ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

IJARMATE

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 2,Special Issue 6, March 2016

An Insight intoIntercloud Topology and Interoperability

@V. Sambasiva, $Pokuri Venkata Radha Krishna murty #K.Venkata Ramana
@,$Assistant Professor, Department of CSE, Audisankara Engineering College,Gudur.
#Associate Professor, Department of CSE, Shree Institute of Technical Education,
E-mail: ramanakaveripakam@gmail.com

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Abstract:*The Intercloud is an interconnected global "cloud of clouds" and an extension of the Internet "network of networks" on which it is based. It became popular and has also been used to describe the datacenter of the future. The Intercloud scenario is based on the key concept that each single cloud does not have infinite physical resources or ubiquitous geographic footprint. The Intercloud scenario would address such situations where each cloud would use the computational, storage, or any kind of resource (through semantic resource descriptions, and open federation) of the infrastructures of other clouds. This is analogous to the way the Internet works, in that a service provider to which an endpoint is attached, will access or deliver traffic from/to source/destination addresses outside of its service area by using Internet routing protocols with other service providers with whom it has a pre-arranged exchange or peering relationship. It is also analogous to the way mobile operators implement roaming and inter-carrier interoperability.This paper gives a glance at IntercloudTopology and Intercloud Interoperability.*

Key words*: -parallel, Distributed, Cloud, virtual computers, Computing, Resources, Service, Multi-Cloud, Inter-Cloud,Topology and Ontology..*

1. INTRODUCTION

The cloud is the service being delivered from remote sites. As public and private industry budgets continue to shrink, executives areplotting new strategies to become more efficient and cost effective. Cloud computing hasgleaned a lot of attention over the past several years as a means to reduce ITexpenditures, improve scalability and reduce administration over head. As savings amount and efficiencies increases, cloud computing will continue to grow. Most of the enterprises are already operating their applications or infrastructure in a cloud environment. Now a day's most of the personal and general purpose services are also provided to personal cloud user by the cloud service providers. Up to 2015 the top 10 cloud services[1] are Rack space, Amazon Web Services(AWS), Site Ground, Storm On Demand, Microsoft Azure, Digital Ocean, Liquid web, Net magic Solutions, Ctrls and Servint.

1.1. Definition of cloud Computing

The National Institute of Standards and Technology has defined Cloud computing[2] as "a model for enabling ubiquitous, 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". (Mell&Grance, 2011, p. 2).

There is little consensus on how to define the Cloud and I add yet another definition [3][4]to the already saturated list of definitions for Cloud Computing:

A large-scale distributed computing paradigm that isdriven by economies of scale, in which a pool ofabstractedvirtualized, dynamically-scalable, managedcomputing power, storage, platforms, and services aredelivered on demand to external customers over the internet.

Cloud Computing is anything that provides hosted services over the internet [5]. These services are sharing to the end users. The main uses of cloud are data storage, process and management services on the internet rather than having local servers. The service provider has to look up all the issues related to the cloud. The end-user doesn't require any server to maintain, simply requesting the services from the cloud and pay for using it.Fig.1 depicts the cloud computing layout diagram.

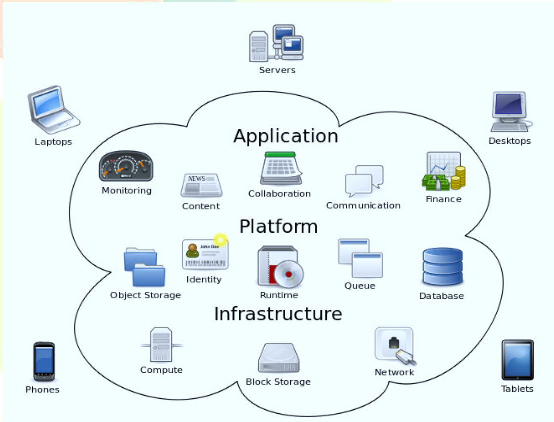
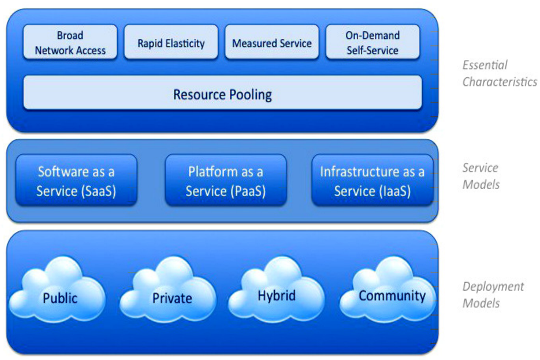


Figure 1: Cloud Computing Layout Diagram

2. CLOUD COMPUTING ENVIRONMENT

NIST also defines five key and essential characteristics, three service models and four deployment models are shown inbelow [2].



