White Paper
November 2014

IT@Intel
Making Private-Public Cloud Decisions on the Way to a Hybrid Cloud

Our methodical approach—considering security, control, cost, location, application requirements, capacity, and availability—enables the best hosting decision for each use case.

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Executive Overview

To accelerate Intel IT's journey to a federated, interoperable, open hybrid cloud, we act as an in-house cloud broker, providing Intel application owners with choice and flexibility through private, public, and hybrid cloud hosting options. Our methodical approach—considering security, control, cost, location, application requirements, capacity, and availability—enables the best hosting decision for each use case.

Our private cloud currently serves about 85 percent of Intel's hosting needs. It gives us ultimate control over hosted applications and allows us to maximize existing investments.

In time, we anticipate growth in our public cloud usage based on several factors:

- An increasing number of public clouds use open source software and open standards that enable the necessary interoperability for dynamic hosting decisions based on workload, business need, and changes in cost structure.
- For many business use cases, public clouds offer key advantages, such as meeting performance, data sovereignty, or compliance requirements in a particular location; supplying unusual resources or technologies; and providing sandboxes for experimental applications and proofs of concept (PoCs).
- More Intel developers are becoming proficient in creating cloud-aware applications that maximize cloud advantages, such as run-anywhere design, self-service provisioning, elasticity, multitenancy, and design for failure.

Contents

Acronyms

API	application programming interface
CMM	Cloud Maturity Model
DBaaS	database as a service
IaaS	infrastructure as a service
PaaS	platform as a service
PoC	proof of concept
SaaS	software as a service
SLA	service level agreement
VM	virtual machine

Our future hybrid cloud model will combine private and public clouds to provide us with greater flexibility to make the right choice for each use case. As our ability to enable dynamic hosting decisions grows, our public cloud usage may expand to include opportunities to scale enterprise capacity based on typical loads rather than peak loads. Guiding such decisions will be our focus on providing choice and balance in agility, scalability, flexibility, and cost savings for Intel application owners.

Background

Four years into our transition to cloud computing, Intel IT continues to progress toward a private-public-hybrid cloud hosting model with a federated, interoperable, and open cloud as our goal. Strategically using private and public cloud resources, we offer choice and flexibility to Intel application owners and IT staff, helping them achieve high levels of performance, agility, scalability, and efficiency.

To guide our cloud journey, Intel IT follows the Cloud Maturity Model (CMM) provided by the Open Data Center Alliance (ODCA).[1] We are working toward CMM Stage 3, which includes complex models of software as a service (SaaS) and full production models of private platform as a service (PaaS) and infrastructure as a service (IaaS), in 2015 (Figure 1).

[1] For more on the Open Data Center Alliance, visit www.opendatacenteralliance.org.

