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Architectural Classification of Inter Cloud & Approaches

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Abstract— Inter Cloud is a federated Cloud computing environment that facilitates just-in-time, opportunistic, and scalable provisioning of application services, consistently achieving QoS targets under variable workload, resource and network conditions. InterCloud research is still in its infancy, and the body of knowledge in the area has not been well defined yet. In this work, we discuss taxonomies related to Inter-Cloud, we present a detailed survey on federated architectures ,a summary of different InterCloud Projects(both academic and industry developments) which executed on various InterCloud architectures.

Keywords— Volunteer Federation , Multi Cloud Federation

I. INTRODUCTION

Inter Cloud is a recently introduced vision of globally interconnected Clouds (Cloud of Clouds), much like the Internet as a network of networks. This vision addresses interoperability across Clouds, focusing on the use of open Cloud standards. Hereby, Cloud consumers should be able to freely choose and effortlessly switch between different Clouds. On the other hand, Cloud providers should be able to distribute their load among geographically distributed data centers in order to meet the need of their customers consistently achieving QoS targets under variable workload, resource and network conditions.

II. ARCHITECTURAL CLASSIFICATION

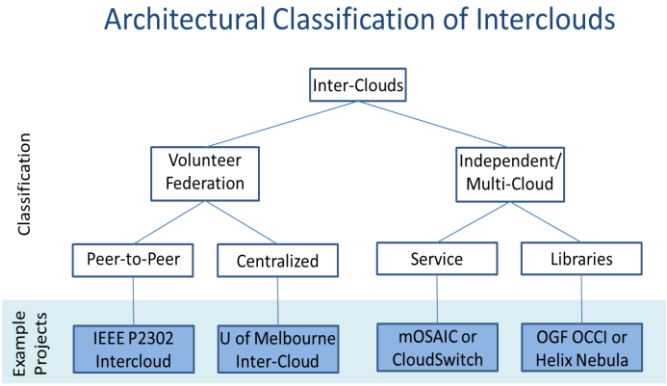

Fig1.Claasification of Inter Cloud

There are two types of Inter Clouds: 1**) Volunteer Federation & 2) MultiCloud**.1) When a set of cloud providers interconnects their infrastructures to share resources among themselves voluntarily, then the Inter Cloud is termed as "Volunteer Federation Cloud".2) When one single organization or clients are connected with multiple cloud providers then the Inter Cloud is termed as "Multi Cloud".

Volunteer Federation can be further classified into two different types. One is **a)Peer-to-Peer and another is b)Centralized**.

b) Peer-to-Peer- In this architecture, clouds communicate and negotiate directly with each other without mediators.

b) Centralized-In this architecture there is a central entity that either performs or facilitates resource allocation .Usually, this central entity acts as a repository where available cloud resources are registered but may also have other responsibilities like acting as a market place for resources.

Multi Cloud can be further classified into classified as **a) Services & b) Libraries.**

a) Services- application provisioning is carried out by a service that can be hosted either externally or in-house by the cloud clients. Most such services include broker components in themselves. Typically, application developers specify an SLA or a set of provisioning rules, and the service performs the deployment and execution in the background, in a way respecting these predefined attributes.

b) Libraries- libraries are designed to abstract the programmers from the differences in the management APIs of clouds and provide control over the provisioning of resources across geographical locations. By using such libraries, application developers can program their own application-specific brokers.

