. Public clouds dramatically simplify implementation and are typically billed based on usage. This transfers the cost from a capital expenditure to an operational expense and can quickly be scaled to meet the organization's needs. Temporary applications or applications with burst resource requirements typically benefit from the public cloud's ability to ratchet up resources when needed and then scale them back when they are no longer needed. In a private cloud, the company would need to provision for the worst case across all the applications that share the infrastructure. This can result in wasted resources when utilization is not at its peak.

Public clouds have the disadvantage of hosting your data in an offsite organization outside the legal and regulatory umbrella of your organization. In addition, as most public clouds leverage a worldwide network of data centers, it is difficult to document the physical location of data at any particular moment. These issues result in potential regulatory compliance issues which preclude the use of public clouds for certain organizations or business applications.

Not all public cloud based applications can provide the necessary flexibility and functionality needed by business users. For this reason, customers require the ability to take preferred functionality from one cloud application and combine it with another, creating a cloud based component application. This is still an emerging area of development with some early companies, such as Cast Iron, providing integration of a wide range of cloud based applications. Ultimately, many customers may decide that the private cloud offers more flexibility and develop new applications themselves.

Hybrid Clouds

To meet the benefits of both approaches, newer execution models have been developed to combine public and private clouds into a unified solution.

Applications with significant legal, regulatory or service level concerns for information can be directed to a private cloud. Other applications with less stringent regulatory or service level requirements can leverage a public cloud infrastructure.

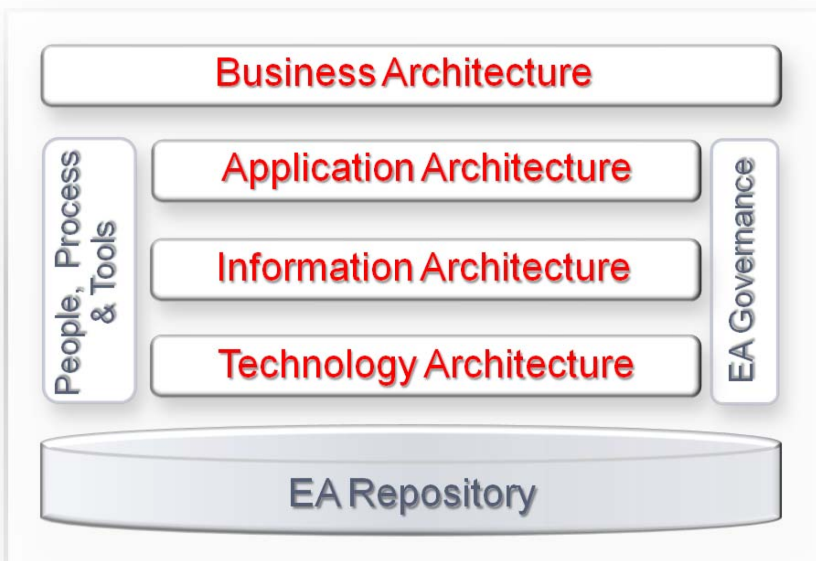
Implementation of a hybrid model requires additional coordination between the private and public service management system. This typically involves a federated policy management tool, seamless hybrid integration, federated security, information asset management, coordinated provisioning control, and unified monitoring systems.

How to Get Started

The considerations listed above are general and derived from the experience of several customers building private clouds. To make sure that your system accomplishes its intended purpose, it is important for the enterprise architect to use a framework for the design and maintenance of any new enterprise architecture. The application of an Enterprise Architecture Framework will lead the architect through the process, from the statement of the architectural vision and the analysis of the business architecture, through the systems and technical architecture designs, to incorporating deployment considerations of migration planning, governance, and change management.

Oracle Enterprise Architecture Framework

Oracle's Enterprise Architecture Framework can be used to streamline the architectural process for designing a public, private, or hybrid cloud infrastructure. Oracle's framework is aligned with other industry EA frameworks but adds Oracle-specific EA artifacts, such as Oracle reference architectures, tools, and prescriptive guidance for best practice implementation and governance.



Summary

For IT departments in larger enterprises, developing a private cloud often makes the most financial and business sense. When developing the architectural vision, an enterprise architect should bear in mind the characteristics of cloud computing as well as consider some of the organizational and cultural issues that might become obstacles to the adoption of the future state architecture. When moving ahead, decisions must be made on whether the future-state technical architecture should emphasize compatibility with the current standard or start from scratch to minimize cost. Future state systems architecture designs involve trade-offs between lower cost/operational efficiency and greater flexibility. Using an Enterprise Architecture framework can help enterprise architects navigate the trade-offs and design a system that accomplishes the business goal.

Conclusion

Cloud computing offers real alternatives to IT departments for improved flexibility and lower cost. Markets are developing for the delivery of software applications, platforms, and infrastructure as a service to IT departments over the “cloud”. These services are readily accessible on a pay-per-use basis and offer great alternatives to businesses that need the flexibility to rent infrastructure on a temporary basis or to reduce capital costs. Architects in larger enterprises find that it may still be more cost effective to provide the desired services in-house in the form of “private clouds” to minimize cost and maximize compatibility with internal standards and regulations. If so, there are several options for future-state systems and technical architectures that architects should consider to find the right trade-off between cost and flexibility. Using an architectural framework will help architects evaluate these trade-offs within the context of the business architecture and design a system that accomplishes the business goal. In any case, Oracle’s complete, open, and integrated product set offers a compelling value proposition at each level of the design and our certified Oracle Enterprise Architects can help customers discover a cloud roadmap that works for them.

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