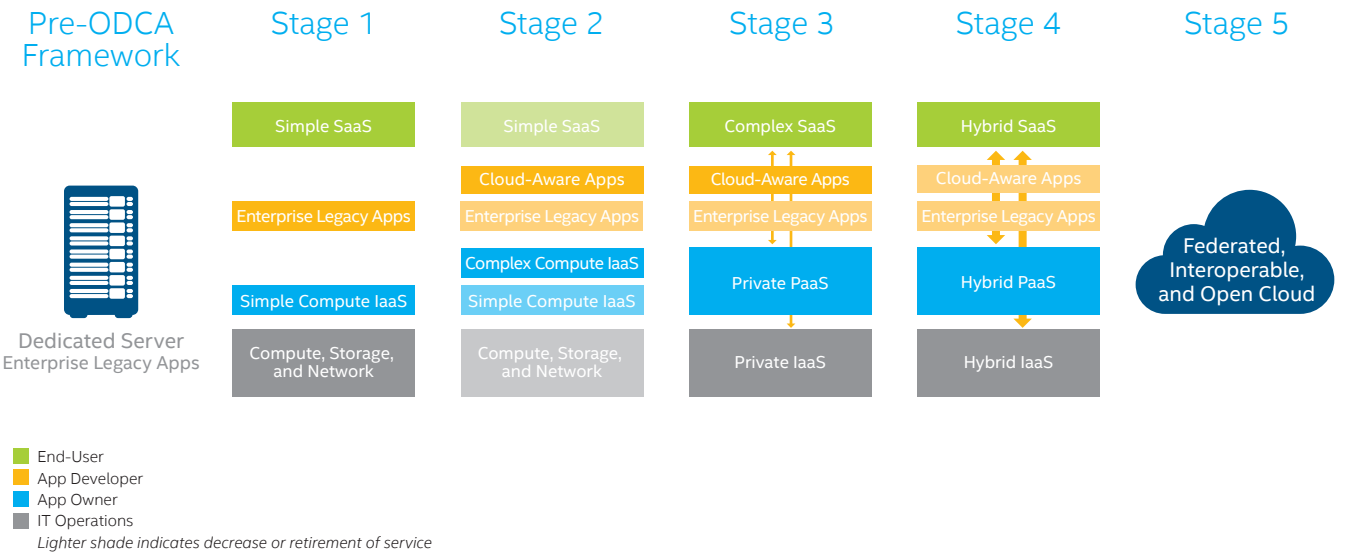


Figure 1. Intel IT uses the Open Data Center Alliance Cloud Maturity Model (CMM) to help guide our progress to a federated, interoperable, and open hybrid cloud, the goal recommended by industry organizations.

Benefits of a Federated, Interoperable, Open Hybrid Cloud

Eventually, we plan to achieve CMM Stage 5, offering a federated, interoperable, and open hybrid cloud spanning all cloud services models—SaaS, PaaS, and IaaS.

CMM Stage 5 will enable us to achieve the following:

- Federate user identities among private and public clouds
- Move workloads across clouds easily with minimal switching costs
- Integrate and automate cloud components across clouds using open standards and APIs
- Take advantage of the fast cadence of open source communities in delivering the latest open cloud software features and capabilities
- Achieve greater agility, scalability, and flexibility in rapidly sourcing cloud services based on criteria such as user demand, cost, location, and regulatory requirements

Private Cloud Advantages

As we advance toward the federated, interoperable, and open hybrid cloud model, we rely on our private cloud hosted on Intel networks. Intel's large, global IT infrastructure provides significant capacity, enabling us to perform cost effectively and efficiently as our own cloud service provider and broker.

We manage our capacity based on historical values, always aiming to maintain enough capacity to handle new hosting requests and enterprise growth. We work directly with Intel business groups to anticipate their requirements and determine timelines for new projects.

Our preference is to use our private cloud first and employ public clouds strategically when we cannot meet certain requirements. Like many IT organizations, we do not place sensitive and valuable data on an infrastructure we do not control. Protecting Intel's intellectual property, sensitive data, and brand is critical.

Current differences in our private cloud and public cloud maturity add to our reluctance to make greater use of public clouds. Shortcomings in public cloud interoperability and openness hinder our opportunities to integrate with public clouds and rapidly provision and scale out workloads in a standardized manner.

Application-owner demand for the perceived advantages in ease of use and deployment speed of public cloud hosting is also waning. Our recent automation and self-service improvements now satisfy the majority of our application owners. Historically, it may have taken up to 90 days to provision a server in response to a request for new capacity; self-service capabilities in our private cloud IaaS now enable application owners to acquire a virtual machine (VM) with a service level agreement (SLA) in less than 3 hours.

Three Factors in Cloud Maturity

In working toward Stage 5 of the Open Data Center Alliance's Cloud Maturity Model (CMM), we look for public cloud providers that offer the following core capabilities.