III. TAXONOMIES

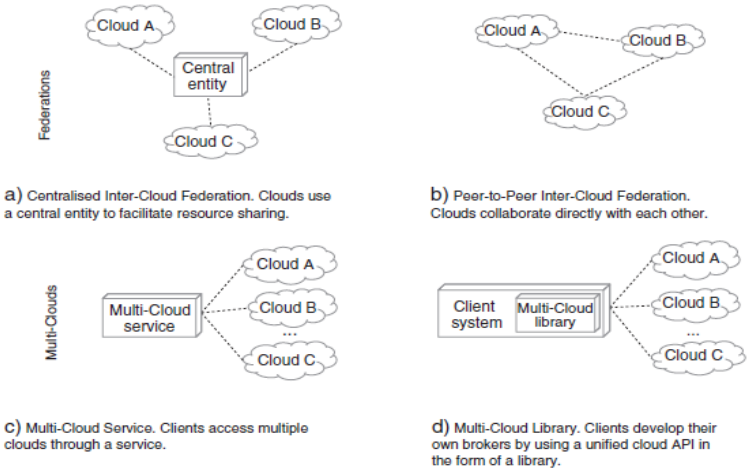

Fig 2.Inter-Cloud developments' architectures

1. Cloud User-The main stakeholders in Cloud Computing scenarios are Cloud users and Cloud providers (CPs). Cloud users can be either software/application service providers (SPs) who have their service consumers or end users who use the Cloud computing services.
2. Cloud Providers-Cloud Service Providers are those who provides infrastructure as service, platform as service and Software as service.
Eg: Amazon, Google, Salesforce, IBM, Microsoft and Sun Microsystems.They are the CPs who provides infruastructure as services, has set up several data centers at different geographical location over Internet to fullfill the needs of the customers.
3. Cloud Broker- A new stakeholder, broker, aggregates services from multiple CPs and offer an integrated service to the SPs or end-users. The deployment and management of components has been abstracted by the third party broker.
4. Cloud Coordinator -A Cloud Coordinator for exporting Cloud services and their management driven by market-based trading and negotiation protocols for optimal QoS delivery at minimal cost and energy.
5. Vendor Lock-in- vendor lock-in is a situation where a customer becomes dependent on a vendor for its products or services and cannot move to another vendor without considerable cost and technical effort.
6. SLA- An SLA specifies the details of the service to be provided in terms of metrics agreed upon by all parties, and incentives and penalties for meeting and violating the expectations, respectively.

IV. RELATED PROJECT WORK ON DIFFERENT INTERCLOUD ARCHITECTURE

In this section, we summarize several Inter Cloud developments. They include both academic and industry projects. Each of the following subsections discusses the projects that fall into one of the architectural groups introduced in Section 1.

Centralized federated Inter-Clouds:

A. Inter Cloud: The *InterCloud* [1] project developed at the University of Melbourne is one of the first initiatives in the field. It extends previous efforts form the InterGrid project to allow the sharing resources across cloud providers. The proposed architecture is centralised and is built around a central entity called **1)Cloud Exchange (CEx).The other members are Cloud Brokers(CB),3)Cloud Coordinators(CC).**

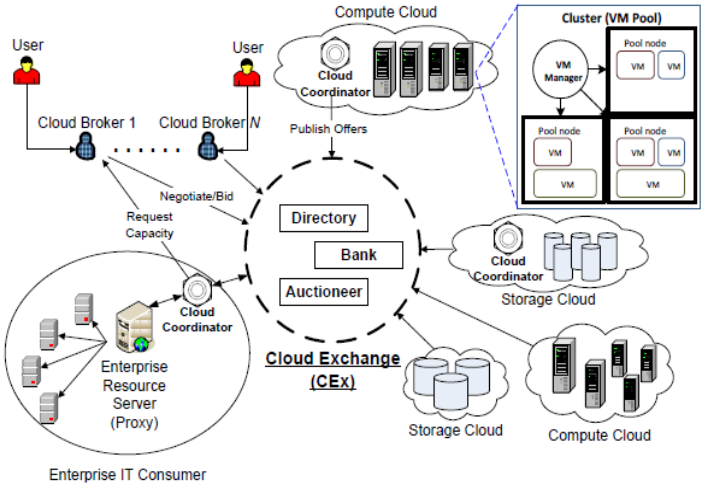

Fig3.InterCloud Architecture a Federated network of clouds mediated by a Cloud exchange

1) Cloud Exchange(CEx): The Cloud Exchange (CEx) acts as a market maker for bringing together service producers and consumers. It aggregates the infrastructure demands from the application brokers and evaluates them against the available supply currently published by the Cloud Coordinators. It supports trading of Cloud services based on competitive economic models such as commodity markets and auctions. CEx allows the participants (Cloud Coordinators and Cloud Brokers) to locate providers and consumers with fitting offers. Such markets enable services to be commoditized and thus, would pave the way for creation of dynamic market infrastructure for trading based on SLAs.