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International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 2,Special Issue 6, March 2016

Figure2: NIST defined Essential characteristics, Service models and Deployment models.

2.2. Characteristics of Cloud

According to National Institute of Standard Technology[2](NIST, U.S.Department of Commerce), cloud has five essential characteristics as follows.

1. On demand self service
2. Broad network access
3. Resource pooling
4. Rapid elasticity
5. Measured service

NIST categorizes Cloud computing into a Service Model and a Deployment Model.

2.3. Service Models of Cloud Computing

As per NIST mainly the Service Model consists ofInfrastructure as a Service (IaaS), Platform as aService (PaaS), and Software as a Service (SaaS) as shown below along with the services provided by the cloud with challenges Security, integrity and privacy at different levels [2].

Apart from the above three main service models there several services oriented cloud models categorized based on the services provided by the clouds and some of them are listed below:

1. Storage-as-a-Service (SaaS)
2. Database-as-a-Service(DaaS)
3. Information-as-a-Service (InfaaS)
4. Process-as-a-Service (PraaS)
5. Software-as-a-Service (SaaS)
6. Platform-as-a-Service (PaaS)
7. Integration-as-a-Service (IntaaS)
8. Security-as-a-Service (SeaaS)
9. Management/Governance-as-a-Service (MaaS)
10. Testing-as-a-Service (TaaS)
11. Infrastructure-as-a-Service (IaaS), etc.

2.4. Cloud Deployment models

Cloud has four deployment models. These are public cloud, private cloud, community cloud, hybrid cloud and inter cloud shown below figure 3.

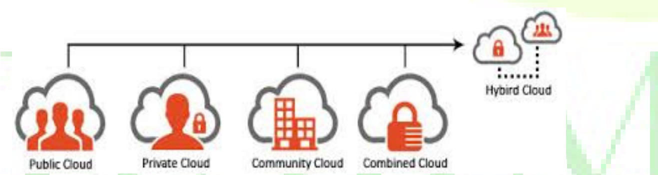

Figure3: Cloud Deployment types.

These deployment models are briefed as follows:

2.4.1.*Public cloud*: The public cloud can utilize for general public, anyone can use it.

2.4.2. *Private cloud*: Private cloud is meant solely for an organization.

2.4.3.*Community cloud*: Community is for special community composed of several organizations with shared concerns.

2.4.4.*Hybrid cloud*: Hybrid cloud is a combination of the clouds. (I.e. public, private or community clouds)

3. INTRODUCTION TO INTER-CLOUD

3.1. What is Intercloud?

The Intercloud [6] is an interconnected global "cloud of clouds"and an extension of the Internet "network of networks" on which it is based.[7] The term was first used in the context of cloud computing in 2007 when Kevin Kelly opined that "eventually we'll have the intercloud, the cloud of clouds". It became popular in late 2008 and has also been used to describe the datacenter of the future. [8]

The Intercloud scenario is based on the key concept that each single cloud does not have infinite physical resources or ubiquitous geographic footprint. If a cloud saturates the computational and storage resources of its infrastructure, or is requested to use resources in a geography where it has no footprint, it would still be able satisfy such requests for service allocations sent from its clients. The Intercloud scenario would address such situations where each cloud would use the computational, storage, or any kind of resource (through semantic resource descriptions, and open federation) of the infrastructures of other clouds. This is analogous to the way the Internet works, in that a service provider, to which an endpoint is attached, will access or deliver traffic from/to source/destination addresses outside of its service area by using Internet routing protocols with other service providers with whom it has a pre-arranged exchange or peering relationship. It is also analogous to the way mobile operators implement roaming and inter-carrier interoperability. Such forms of cloud exchange, peering, or roaming may introduce new business opportunities among cloud providers if they manage to go beyond the theoretical framework.[9]

3.2. Intercloud definition

Inter-cloudor 'cloud of clouds' is a term refer to a theoretical model for cloud computing services based on the idea of combining many different individual clouds into one seamless mass in terms of on-demand operations. The inter-cloud would simply make sure that a cloud could use resources beyond its reach, by taking advantage of pre-existing contracts with other cloud providers. Cisco inter-cloud strategy is shown below.

