



# ***Cloud Computing Use Cases White Paper***

Version 1.0

*A white paper produced by the  
**Cloud Computing  
Use Case Discussion Group***

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Public comments on this document are welcomed and encouraged at <http://groups.google.com/group/cloud-computing-use-cases>.



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## 1 Introduction

The Cloud Computing Use Case group brought together cloud consumers and cloud vendors to define common use case scenarios for cloud computing. The use case scenarios demonstrate the performance and economic benefits of cloud computing and are based on the needs of the widest possible range of consumers.

The goal of this white paper is to highlight the capabilities and requirements that need to be standardized in a cloud environment to ensure interoperability, ease of integration and portability. It must be possible to implement all of the use cases described in this paper without using closed, proprietary technologies. Cloud computing must evolve as an open environment, minimizing vendor lock-in and increasing customer choice.

The use cases:

- Provide a practical, customer-experience-based context for discussions on interoperability and standards.
- Make it clear where existing standards should be used.
- Focus the industry's attention on the importance of Open Cloud Computing.
- Make it clear where there is standards work to be done. If a particular use case can't be built today, or if it can only be built with proprietary APIs and products, the industry needs to define standards to make that use case possible.

A use case that clearly describes a common task and outlines the difficulties in accomplishing it is the best possible justification for any standards effort.

The Open Cloud Manifesto ([opencloudmanifesto.org](http://opencloudmanifesto.org)) is a statement of the principles for maintaining openness in cloud computing. Within two months of its announcement, 250 organizations signed on as supporters. This group's activity is done in light of the six principles of the Open Cloud Manifesto:

- Cloud providers must work together to ensure that the challenges to cloud adoption are addressed through open collaboration and the appropriate use of standards.
- Cloud providers must use and adopt existing standards wherever appropriate. The IT industry has invested heavily in existing standards and standards organizations; there is no need to duplicate or reinvent them.

## Cloud Computing Use Cases White Paper

- When new standards (or adjustments to existing standards) are needed, we must be judicious and pragmatic to avoid creating too many standards. We must ensure that standards promote innovation and do not inhibit it.
- Any community effort around the open cloud should be driven by customer needs, not merely the technical needs of cloud providers, and should be tested or verified against real customer requirements.
- Cloud computing standards organizations, advocacy groups, and communities should work together and stay coordinated, making sure that efforts do not conflict or overlap.
- Cloud providers must not use their market position to lock customers into their particular platforms and limiting their choice of providers.

This paper is part of the ongoing effort to make these principles a reality.

## 2 Definitions and Taxonomy

The following definitions and taxonomy are included to provide an overview of cloud computing concepts. However, the focus of this white paper is defining cloud scenarios and use cases based on real-world applications and requirements, not defining cloud computing itself. Our goal is to provide use case scenarios that are clear, interesting and useful, regardless of how those scenarios might be defined or placed into a taxonomy.

### 2.1 Definitions of Cloud Computing Concepts

**Cloud Computing:** Cloud computing is a model for enabling 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. (This definition is from the latest draft of the NIST Working Definition of Cloud Computing published by the U.S. Government's National Institute of Standards and Technology<sup>1</sup>.)

#### 2.1.1 Delivery Models

The NIST definition of cloud computing defines three delivery models:

- **Software as a Service (SaaS):** The consumer uses an application, but does not control the operating system, hardware or network infrastructure on which it's running.
- **Platform as a Service (PaaS):** The consumer uses a hosting environment for their applications. The consumer controls the applications that run in the environment (and possibly has some control over the hosting environment), but does not control the operating system, hardware or network infrastructure on which they are running. The platform is typically an application framework.
- **Infrastructure as a Service (IaaS):** The consumer uses "fundamental computing resources" such as processing power, storage, networking components or middleware. The consumer can control the operating system, storage, deployed applications and possibly networking

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<sup>1</sup> You can find the full document on the NIST Cloud Computing page at <http://csrc.nist.gov/groups/SNS/cloud-computing/>. The document states, "This material is public domain although attribution to NIST is requested. It may be freely duplicated and translated." The essential characteristics, delivery models and deployment models discussed in this paper are based on Version 14 of the document, dated 6-1-09.

components such as firewalls and load balancers, but not the cloud infrastructure beneath them.

### 2.1.2 Deployment Models

The NIST definition defines four deployment models:

- **Public Cloud:** In simple terms, public cloud services are characterized as being available to clients from a third party service provider via the Internet. The term “public” does not always mean free, even though it can be free or fairly inexpensive to use. A public cloud does not mean that a user’s data is publically visible; public cloud vendors typically provide an access control mechanism for their users. Public clouds provide an elastic, cost effective means to deploy solutions.
- **Private Cloud:** A private cloud offers many of the benefits of a public cloud computing environment, such as being elastic and service based. The difference between a private cloud and a public cloud is that in a private cloud-based service, data and processes are managed within the organization without the restrictions of network bandwidth, security exposures and legal requirements that using public cloud services might entail. In addition, private cloud services offer the provider and the user greater control of the cloud infrastructure, improving security and resiliency because user access and the networks used are restricted and designated.<sup>2</sup>
- **Community Cloud:** A community cloud is controlled and used by a group of organizations that have shared interests, such as specific security requirements or a common mission. The members of the community share access to the data and applications in the cloud.
- **Hybrid Cloud:** A hybrid cloud is a combination of a public and private cloud that interoperates. In this model users typically outsource non-business-critical information and processing to the public cloud, while keeping business-critical services and data in their control.<sup>3</sup>

### 2.1.3 Essential Characteristics

The NIST definition describes five essential characteristics of cloud computing.

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<sup>2</sup> A private cloud can be managed by a third party and can be physically located off premises. It is not necessarily managed and hosted by the organization that uses it.

<sup>3</sup> A Hybrid Cloud is a superset of the technology used in a Community Cloud. For that reason, the requirements for the two deployment models are discussed together under the heading "Hybrid Cloud" in Section 3.

- **Rapid Elasticity:** Elasticity is defined as the ability to scale resources both up and down as needed. To the consumer, the cloud appears to be infinite, and the consumer can purchase as much or as little computing power as they need. This is one of the essential characteristics of cloud computing in the NIST definition.
- **Measured Service:** In a measured service, aspects of the cloud service are controlled and monitored by the cloud provider. This is crucial for billing, access control, resource optimization, capacity planning and other tasks.
- **On-Demand Self-Service:** The on-demand and self-service aspects of cloud computing mean that a consumer can use cloud services as needed without any human interaction with the cloud provider.
- **Ubiquitous Network Access:** Ubiquitous network access means that the cloud provider's capabilities are available over the network and can be accessed through standard mechanisms by both thick and thin clients.<sup>4</sup>
- **Location-Independent Resource Pooling:** Resource pooling allows a cloud provider to serve its consumers via a multi-tenant model. Physical and virtual resources are assigned and reassigned according to consumer demand. The location of the physical resources underneath the cloud infrastructure is not known to the consumer, and can change dynamically.<sup>5</sup>

### 2.1.4 Other Terms

**Interoperability:** Interoperability is concerned with the ability of systems to communicate. It requires that the communicated information is understood by the receiving system. Interoperability is not concerned with whether the communicating systems do anything sensible as a whole.<sup>6</sup>

**Integration:** Integration is the process of combining components or systems into an overall system. Integration among cloud-based components and systems can

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<sup>4</sup> This does not necessarily mean Internet access. By definition, a private cloud is accessible only behind a firewall. Regardless of the type of network, access to the cloud is typically not limited to a particular type of client.

<sup>5</sup> In many cases privacy laws and other regulations require the cloud provider's resources to be in a particular location. The cloud provider and cloud consumer must work together to adhere to those regulations.

<sup>6</sup> The definitions of interoperability, integration and portability are based on the work at [http://www.testingstandards.co.uk/interop\\_et\\_al.htm](http://www.testingstandards.co.uk/interop_et_al.htm).



be complicated by issues such as multi-tenancy, federation and government regulations.

**Portability:** Portability is the ability of moving components or systems between environments. In the world of cloud computing, this includes software and hardware environments (both physical and virtual).

**Service Level Agreement (SLA):** An SLA is contract between a provider and a consumer that specifies consumer requirements and the provider's commitment to them. Typically an SLA includes items such as uptime, privacy, security and backup procedures.

**Federation:** Federation is the act of combining data or identities across multiple systems. Federation can be done by a cloud provider or by a cloud broker.

