Building Clouds with OpenNebula: A Grid Computing Perspective

Ruben S. Montero
dsa-research.org
Distributed Systems Architecture Research Group
Universidad Complutense de Madrid
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• Provide an overview of Cloud Computing
• Describe how Clouds can help Grids
• Experiences using Clouds and Grids
• Hands on: Using a OpenNebula Cloud
# Cloud Computing in a Nutshell

<table>
<thead>
<tr>
<th>What</th>
<th>Who</th>
</tr>
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<tbody>
<tr>
<td>On-demand access to any application</td>
<td><strong>End-user</strong> (does not care about hw or sw)</td>
</tr>
<tr>
<td>Platform for building and delivering web applications</td>
<td><strong>Developer</strong> (no managing of the underlying hw &amp; sw layers)</td>
</tr>
<tr>
<td>Delivery of a <em>raw</em> computer infrastructure</td>
<td><strong>System Administrator</strong> (complete management of the computer infrastructure)</td>
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**Software as a Service**

- Skype
- Gmail
- Facebook

**Platform as a Service**

- Windows Azure
- force.com

**Infrastructure as a Service**

- GoGRID
- flexiscale
- Amazon WebServices
The Public IaaS Cloud

- Simple Web Interface
- Raw *Infrastructure* Resources
  - Total control of the resources
  - Capacity leased in the form of Vms
  - Complete Service-HW decoupling
- Pay-as-you-go (On-demand access)
  - A single user can not get all the resources
  - Multi-tenancy
- Elastic & *"infinite"* Capacity
Using a Public IaaS Cloud

Total control of service layout
- Resources allocated
- Software Stack
- Type & Number of components
- Service Elasticity

Service End-Users

Web Server (Load Balancer)

App Server

App Server

App Server

Network

Virtual Machines

IaaS Cloud

DBs (storage)
The Private IaaS Cloud

A “Public Cloud behind the firewall”

- Security concerns
- Flexible management (consolidation, adaptation, provisioning...)

VMs are great!!... *(the BUT's)*

- Where did/do I put my VM? *(scheduling & monitoring)*
- How do I provision a new cluster node? *(clone & context)*
- What MAC addresses are available? *(networking)*

Cloud Management Layer (e.g. OpenNebula)

- Provides a *uniform view* of the physical resource pool
- *Life-cycle management* and monitoring of VM
- *Integrates* Image, Network and Virtualization
The Hybrid IaaS Cloud

• Supplement the capacity of the local infrastructure
• Transparent access to the resulting hybrid cloud
• Utility Computing dream made a reality!
What is OpenNebula?

OpenNebula is a standard-based open-source toolkit to build private, public and hybrid clouds.

Design Philosophy

• One solution can not fit all data-center and user requirements and constraints
• Open, Flexible and extensible architecture that allows multiple components to be orchestrated
• Provide basic components, but allow them to be easily replaceable by others
What is OpenNebula?
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Current Grid Infrastructures...

- High degree of heterogeneity (software & hardware)
- High operational costs
- Isolate and partition resources contributed to the Grid
- Specific environment requirements for different Vos
- Users simply do not feel like adopting our execution models (*pilot jobs*...)

Grids are difficult to maintain, operate and use
Grids, Clouds... and Virtual Machines

• A VM is an isolated runtime environment (guest OS and apps)
• Hypervisors: Full Virtualized, para-virtualization, HW Virtualization

Execution of legacy applications

Virtualization (Xen, KVM...)

Physical Hardware

Domains are isolated

Natural way to deal with the heterogeneity

Application / HW decoupling

VMs can be provided with a Cloud-like model!
Grids, Clouds... and Virtual Machines

Cluster users

Service Layer

Cluster Front-end

Virtual workernodes

OpenNebula

Infrastructure Layer

Physical Infrastructure
Grids, Clouds... and Virtual Machines

Cluster users

Infrastructure Layer

User Requests
- Typical LRMS interface
- Virtualization overhead

Service Layer

Physical Infrastructure

Cluster Front-end

Virtual workernodes

OpenNebula
Grids, Clouds... and Virtual Machines

Cluster users

Service Layer

Infrastructure Layer

Cluster Consolidation
- Multiple worker nodes in a single resource
- Dynamic provision rules (inf. adaptation)
- VMM functionality (e.g. live migration)
Clusters, Clouds... and Virtual Machines

Cluster users

Cluster Partitioning
- Performance partitioning (dedicated nodes)
- Isolate cluster workload
- Dedicated HA partitions

Service Layer

OpenNebula

Infrastructure Layer

Physical Infrastructure
Grids, Clouds... and Virtual Machines

Heterogenous Workloads

- Dynamic provision of cluster configurations
- Simultaneous support of different services
- E.g. on-demand VO workernodes in Grids
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Grids, Clouds... and Virtual Machines

• Use VMs as basic building block for Grid Services

• Current Trends:
  • VMs as Job Container
  • VMs as Grid execution service component
    • Deal with heterogeneity
    • Simplify & Improve site management
    • Give VOs control over the worker-node SW

• IaaS interfaces for a Grid Site
  • Attract business users
  • Support novel execution models
VM as a Job Container

- Job request with a VM environment
- Grid middleware (WMS, CE-CREAM...)
- LRMS (e.g. LSF, PBS...)
- Jobs executed in a VM

Features
- Single LRMS-based
- Integrated with Grid MW

Drawbacks
- Jobs and VMs are different
- Need to integrate other resources (network, storage...)
- Do not decouple totally infrastructure from the Grid services
- Can not leverage VM features (e.g. Migration...)
- Focused on Job execution
VM as Grid Service Component

Grid middleware (WMS, CE-CREAM...)

LRMS (e.g. LSF, PBS...)