- **Federation.** This term refers to the ability of identity- and access-management software to securely share user identities and profiles. Through federation, users within an organization can use resources located in multiple clouds without having to generate separate credentials in each cloud. Federation enables IT to manage one set of identities, authorizations, and security review processes. From the user perspective, federation enables seamless integration of systems and applications.
- **Interoperability.** This capability covers two concepts. The first is the ability to connect two applications that are concurrently running in cloud environments. The second is the ability to quickly and easily port an application from one cloud to another with minimal switching costs. Both concepts use standard mechanisms for service orchestration and management, enabling elastic operation and flexibility for dynamic business models while minimizing supplier lock-in.
- **Openness.** "Open" refers to both standards and software. Open source software evolves quickly and is supported by a diverse, vibrant community. The frequent update cycles provide fast access to new features and capabilities, including performance and efficiency improvements. The use of standard, common APIs and abstraction layers makes it easier for end users to rapidly consume cloud services from different providers to meet business requirements. In cases where software is not open source, adherence to open standards is important for enabling users to maximize the benefits of cloud deployment. Open standards are publicly available specifications for hardware or software that are developed by a standards organization or consortium. Nonproprietary in nature, open standards help support interoperability.

Our private cloud self-service PaaS solution enables developers to rapidly build and host custom applications in our private cloud without having to deal with server provisioning or management.[2] Additionally, our recently introduced database-as-a-service (DBaaS) solution enables application teams to define new databases and manage their tables and data without the burden of full database administration.

Public Cloud Use

Our private cloud maturity, capacity, and ease of use results in public clouds providing only approximately 15 percent of our hosting needs, as measured by number of servers and virtual instances, including IaaS and PaaS across all hosting segments. In the cases when Intel's private cloud does not meet specific needs, we use our experience and relationships with approved public cloud providers to advise application owners on the best hosting solution. We turn to public clouds today for the following main reasons:

- To meet performance, data sovereignty, or compliance requirements in a particular location
- To locate processing, storage, and security resources closer to applications and teams
- To supply hardware or software resources Intel IT does not currently have and may not want to purchase
- To provide sandboxes for safely conducting experimental applications and proofs of concept (PoCs)

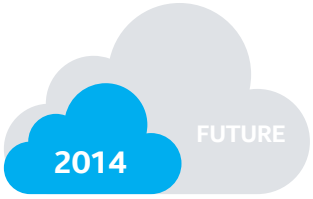
As the public cloud industry matures and our needs for choice and flexibility grow, we expect the ratio of our private-to-public hosting to change. We anticipate that the ratio will vary dynamically to take to advantage of the best hosting solutions, private or public, at a particular time based on various criteria.

Solution

Intel IT believes that private and public clouds each hold advantages. To make the best hosting choice in each situation, we position ourselves as an in-house cloud broker, helping Intel application owners base their decisions on circumstances, resources, and needs. In making these decisions, we take a methodical approach, considering application requirements for security, control, cost savings, location, capacity, and high availability on an individual basis.

This section explores the criteria we consider when deciding whether to host an application on a public cloud. We also discuss steps we are taking to expand our use of public cloud services.

[2] See the Intel IT white paper "Extending Intel's Enterprise Private Cloud with Platform as a Service."



15%

Public Cloud Hosting

We expect our need for public cloud services to increase over time.

Cloud Deployment Models

Cloud computing enables convenient, on-demand network access to a shared pool of configurable computing resources designed for rapid provisioning and release with minimal management effort or cloud provider interaction. These resources include networks, servers, storage, applications, and services. In this paper we discuss three cloud deployment models.

- **Private cloud.** This infrastructure is provisioned for the use of a single organization to serve multiple business units. It is typically owned, managed, and operated by the organization, or in some cases, a third party. A private cloud can be on-premises (enterprise private cloud) or off-premises (virtual private cloud).
- **Public cloud.** This infrastructure is provisioned and hosted for use by the general public to provide resources to a variety of customers. It is owned, managed, and operated by a third-party cloud provider on the provider's premises.
- **Hybrid cloud.** This infrastructure is composed of two or more distinct clouds–which can be private, public, or private and public–that remain separate entities but through open source and standardized technology enable data and application portability such as load balancing between clouds.