**Broker:** A broker has no cloud resources of its own, but matches consumers and providers based on the SLA required by the consumer. The consumer has no knowledge that the broker does not control the resources.

**Multi-Tenancy:** Multi-tenancy is the property of multiple systems, applications or data from different enterprises hosted on the same physical hardware. Multi-tenancy is common to most cloud-based systems.

**Cloud bursting:** Cloud bursting is a technique used by hybrid clouds to provide additional resources to private clouds on an as-needed basis. If the private cloud has the processing power to handle its workloads, the hybrid cloud is not used. When workloads exceed the private cloud's capacity, the hybrid cloud automatically allocates additional resources to the private cloud.

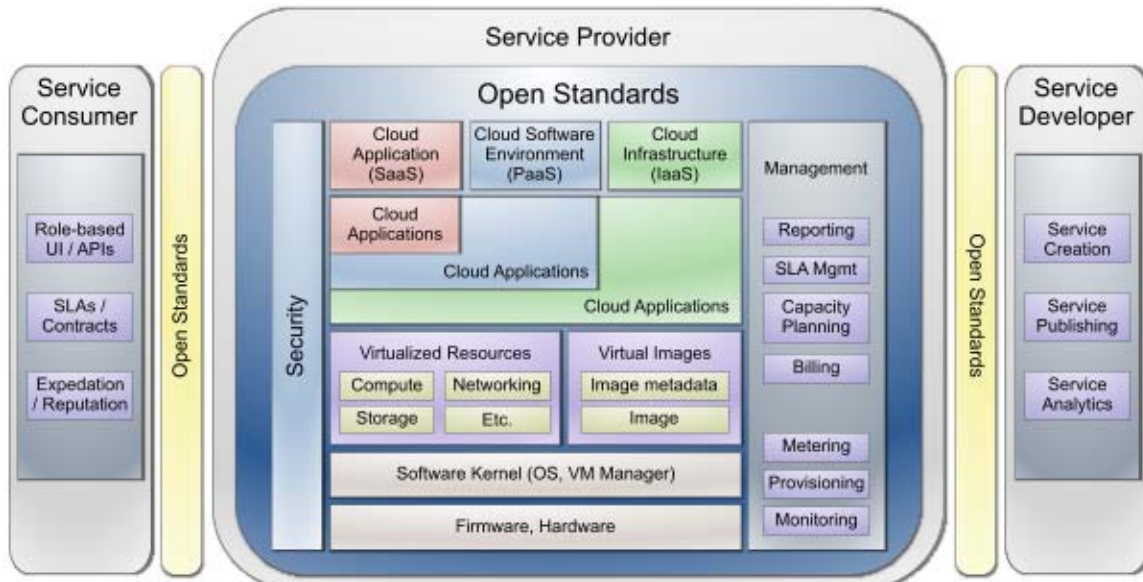
**Policy:** A policy is a general term for an operating procedure. For example, a security policy might specify that all requests to a particular cloud service must be encrypted.

**Governance:** Governance refers to the controls and processes that make sure policies are enforced.

**Virtual Machine (VM):** A file (typically called an image) that, when executed, looks to the user like an actual machine. Infrastructure as a Service is often provided as a VM image that can be started or stopped as needed. Changes made to the VM while it is running can be stored to disk to make them persistent.

## 2.2 Taxonomy

This diagram defines a taxonomy for cloud computing:



In this diagram, Service Consumers use the services provided through the cloud, Service Providers manage the cloud infrastructure and Service Developers create the services themselves. (Notice that open standards are needed for the interactions between these roles.) Each role is discussed in more detail in the following sections.

### 2.2.1 Service Consumer

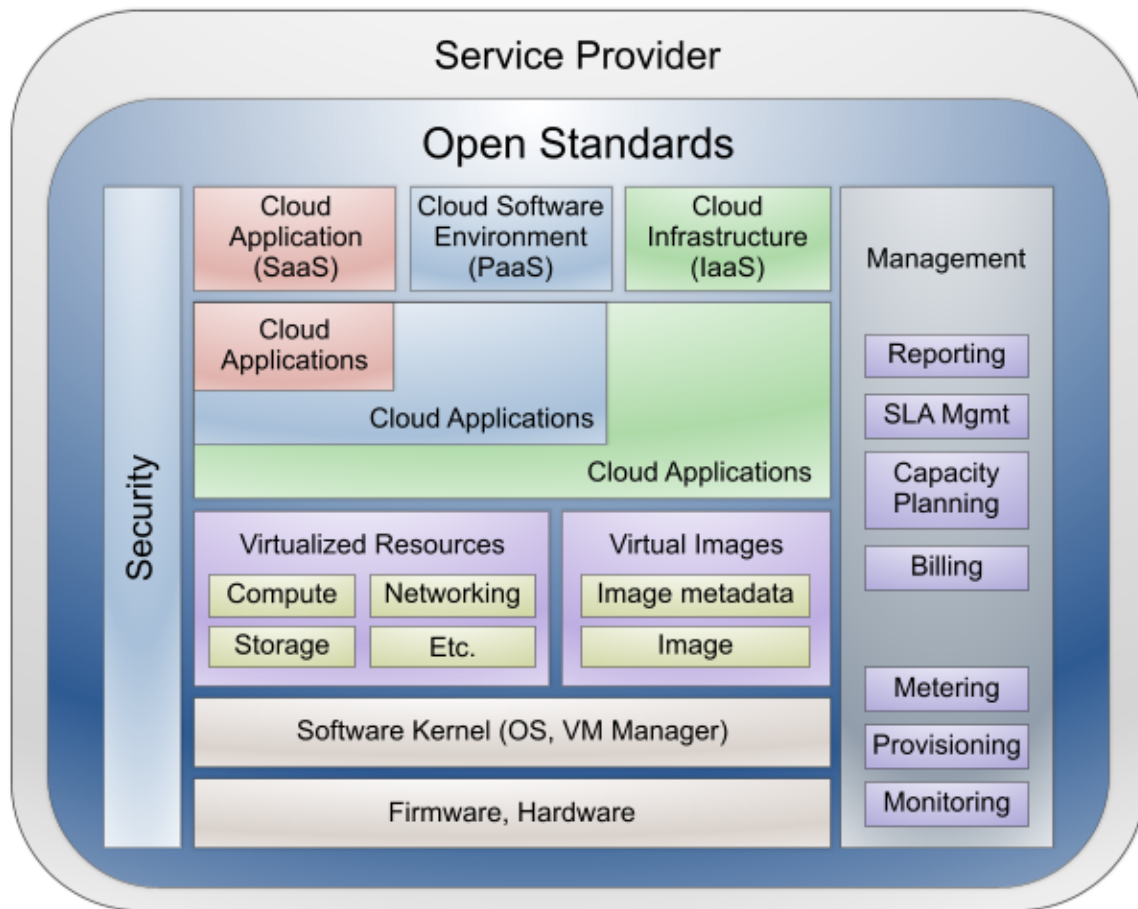
The service consumer is the end user or enterprise that actually uses the service, whether it is Software, Platform or Infrastructure as a Service.

Depending on the type of service and their role, the consumer works with different user interfaces and programming interfaces. Some user interfaces look like any other application; the consumer does not need to know about cloud computing as they use the application. Other user interfaces provide administrative functions such as starting and stopping virtual machines or managing cloud storage. Consumers writing application code use different programming interfaces depending on the application they are writing.

Consumers work with SLAs and contracts as well. Typically these are negotiated via human intervention between the consumer and the provider. The expectations of the consumer and the reputation of the provider are a key part of those negotiations.



## 2.2.2 Service Provider



The service provider delivers the service to the consumer. The actual task of the provider varies depending on the type of service:

- For Software as a Service, the provider installs, manages and maintains the software. The provider does not necessarily own the physical infrastructure in which the software is running. Regardless, the consumer does not have access to the infrastructure; they can access only the application.
- For Platform as a Service, the provider manages the cloud infrastructure for the platform, typically a framework for a particular type of application. The consumer's application cannot access the infrastructure underneath the platform.
- For Infrastructure as a Service, the provider maintains the storage, database, message queue or other middleware, or the hosting environment for virtual machines. The consumer uses that service as if it were a disk

drive, database, message queue, or machine, but they cannot access the infrastructure that hosts it.