Direct Jobs execution

Virtual WN (VO)

Physical WNs

VM, network & storage Management

Load-VO Driven Adaptation

Public Cloud

Cloud WNs

External Cloud

Job request with a VM environment

VIM (OpenNebula)
IaaS Interface for a Site

Grid User
with a VM
environment

Grid middleware

LRMS (e.g. LSF, PBS...)

Virtual WorkerNode

Other (web, mail...)

Raw machines

Physical Infrastructure

Pilot job / ssh

IaaS Interface

Industry Business Services

VIM (OpenNebula)

Grid User

OpenNebula in the Grid Arena

- A team at Clemson University and CERN has used OpenNebula to deploy ~ 10,000 VMs on 500 physical hosts running Xen.
- These VMs are used to run batch jobs (submitted via WLG-CE and managed by LSF)
- Used XMLRPC API to add autonomic functionality, and to integrate with CERN's Quattor (http://www.quattor.org/)
- Created, and contributed, drivers for using LVM-based disk images.
OpenNebula in the Grid Arena

• The D-Grid Resource Center Ruhr (DGRZR) has used OpenNebula to manage 247 Blades with a total of 1,972 cores.

• Entire D-Grid software stack is run on VMs. Worker nodes currently managed with OpenNebula, frontend nodes to follow shortly.

• The BiG Grid Virtual Machine Working Group (in NIKHEF) did an evaluation of several cloud solutions, and recommended using OpenNebula for managing worker node VMs in BiG Grid.
OpenNebula in the Grid Arena

• SARA is the Dutch National HighPerformance Computing and e-Science Support Center, and the Dutch supernode in the international Science Grid.

• They offer an HPC cloud that uses OpenNebula. Starting with 128 cores across 16 physical machines running KVM.

• Users use a management console developed at SARA to request a new VM (several templates are provided for them)
The StratusLab Project

Vision
• Grid and cloud embody complementary computing models that will coexist and cooperate in existing and future e-infrastructures

Aim
• To produce the StratusLab Toolkit open source cloud distribution, bringing cloud/virtualization innovation to existing Grid infrastructures.
• Service Centred Project driven to support production infrastructures
The StratusLab Project

Y0: Grid and community services running directly on RC hardware.

Y1: Grid services running on private clouds. Scaling out to commercial providers possible.

Y2: Cloud API provided. Virtualized machines available to end users.

Y3: Community services run on standard resources via StratusLab cloud API.

Y4: Additional community services and novel services are built on top of cloud API.
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The Anatomy of an OpenNebula Cloud

Network

OpenNebula

Image Repositories (Storage)

Physical Infrastructure

StratusLab Cloud API

Grid Service

VM

VM

VM

Grid Service

VM

VM

VM
Overview of Main Components

- **FRONT-END**
  - ONED
  - Drivers
  - Images
  - Repository of VM images
  - *Multiple backends (LVM, iSCSI...)*
  - *Executes the OpenNebula Services*
  - *Usually acts as a classical cluster front-end*  

- **Cluster Node 1**
  - Hypervisor
  - SSH
  - Images

- **Cluster Node 2**
  - Hypervisor
  - SSH
  - Images

- Modular components to interact with the cluster services
- *Types: storage, monitoring, virtualization and network*

- Provides physical resources to VMs
- *Must have a hypervisor installed*
Using Virtual Networks and Hosts

- Define VM NICs attached to a given virtual network. The VM will get a NIC with a free MAC in the network.

```bash
#A VM with two interfaces each one in a different vlan
NIC=[NETWORK="Blue LAN"]
NIC=[NETWORK="Red LAN"]

#Ask for a specific IP/MAC of the Red vlan
NIC=[NETWORK="Red LAN", IP=192.168.0.3]
```

- Prepare the VM to use the IP. Sample scripts to set the IP based on the MAC are provided.

![IP-MAC address correspondence](oned.conf)
Defining a Virtual Machine

- A capacity in terms memory and CPU
- A set of NICs attached to one or more virtual networks
- A set of disk images, to be “transferred” to/from the execution host.
- A state file (optional) or recovery file, with the memory image of a running VM plus some hypervisor specific information.

- Virtual Machines are defined in a VM template
- Each VM has an unique ID in OpenNebula the VM_ID
Context for Virtual Machines

- Custom data to be passed to the VM at boot time
- Boot Process
  - Mount an iso image with context data
  - Use context.sh to look for variables
  - Access any file to setup VM services (e.g. ssh keys...)

![Diagram of Virtual Machine and ISO Image]
Hybrid Cloud Computing

- VMs can be local or remote
- VM connectivity has to be configured, usually VPNs

- External Clouds are like any other host
- Placement constraints

OpenNebula

Cloud Provider

Local Physical Infrastructure

Virtual Network
Using the EC2 Cloud with OpenNebula

- Several accounts or zones can be configured
- The capacity allocated in EC2 can be limited
- VMs must be prepared to be instantiated locally or in the EC2
- The template must provide a description for both instantiation methods.
- The EC2 counterpart of your VM (AMI_ID) must be available for the driver account

```
EC2 = [
    AMI = "ami_id for this VM",
    KEYPAIR = "the keypair to use the instance",
    AUTHORIZED_PORTS = "ports to access the instance",
    INSTANCETYPE = "m1.small...",
    ELASTICIP = "the elastic ip for this instance",
    CLOUD = "EC2 cloud to use"
]
```
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Resource Provisioning Models

How are the resources provisioned?

Where are the resources provisioned from?

- Remote
- Local

- Physical
- Virtual

- GRID
- YOUR SITE
- PRIVATE CLOUD
- CLOUD
THANK YOU FOR YOUR ATTENTION

QUESTIONS?