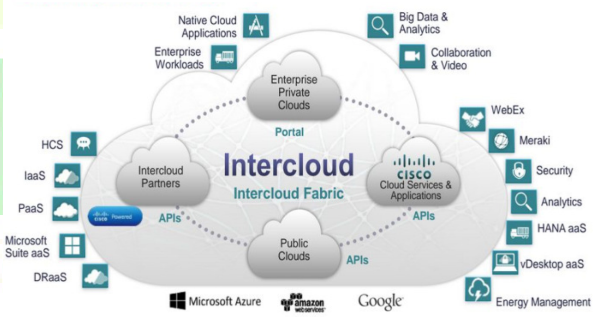

Figure 4: Cisco Inter-cloud Strategy

Essentially, an Inter-Cloud allows for the dynamic coordination and distribution of load among a set of cloud data centers [13] - see figure 5.

ISSN (ONLINE): 2454-9762
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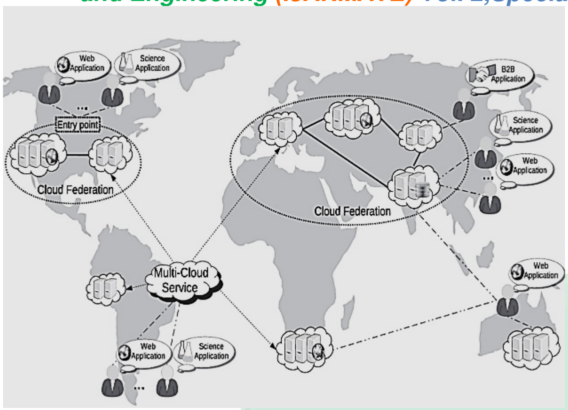

Figure 5.Overviews of Inter-Cloud approaches and use cases.

3.3. Interclоud History

- In July 2009 in Japan, an effort called the Global Inter-Cloud Technology Forum (GICTF)[10] was launched with the stated goal of "We aim to promote standardization of network protocols and the interfaces through which cloud systems interwork with each other, and to enable the provision of more reliable cloud services than those available today".

- In February 2011 the IEEE launched a board cloud computinginitiative IEEE Cloud Computing including a technical standards effort called P2302 - Standard for Intercloud Interoperability and Federation (SIIF).[11] The stated goal of the working group is to produce a standard as such: "This standard defines topology, functions, and governance for cloud-to-cloud interoperability and federation. Topological elements include clouds, roots, exchanges (which mediate governance between clouds), and gateways (which mediate data exchange between clouds). Functional elements include name spaces, presence, messaging, resource ontology (including standardized units of measurement), and trust infrastructure. Governance elements include registration, geo-independence, trust anchor, and potentially compliance and audit. The standard does not address intra-cloud (within cloud) operation, as this is cloud implementation-specific, nor does it address proprietary hybrid-cloud implementations."

- In mid-2011 the NIST Cloud Computing Reference Architecture was published fully describing hybrid clouds, cloud brokers, and so on. In late 2011 NIST published a whole set of Cloud Computing Technology Roadmaps including referencing the IEEE P2302 approach as an example of a future national/global federated cloud architecture.

- In March 2012 "Intercloud" made the Wired Magazine Jargon Watch list and in October 2013 the IEEE announced a Global Testbed initiative.

- In late 2013 Cisco made their first announcement relating to the Intercloud. Their product Cisco Intercloud Fabric (ICF) allows VM migrations between public and private clouds. In 2014 Cisco made another announcement [12] Cisco revealed that it "will invest $1Bn in the next two years to build its expanded cloud business" and that "Our cloud will be the world's first truly open, hybrid cloud. The Cisco Intercloud will be built upon Open Stack for its open standards-based global infrastructure. We plan to support any workload, on any hypervisor and interoperate with any cloud" (again assuming all clouds are using Cisco's proprietary technology).

- As of June 2015, The Intercloud has yet to show real world demonstration of federation and interoperability, and challenges remain regarding security and trust, governance and legal issues, QoS, monitoring, arbitrage, and billing.

