

## Approach for Deploying the Hybrid Cloud in Diverse Open-Source Tools

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**Abstract:** Cloud computing is an attractive computing model since it allows for resources to be provisioned according on a demand basis, i.e., cloud users can rent resources as they become necessary. This model motivated several academic and non-academic institutions to develop open-source cloud solutions. This paper presents and discusses the state-of-the of open-source solutions for cloud computing. We hope that the remark and classification of such solutions can control the cloud computing research area providing a good starting point to cope with some of the problems present in cloud computing environments.

**Keywords:** Open Stack, Cloud computing, Eucalyptus, IBM Bulemix, Hybrid Cloud.

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### I. Introduction

At present, it is common to access content across the Internet with little reference to the underlying hosting infrastructure, which is formed by data centers maintained by content providers. The entire technology used to provide such level of locality transparency offers also a new model for the provision of computing services, stated as Cloud Computing. In such a model, enterprises put their applications in the cloud – a very large computational entity from a developer’s perspective – without concern for where the services are actually hosted or how they are delivered. Through access to slice of computational power over a scalable network of nodes, enterprises can reduce or eliminate costs associated with internal infrastructure for the provision of their services. A further viewpoint of cloud users, in addition to costs reduction, comes from the fact that the cloud computing model can be attractive since it allows resources to be provisioned according to the enterprise needs. This is in contrast, to traditional practices, where resources are often dimensioned according to the worst case use and peak scenarios. Hence cloud users can rent resources as they become necessary, in a much more scalable and elastic way. Moreover, enterprises can transfer operational risks to cloud providers. In the viewpoint of cloud providers, the model offers a way for better utilization of their own infrastructure [3]. The model benefits from a form of statistical multiplexing, since it allocates resources for several users concurrently. This statistical multiplexing of data centers is guaranteed through several decades of research in many areas as: distributed computing, grid computing, web technologies, service computing, and virtualization [3], [5], [6] research areas virtualization brought the key technologies to leverage cloud computing.

Clouds are a large pool of easily usable and accessible virtualized resources. These resources can be dynamically reconfigured to adjust to a variable load, allowing also for optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized SLA

Since the popularization of the cloud computing term in 2007, with IBM Blue Cloud [11], several enterprises become cloud computing providers: Amazon and their Elastic Compute Cloud (EC2)<sup>1</sup>, Google with Google App Engine<sup>2</sup>, Microsoft with their Windows Azure Platform<sup>3</sup>, Sales force and their Force.com<sup>4</sup> and so on. Though these solutions fit the cloud computing definition they differ in their programmability. A concept borrowed from the network virtualization area [7], programmability is relative to the programming features a network element offers to developers, measuring how much freedom the developer has to manipulate resources and/or devices. This concept can be applied to compare cloud computing solutions. More programmable clouds offer environments where developers are free to choose their own programming paradigm, languages, and platforms, having total control over their virtualized resources. Less programmable clouds restrict developers in some way: forcing a set of programming languages, or allowing support for only one application paradigm. On the other hand, a high level of programmability turns hard the cloud management because the cloud provider will have a much more heterogeneous environment to manage. For example, if a cloud provider allows their users to use any operating system in a virtual machine, the cloud operator will have to cope with a large number

of solutions to provide fault-tolerance services. Moreover, less programmable solutions abstract some operational issues (processes communication, network access, storage functions, etc.) through some type of middleware. An instance of a cloud solution with high programmability is the Amazon EC2, where users can choose their operating system from a set of supported operating systems given by Amazon and they can configure their virtual machines to work as they see fit. The Google App Engine is an example of a less programmable solution, since it restricts developers to the Web paradigm and to some programming languages. A common characteristic present in all the cited cloud solutions is that cloud owners understandably avoid revealing the underlying features of their solution, since this is seen as part of their strategic information. Despite this, one may point out the considerable efforts made by several academic and non-academic institutions to develop open-source cloud solutions.

## **II. Challenges**

The development of cloud computing solutions brings several technical challenges to cloud developers. These challenges can be grouped in three main areas: negotiation, decision, and operation. In the negotiation area, these are the challenges relative to how application developers interface with the cloud as well as the description of the cloud offerings. It includes also the definition of the programmability level that the cloud solution will offer. The decision area copes with the main problem that clouds faces behind the scenes: How virtual resources can be scheduled to meet user requirements, for example? Last, the operation area is associated with the enforcement of decisions and the communication between cloud elements. The following sub-sections discuss in details the main challenges in each one of these areas.