Criteria for Public Cloud Hosting

As our cloud operations grow, we find many cases in which a public cloud makes good business sense or provides a stepping stone to our goal of a federated, interoperable, open hybrid cloud. In making our hosting decision, we consider security, control, cost, location, application requirements, capacity, and high availability.

Security

Security and privacy concerns present a significant obstacle to extensive adoption of public cloud hosting for Intel IT and for IT groups across the industry. Whether hosted in our private cloud or in a public cloud, all Intel applications are required to follow all relevant security policies.

Because of high risk and security ratings, many Intel workloads require private cloud hosting. These workloads may be too critical to Intel's operations or the data too sensitive, valuable, and important to host outside the enterprise.

Intel Security provides four classifications of data:

- **Public data.** Informational only, with no login credentials or data collected from users.
- **Intel Confidential.** May require registration with username, email, and other identification data. Access to the information does not require collecting credit card information, medical data, or other more sensitive personal data.
- **Intel Restricted Secret.** Bank information, medical information, and other sensitive personal data.
- **Intel Top Secret.** Chip designs, financial data, and other forms of intellectual property or highly confidential information.

Currently, depending on the public cloud provider's security capabilities, we permit public hosting of applications only if the applications either already provide publicly available data or require only Intel Confidential security levels. In these instances, the public cloud providers we choose must offer a broad set of security capabilities that can protect data and intellectual property. Our Intel Secure External Presence program works with application owners to help ensure that all publicly hosted Intel property is compliant with Intel external presence security policies.

Some technologies that help increase our confidence in a public cloud provider's security include private virtual LANs that isolate VMs and separate network and server administrative duties. We also look for use of Intel® architecture designed to provide secure virtualization capabilities through hardware-assisted security, such as Intel® Trusted Execution Technology (Intel® TXT).

Exploring Data Anonymization

Intel IT is exploring data anonymization—the process of obscuring published data to prevent the identification of key information—as a means of protecting sensitive and personally identifiable information hosted on a public cloud. This security technique may expand the range of use cases for which we will consider and use a public cloud provider.

Read more about the exploration in the Intel IT white paper, "Enhancing Cloud Security Using Data Anonymization."

Control

In our journey to open hybrid cloud, one goal is the ability to treat the public cloud environment as an extension of our data center services—and control it just as tightly. Such control requires federation and seamless operations between public and private cloud services through interoperability between web services, data services, and identity services.

Unless the service level agreement (SLA) specifies all the parameters necessary to ensure this interoperability—and unless the provider can fulfill those parameters—Intel IT will instead prefer its private cloud or seek a different provider. We anticipate public cloud providers will meet these criteria through growth in the industry's use of open standards and open source cloud solutions.

The use of an abstraction layer and common APIs makes it easier for us to consume compute, storage, and networking from different providers. Open source web services (published APIs) play an important role here, providing software functions at a network address over the web or cloud. Offering such consumable web services facilitates cloud automation (private and public) and self-service.

If all software products and infrastructure include open source web services written in a manner consistent with good API design and cloud computing practices, we have more control in automating and integrating capabilities within complex business workflows. Also, Intel developers can more quickly deploy applications through our existing user portal, which interacts with infrastructure, platform, and software components as consumable services.

We use OpenStack as our control plane for IaaS in our private cloud. We expect any public cloud provider that we work with on hybrid models to support OpenStack APIs. This important requirement enables us to reduce the overhead of wiring connections to individual providers.

In most cases we find our desired level of control over public cloud resources lacking. Until this is resolved, we plan to limit most public cloud usage to special cases that don't require high security levels or interaction with applications on our private cloud or behind our firewall.