3.4. Benefits of Intercloud

The benefits of an Inter-Cloud environment for cloud clients are numerous and can be broadly summarized as follows:

3.3.1. Diverse geographical locations. Leading cloud service providers have established data centers worldwide. Only by utilizing multiple clouds can one gain access to so widely distributed resources and provide well-performing and legislation-compliant services to clients.

3.3.2. Better application resilience. In the present days most of the major cloud vendors advised their clients to design their applications to use multiple data centers for fault tolerance [14]. Furthermore, in Berkeley's report on Cloud computing, Armbrust*et al.* emphasize that potential unavailability of service is the number one inhibitor to adopting Cloud computing [15]. Thus, they advise the use of multiple providers. Besides fault tolerance, using resources from different providers acts as an insurance against a provider being stopped because of regulatory or legal reasons as well.

3.3.4. *Avoidance of vendor lock-in*. By using multiple clouds and being able to freely transit workload among them, a cloud client can easily avoid vendor lock-in. In case a provider changes a policy or pricing that impact negatively its clients, they could easily migrate elsewhere.

A cloud provider should ensure enough resources at all times. But how much is enough? Workload spikes can come unexpectedly, and thus, cloud providers need to overprovision resources to meet them.

Cloud providers' benefits can be summarized as follows:

- *Expand on demand.* A cloud should maintain in a ready to use state enough resources to meet its expected load and a buffer for typical load deviations. If the workload increases beyond these limits, resources from other clouds can be leased.

- *Better service level agreement (SLA) to customers.* Knowing that even in a worst-case scenario of data centre outage or resource shortage the incoming workload can be moved to another cloud, a cloud provider can provide better SLAs to customers.

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4.INTERCLOUD INTEROPERABILITY

Currently, Intercloud computing is an emerging computation paradigm in the area of cloud computing. Although Intercloud Computing shared cloud a service has been increasingly utilized by diverse users, the research on Intercloud computing is still at an early stage. There are many challenges that have not been fully addressed in Intercloud Computing in addition to the new emerging issues introduced by enterprise applications. One of the existence challenges is the Inter-cloud Interoperability issue.

Intercloud addresses the interoperability between various cloud computing instantiations where each cloud would use computing resources of other clouds. Cloud Computing environments need to be interoperable in order to reduce scaling/producing cost within the development of the components. Cloud costumers should be able to migrate in and out of the cloud and switch between providers based on their needs, without a lock-in which restricts customers from selecting an alternative provider. Furthermore, cloud providers should be able to interoperate among themselves to find an alternative cloud provider to give better services. The present Intercloud network merely connects different cloud systems and each cloud provider has its own way on how cloud applications/customers interact with the cloud. Fieldhouse [16]summarized the current challenges in Cloud Interoperability as follow:

- Several different Cloud Standards from different parties are available.
- Existing Open Grid Forum (OGF) standards not or only partly ready for the cloud.
- A consistent OGF Cloud Portfolio is needed.
- Strategies for combining different Cloud Standards / APIs are needed.
- Existing implementations of Cloud APIs need to get interoperable.
- Combined Interoperability Verification Suites need to be developed.
- It is essential to discuss on issues related to specifications and implementation.

Currently different organizations, such as IEEE, are working on developing essential standards and appropriate APIs for Intercloud Interoperability. The future Intercloud network will expand the required functions to prepare collaboration among cloud services. Grozev&Buyya summarized their studies and classified 20 major Intercloud developments including both academic and industry projects [17]. According to their studies, Intercloud is classified as *Volunteer federation* and *Independent* shown in the figure 6.

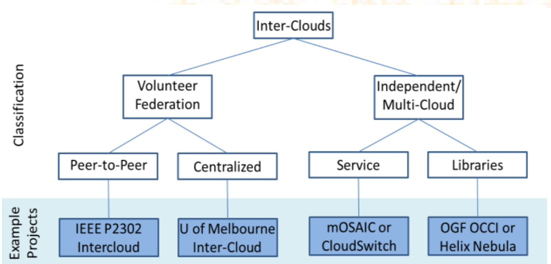

Figure**6**. Architectural classification of Intercloud[17].