In the service provider diagram, the lowest layer of the stack is the firmware and hardware on which everything else is based. Above that is the software kernel, either the operating system or virtual machine manager that hosts the infrastructure beneath the cloud. The virtualized resources and images include the basic cloud computing services such as processing power, storage and middleware. The virtual images controlled by the VM manager include both the images themselves and the metadata required to manage them.

Crucial to the service provider's operations is the management layer. At a low level, management requires metering to determine who uses the services and to what extent, provisioning to determine how resources are allocated to consumers, and monitoring to track the status of the system and its resources.

At a higher level, management involves billing to recover costs, capacity planning to ensure that consumer demands will be met, SLA management to ensure that the terms of service agreed to by the provider and consumer are adhered to, and reporting for administrators.

Security applies to all aspects of the service provider's operations. (The many levels of security requirements are beyond the scope of this paper.) Open standards apply to the provider's operations as well. A well-rounded set of standards simplify operations within the provider and interoperability with other providers.

### 2.2.3 Service Developer

The service developer creates, publishes and monitors the cloud service. In most cases this is an application delivered via SaaS, although a small number of developers create cloud middleware (IaaS) and cloud platforms (PaaS).

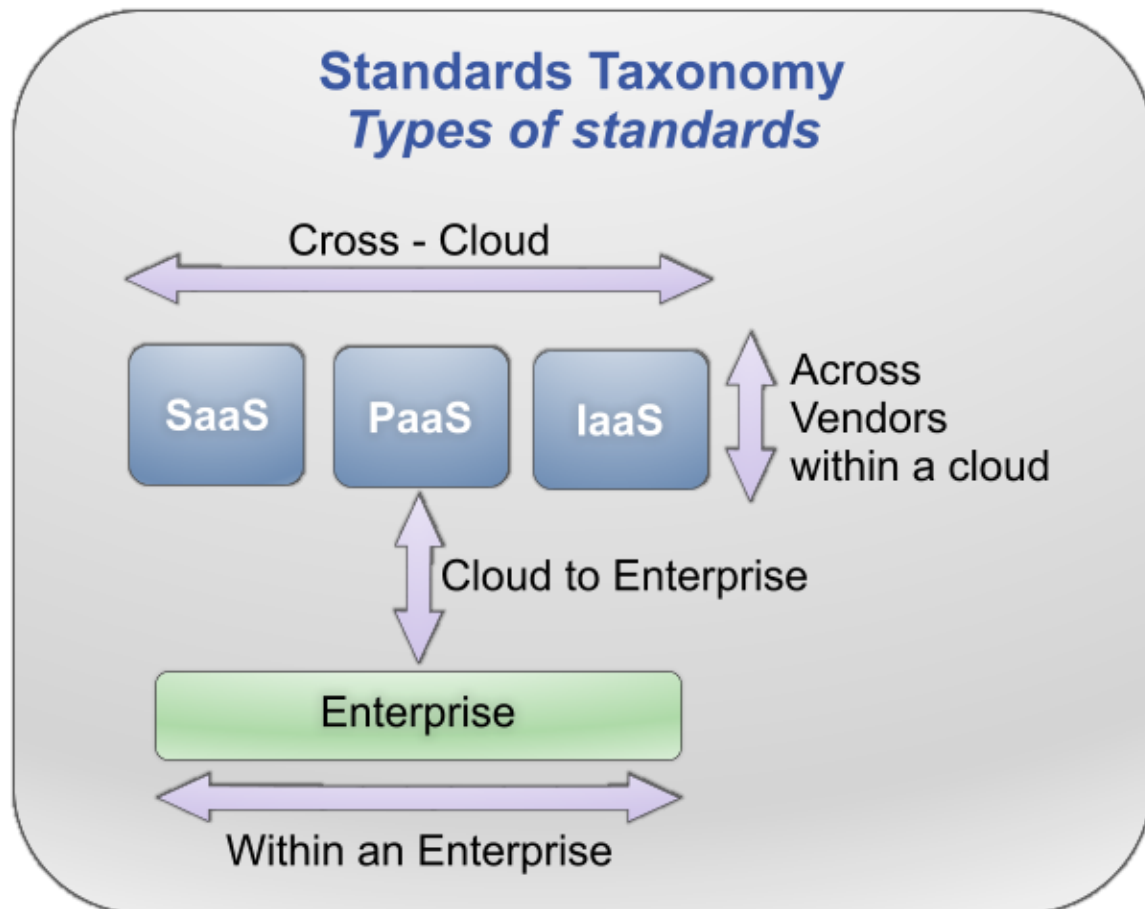
Development environments for service creation vary. If developers are creating a SaaS application, they are most likely writing code for an environment hosted by a cloud provider. In this case, publishing the service is deploying it to the cloud provider's infrastructure.

During service creation, analytics involve remote debugging to test the service before it is published to consumers. Once the service is published, analytics allow developers to monitor the performance of their service and make changes as necessary.



## 2.3 Relationships Between Standards and Taxonomies

There are four different ways standards will affect cloud use case scenarios. Standards will have an impact within each type of cloud service, across the different types of cloud services, between the enterprise and the cloud, and within the private cloud of an enterprise.



### 2.3.1 Standards Across Cloud Service Types

As cloud computing becomes more common, applications will likely use different types of cloud services. An application might use a cloud storage service, a cloud message queue, and manage (start/stop/monitor) virtual machines running in the cloud. Standards to define how these different services work together should provide value.

### 2.3.2 Standards Within Cloud Service Types

Within each type of cloud service (IaaS, PaaS or SaaS), open standards make it possible to avoid vendor lock-in.

For Infrastructure as a Service, a standard set of APIs to work with cloud databases would allow applications to work with data from multiple vendors. That common API would give users the freedom to move to another cloud database provider without major changes, and it would make it much easier to integrate new data sources with existing applications. Common APIs for other cloud infrastructure services such as storage, message queues or MapReduce would provide similar benefits, as would common formats for data and data interchange. In the case of virtual machines, a common virtual machine format is crucial. Users should be able to take a VM built and deployed with one cloud provider and deploy it to another cloud provider without changes.

For Platform as a Service, many of the platforms provided in the cloud are application frameworks. Those frameworks typically provide common services such as user interfaces, storage and databases, but they are accessible only through the APIs of the framework.

For Software as a Service, open standards apply at the application level. Very little of the standards work here is cloud-specific, so those standards are beyond the scope of this paper. For example, a cloud-based word processing application should support standards for document portability; the requirement for standards support in a word processing application has nothing to do with whether the application is running in the cloud.

### **2.3.3 Standards Between the Cloud and the Enterprise**

Even as cloud computing emerges, enterprise architectures such as Java EE are not going away. Standards that define how an enterprise application communicates with resources such as a cloud database or a cloud message queue would enable those applications to use cloud services with little or no changes. Figuring out how to integrate cloud computing with existing architectures and development paradigms will be a major challenge for this group.

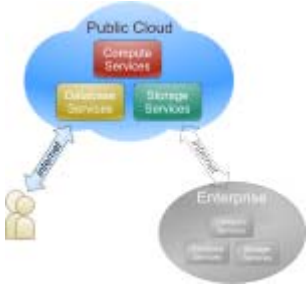


### **2.3.4 Standards Within an Enterprise**

Standards within an enterprise will be determined by requirements such as interoperability, auditability, security and management, and will build upon the standards that apply between enterprises and the cloud. The enterprise will interact with some combination of private, public and hybrid clouds.

### 3 Use Case Scenarios

The Enterprise Cloud Usage scenarios are intended to illustrate the most typical cloud use cases and are not meant to be an exhaustive list of realizations within a cloud environment.

The graphics in this section have common elements throughout. If a given element does not apply to a particular use case, it is grayed out or drawn with a dashed line. As an example, the Private Cloud use case does not involve the End User or the Public Cloud, so only the Enterprise appears in color.

