Cloud Federation and the Evolution of Cloud Computing

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Cloud computing allows users to access computing services and resources on demand without having to buy their own infrastructures, and to pay only for what they use. Many cloud companies—such as Amazon and Google—have developed their own platforms featuring proprietary interfaces, which isn’t a problem as long as a single provider can fully satisfy its customers. However, the lack of standardization for interconnecting platforms makes it difficult for customers who need the combined services or resources of multiple providers. This often results in users being locked into specific providers and platforms.

This issue has led to the idea of interconnected clouds, also known as interclouds. Interclouds address single-provider approaches’ limitations such as the lack of interoperability between platforms, limited resources being exhausted during times of peak customer demand, service interruptions, and quality-of-service (QoS) degradation.

**INTERCLOUD**

An intercloud is a cloud of clouds. In essence, it’s a large cloud comprising many smaller clouds, each having its own characteristics and serving different needs. An intercloud implementation could be any one or combination of:

- **hybrid clouds**, in which private clouds access the resources of public clouds without the latter being aware of their participation;
- **multiclouds**, which utilize libraries from applications that enable the use of resources from multiple clouds, without any of them being aware of their participation;
- **sky computing**, an emerging model in which resources from multiple cloud service providers (CSPs) create a large, distributed, virtual infrastructure.

To satisfy the demand for collective and collaborative cloud use, academia and industry want to interconnect heterogeneous clouds to form a federated system. This approach is promising but also faces significant challenges.
CLOUD FEDERATION

Intercloud researchers have shown the most interest in cloud federations because it enables power-efficient, cost-effective, dynamic sharing of idle cloud resources and services. Federation members can sign service-level agreements (SLAs) to ensure QoS and availability.

The federation should

› have a defined marketing system that describes the cost of utilizing resources and services and that helps to valorize use,
› feature efficient geographic dispersion by allocating resources close to users to eliminate network problems that could interrupt service access, and
› follow rules in a federal-level agreement (FLA) describing the cooperation and relationship among participating clouds.

We disagree with the research literature’s frequent interchangeable use of the terms “cloud federation” and “intercloud.” In federations, cloud organizations participate voluntarily after signing an FLA. In an intercloud organization, no private or public cloud is necessarily aware of its participation. Also, interclouds are based on open standards that provide interfaces for interoperability. Cloud federations use a broker to translate and connect CSPs’ own interfaces.

CLOUD FEDERATION ARCHITECTURE

For federations or interclouds to work properly, heterogeneous clouds must be able to interoperate. However, this can be difficult to achieve. For example, participating clouds might use different techniques to describe the services they offer. Users, however, need a mechanism to provide common access to available services. Thus, the cloud federation’s architecture must employ interface standards, a service broker that translates between interfaces and provides updates on offered services and users’ status changes, or a combination of the two.

Cloud federations most often use brokerages. The common object request broker architecture (CORBA) and object request broker (ORB) middleware were initially the most popular approaches. However, the advent of XML-based technologies such as SOAP has provided the ability to use the same language in the descriptions of all services, thereby avoiding the need for translation.

Figure 1 shows a cloud federation architecture with the broker playing a central role and the CSPs at the edges communicating mainly through the broker. The brokering system is in the cloud and matches the available federation resources with user demand, taking into consideration participants’ SLAs. To achieve this, the broker must understand the various ways that each cloud describes its available resources and services and then combine the gathered information seamlessly for the user. In some cases, the broker could provide users with resource and service pricing information, as well as bill them.

For the federation to function properly, all interested parties must sign an FLA that specifies interconnection rules and describes each participant’s responsibilities and permissible behaviors, along with the financial, administrative, or other penalties for violating its terms. The parties can leave

Figure 1. Cloud federation architecture. Users send requests for resources and cloud service providers (CSPs) send their responses to the broker (left), which matches users with providers based on billing, ratings, and service-level agreements (SLAs). This results in a federation (right), governed by a federal-level agreement (FLA).