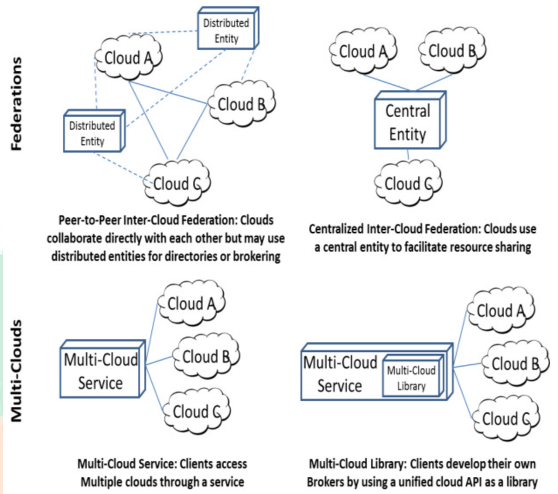

Figure 7: Intercloud developments' architecture.

1. *Volunteer federation*: when there is voluntarily collaboration between cloud providers that is often feasible for governmental clouds or private cloud portfolios and is classified as two architectural categories *Centralised &Peer-to-Peer*as in figure 7.
2. *Independent:* when an application or its broker independently from the cloud providers (both governmentally and private clouds) exploit multiple clouds and is classified in two architectural categories *Services&Libraries* as in figure 7.

5. INTERCLOUD TOPOLOGY

Cloud instances must be able to dialog with eachother. One cloud must be able to find one or more otherclouds, which for a particular interoperability scenario isready, willing, and able to accept an interoperabilitytransaction with and furthermore, exchanging whateversubscription or usage related information which mighthave been needed as a pre-cursor to the transaction.Thus, an Intercloud Protocol for presence andmessaging needs to exist which can support the 1-to-1,1-to-many, and many-to-many Cloud to Cloud use cases.The vision and topology for the Intercloud we willrefer to is as follows. At the highest level, theanalogy is with the Internet itself: in a world of TCP/IPand the WWW, data is ubiquitous and interoperable in anetwork of networks known as the "Internet"; in a worldof Cloud Computing, content, storage and computing isubiquitous and interoperable in a network of Cloudsknown as the "Intercloud"; this is illustrated in Figure 8.

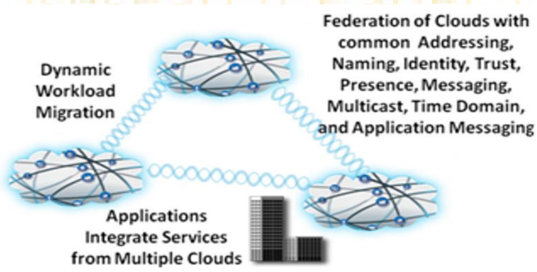

Figure 8. The Intercloud Vision

The reference topology for realizing this vision ismodelled after the public Internet infrastructure. Again,using the generally accepted terminology [18][19][20][21], there are Public Clouds,which are analogous to ISP's and Service Providersoffering routed IP in the Internet world. There arePrivate Clouds which is simply a Cloud which anorganization builds to serve itself.

There are Intercloud Exchanges (analogous toInternet Exchanges and Peering Points) where cloudscan interoperate, and there is an Intercloud Root,containing services such as Naming Authority, TrustAuthority, Directory Services, and other "root"capabilities. It is envisioned that the Intercloud root is ofcourse physically not a single entity, a global replicatingand hierarchical system similar to DNS [23] would beutilized. All elements in the Intercloud topology containsome gateway capability analogous to an Internet Router,implementing Intercloud protocols in order toparticipate in Intercloud interoperability. We call theseIntercloud Gateways. The entire topology is detailed in Figure 9.

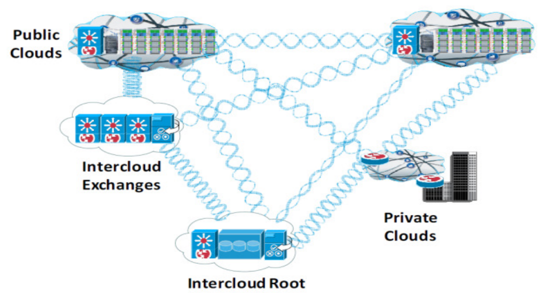

Figure 9: Reference Intercloud Topology

The Intercloud Gateways would provide mechanism for supporting the entire profile of Intercloud protocols and standards. The Intercloud Root and Intercloud Exchanges would facilitate and mediate the initialIntercloud negotiating process among Clouds. Once the initial negotiating process is completed, each of these Cloud instance would collaborate directly with eachother via a protocol and transport appropriate for the interoperability action at hand; for example, a reliableprotocol might be needed for transaction integrity, or ahigh speed streaming protocol might be neededoptimized for data movement over a particular link.