<p><b>End User to Cloud</b></p>	<p>Applications running on the cloud and accessed by end users</p>	
<p><b>Enterprise to Cloud to End User</b></p>	<p>Applications running in the public cloud and accessed by employees and customers</p>	
<p><b>Enterprise to Cloud</b></p>	<p>Cloud applications integrated with internal IT capabilities</p>	

<p><b>Enterprise to Cloud to Enterprise</b></p>	<p>Cloud applications running in the public cloud and interoperating with partner applications (supply chain)</p>	
<p><b>Private Cloud</b></p>	<p>A cloud hosted by an organization inside that organization's firewall.</p>	
<p><b>Changing Cloud Vendors</b></p>	<p>An organization using cloud services decides to switch cloud providers or work with additional providers.</p>	
<p><b>Hybrid Cloud</b></p>	<p>Multiple clouds work together, coordinated by a cloud broker that federates data, applications, user identity, security and other details.</p>	

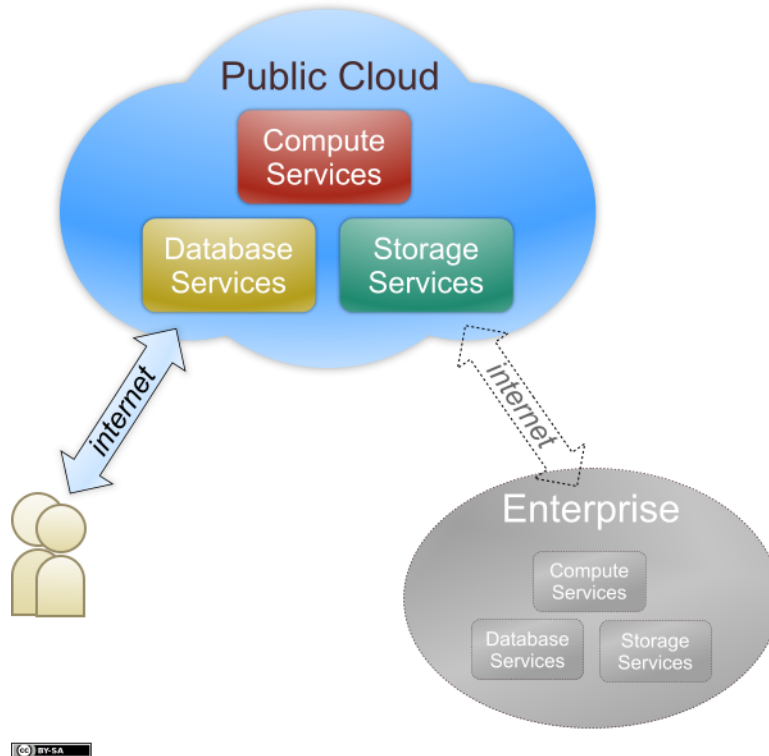
### 3.1 End User to Cloud

In this scenario, an end user is accessing data or applications in the cloud. Common applications of this type include email hosting and social networking sites. A user of Gmail, Facebook or LinkedIn accesses the application and their data through any browser on any device. The user doesn't want to keep up with anything more than a password; their data is stored and managed in the cloud.



Most importantly, the user has no idea how the underlying architecture works. If they can get to the Internet, they can get to their data.

### *End User to Cloud*



#### 3.1.1 Requirements

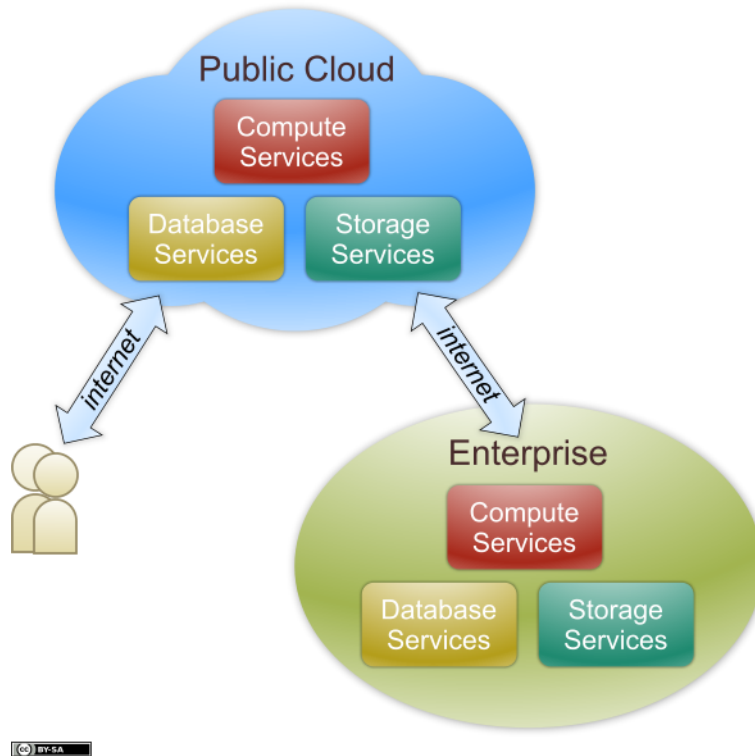
- **Identity:** The cloud service must authenticate the end user.
- An **open client:** Access to the cloud service should not require a particular platform or technology.
- **Security:** Security (including privacy) is a common requirement to all use cases, although the details of those requirements will vary widely from one use case to the next. A full discussion of security in cloud computing is beyond the scope of this paper.
- **SLAs:** Although service level agreements for end users will usually be much simpler than those for enterprises, cloud vendors must be clear about what guarantees of service they provide.

#### 3.2 *Enterprise to Cloud to End User*

In this scenario, an enterprise is using the cloud to deliver data and services to the end user. When the end user interacts with the enterprise, the enterprise accesses the cloud to retrieve data and / or manipulate it, sending the results to

the end user. The end user can be someone within the enterprise or an external customer.

### *Enterprise to Cloud to End User*



#### 3.2.1 Requirements

- **Identity:** The cloud service must authenticate the end user.
- An **open client:** Access to the cloud service should not require a particular platform or technology.
- **Federated identity:** In addition to basic the identity needed by an end user, an enterprise user is likely to have an identity with the enterprise. The ideal is that the enterprise user manages a single ID, with an infrastructure federating other identities that might be required by cloud services.
- **Location awareness:** Depending on the kind of data the enterprise is managing on the user's behalf, there might be legal restrictions on the location of the physical server where the data is stored. Although this violates the cloud computing ideal that the user should not have to know details of the physical infrastructure, this requirement is essential. Many applications cannot be moved to the cloud until cloud vendors provide an API for determining the location of the physical hardware that delivers the cloud service.

- **Metering and monitoring:** All cloud services must be metered and monitored for cost control, chargebacks and provisioning.
- **Management and Governance:** Public cloud providers make it very easy to open an account and begin using cloud services; that ease of use creates the risk that individuals in an enterprise will use cloud services on their own initiative. Management of VMs and of cloud services such as storage, databases and message queues is needed to track what services are used.

Governance is crucial to ensure that policies and government regulations are followed wherever cloud computing is used. Other governance requirements will be industry- and geography-specific.

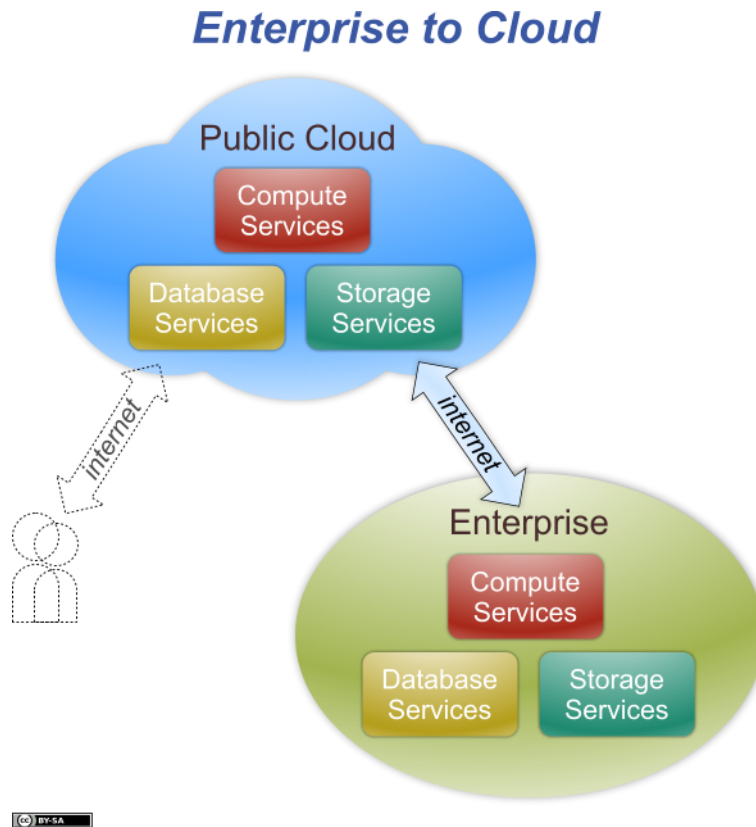
- **Security:** Any use case involving an enterprise will have more sophisticated security requirements than one involving a single end user. Similarly, the more advanced enterprise use cases to follow will have equally more advanced security requirements.
- **A Common File Format for VMs:** A VM created for one cloud vendor's platform should be portable to another vendor's platform.
- **Common APIs for Cloud Storage and Middleware:** The enterprise use cases require common APIs for access to cloud storage services, cloud databases, and other cloud middleware services such as message queues.