### **1. Negotiation**

The negotiation area concerns itself with challenges relative to the interface between the application developers and the cloud. Generally, the interface between the cloud and application developers assumes the form of an Application Programming Interface (API), but, depending on the programmability level offered by the cloud, this API can be implemented in several ways ranging from a web-service based toolkit to control virtual machines in the cloud to a set of programming primitives used to develop distributed applications in the cloud. In addition to these basic functions, such APIs must allow developers to request– and control, possibly – additional functionalities offered by a cloud operator like service quality assessment, load balance, elastic application growth, backup strategies, and so on. There are still some other requirements that can be considered in the cloud API like geographical restrictions enforced to allocate virtual machines due to legal issues. One may think of some type of content or application that is strategically limited to a country or a region for copyright or security reasons. At the present, APIs and the negotiation process offered by cloud providers follow a semi-automatic scheme where a human interacts with the cloud through programming primitives or a visual interface. But, next generation clouds can offer sophisticated ways to interact with human users through high-level abstractions and service-level policies. Such an interface type will need some formalism to specify both cloud offerings and application requirements as well as offering the support for an automatic negotiation process.

### **2. Decision**

The main target of any cloud operator is to schedule developer applications aiming for the maximum utilization of cloud resources. A developer’s application covers, beyond the actual code, some additional information about application’s needs and services negotiated previously. In other words, one can abstract this additional information to some type of network virtualization demand with a topology formed by virtual nodes where the application runs and virtual links for communication. Therefore, the cloud operator problem turns into that of selecting the best suitable physical resources to accommodate these virtual resources. This careful mapping requires advanced strategies. The first challenge imposed by this optimization problem is that it is NP-hard [3] and hence any useful solution would need to relax some of its problem conditions and constraints to obtain an approximate solution in a polynomial time. The second challenge is to meet all the clauses negotiated with the developer. Depending on the nature of such contract, application scheduling algorithms will cope with quality restrictions, jurisdiction restrictions, elastic growth, and so on.

### **3. Operation Metaphorically,**

One can say that while in the decision area the cloud operator must identify solutions for the “brain” of the cloud, in the operation area it must attack the problems of the “limbs” of the cloud, i.e., they must provide some form to enforce decisions. The enforcement here covers the communication protocols and the configuration of cloud elements. A communication protocol can be used to monitor and reserve resources in the cloud. The cloud is composed by different elements like processing servers, switches, routers, links and storage components. Due to such heterogeneity, the communication between the decision-maker and elements puts a

challenge on cloud design. Overall, existing cloud solutions use Web Services to provide communication with processing and storage nodes, but many communication elements do not support such implementations. Thus, cloud architects are using traditional traffic engineering protocols to provide reservation of network elements. One possible idea to cope with this challenge is to use smart communication nodes with an open interface to create new services in the node the emerging Open flow-enabled switches [4]. Node communication is just one part of the problem; the other one is to configure this. Here, the recent advances in server virtualization have provided several solutions for operators to benefit from.

### III. Standardization Efforts

A considerable challenge present in many of the raised discussions around the cloud is related to the need for standardization. All the three areas presented in Section 2 face the standardization challenge in some way, but the main challenge occurs in the negotiation area. Currently, cloud providers offer proprietary interfaces to access their services. This locks users within a given provider as they cannot migrate their applications and services easily between cloud providers [6]. It is hoped that cloud providers see such a problem and work together to offer a standardized API based on open standards like SOAP and REST. An important effort in the standardization comes from the Open Cloud Manifesto [8]. This is an initiative supported by hundreds of companies that aims to discuss with cloud organizations a way to produce open standards for cloud computing. Their major doctrines are collaboration and coordination of efforts on the standardization, adoption of open standards wherever appropriate, and the development of standards based on customer requirements. Participants of the Open Cloud Manifesto through the Cloud Computing Use Case group produced an interesting white paper [9] highlighting the requirements that need to be standardized in a cloud environment to ensure interoperability in the most typical scenarios of interaction – Use Cases – in cloud computing.

### IV. Open-Source Solutions For Cloud Computing

Due to the large growth of cloud computing, there are several solutions in this area. This article is focused on open source solutions, highlighting their main characteristics and architectures proposed.