5.1. Intercloud Root, Exchanges, and Catalog

Various providers will emerge in the enablement ofthe Intercloud. We first envision a community governedset of Intercloud Root providers who will act as brokersand host the Cloud Computing Resource Catalogs forthe Intercloud computing resources. They would begoverned in a similar way in which DNS, Top LevelDomains [24] or Certificate Authorities [25] are, by anorganization such as ISOC [26] or ICANN [27]. Theywould also be responsible for mediating the trust basedfederated security among disparate clouds by acting asSecurity Trust Service providers using standards such asSASL [28] and SAML [29].

5.1.1 Intercloud Root: The Intercloud Root instances will work withIntercloud Exchanges to solve the n2 problem byfacilitating as mediators for enabling connectivityamong disparate cloud environments. This is a muchpreferred alternative to each cloud vendor establishingconnectivity and collaboration among themselves(point-to-point), which would not scale physically or ina business sense.

5.1.2 Intercloud Exchanges: Intercloud Exchange providers will facilitate thenegotiation dialog and collaboration among disparateheterogeneous cloud environments, working in concert with Intercloud Root instances as described previously[22]. Intercloud Root instances will host the root XMPPservers containing all presence information forIntercloud Root instances, Intercloud ExchangeInstances, and Internet visible Intercloud capable Cloudinstances. Intercloud Exchanges will host second-tierXMPP servers. Individual Intercloud capable Cloudswill communicate with each other, as XMPP clients, via XMPP server environment hosted by Intercloud Roots and Intercloud Exchanges.

5.1.3 Intercloud Catalog: In order for the Intercloud capable Cloud instances tofederate or otherwise interoperate resources, a CloudComputing Resources Catalog system is necessaryinfrastructure. This catalog is the holistic and abstractedview of the computing resources across disparate cloudenvironments. Individual clouds will, in turn, will utilizethis catalog in order to identify matching cloudresources by applying certain Preferences andConstraints to the resources in the computing resourcescatalog.The technologies to use for this are based on theSemantic Web which provides for a way to add"meaning and relatedness" to objects on the Web. Toaccomplish this, one defines a system for normalizingmeaning across terminology, or Properties. Thisnormalization is called Ontology.

5.2. Ontology based Cloud ComputingResources Catalog

The Intercloud system not only focuses on theprovisioning of computing resources inside a singlecloud; it provides a holistic and abstracted view of thecomputing resources across disparate cloudenvironments. Participating cloud providers willadvertise their resource capabilities within the cloudcomputing resources catalog hosted by Intercloud RootProviders. Management of the thousands of resourcesand configurations requires careful control and planningto achieve business objectives and avoid errors. Thechief objectives of the planned configuration are toprovide cost effective use of computing resources and tomeet the business objectives of the enterprise.

In order to automate an environment wherebysoftware agents versus traditional human users discoverand consume services, intelligent ontology based serviceregistries are needed for dynamically discovering andprovisioning computing resources across variouscomputing cloud environments (Amazon, Azure etc.etc.).

Comprehensive semantic descriptions of services are essential to exploit them in their full potential. That isdiscovering them dynamically, and enabling automatedservice negotiation, composition and monitoring. Thesemantic mechanisms currently available in serviceregistries such as UDDI [30] are based on taxonomiescalled "tModel" [31]. tModel fails to provide the meansto achieve this, as they do not support semanticdiscovery of services [32][33]. tModel supports aconstruct which serves two purposes: it can serve as anamespace for a taxonomy or as a proxy for a technicalspecification that lives outside the registry. Such atModel construct has some intrinsic limitations, forexample classifications for the Intercloud use case canalso be defined for individual operations or

IJARMATE
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theirargument types. However, this requires searchingmechanisms for services that are distinct from those fortheir argument types. Likewise, tModel's reference to anexternal technical specification, as applied in UDDI alsoimplies that a different mechanism is required forreasoning over service interfaces.