Writing custom code that works only for a particular vendor's cloud service locks the enterprise into that vendor's system and eliminates some of the financial benefits and flexibility that cloud computing provides.

- **Data and Application Federation:** Enterprise applications need to combine data from multiple cloud-based sources, and they need to coordinate the activities of applications running in different clouds.
- **SLAs and Benchmarks:** In addition to the basic SLAs required by end users, enterprises who sign contracts based on SLAs will need a standard way of benchmarking performance. There must be an unambiguous way of defining what a cloud provider will deliver, and there must be an unambiguous way of measuring what was actually delivered.
- **Lifecycle Management:** Enterprises must be able to manage the lifecycle of applications and documents. This requirement includes versioning of applications and the retention and destruction of data. Discovery is a major issue for many organizations. There are substantial legal liabilities if certain data is no longer available. In addition to data retention, in some cases an enterprise will want to make sure data is destroyed at some point.

### 3.3 Enterprise to Cloud

This use case involves an enterprise using cloud services for its internal processes. This might be the most common use case in the early stages of cloud computing because it gives the enterprise the most control.



In this scenario, the enterprise uses cloud services to supplement the resources it needs:

- Using cloud storage for backups or storage of seldom-used data
- Using virtual machines in the cloud to bring additional processors online to handle peak loads (and, of course, shutting down those VMs when they're not needed anymore)
- Using applications in the cloud (SaaS) for certain enterprise functions (email, calendaring, CRM, etc.).
- Using cloud databases as part of an application's processing. This could be extremely useful for sharing that database with partners, government agencies, etc.

### 3.3.1 Requirements

The basic requirements of the Enterprise to Cloud use case are much the same as those for the Enterprise to Cloud to End User use case. An **open client, federated identity, location awareness, metering and monitoring, management and governance, security, a common file format for VMs, common APIs for cloud storage and middleware, data and application federation, SLAs and lifecycle management** all apply.

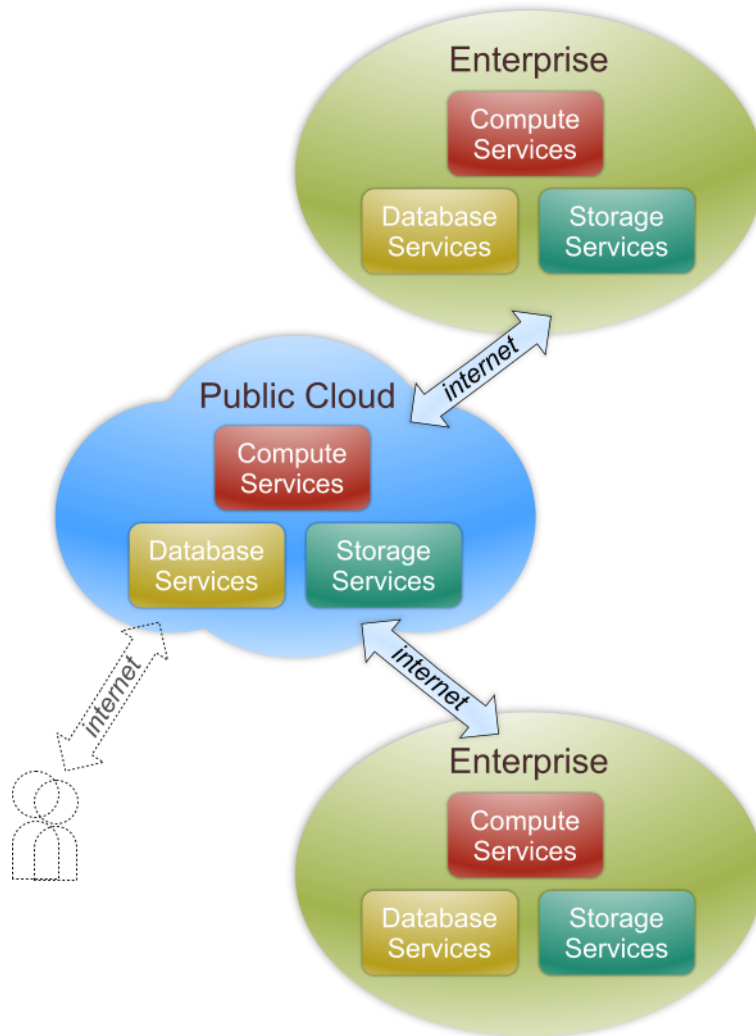
Other requirements for this use case are:

- **Deployment:** It should be simple to build a VM image and deploy it to the cloud as necessary. When that VM image is built, it should be possible to move that image from one cloud provider to another. Deployment of applications to the cloud should be straightforward as well.
- **Industry-specific standards and protocols:** Many cloud computing solutions between enterprises will use existing standards such as RosettaNet or OAGIS. The applicable standards will vary from one application to the next and from one industry to the next.

### 3.4 *Enterprise to Cloud to Enterprise*

This use case involves two enterprises using the same cloud. The focus here is hosting resources in the cloud so that applications from the enterprises can interoperate. A supply chain is the most obvious example for this use case.

## *Enterprise to Cloud to Enterprise*



### 3.4.1 Requirements

The basic requirements of the Enterprise to Cloud to Enterprise use case are much the same as those for the Enterprise to Cloud use case. **Identity, an open client, federated identity, location awareness, metering and monitoring, management and governance, security, industry-specific standards, common APIs for storage and middleware, data and application federation, SLAs and lifecycle management** all apply.

Other requirements for this use case are:

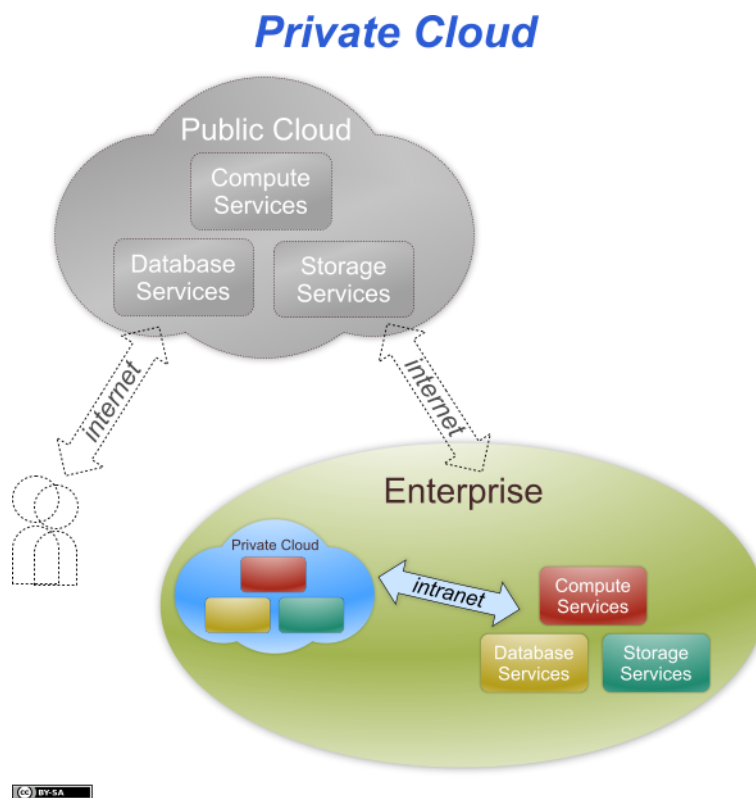
- **Transactions and concurrency:** For applications and data shared by different enterprises, transactions and concurrency are vital. If two enterprises are using the same cloud-hosted application, VM, middleware

or storage, it's important that any changes made by either enterprise are done reliably.

- **Interoperability:** Because more than one enterprise is involved, interoperability between the enterprises is essential.

