Cloud Computing

Part 4: Research

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Summary

1. Active Cloud Computing research fronts
2. Elastic Scalability, PaaS and SOA
3. Monitoring and Control
4. Private and Hybrid Cloud
5. Multitenant data and app architecture

Research fronts - Open challenges

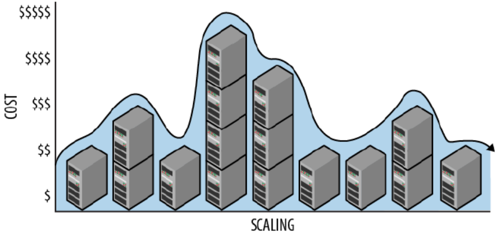
- PaaS, SOA, Elastic Scalability ⇒ role of PaaS, SOA applied to PaaS
- Monitoring and Control SPI stack ⇒ get indicators, analyze and forecast, act
- Private and Hybrid Cloud ⇒ hw consolidation, bursting, federation
- Multitenancy data and apps ⇒ cloud-enabled application arch, economy of scale

*Approach: set objectives ⇒ get results !!
Agile method and measurable progress to solve enterprises use cases

- theory = comprehension
  - review literature: books, articles, documentation, tutorials
  - survey of tech and and comparison on paper of spec & features
- practice = application + experience
  - technical knowledge & solution convenience
  - use open-source technologies and tools to build solutions (PoC)

Elastic Scalability and the PaaS layer - Business concerns

- Rapid elasticity, or Elastic Scalability, allows the cloud provider to dynamically adapt service capacity according to the use profile determined by customers
- an ISV supplies a service at the SaaS level, normally via a web application. As part of that, it needs the infrastructure to support the service that is selling
- the provider wants to avoid over-provisioning of resources so to take advantage of the infrastructure in the most cost-effective way (dynamic compromise)
- The PaaS can help



Elastic Scalability and the PaaS layer - PaaS role

- PaaS = capability to develop, deploy, and orchestrate onto the cloud
- analogy between PaaS and traditional OS ⇒ "cloud OS"

- the PaaS layer and its role is not yet completely understood
  - technology concerns
  - deployment framework model
  - elastic scalability
  - service orchestration

- PaaS can be very powerful
  - provisioning responsibilities can be better apportioned
  - SaaS provider can escape from lock-in relations with the particular infrastructure used
  - elastic scalability of services can be implemented openly

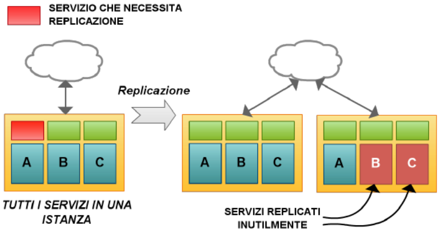
Service-orientation and SOA - Overview

- Service-orientation = architectural paradigm/approach that adopts the concept of services as the main building blocks of application and system development
  ⇒ core reference model for cloud computing systems
- SOA = Service Oriented Architecture
- Its main principles are:
  - standardized contracts
  - loose coupling
  - abstraction
  - reusability
  - autonomy
  - statelessness
  - discoverability
  - composability

Granularity matters! ⇒ SOA has the right granularity for business processes distributed over a landscape of existing and new heterogeneous systems that are under the control of different owners

Service-orientation and SOA - Cacco's remark

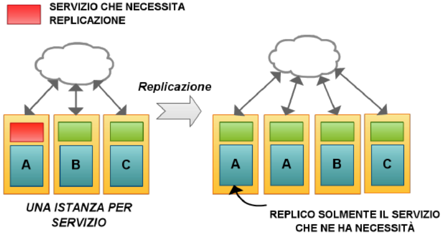
Replicate only the components that need it!