#### 1. Xen Cloud Platform (XCP)

The Xen hypervisor [10] is a solution for infrastructure virtualization that provides an abstraction layer between servers' hardware and the operating system. A Xen hypervisor allows each physical server to run several "virtual servers" handling the operating system and its applications from the underlying physical server. The Xen solution is used by many cloud solutions such as Amazon EC2, Nimbus and Eucalyptus. Recently, Xen.org announced the Xen Cloud Platform (XCP) [9] as a solution for cloud infrastructure virtualization. But, differently from existent open source cloud solutions, XCP does not provide the overall architecture for cloud services. Their goal is to provide a tool to cope with automatic configuration and maintenance of cloud platforms [9].

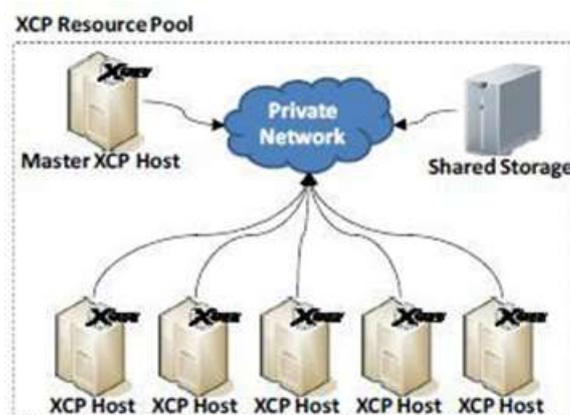


Figure 1: XCP Architecture

XCP resource pool and using a Shared Storage the virtual machines can be started and restarted on any XCP host. The Master XCP host offers an administration interface and forwards command messages to others XCP hosts.

#### 2. Nimbus

Nimbus [14] is an open source solution (licensed under the terms of the Apache License) to turn clusters into an Infrastructure as a Service (IaaS) for Cloud Computing focusing mainly on scientific applications. This solution gives to users the possibility to allocate and configure remote resources by deploying VMs – known as Virtual Workspace Service (VWS). A VWS is a VM manager that different frontends can invoke. To deploy applications, Nimbus offers a “cloudkit” configuration that consists of a manager service hosting and an image repository. The workspace components are shown in Figure 2.

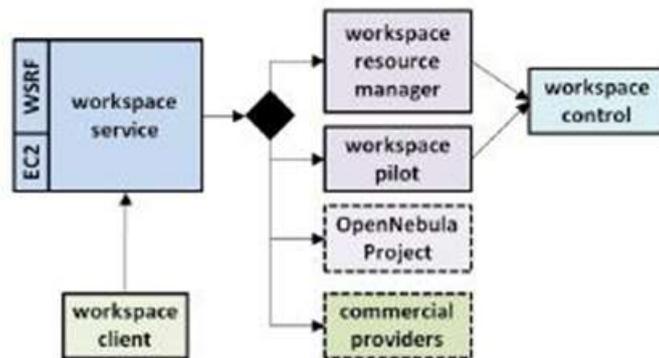


Figure 2: Workspace components of Cloudkit of Nimbus

**Workspace service:** is web services based and provides security with the GSI authentication and authorization. Currently, Nimbus supports two frontends: Amazon EC2 and WSRF.

- **Workspace control:** is responsible for controlling VM instances, managing and reconstructing images, integrating a VM to the network and assigning IP and MAC addresses. The workspace control tools operate with the Xen hypervisor and can also operate with KVM5.
- **Workspace resource management:** is an open source solution to manage different VMs, but can be replaced by other technologies such as OpenNebula.
- **Workspace pilot:** is responsible for providing virtualization with few changes in cluster operation. This component handles signals and has administration tools.

### 3. OpenNebula

OpenNebula [15] is an open-source toolkit used to build private, public and hybrid clouds. It has been designed to be integrated with networking and storage solutions and to fit into existing data centers. The OpenNebula architecture (Figure 3) is based on three basic technologies to enable the provision of services on a distributed infrastructure: virtualization, storage and network. All resource allocation is done based on policies.