Although the terms "taxonomy" and "ontology" are sometimes used interchangeably, there is a critical difference. Taxonomy indicates only class/subclass relationship whereas Ontology describes a domain completely. The essential mechanisms that ontology languages provide include their formal specification (which allows them to be queried) and their ability to define properties of classes. Through these properties, very accurate descriptions of services can be definedand services can be related to other services or resources.We are proposing a new and improved service directoryon the lines of UDDI but based on RDF/OWL [34]ontology framework instead of current tModel basedtaxonomy framework. This catalog captures thecomputing resources across all clouds in terms of"Capabilities", "Structural Relationships" and Policies(Preferences and Constraints).

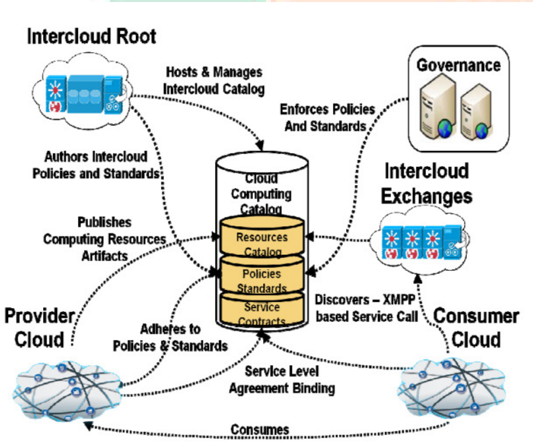

Figure 10. Cloud Computing Catalog

Effective cloud computing resources ontologyinformation captured in the catalog provides thefollowing advantages:

- Consolidated view of Computing Resources across clouds. Consistent way to expose Services Offered.
- Provide visibility and access to contractual information at any point in time.
- Provides the ability to protect sensitive information from unauthorized access. Configuration resources will have security restrictions applied against them.
- Governance Processes
- One-Stop/Consistency
- Time-to-Value
- Overall Effectiveness

6. INTERCLOUD PROTOCOLS TAXONOMY

Working groups have proposed building a layered set of protocols to solve the Cloud Computing interoperability challenge called "Intercloud Protocols". Instead of each cloud provider establishing connectivity with another cloud provider in a Point-to-Point manner resulting in the n^2 complexity problem, Intercloud Directories and Exchanges will act as mediators for enabling connectivity and collaboration among disparate cloud providers. Point to Point protocols such as HTTP are not suitable beyond 1-to-1 models, therefore the discussions around many-to-many mechanisms have been proposed, including XMPP. The protocols taxonomy[35][36] of Intercloud contains IP is the bottom most layer which deals with the network, On top of IP it has TCP, UDP and IP Routing (for VPN) which deals with the virtual machines in the Intercloud. Top most layers contain XAMPP, HTTP, DNS, sUDT, Web Stack, and Bit Torrent etc..., those are the applications and services which are running on the virtual machines in the Intercloud. A simple Intercloud Protocols Taxonomy is shown in the billow diagram

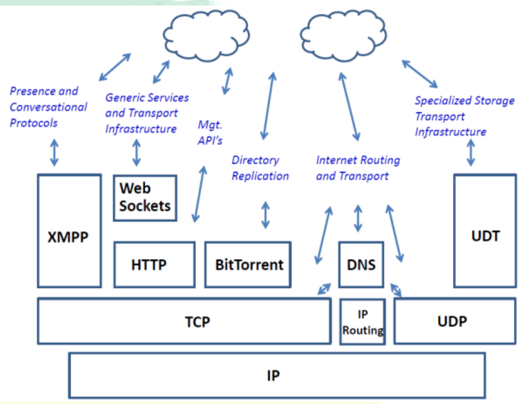

Figure 11: Intercloud Protocols Taxonomy

7. CONCLUSION

As of June 2015, The Intercloud has yet to show real world demonstration of federation and interoperability, and challenges remain regarding security and trust, governance and legal issues, QoS, monitoring, arbitrage, and billing. The Intercloud is the only solution to the clouds to provide the unlimited services with no barriers by giving flexibility to the users. Hear I give a glans on Intercloud issues and are still under research and development led by the major companies like CISCO pumped with billions of funds.

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AUTHOR

V. Ashok kumarwas born in Srikalahasti, Andhra Pradesh, India on May 22, 1982, Since 2006, he has been working as an Assistant Professor in Dept. of CSE, Srikalahasteeswara Institute of Technology, Srikalahasti, India. He received B.Tech (CSE) in 2005 from SKIT, Srikalahsti, M.Tech in 2010 from School of IT, JNTUH, Hyderabad. His research interests Virtualization Techniques and Cloud Computing.