2) Cloud Broker(CB): The Cloud Broker acting on behalf of users identifies suitable Cloud service providers trough the Cloud Exchange and negotiates with Cloud Coordinators for an allocation of resources that meets QoS needs of users.

3) Cloud Coordinator(CC): On receiving a user application, the Coordinator does the following: (i) consults the Application Composition Engine about availability of software and hardware infrastructure services that are required to satisfy the request locally, (ii) asks the Sensor component to submit feedback on the local Cloud nodes' energy consumption and utilization status; and (iii) enquires the Market and Policy Engine about accountability of the submitted request. A request is termed as accountable if the concerning user has available credits in the Cloud bank and based on the specified QoS constraints the establishment of SLA is feasible. In case all three components reply favourably, the application is hosted locally and is periodically monitored until it finishes execution.

B. Contrail: The architecture of the European project Contrail [2] is built around a centralised composite entity that acts as a single entry point to a federation of cloud providers. Contrail[2]aims at two way integration i)a vertical & ii)a horizontal.i)a vertical integration ,which provides a unified patform for the different kind of resources whereas ii)a horizontal integration abstracts the interaction models of different cloud providers. Federation architecture of Contrails have 3 layers- 1) Interface Layer
2) Core Layer
3) Adapter Layer

1) Interface Layer-It is the top most layer that gather requests from users as well as from other Contrail components that rely on the federation functionalities &facilities.

2) Core Layer-It contains modules that fulfill the functional& non-functional requirements of the federation. on-functional requirements deals with security & functional requirements deals with application life-cycle management.

3) Adapter Layer- The bottom layer, called adapters, contains the modules that retrieve information and operate on different cloud providers.

i) Internal adapters – for clouds running the Contrail software. These are called Contrail clouds. Contrail clouds allow for the federation management component store serve and configure their resources.

ii)External adapters – for clouds that do not run the Contrail software.

C. Dynamic Cloud Collaboration (DCC)- In this project a centralised federated architecture is designed whose main purpose is to form a group of CPs before joining the auction and to publish their group of bids as a single bid to fulfil the service requirements completely. But to find out the model is a NP hard problem. Here in this project a CACM[3] model is proposed & implemented. The model allows bidders to make groups and submits their bids for a set of services to auctioneer as a single bid while also supporting the bidders to submit bids separately for a set of services.

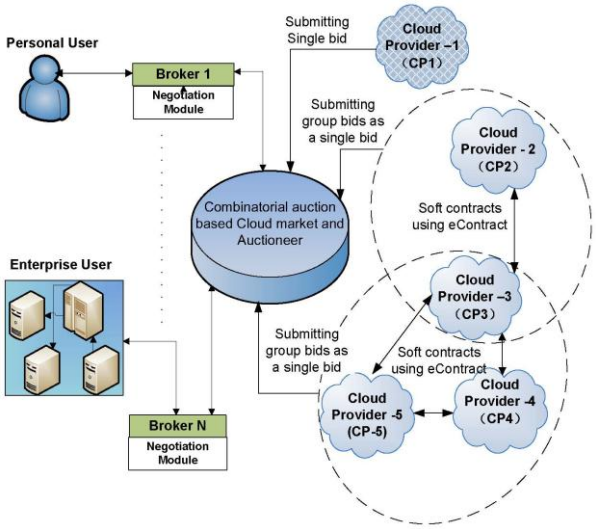

Fig 4. Proposed CACM Model for dynamic collaborative Cloud services among CPs

The CACM [3] model in which the main participants are brokers, users/consumers, Cloud resource/service providers, and trustworthy auctioneers. Brokers in the CACM model mediate between consumers and CPs. A broker can accept requests for a set of services or composite services requirements from different users. A broker is equipped with a negotiation module that is informed by the current conditions of the resources/services and the current demand to make its decisions. Consumers, brokers and CPs are bound to their requirements and related compensations through SLAs.