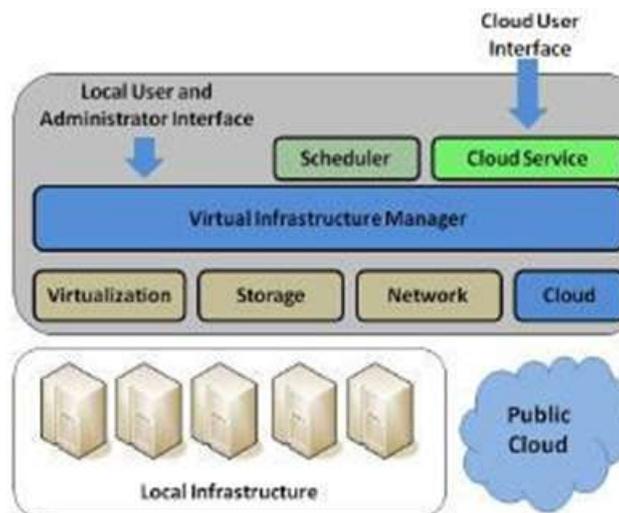


Figure 3: Open Nebula Architecture

The Cumulus Project [16] is an academic proposal based on OpenNebula. Cumulus intends to provide virtual machines, virtual applications and virtual computing platforms for scientific applications. Visualizing the integration of already existing technologies, the Cumulus project uses HP and IBM blade servers running Linux and Xen hypervisor. The Cumulus networking solution was called the “forward” mode, where users do not need to specify any network configuration information. Instead the backend servers are responsible for allocating a dynamic IP address for a VM and returning these to the users, making such networking solution transparent to the users. The Cumulus design is a layered architecture (Figure 4) with three main entities: Cumulus frontend, OpenNebula frontend, and OS Farm. This proposal focuses on reaching scalability and autonomy of data centers.

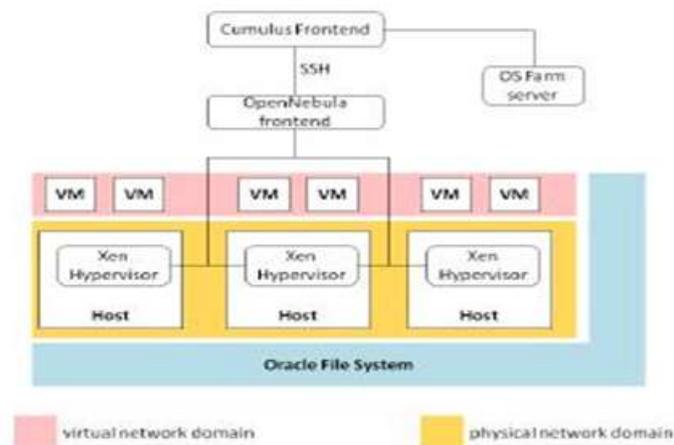


Figure 4: Cumulus Layered Architecture

**Cumulus frontend:** the Cumulus frontend is the access point for a Cumulus system and is responsible for handling VM requirements.

**OpenNebula frontend:** the OpenNebula frontend provides an interface to manage the distributed blade servers and the resources for VM deployment. To administrate a common user system, Cumulus uses NIS (Network Information System) and NFS (Network File System) to manage shared directory. Moreover, OpenNebula was merged with secure infrastructure solutions, such as LDAP (Lightweight Directory Access Protocol) and the Oracle Cluster File System.

**OS Farm:** the OS Farm is a tool for VM template management that operates to generate and to store Xen VM images and virtual appliances.

#### 4. Eucalyptus

Eucalyptus [12] is an open source cloud computing framework focused on academic research. It provides resources for experimental instrumentation and study. Eucalyptus users are able to start, control, access and terminate entire virtual machines. In its current version, Eucalyptus supports VMs that run atop the Xen supervisor [4]. According to [12], the Eucalyptus project presents four characteristics that differentiate it from others cloud computing solutions:

- a) Eucalyptus was designed to be simple without requiring dedicated resources;
- b) Eucalyptus was designed to encourage third-party extensions through modular software framework and language-agnostic communication mechanisms;
- c) Eucalyptus external interface is based on the Amazon API (Amazon EC2) and
- d) Eucalyptus provides a virtual network overlay that both isolates network traffic of different users and allows clusters to appear to be part of the same local network.

The Eucalyptus architecture is hierarchical (Figure 5) and made up of four high level components, where each one is implemented as a stand-alone web service.

**Node Controller (NC):** this component runs on every node that is destined for hosting VM instances. An NC is responsible to query and control the system software (operating system and hypervisor) and for conforming requests from its respective Cluster Controller. The role of NC queries is to collect essential information, such as the node’s physical resources (e.g. the number of cores and the available disk space) and the state of VM

instances on the nodes. NC sends this information to its Cluster Controller (CC). NC is also responsible for assisting CC to control VM instances on a node, verifying the authorization, confirming resources availability and executing the request with the hypervisor.