All services within a unique instance

- to scale a service I have to replicate the instance that provides all services

$\Rightarrow$ monolithic = waste



One service within each instance

- to scale a service I can replicate the instance that provides that service

Service-orientation and SOA - Jolie

- Jolie is a service-oriented language born in Bologna (SOC research scope)
- built on a strong mathematical foundation (SOCK)
- based on Java, provides an intuitive and easy to use C-like syntax to deal with the implementation of architectures made of services
- service as a first-class citizen

Example: minimal multi-threading server (service) with Jolie:

SOURCE

```
/* server.ol */
execution { concurrent }
interface TwiceInterface {
    RequestResponse:  twice( int )( int )
}
inputPort TwiceServiceIn {
    Location:  "socket://localhost:8000"
    Protocol:  sodep
    Interfaces:  TwiceInterface
}
main {
    twice( number )( result ) {
        result = number * 2
    }
}
```

EXECUTION

```
$ jolie server.ol
```

SOURCE

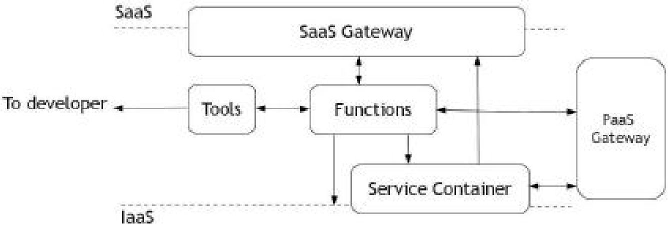
```
/* client.ol */
include "console.iol"
interface TwiceInterface {
    RequestResponse:  twice( int )( int )
}
outputPort TwiceServiceOut {
    Location:  "socket://localhost:8000"
    Protocol:  sodep
    Interfaces:  TwiceInterface
}
main {
    twice@TwiceServiceOut( 5 )( response );
    println@Console( response )()
}
```

EXECUTION

```
$ jolie client.ol
10
$
```

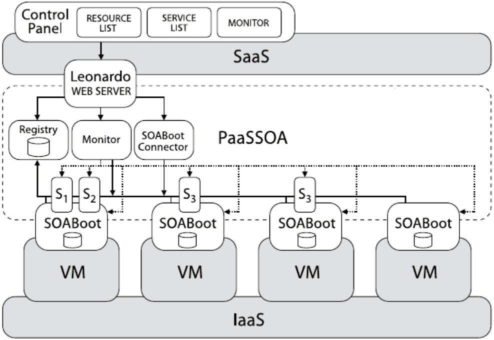
PaaSSOA - Inception

- Jolie is the enabling technology of PaaSSOA ⇒ deploying SOA principles could greatly facilitate build an open cloud platform
- the primary purpose of the PaaSSOA project is to explore the role of a SOA PaaS layer in the Cloud SPI stack (it began in Bologna)
- open PaaS framework ⇒ understanding interaction protocols between the SPI stack layers
- Vision ⇒ prototype framework to control the deployment and the execution of Jolie services, where the latter are the building blocks of cloud applications



Prior PaaSSOA - Architecture & features

- PaaSSOA resource model provides base abstractions for Jolie services at two levels
  - virtualization layer = capabilities for deploying and executing VM images
  - SOABoot services = container service of PaaSSOA, one for each VM
- PaaSSOA can manage two types of resources
  - VM hosts = virtualized environments controlled by SOABoots
  - Jolie services = services deployed and executed within SOABoots



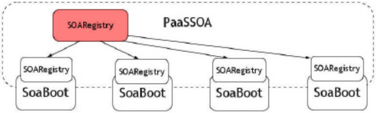
Prior PaaSSOA - Web Dashboard - Registry List

PaaSSOA control Panel

See services
See registries
See runtime monitor

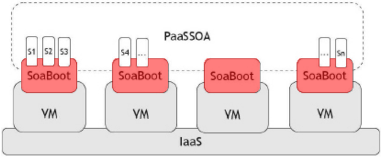
Domain	Protocol	Location	Actions
passoa/soaboot/1.1.1.1/	sodep	socket://localhost:10000	Get Services

- SOARegistry ⇒ keep track of resources
- federated architecture
- 2nd level registry:
  - store Jolie services descriptions
  - promote res names to the upper level
- 1st level registry:
  - centralize requests
  - forward request to 2nd level registry, which has the resource