The consumers can be enterprise user or personal user. In the proposed CACM model, each user can bid a single price value for different composite/collaborative Cloud services provided by CPs. A CP participates in an auction based on its interest and profit. The responsibility of an auctioneer includes setting the rules of the auction and conducting the combinatorial auction. The auctioneer first collects bids (single or group bids) from different CPs participating in the auction and then decides the best combination of CPs who can meet user requirements for a set of services using a winner determination algorithm**.**

Peer-to-Peer federated Inter-Clouds:

D. RESERVOIR [4]: It is a European project that extends previous research on interconnecting Grids. The primary goal of this project is to develop technologies needed to deal with the scalability problem of a single cloud provider. The RESERVOIR[4] model for federated cloud computing environment join cloud providers together so that they can share resources, for an agreed upon price and thus helping the cloud providers from over provisioning of resources with high spikes in capacity demand. RESERVOIR model includes three different abstract layers; Service Manager, Virtual Execution Environment Manger(VEEM) and Virtual Execution Environment Host (VEEH).The Service Manger, highest Receives aservicemanifestfromserviceprovider.ServiceManagerhandlesseveraltaskssuchas:deployingandprovisioningVEEs,billing, accounting,andmonitoringSLAcompliance.VEEM,secondlayer,is responsible for managing VEEs and interacting with VEEM on remote sites allowing federationofinfrastructures.VEEMisalsoresponsibleforoptimalplacementofVEEs into VEE Hosts according to constraints determined by Service Manager. The lowest level, VEEH, supports different virtualization platforms for control and monitoring of VEEs. Moreover, transparent VEE migration within the federated Cloud is supported by VEEH[7].

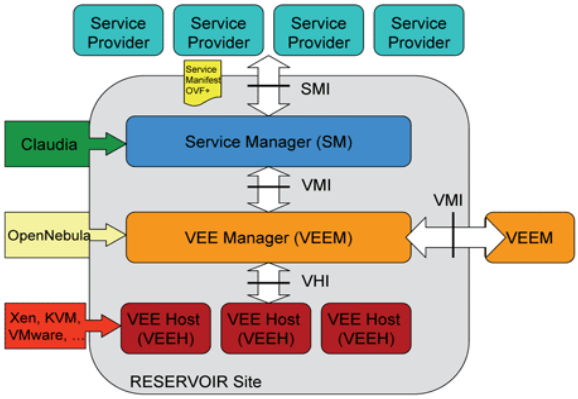

Fig 5.RESERVOIR Architecture

Multi-Cloud Services:

E. mOSAIC[5]-The diversity of Cloud computing services is challenging the application developers as various and non-standard interfaces are provided for these services. Few middleware solutions were developed until now to support the design, deployment and execution of service-independent applications as well as the management of resources from multiple Clouds. One of these advanced middleware solutions, called mOSAIC [5].The Platform components of mOSAIC[5] is shown in Fig 6.