**Cluster Controller (CC):** this component generally executes on a cluster frontend machine, or any machine that has network connectivity to two nodes: one running NCs and another running the Cloud Controller (CLC). A CC is responsible to collect/report information about and schedule VM execution on specific NCs and to manage virtual instance network overlay.

**Storage Controller (Walrus):** this component is a data storage service that provides a mechanism for storing and accessing virtual machine images and user data. Walrus is based on web services technologies and compatible with Amazon's Simple Storage Service (S3) interface [1].

**Cloud Controller (CLC):** this component is the entry-point into the cloud for users. Its main goal is to offer and manage the Eucalyptus underlying virtualized resources. CLC is responsible for querying node managers for resources' information, making scheduling decisions, and implementing them by requests to CC. This component is composed by a set of web services which can be grouped into three categories, according their roles: resource services, data services, and interface services.

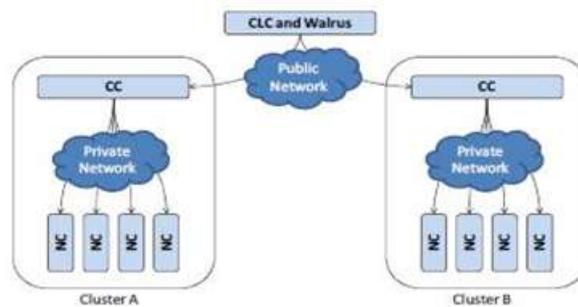


Figure 5: Eucalyptus Overview

Ubuntu Enterprise Cloud (UEC) 6 is an Amazon EC2 like infrastructure and is powered by Eucalyptus. Its main goal is to provide a simple process of building and managing internal infrastructure for cloud. The Ubuntu 9.04 Server Edition is integrated with Eucalyptus that uses the KVM hypervisor. The UEC architecture is based on the Eucalyptus architecture in which each element is an independent web service that publishes a Web Service Description Language (WSDL) document defining the API to interact with it. Furthermore, UEC defines three layers for security: authentication and authorization, network isolation and Machine Instance Isolation (MInst). The authentication and authorization layer is responsible for locally generated X.509 certificates; the network isolation layer is important to prevent eavesdropping of network traffic and; the MInst layer consists of Networking isolation, Operating System isolation, and Hypervisor based machine isolation.

## 5. TPlatform

TPlatform [17] is a cloud solution that provides a development platform for web mining applications, which is inspired in Google cloud technologies, and which acts as a Platform as a Service (PaaS) solution. Their infrastructure is supported by three technologies: a scalable file system called Tianwang File System (TFS) what is similar to the Google File System (GFS), the BigTable data storage mechanism, and the MapReduce programming model. The TPlatform framework is composed by three layers (Figure 6):

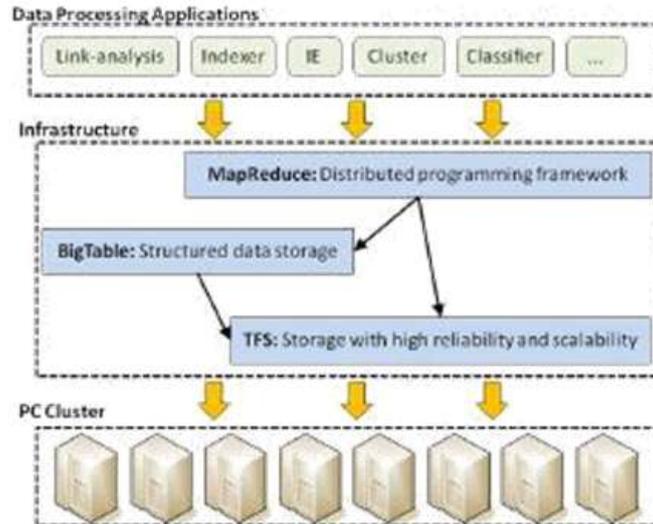


Figure 6: Tplatform Framework

**PC Cluster:** this layer provides the hardware infrastructure for data processing.

**Infrastructure:** this layer consists of file system (TFS), distributed data storage mechanism (BigTable), and programming model (MapReduce).

**Data Processing Applications:** this layer provides the services for users to develop their application (e.g. web data analysis and language processing).