### 3.5 Private Cloud

The Private Cloud use case is different from the others in that the cloud is contained *within* the enterprise. This is useful for larger enterprises. For example, if the payroll department has a surge in workload on the 15th and 30th of each month, they need enough computing power to handle the maximum workload, even though their everyday workload for the rest of the month is much lower. With a private cloud, computing power is spread across the enterprise. The payroll department gets extra cycles when they need it and other departments get extra cycles when they need it. This can deliver significant savings across the enterprise.



#### 3.5.1 Requirements

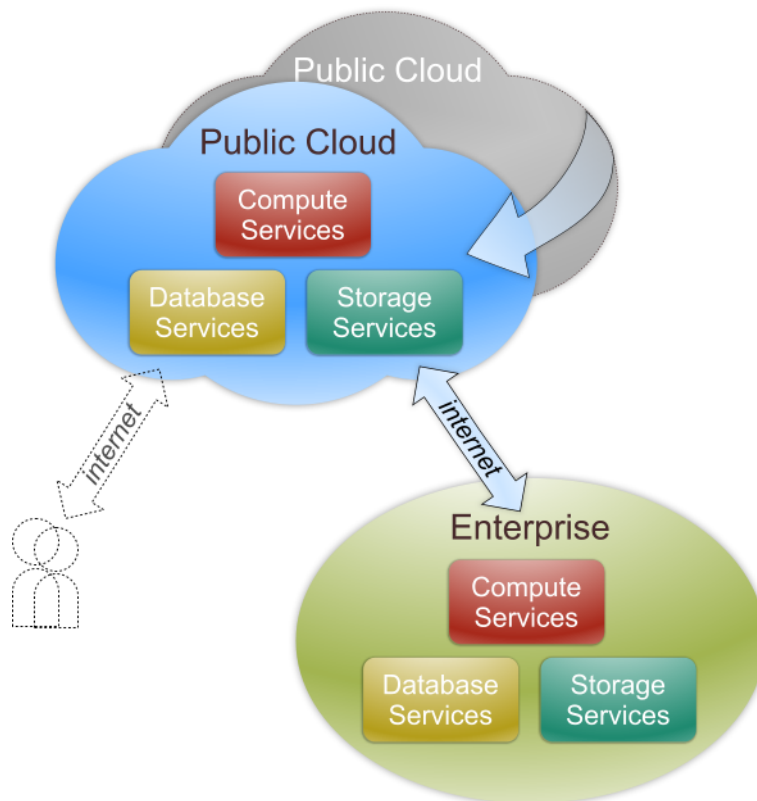
The basic requirements of the Private Cloud use case are an **open client**, **metering and monitoring**, **management and governance**, **security**, **deployment**, **interoperability**, a **common VM format**, and **SLAs**.

Note that a private cloud does not require identity, federated identity, location awareness, transactions, industry standards, common APIs for cloud middleware and lifecycle management. In many cases, consumers have to use a private cloud so that location awareness will no longer be an issue. Keeping the cloud inside the enterprise removes many of the requirements for identity management, standards and common APIs.

### 3.6 Changing Cloud Vendors

This use case involves working with a different cloud vendor, either adding an additional vendor or replacing an existing one. It applies to all of the other use cases discussed in this paper. Being able to work with other vendors without major changes is one of the main benefits of openness and standardization.

#### Changing Cloud Vendors



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There are four different scenarios here, each of which has slightly different requirements. In general, changing cloud vendors requires an **open client**, **location awareness**, **security**, **SLAs**, a **common file format for VMs** and **common APIs for cloud storage and middleware**. The details of those requirements are discussed in each of the following subsections.



### 3.6.1 Scenario 1: Changing SaaS vendors

In this scenario a cloud customer changes SaaS vendors. Both SaaS vendors provide the same application (CRM, accounting, word processing, etc.). Documents and data created with one vendor's software should be importable by the second vendor's software. In some cases, the customer might need to use the two vendors interchangeably.

#### 3.6.1.1 Requirements

- **Industry-specific standards:** Moving documents and data from one vendor's application to another requires both applications to support common formats. The formats involved will depend on the type of application.

In some cases, standard APIs for different application types will also be required.

It is important to note that there is nothing cloud-specific to these requirements. The standards for moving a document from Zoho to Google Docs, are the same standards for moving a document from Microsoft Office to OpenOffice.

### 3.6.2 Scenario 2: Changing middleware vendors

In this scenario a cloud customer changes cloud middleware vendors. Existing data, queries, message queues and applications must be exportable from one vendor and importable by the other.<sup>7</sup>

#### 3.6.2.1 Requirements

- **Industry-specific standards:** Moving documents and data from one vendor's middleware to another requires both applications to support common formats. The formats involved will depend on the type of application.
- **Common APIs for Cloud Middleware:** This includes all of the operations supported by today's cloud services, including cloud databases, cloud message queues and other middleware. APIs for connecting to, creating and dropping databases and tables.

Cloud database vendors have enforced certain restrictions to make their products more scalable and to limit the possibility of queries against large

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<sup>7</sup> Because of the popularity of cloud storage, cloud middleware (databases, message queues, Map Reduce) and cloud storage are considered separate scenarios, even though both are classified as PaaS.

data sets taking significant resources to process. For example, some cloud databases don't allow joins across tables, and some don't support a true database schema. Those restrictions are a major challenge to moving between cloud database vendors, especially for applications built on a true relational model.

Other middleware services such as message queues are more similar, so finding common ground among them should be simpler.

### 3.6.3 Scenario 3: Changing cloud storage vendors

In this scenario a cloud customer changes cloud storage vendors.

#### 3.6.3.1 Requirements

- **A Common API for Cloud Storage:** Code that reads or writes data in one cloud storage system should work with a different system with as few changes as possible; those changes should be confined to configuration code. In a JDBC application, as an example, the format of the URL and the driver name are different for different database vendors, but the code to interact with the database is identical.

### 3.6.4 Scenario 4: Changing VM hosts

In this scenario a cloud customer wants to take virtual machines built on one cloud vendor's system and run it on another cloud vendor's system.

#### 3.6.4.1 Requirements

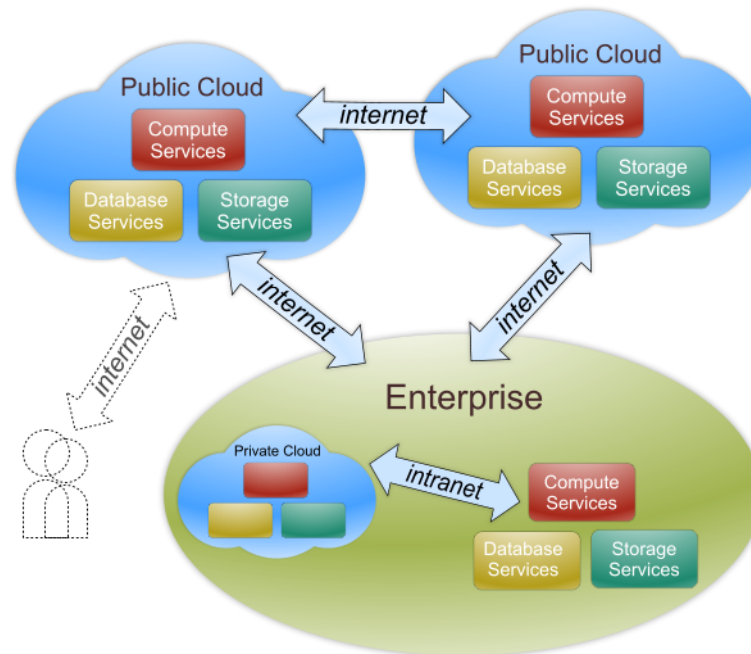
- **A common format for virtual machines:** The VM format should work with any operating system.

The assumption here is that the virtual machines themselves are running an operating system such as Windows or Linux. This means that the user of the virtual machine has chosen a platform prior to building a VM for the cloud, so there are no cloud-specific requirements for the software running inside the VM.

## 3.7 Hybrid Cloud

This use case involves multiple clouds working together, including both public and private clouds. A hybrid cloud can be delivered by a federated cloud provider that combines its own resources with those of other providers. A broker can also deliver a hybrid cloud; the difference is that a broker does not have any cloud resources of its own. The provider of the hybrid cloud must manage cloud resources based on the consumer's terms.