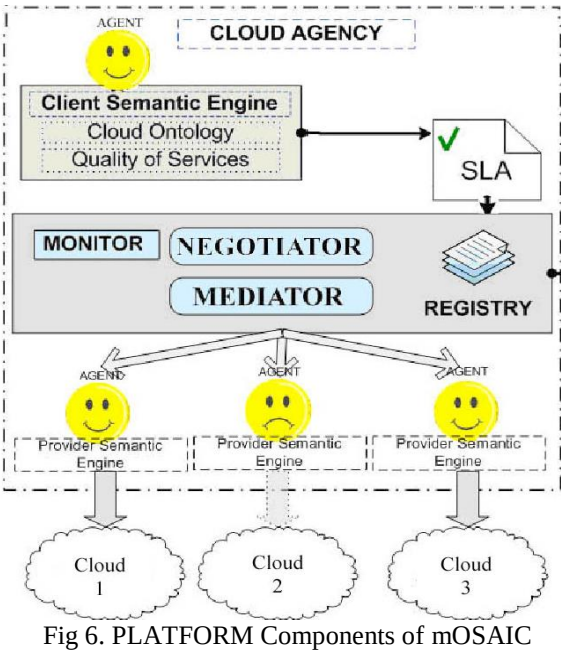

Fig 6. PLATFORM Components of mOSAIC

The *mOSAIC* open source API and platform allow for the development and deployment of applications that use multiple clouds .Here one application is divided into several application components. Resource Brokers are responsible for application brokering in mSOAIC.The Resource Broker acts as a mediator between clients & cloud providers. Resource Broker is further composed of a *Cloud Agency*, which is responsible for discovery and negotiation with cloud providers and a *Client Interface* responsible for requesting additional resources from the *Application Executor* component. The *Application Executor* component manages the deployment, execution and monitoring of the application within the reserved resources [5]. In this architecture, pricing awareness is promoted through the *Cloud Agency* component, which takes into consideration and negotiates on the pricing policies of the cloud providers.

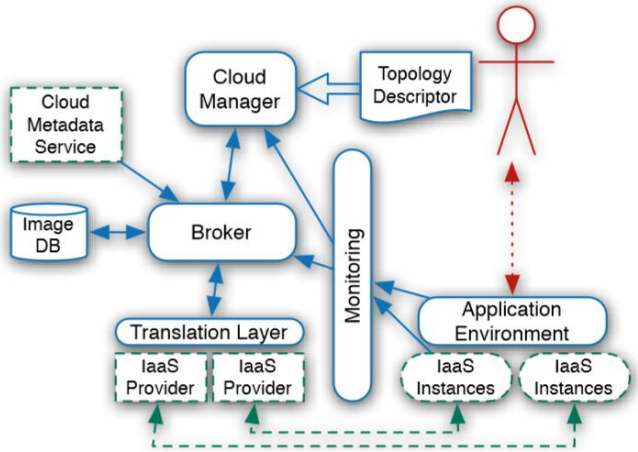

Fig .5 STAROS Architecture

F. STRATOS [6]–It is a Cloud Broker Service which facilitates deployment and runtime management of a cloud application in a multi cloud environment. It is based on a problem that is known as RAD(Resource Acquisition Problem).It involves the selection of n resources from a set of m providers such that the deployer's set of constraints, requirements, and preferences (collectively, the deployer's objectives) are met (or best approximated). In order to automate resource acquisition decisions(RADs),a broker service layer is envisioned between adjacent layers of the three layered (i.e., IaaS, PaaS and SaaS) cloud architecture .

V. DISCUSSION

Here **Table 1** has shown the summarized "InterCloud" projects those are deployed in various "Inter-Cloud" architectures by several companies**.** Some of the projects are surveyed here. Some are not. The following table1 has shown the name of the projects, type of organization and the architecture.

PROJECT	TYPE OF ORGANIZATION	ARCHITECTURE
InterCloud	Research Project ,University of Melbourne	Centralized Federation
Contrail	Private and public, European research organizations funded by EU	Centralized federation and independent service
Dynamic Cloud Collaboration (DCC)	Academic research project supported by South Korean research funds	Centralized federation
Federated Cloud Management	Academic research project supported by EU funds	Centralized federation
RESERVOIR	Private and public, European research organizations funded by EU	Peer-to-peer federation
Open Cirrus	Research tested by academic and industry partners. Partially funded by US NSF	Peer-to-peer federation
OPTIMIS	Private and public, European research organizations funded by EU	Peer-to-peer federation and Independent service
Arjuna Agility	Commercially owned	Peer-to-peer federation
Global Inter-Cloud by Bernstein *et al.*	Publications are by people from miscellaneous companies – CISCO, Huawei Technologies, EMC Corporation	Peer-to-peer federation
mOSAIC	Private and public, European	Independent service

	research organizations funded by EU	
STRATOS	York University. Supported by Canada's NSERC funds, Amazon and CA Inc.	Independent service
Commercial Cloud Management Systems(Right Scale, EnStratus, Scalr, Kaavo)	Commercially owned	Independent service
Libraries (JClouds, LibCloud, DeltaCloud, SimpleCloud, Apache Nuvem)	Open source projects	Multi-Cloud libraries

VI. RELATED WORK

The other related **Peer-to-Peer federated Inter Clouds** research projects are as follows:
Open Cirrus, OPTIMIS, Arjuna Agility, and Global Inter Cloud etc.
There are also some **Multi-Cloud research projects** are deployed by several companies. Some of them are as follows:
OPTIMIS, Contrail, Commercial Cloud Management System.