### 6. Apache Virtual Computing Lab (VCL)

Apache VCL [18] is an open-source solution for the remote access over the Internet to dynamically provision and reserve computational resources for diverse applications, acting as Software as a Service (SaaS) solution. VCL has a simple architecture formed by three tiers:

**Web server:** represents the VCL portal and uses Linux/Apache/PHP solution. This portal provides an user interface that enable the requesting and management of VCL resources;

**Database server:** stores information about VCL reservations, access controls, machine and environment inventory. It uses Linux/SQL solution;

**Management nodes:** is the processing engine. A management node controls a subset of VCL resources, which may be physical blade servers, traditional rack, or virtual machines. It uses Linux/VCLD (perl)/image library solution. VCLD is a middleware responsible to process reservations or jobs assigned by the VCL web portal. According to type of environment requested, VCLD should assure that service (computational environment) will be available to user. Figure 7 shows a conceptual overview of the VCL, where the user must connect firstly to the VCL Scheduling Application in order to access its resources through a web interface. Users may request a reservation to use the environment immediately or schedule to use it in the future.

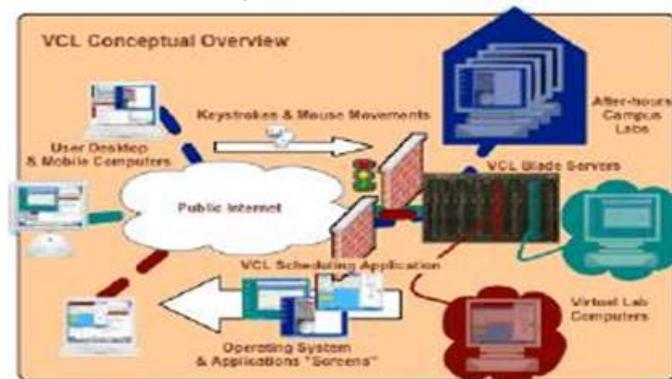


Figure 7: Overview of VCL

### 7. Enomaly Elastic Computing Platform

Enomaly ECP Community Edition under the AGPL license [13] is the open source cloud solution offered by Enomaly Inc. This version focuses on virtual machine administration in small clouds environments. Compared with the Enomaly commercial solution (called Service Provider Edition), the Enomaly open source edition suffers from many restrictions, such as limited scalability, no capacity control mechanism, no support for accounting and metering, and so on.

### 8. IBM Bluemix

IBM Bluemix Local brings the power and agility of the Bluemix cloud-based platform to your data center. With Bluemix Local, you can protect your most sensitive workloads behind your company firewall, while staying securely connected and in sync with Bluemix Public [11]. IBM uses cloud operations as a service to monitor and maintain your environment, so that you can focus on building apps and services that run on top of the environment. IBM also handles platform updates, so that you can focus on the business.

Bluemix Local environments have the same security standards as the public Bluemix in terms of operational security. You provide the hardware and infrastructure, which gives you control over infrastructure and physical security. Developer access to the local Bluemix is controlled by your LDAP policies, which can be configured by the Bluemix team when they set up your environment. Within the local environment, using the Administration page, you can manage user roles and permissions. Bluemix Local includes a private syndicated catalog that displays the local services that are available exclusively to you. It also includes additional services that are made available to you to use from Bluemix Public. The syndicated catalog provides the function to create hybrid applications that consist of public and private services. You have the option to decide which public services meet the requirements for your business based on your data privacy and security criteria. You see specific icons attached to service tiles in your catalog if, for example, it is a private service. Bluemix Local comes with all included Bluemix runtimes and 64 GB of computer memory. Figure 8 shows overview of Bluemix.