## Hybrid Cloud



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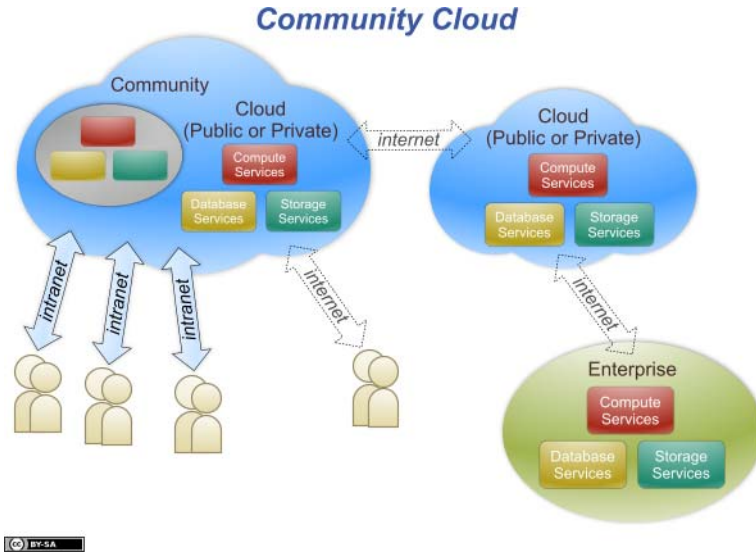
It is important to note that to the consumer of a hybrid cloud, this use case is no different from the End User to Cloud use case discussed earlier. The user has no knowledge of what the hybrid cloud provider actually does.

### 3.7.1 Requirements

- All of the requirements of the previous use cases (except **Transactions and concurrency**) apply here, particularly **Security, Data and Application Federation and Interoperability**.
- **SLAs:** A machine readable, standard format for expressing an SLA. This allows the hybrid cloud provider to select resources according to the consumer's terms without human intervention.

As mentioned in Section 2, the requirements for a community cloud are a subset of the requirements for the hybrid cloud. A community cloud has an infrastructure shared among enterprises with a common purpose. Here is the diagram for a community cloud:

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Notice that the communication between the community and the community cloud is done across an intranet. This could be a VPN, but access is not via the public Internet.

The following table summarizes the requirements for all of the use cases:

Requirement	End User to Cloud	Enterprise to Cloud to End User	Enterprise to Cloud	Enterprise to Cloud to Enterprise	Private Cloud	Changing Cloud Vendors	Hybrid Cloud
Identity	✓	✓		✓			✓
Open Client	✓	✓	✓	✓	✓	✓	✓
Federated Identity		✓	✓	✓			✓
Location Awareness		✓	✓	✓		✓	✓
Metering and Monitoring		✓	✓	✓	✓		✓
Management and Governance		✓	✓	✓	✓		✓
Security	✓	✓	✓	✓	✓	✓	✓

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Requirement	End User to Cloud	Enterprise to Cloud to End User	Enterprise to Cloud	Enterprise to Cloud to Enterprise	Private Cloud	Changing Cloud Vendors	Hybrid Cloud
Deployment			✓		✓		✓
Transactions and Concurrency				✓			
Interoperability				✓			✓
Industry-Specific Standards			✓	✓			✓
VM Image Format		✓	✓	✓	✓	✓	✓
Cloud Storage API		✓	✓	✓		✓	✓
Cloud Database API		✓	✓	✓		✓	✓
Cloud Middleware API		✓	✓	✓		✓	✓
Data and Application Federation		✓	✓	✓			✓
SLAs	✓	✓	✓	✓	✓	✓	✓
Lifecycle Management		✓	✓	✓			✓

## 4 Customer Scenarios

This section describes customer experiences with the use cases. Here is a summary of those customer scenarios:

Customer Scenario	Customer Problem Solved	Requirements & Capabilities	Applicable Use Case
<a href="#">Payroll Processing</a>	<ul style="list-style-type: none"> <li>• Processing time reduced</li> <li>• Hardware requirements reduced</li> <li>• Scalability enabled for future expansion</li> </ul>	IaaS (VMs), cloud storage	Enterprise to Cloud
<a href="#">Logistics &amp; Project Management</a>	<ul style="list-style-type: none"> <li>• Processing time reduced</li> <li>• Manual tasks eliminated</li> <li>• Development environment updated and streamlined</li> </ul>	PaaS (app framework), cloud storage	Enterprise to Cloud to End User
<a href="#">Central Government</a>	<ul style="list-style-type: none"> <li>• IT expertise consolidated</li> <li>• Hardware requirements reduced</li> </ul>	IaaS, PaaS	Private Cloud
<a href="#">Local Government</a>	<ul style="list-style-type: none"> <li>• IT expertise consolidated</li> <li>• Hardware requirements reduced</li> </ul>	IaaS, PaaS	Hybrid Cloud
<a href="#">Astronomic Data Processing</a>	<ul style="list-style-type: none"> <li>• Hardware expense greatly reduced (processing power and storage)</li> <li>• Energy costs greatly reduced</li> <li>• Administration simplified</li> </ul>	IaaS (VMs), cloud storage	Enterprise to Cloud to End User

### 4.1 Customer Scenario: Payroll Processing in the Cloud

#### 4.1.1 Applicable Use Case Scenario from Section 3:

#### Enterprise to Cloud

#### **4.1.2 Customer scenario:**

In this scenario, two servers were dedicated to payroll processing, a complex and time-consuming process. The organization decided to see how practical it would be to run the payroll process in the cloud. The existing payroll system was architected as a distributed application, so moving it to the cloud was relatively straightforward.

The payroll application used an SQL database for processing employee data. Instead of rewriting the application to use a cloud database service, a VM with a database server was deployed. The database server retrieved data from a cloud storage system and constructed relational tables from it. Because of the size of the original (in-house) database, extraction tools were used to select only the information necessary for payroll processing. That extracted information was transferred to a cloud storage service and then used by the database server.

The payroll application was deployed to four VMs that run simultaneously; those four VMs work with the VM hosting the database server. The configuration of the payroll application was changed to use the VM hosting the database server; otherwise the application was not changed.

#### **4.1.3 Customer problem solved:**

In the cloud-based version of the application, processing time for the payroll task was reduced by 80%. As an added benefit, two servers formerly dedicated to processing payroll were freed up for other tasks. Finally, the cloud-based version is much more scalable; that will be a significant advantage as the organization expands.

#### **4.1.4 Requirements and Capabilities:**

The cloud services used were virtual machines and cloud storage (IaaS). The payroll application did not have to be modified, it was simply deployed to the virtual machine. The original application used a relational database. To avoid changing data structures and applications to use a cloud database, a relational database server was deployed into the cloud.

The only API used was the S3 cloud storage API.

#### **4.1.5 Portability Concerns:**

The payroll application runs on Fedora and Java 1.5, so it will run without changes on any cloud provider's platform that supports Fedora. Modifying the application to use a different cloud storage provider could be a problem if the other vendor doesn't support the specific S3 APIs used in the payroll process. Finally, changing the application to use a cloud database could be extremely

difficult, particularly if it involved moving to a cloud database that does not support the relational model.

## **4.2 *Customer Scenario: Logistics and Project Management in the Cloud***

### **4.2.1 Applicable Use Case Scenario from Section 3:**

#### **Enterprise to Cloud to End User**

#### **4.2.2 Customer scenario:**

A small construction company with approximately 20 administrative employees needed a way to manage their resources, optimize project scheduling and track job costs. The company had very specific requirements that no commonly available system addressed, so they used a combination of Quickbooks and spreadsheets. This system was not scalable and was a huge waste of human resources.

The solution to the problem was to build a custom client-side application. All of the business logic resides on the client. Data for the application is served from a Google App Engine (GAE) datastore. The datastore does not enforce any sort of schema other than an RDF graph, although it does host an RDF-OWL ontology. The client uses that ontology to validate data before displaying it to the user or sending it back to the GAE.

Data operations are communicated with the datastore using an application-specific RESTful protocol over HTTP. The datastore maintains RDF graphs specific to the applications it is serving within silos managed on the server. Security is implemented separately for each silo depending on the requirements of the application using a particular silo of data. Using this system, any number of applications can use the datastore without building a new code base for each one.

Data was moved into the datastore on GAE from the locally hosted Quickbooks SQL server and the custom spreadsheets using a one-time data migration script that reconciled the data before uploading it to the GAE datastore. The data set was small and easily processed using local resources.