Cost

In deciding the cost advantages and disadvantages of hosting an application on a public cloud, our goal is to not simply find the least expensive solution; other factors are also used in our decision. For a short-term project, such as a PoC, it may be more convenient and less expensive to use a public cloud provider. If a project subsequently requires long-term hosting, it can be moved back to the private cloud to reduce the long-term expense and avoid locking in to a vendor.

IT as a Cloud Broker

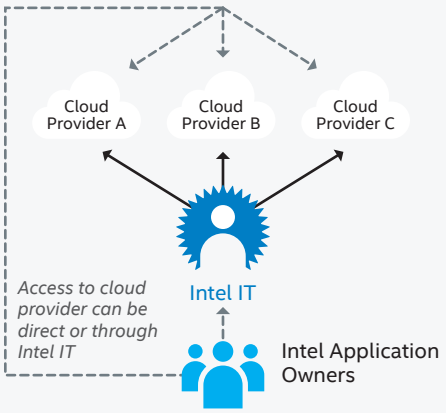
Intel IT ensures that application owners use private and public clouds wisely, cost effectively, and securely. To deliver excellent service, we act as an in-house cloud broker, matching application owners' needs to available cloud services and making the acquisition and use of these services quick and easy.

Operating as a cloud broker requires new skills and perspectives. Instead of viewing public clouds as competition, IT must take ownership of the entire cloud, private and public, regardless of who builds it.

We acquire public cloud services in advance and perform evaluations continuously. Our considerations include our goal of cloud federation and maximizing agility and efficiency by enabling easy transition of workloads and services between IT infrastructures within and outside the enterprise.

By acting as a cloud broker, we:

- Help make the acquisition and use of services faster and easier
- Ensure that cloud instances across our portfolio of cloud services meet Intel IT's standards for security, interoperability, redundancy, cost effectiveness, and conformance to open standards and corporate branding guidelines
- Enable, where desired, the same flexibility between public clouds as we have internally
- Educate application developers on cloud-aware design concepts and other design, implementation, and support considerations



At current capacity, our private cloud total cost of ownership is very competitive with external providers. Our low incremental cost for additional capacity offers compelling cost advantages over pay-per-use providers. Oversubscription techniques and provision of in-place capacity bring this incremental cost to near zero. Therefore, on a financial basis, absent other considerations, it makes more sense to host cloud computing applications on our private cloud.

If, for other reasons, we decide to host an application on a public cloud, we conserve costs by consolidating workloads with just a few cloud providers. By contracting with as few cloud providers as possible, we can achieve economies of scale and avoid managing more connections than necessary.

Factors other than cost help us choose between two public cloud providers. We will often select a more expensive provider if extra capabilities—such as enhanced features, performance, reliability, or security—make that provider a better choice.

Location

Location is often a driving factor for using a public cloud provider. In areas of the world where we don't have a data center, we use a local provider to reduce latency and provide performance, which results in a better user experience. If we know all of the users of a particular application are external to Intel and reside in a specific geography, we may choose to host that application in a physical location close to those users.

If we discover data sovereignty or compliance requirements in a particular location, public cloud services help us comply by keeping the processing, storage, and security resources closer to the applications and teams using them. Data sovereignty is a legal concept wherein information that is converted and stored in binary digital form is subject to the laws of the country in which it is located. In such countries, companies must keep customer data within the country the customer resides. The solution is a local public cloud provider. As widespread adoption of cloud computing breaks down traditional geopolitical barriers in new ways, we may see more of such instances.

Application Requirements

Sometimes our private cloud lacks a capability or feature that an application owner needs. An application owner might need a specific tool, a higher level of scripting for application deployment, certain compute requirements, an application code generator, or something else not currently supported or planned for support by us. In these cases, we help place the owner's application in a public cloud with which we have a services agreement and an SLA.