VII. SLA-BASED vs. TRIGGER-ACTION BASED APPLICATION BROKERING

SLA-BASED	TRIGGER-ACTION BASED
1)Application developers specify the brokering requirements in an SLA in the form of constraints and objectives	1)The application developers specify a set of triggers and associate one or more actions to each of them.
2) The cloud provider or the Inter-Cloud service acting on behalf of the client decides on brokering approach honouring the specified SLA	2) A trigger becomes active when a predefined condition considering the externally visible application performance indicators becomes true. An action is executed when a correspondent trigger becomes active
3) The main benefit of the SLA-based brokering approaches is that they are completely transparent to the application developers	3) The Trigger-Action approach is less transparent than the SLA-based one
4)Eg:Contrail,Reservoir	4)Right Scale

VIII. CHALLENGES

Cloud Challenges are as follows:

1. Provisioning
2. Portability
3. Service Level Agreement
4. Security
5. Monitoring
6. Economy
7. Network
8. Autonomics

Some of the research issues are discussed here. They are as follows:

1. Provisioning -

- **a) Discovery**: It allows that what resources and services are provided by the cloud providers.
- **b) Selection**: In this step the cloud customers will select the cloud provider who meets its requirements based on QoS criteria.
- **c) Allocation:** In this next step the cloud provider allocates resources to customer .To allocate resources is a challenge.

2. Portability-

- **a) VM Mobility: VM mobility means** migration of VMs from one host to another host .In Inter Cloud environment VM mobility is a challenge as it should not violate the independence of the respective Clouds in terms of autonomy, privacy, and security.

b) **Data Portability:** Users often want to access data from cloud for their SaaS and PaaS applications. If the cloud providers save the data in another format, it will be difficult for the users as they cannot move their data to other vendors without considerable cost and technical effort. This problem is known as "**data-lock-in" and to avoid it is a challenge.**

3. SLA –Challenges are:

a) **Federated SLA Management**
b) **Federation Level Agreement**
c) **SLA Monitoring**
d) **SLA Dependency**

IX. CONCLUSION

In this paper , a survey has been done on different types of Inter Cloud architectures, their taxonomies, different projects and their architectures, type of organizations, of those projects, related works and challenges of Inter Cloud.

At the beginning, mainly the types of Inter Cloud architectures have been discussed. There are two types of Inter Clouds as follows:

1) Federated Cloud-When a group of cloud providers voluntarily collaborate with each other to exchange resources.

2) Multi Cloud or Independent Cloud-When multiple clouds are used in aggregation by an application or its broker. After that some related terms those are used in InterCloud brokering are discussed. Those are known as taxonomies. They are as follows:

Cloud Broker(s), Cloud Provider(s), Cloud End-user(s),Cloud Coordinator(s) etc.

After that We have given a brief of architectures of some Inter Cloud projects like Conrail, DCC, OPTIMIS, RESERVOIR, Startos, mSOAIC etc.After analysing their architectures We have made a summary of the projects by mentioning their names, type of organizations, architectures etc.We also mentioned two different mechanisms of application brokering. After that We compare between SLA –Based Brokering and Trigger-Based Brokering.Then at the end section, some related project works and their types of architecture are also mentioned. Then the current challenges of Inter Cloud are also given.

So, It can be concluded like that, most of the projects discussed above, facilitates the application brokering in a federated inter cloud environment. There are different mechanisms of application brokering are available. They are **SLA Based Brokering and Trigger-Action Based Brokering and Directly Managed Brokering**. Both this two trends require future work. The D**irectly Managed Brokering** mechanisms are mostly used when there is no mediator between the application and the set of utilized clouds. Directly managed brokers are hosted separately and need to keep track of the performance characteristics of the application themselves. It is the responsibility of the application developers to develop such brokers in a way that meets the availability and dependability requirements.

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