The client application maintains a local datastore that contains a subset of the most recent changes to the data. The REST architecture of the application allows HTTP's built-in caching support to automatically propagate changes to the master datastore down to the client. In addition to the performance benefits of using a subset of the data, this design simplifies security. If a client application does not need to access to certain fields or records, that portion of the datastore never leaves the server.



#### **4.2.3 Customer problem solved:**

Data was moved from an inefficient system of software and spreadsheet macros into a cloud-based system. The resulting datastore can be used by a wide range of applications, making future development and maintenance much simpler.

Although the original application infrastructure is still in use, the applications built on that infrastructure no longer rely on spreadsheets to analyze and manipulate the data. Significant savings will come from the fact that maintaining the spreadsheets will no longer be necessary. In addition, cutting and pasting data by hand is no longer part of the process, removing a tedious task and eliminating a source of errors.

#### **4.2.4 Requirements and Capabilities:**

The cloud service used the Google App Engine, a PaaS implementation that provides database support. The combination of a RESTful API and the cloud datastore made the application more scalable than an application built around a traditional relational database.

#### **4.2.5 Portability Concerns:**

The application runs on the Google App Engine and its BigTable database. BigTable is a sparse, distributed, persistent, multi-dimensional sorted map that achieves scalability by prioritizing denormalization over normalization. This is a significant difference from most datastores, and requires a fundamental rethinking of application development. Porting the application to run on top of a more traditional datastore would require major changes to the application's architecture.

### ***4.3 Customer Scenario: Central Government Services in the Cloud***

#### **4.3.1 Applicable Use Case Scenario from Section 3:**

##### **Private Cloud**

#### **4.3.2 Customer scenario:**

The ministries of the Japanese Government have thousands of servers across their infrastructures. The central government has announced a private "Kasumigaseki" cloud environment to provide a secure, centralized infrastructure for hosting government applications.

Existing back office systems, such as payroll, accounting and personnel management, will be virtualized and hosted in the private cloud. Some front office systems, such as electronic procurement, will be virtualized to a public cloud, but

that is outside the scope of this project. The ultimate goal of the project is to reduce the total cost of ownership by eliminating redundant systems and the need for administrators in each ministry.

#### **4.3.3 Customer problem solved:**

The three problems solved by the Kasumigaseki cloud are reduced costs, reduced energy consumption and reduced IT staff.

#### **4.3.4 Requirements and Capabilities:**

The cloud infrastructure will be built on a private network built by Japanese telecommunications companies. Because privacy and security are major concerns, a private cloud is required. It is illegal for many types of personal data to be stored on a server outside of Japan.

#### **4.3.5 Portability Concerns:**

Because the government is building its own private cloud to host its own applications, portability is not a concern. The government has no intention of moving its centralized applications and data from the private cloud to a public one.

### ***4.4 Customer Scenario: Local Government Services in a Hybrid Cloud***

#### **4.4.1 Applicable Use Case Scenario from Section 3:**

##### **Hybrid Cloud**

#### **4.4.2 Customer scenario:**

There are more than 1800 local governments across Japan, each of which has its own servers and IT staff. A secondary goal of the Kasumigaseki cloud is to provide a hybrid cloud environment. Some data will be stored in the government's private cloud, while other data will be stored locally. Wherever possible, existing systems will be virtualized and hosted in the Kasumigaseki cloud.

#### **4.4.3 Customer problem solved:**

The three problems solved by the hybrid cloud are reduced costs, reduced energy consumption and reduced IT staff.

#### **4.4.4 Requirements and Capabilities:**

Privacy and security are crucial in this scenario. Japanese law prevents some types of data from being stored outside the local government's servers, so moving applications and data into the Kasumigaseki cloud is not an option. Because some processing will be on the local government's infrastructure, federation of applications and data inside the hybrid cloud is crucial.

#### **4.4.5 Portability Concerns:**

As with the previous customer scenario, portability is not a concern because the government is building its own private cloud. The government has no intention of moving its centralized applications and data from the private cloud to a public one.

### **4.5 Customer Scenario: Astronomic Data Processing**

#### **4.5.1 Applicable Use Case Scenario from Section 3:**

##### **End User to Cloud**

#### **4.5.2 Customer Scenario:**

Gaia<sup>8</sup> is a mission of the European Space Agency that will conduct a survey of one billion stars in our galaxy. It will monitor each of its target stars about 70 times over a five-year period, precisely charting their positions, distances, movements, and changes in brightness. It is expected to discover hundreds of thousands of new celestial objects, such as extra-solar planets and failed stars called brown dwarfs.

This mission will collect a large amount of data that must be analyzed. The ESA decided to prototype a cloud-based system to analyze the data. The goals were to determine the technical and financial aspects of using cloud computing to process massive datasets.

The prototype system contains the scientific data and a whiteboard used to publish compute jobs. A framework for distributed computing (developed in house) is used for job execution and data processing. The framework is configured to run AGIS (Astrometric Global Iterative Solution). The process runs a number of iterations over the data until it converges.

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<sup>8</sup> See [http://www.esa.int/esaSC/120377\\_index\\_0\\_m.html](http://www.esa.int/esaSC/120377_index_0_m.html) for an overview of the project.

For processing, each working node gets a job description from the database, retrieves the data, processes it and sends the results to intermediate servers. The intermediate servers update the data for the following iteration.

The prototype evaluated 5 years of data for 2 million stars, a small fraction of the total data that must be processed in the actual project. The prototype went through 24 iterations of 100 minutes each, equivalent to running a grid of 20 VMs for 40 hours. For the full billion-star project, 100 million primary stars will be analyzed along with 6 years of data, which will require running the 20 VM cluster for 16,200 hours.

To evaluate the scalability of a cloud-based solution, the prototype ran a second test with 120 high CPU extra large VMs. With each VM running 12 threads, there were 1440 processes working in parallel.

### **4.5.3 Customer Problem Solved:**

The estimated cost for the cloud-based solution is less than half the cost of an in-house solution. That cost estimate does not include the additional electricity or system administration costs of an in-house solution, so the actual savings will be even greater. Storage of the datasets will be cloud-based as well.

In the second test, a couple of performance problems with SQL queries and lock contention at the database were detected and solved. These problems could not have been detected with the current in-house system. The prototype allowed the organization to find and solve performance and scalability problems before going to production.

### **4.5.4 Requirements and Capabilities:**

The prototype used VMs for the AGIS software and the database. The database is a traditional database running inside a VM; it is a full relational database, not a cloud database service. For storage, five cloud-based storage volumes (100GB each) were attached to the database server.

### **4.5.5 Portability Concerns:**

All of the VMs are running standard operating systems and none of the software used in the project is cloud-specific. The portability concern for this application would be the ability to migrate those VM images to another provider without having to rebuild or reconfigure the images.

## 5 Conclusions and Recommendations

Cloud computing builds on and complements many trends in the industry, including virtualization, SOA and Web 2.0. As a result, standards already exist for many of the requirements outlined in this paper. As we go forward, we will work together as a community to specify the existing standards that meet customer needs, leverage standards work already in progress, and identify what is needed to fill in the gaps not addressed by existing standards.

This paper was created by an open Web community of more than 750 participants. The initial group consisted of supporters from the Open Cloud Manifesto, but it quickly grew to include many other individuals around the world. The community included representatives from large and small companies, government agencies, consultants and vendors.

As the paper was developed, three principles from the manifesto were crucial: 1) users should work together, 2) activities to keep the cloud open should be customer driven and 3) existing standards should be used wherever possible. This paper is validation that those principles work, and they will be central to any follow-on work.

The use cases described here demonstrate the following general requirements:

- **Common VM Formats, Data Formats and APIs:** Virtual machines, data and applications created for one cloud provider should run on another cloud provider without changes.
- **Cloud Management:** Cloud computing is not feasible without service management, governance, metering, monitoring, federated identity, SLAs and benchmarks, data and application federation, deployment, and lifecycle management. These requirements are defined in Section 3295832 \r \h [3].
- **Security:** Security in cloud computing is vital, although the requirements for security will vary widely depending on the application and data types.
- **Location awareness:** A way of identifying the location of the physical machine hosting the cloud infrastructure is an absolute requirement for many government regulations.

It must be possible for consumers to implement any of the use cases outlined here without resorting to closed, proprietary solutions that lead to vendor lock-in. Where existing standards meet requirements, we must ensure those standards are implemented pervasively and consistently. Where existing standards do not meet requirements, we must define and implement the standards needed to meet them. This community-written paper is meant to be the reference for establishing a truly open cloud computing environment.