Other times, Intel IT may not want to host an application because it is experimental or short-term. In this case, we look for a public cloud solution that supports our SLA and provides perhaps a locational or special capabilities advantage for the application and its users.

Theoretical Financial Model

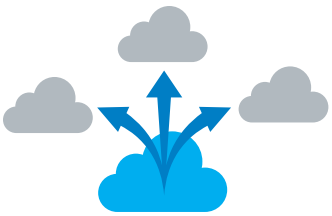
In 2013 we developed a theoretical financial model as a PoC for analyzing cloud computing cost. This model provides valuable information about potential savings in a hybrid cloud hosting solution. It helps us determine an efficient private-to-public ratio that varies with demand in terms of capacity and capability. Overall, the model suggests that the ultimate goal for our cloud hosting should be about two-thirds private and one-third public. Since the publication of an Intel IT brief on this model, a primary assumption changed, reducing our goal amounts for public cloud hosting. This change demonstrates the need for a flexible approach to private-public-hybrid hosting to adjust for current business conditions.

Read more about the PoC in the Intel IT brief, "Cloud Computing Cost: Saving with a Hybrid Model."

Sometimes an application owner wants to reach a specialized internal or external audience—or both—in which case, a public cloud provider might make more sense. Intel marketing teams around the world engage customers through short-term marketing campaigns using agency-developed microsites to promote specific programs, contests, or products. Advantages of public cloud hosting for such microsites include detailed cost estimates, tracking of agency users for enhanced security, compliance with local laws and regulations, and the ability to proactively manage site terminations. In these cases, it is our responsibility to help application owners find a provider that fulfills these and any other specific needs.

Capacity

Some hosting needs might require the ability to expand or contract capacity quickly. For example, a few years ago Intel had a promotion that offered a free game called Angry Birds* that created massive demand. In this case, public cloud services—as part of a hybrid cloud model—helped enable cloudbursting to a public cloud.



Cloudbursting

If demand for computing capacity spikes, applications that run in a private cloud can use capacity in a public cloud.

Cloudbursting is an application deployment model in which an application that runs in a private cloud uses capacity in a public cloud when the demand for computing capacity spikes. This approach to adding public cloud resources as needed enables us to rapidly scale out application instances while continuing to manage instances in our private cloud. We plan to use OpenStack architecture to create automation to burst to multiple public providers and minimize switching costs. To enable bursting, applications and data must be structured in a way which permits this level of automation.

As another example, there may be a high number of applications that need to be hosted on the U.S. West and East Coasts. We could use public hosting on the East Coast to reduce latency. Over time, to reduce costs we might invest in a data center there and pull the publicly hosted applications back into the private cloud using the new facility. The initial use of a public cloud would be an expedient, short-term solution, which could be followed by a return to a private hosting model when potential savings justify it, even if it means a capital expenditure.

In our journey to a hybrid cloud, we see the ability to handle unpredictable demand and relinquishing resources as a primary use case. By having public cloud resources set up and ready with SLAs, we can use a public cloud instead of relying on Intel data centers in other regions, which, because of distance, might increase latency.

As another capacity application, a trial application may need significant computing capacity and we do not want to invest in servers until the application is proven. A few years ago, an Intel business group needed considerable computing capacity to try streaming content to set-top boxes. By using a public cloud we were able to monitor whether the business was successful before committing resources.

High Availability

Some applications, such as traditional enterprise applications (finance applications, corporate services, sales and marketing, supply chain) require 99.99-percent availability. This level of availability translates to less than 53 minutes of annual downtime, yet satisfying the general public is often even more demanding. Consumers expect a service to be always available.

In such cases, hosting applications in three locations (two at Intel and one at a public cloud provider) using an active/passive or active/active model enables a distributed hosting presence that supports such high availability (Figure 2). By designing the applications and the hosting environment for automated self-healing using three data center network locations, we enable expeditious detection and correction of application and infrastructure failures.