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Brokering system
- Handles requests and offers for resources
- Matches participants according to the SLAs
- Initiates federation
- Provides rating system
- Provides billing

FLA

Request for resources
Offer for resources
CSP matching
Initiation of federation after matching

Small CSP
Medium CSP
Huge CSP
the federation when they want, as long as they follow FLA procedures.

**ADVANTAGES AND LIMITATIONS OF CLOUD FEDERATION**

Cloud federations have pros and cons.

**Advantages**

Federation performance is guaranteed by the dynamic resource allocation—or elasticity—that lets clouds ask for other participants’ idle resources or services when their own are exhausted. This achieves both uninterrupted service delivery and resource scalability, the latter being the result of the seamless, transparent operation between clouds for the delivery of an agreed-upon QoS level.

Federations also enable the geographic dispersion of resources, efficiently locating some near users but also allowing participants to access more distant resources in case of local outages. This enables efficient commercialization of the offered resources and lower prices than single-cloud services can charge.11

And because the FLA clearly describes what each participant is offering, as well as the federation’s rules, it ensures the commitment of the involved parties to the operation’s performance.

**Limitations**

Although federation mechanisms can provide the agreed-upon performance, constant monitoring and increased security mechanisms are required to guard against accidents and malicious users.

Selecting which services a federation will offer is not trivial because they will have to come from multiple providers that have different cloud characteristics and that offer varying QoS levels. Thus, federation participants should deploy a service-selection mechanism, preferably automated, that uses a predefined set of criteria regarding the QoS that providers offer. Or they could dynamically negotiate SLAs to address user needs.

Federation members could also address the lack of a common repository for available services via peer-to-peer approaches using a distributed hash table overlay network for service discovery.12 They could also utilize an intercloud root,13 which produces an abstract view of a global catalog of federation services and resources offered in the connected clouds.

The mobility of virtual machines (VMs), which are common in cloud services, is important for providing uninterrupted performance and expected QoS levels. Hosts must meet requirements for factors such as memory use, state, status of running processes and applications, and LAN connectivity to be able to migrate a live VM from one physical node to another without disrupting network traffic. This is particularly critical in real-time services. In cloud environments, this migration could be challenging for VMs belonging to different clouds that have never shared resources and thus have no knowledge about each other’s networking configurations. Thus, it’s important to re-create the originating cloud’s networking and communication environment in the destination cloud quickly enough to avoid excessive delays.

Federation participants must address data portability, focusing particularly on issues such as security and privacy, because services belonging to one CSP must frequently access data stored in another cloud.

**LOOKING AHEAD**

Early attempts at cloud federations haven’t had all the characteristics that a true federation should possess. Instead, there have been multiclouds or hybrid clouds enhanced with some federation characteristics. However, these aren’t as efficient as fully federated approaches.

True federations require brokering systems that can quickly communicate with cloud interfaces and find the right combination of resources and QoS to meet users’ needs in the heterogeneous environment. In the process, the brokerages must keep in mind users’ performance and cost requirements.

Content delivery networks (CDNs)—which have successfully provided high-quality data access for many users over the Internet—could serve as the framework for cloud-broker communication. But regardless of which approach is adopted, the CSPs’ role is important, particularly for providing APIs that enable communication with brokers. Standards organizations such as IEEE could also play a major role in cloud-federation evolution by developing a reliable brokering system that is compatible with most cloud frameworks.

Federation participants must take special care in composing the terms of an FLA, which is the mechanism that ensures the system’s integrity. A key concern is translating abstractly expressed requirements into concrete technical terms and functionalities.

Other issues include the establishment of trust among participants and the security of resource access and use, which is extremely important.
in a dynamic environment such as a cloud federation.

IEEE's effort\(^{14}\) to introduce a standard for a brokering-system is an important step toward the realization of true cloud federations. Researchers should also examine the characteristics proposed in different cloud technologies and architectures—such as fog computing's local hardware awareness\(^{15}\)—that provide the technical capabilities that VMs could use to learn about cloud environments.

**REFERENCES**


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