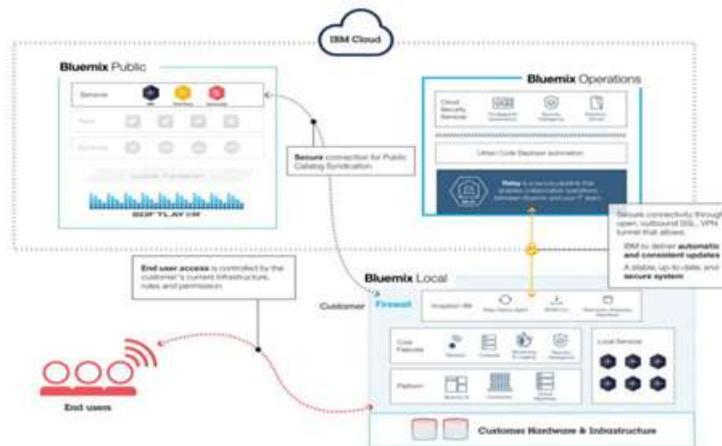


Figure 8: Overview of Bluemix

## V. Discussion

As pointed out earlier in this paper, there are several solutions for cloud computing focusing on different areas and ranging from hardware resource outsourcing to user services providing. Each solution presents a different vision about cloud architecture and implementation. Moreover, each approach has an implication that directly impacts its business model: the closer to the hardware level, the more options a user can handle but at the cost of having to configure her cloud (more configuration flexibility). Amazon EC2 and IBM Capacity on Demand (CoD) are solutions that offer to their users this configuration flexibility. In this business model, users can choose and configure computational resources at the hardware level and OS levels. At the other extreme, solutions like Google App Engine and Windows Azure, try to turn development easy to their users, but at the same time, confine them to specific APIs and software platforms. Moreover, solutions like JoliCloud8 are more limited as they offer a single service (operating system). In the middle, there are solutions that offer a middleware-like approach to users, where the hardware resources can be configured and handled subject to some restrictions and where applications can also be developed.

All the presented open-source solutions and the cited commercial solutions are categorized into Figure 9. The graphic compares solutions and their business model (hardware, middleware and user level) according to configuration flexibility.

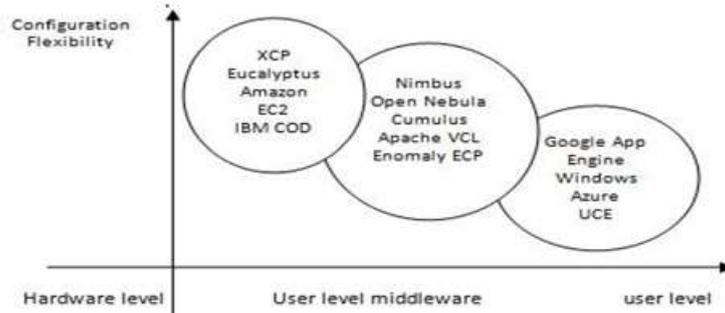


Figure 9: Cloud Computing Sources

Open-Sources	Hybrid Services	Main Characteristics	Infrastructure	Used By
XCP	H-IaaS	Only a tool for automatic Maintenance of cloud	Xen	XCP community
Nimbus	H-IaaS	Aims to turn legacy clusters into IaaS clouds	Xen Hypervisor	Brookhaven National Labs
OpenNebula	H-IaaS	Policy-driven resource allocation	Xen hypervisor	Cumulus project
Eucalyptus	H-IaaS	Hierarchical Architecture	Xen Hypervisor & KVM	UCE
TPlatform	H-PaaS	Focus on web text mining applications	TFS, Big Table & Mapreduce	TPlatform Project
Apache VCL	H-SaaS	Internet access for several applications	VMWare	Educational & Government uses
Enomaly	H-IaaS	Open version is focused in small clouds	Xen, KVM & VirtualBox	Several Companies
IBM Bluemix	H-IaaS	Provides Autoscaling	VMWare	Several Companies

## VI. Conclusions And Future Works

There is a clear need for the standardization of current cloud platforms at least of terms of interface, negotiation and access through Web services. Understandably, this is a considerable task as many clouds use different abstraction levels, some are generic whereas others focus on a specific application domain, etc. Some initial steps have been taken into this direction with the setup of the Open Cloud Manifesto, an initiative supported by hundreds of companies. In the mean time we will continue to see some clouds such as Nimbus implementing a number of front ends (e.g. Amazon EC2 and WSRF) to ensure access to their existing users. Interestingly, some solutions such as the OpenNebula have been first to adopt policies for resource management. The use of policies remains a challenge in many areas and clouds may benefit from it. It is also important to acknowledge the leadership and string presence of academic efforts such as Eucalyptus and Xen. These have been at the forefront of innovation supported by the many commercial cloud systems that currently are based on these. These efforts are expected to continue as more work is needed to remove much of the mysticism and conflicts surrounding the use of clouds.

As future work, we propose a quantitative comparison of the presented solutions through performance evaluation measurements and to build a tool to deploy hybrid or dedicated cloud for the diverse applications.

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