Our recent focus on cloud-aware applications is expected to enable a higher percentage of our applications with the ability to accommodate infrastructure outages by being concurrently active (active/active) at multiple locations.[3] This helps enable the application to redundantly distribute data in case a component fails with minimal impact to end users. By using cloud-aware applications and setting up our hybrid cloud to automatically meet unpredictable demand spikes, we help ensure service quality and customer satisfaction.

Ways to Increase Public Cloud Usage

As we progress in the CMM, we anticipate increasing public cloud usage. To make a smooth transition, we are embracing open standards and open source software to simplify and accelerate our users' consumption of cloud services and encouraging the design of cloud-aware applications.[4] By enabling a common orchestration layer and control plane, the open cloud technologies we use will help us increase automation of resource management and deliver greater business flexibility.

[3] See the Intel IT white paper "Maximizing Cloud Advantages through Cloud-Aware Applications."

[4] See the Intel IT white papers "Accelerating Deployment of Cloud Services Using Open Source Software" and "Simplifying the Path for Building an Enterprise Private Cloud."

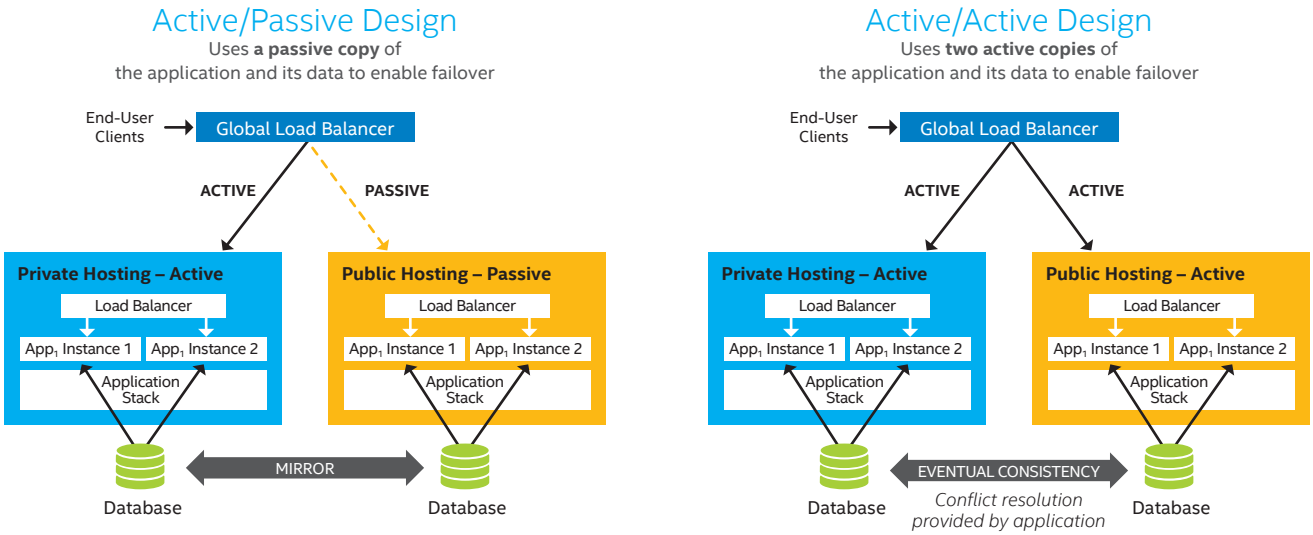


Figure 2. Intel IT's active/passive design uses a passive copy of the database to enable failover. Our active/active design uses two active copies of the application and its data to provide improved availability as well as enabling failover.

Using these technologies and finding public cloud providers that support them will help enable us to offer public and private cloud services much like a cloud service provider.

To speed the transition of Intel software development to cloud-aware applications, we provide training to business groups. Cloud-aware applications maximize cloud advantages such as run-anywhere (public or private cloud) design, self-service provisioning, elasticity, multitenancy, and design for failure. Bolstering the reliability, security, and agility of our applications wherever they reside, cloud-aware applications help us move toward a hybrid cloud. We have recently defined criteria within our application profiling system to identify cloud-aware applications and help track our progress in cloud-aware application use.

Even with our future smart orchestration layer and cloud-aware applications, we expect to see business reasons to host an application directly in the public cloud. Generally, such applications would include those that we purposely choose not to invest in additional resources for our private cloud operations.

Results

In helping application owners decide whether to host cloud services on a private, public, or hybrid cloud, we see excellent results by acting as a cloud broker. By providing clear criteria for choosing between private and public cloud hosting, we enable application owners to quickly and efficiently acquire the resources, performance, security, and regulatory compliance they need to move forward.

Acting as a cloud broker, we directed application owners to an Intel IT public cloud solution with which we had a services agreement and an SLA. Here are some examples:

- **Meeting Application Requirements: PoC.** The Intel Education business group came to us for resources for a PoC. They had four applications for managing education policy and services for education administrators and instructors that they wanted to implement across various regions where Intel did not have a data center. For this testing phase, we landed the applications at an external cloud provider who met the business group's regional hosting needs as well as Intel security requirements.
- **Meeting Application Requirements: Special Resources.** An Intel application team required specific GPUs for their product. Not having any private cloud infrastructure with the specific GPUs installed on servers, we chose to land the application with a public cloud provider offering the GPUs as part of their VMs. The application team eventually decided not to release the product. This use case provides an excellent example of avoiding capital investment through use of a public cloud until a product requiring unusual resources reaches production.
- **Meeting Location Requirements.** An India-based Intel service that gathered user information needed a cloud location in the Asia-Pacific region. For legal reasons, the data could not be hosted in an Intel data center. To meet the legal requirements, we chose a public cloud environment in Singapore that offered a disaster recovery facility in Tokyo. We worked with the cloud provider as well as Intel Security to ensure that this provider met our requirements to host data above the Intel Confidential data level.

In another use case, an Intel acquisition resulted in a product group needing to keep user data "in country." To meet this requirement, we used public cloud hosting in the countries where we did not have an Intel data center.

Conclusion

As interoperability and openness enable flexibility between private and public clouds—and between public clouds—increasing Intel IT's use of public cloud resources will transform Intel's cloud usage model into a large-scale automated hybrid cloud infrastructure. This infrastructure will enable us to deliver the ultimate choice and balance in agility, scalability, flexibility, and cost savings for Intel application owners.

While we progress toward cloud maturity, providing in-house cloud broker services enables us to use the public cloud when it makes sense for Intel and application owners. As public cloud providers join us in progressing in cloud maturity, we anticipate greater, more efficient use of public clouds through an automated decision-making process. This process enables us to offer a choice of private and public hosting solutions and the ability to switch between them for a greater range of applications.

To accomplish this automation, we are continuing our work on an intelligent orchestration layer that uses policies to place workloads on hosts. The resulting private-public-hybrid cloud will handle the vast majority of our cloud placements, automatically choosing where to host applications based on the application, its security requirements, geographical considerations, and other criteria.

Though we still expect our private cloud to continue to host the majority of our applications, the availability of seamless transition to public clouds will provide an important on-demand resource for peak periods and for applications that require public cloud resources for certain business needs. As cloud operations mature internally and externally, we will use the public cloud more to help us provide quickly obtainable consumable services to empower Intel application owners, increase business velocity, offer new services and revenue channels, and deliver better user experiences.

For more information on Intel IT best practices, visit www.intel.com/IT.

IT@Intel

We connect IT professionals with their IT peers inside Intel. Our IT department solves some of today's most demanding and complex technology issues, and we want to share these lessons directly with our fellow IT professionals in an open peer-to-peer forum.

Our goal is simple: improve efficiency throughout the organization and enhance the business value of IT investments.

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