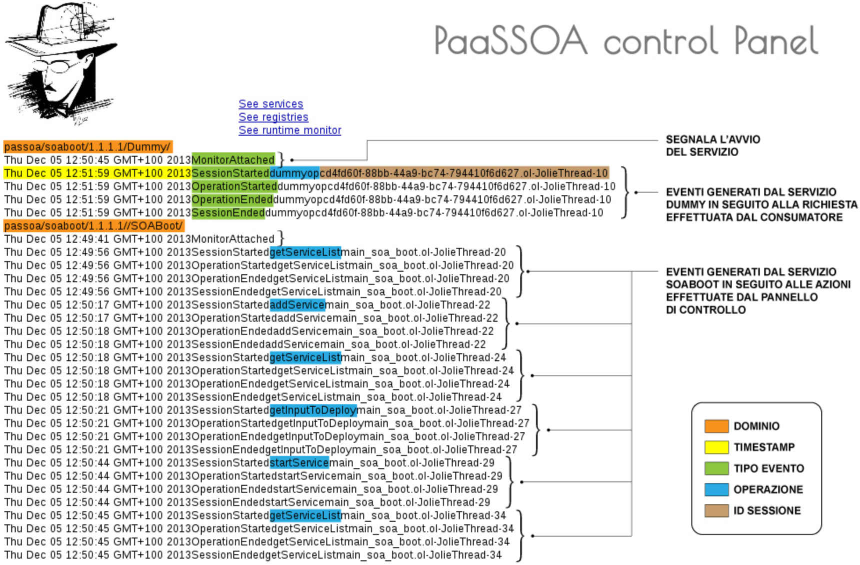


Prior PaaSSOA - Web Dashboard - Service List

- SOABoot = Jolie services container
- list of services contained by each SOABoot
- actions on services:
  - deploy, start, stop, undeploy, details
  - make available a subset of "ports"



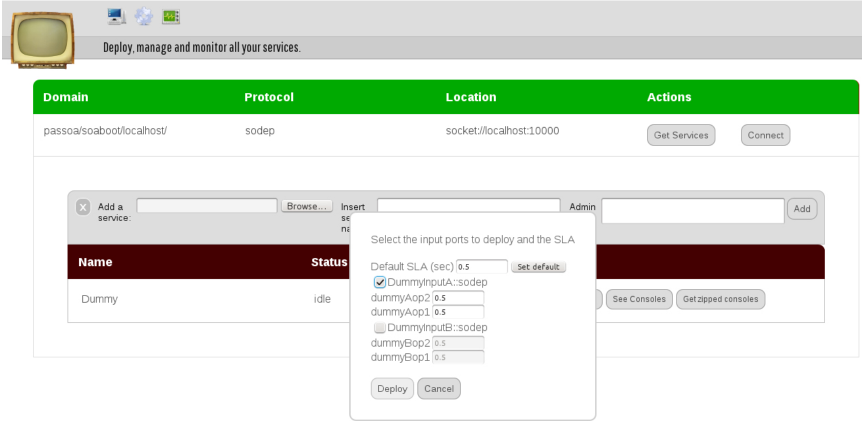
Prior PaaSSOA - Web Dashboard - Service Monitor



Prior PaaSSOA - Lack of elastic scalability

- the idea of PaaSSOA seems promising but... it lacked the elastic scalability characteristic to demonstrate its usefulness as a cloud PaaS layer
- an entire master thesis dedicated on the theme of elastic scalability and runtime enforcement of Service Level Agreements (by Zuccato A.)
- challenges:
  - SLA definition
  - SLA enforcement
  - events collection
  - events interpretation
  - actions to perform
  - test
  - paradigm shift
  - new technologies

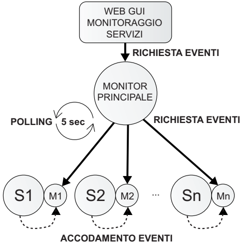
Zuccato's PaaSSOA - Enaling SLA input



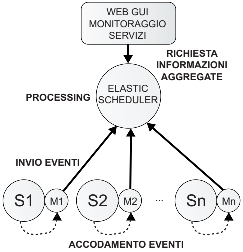
- SLA = limit on service response time
- SLA input enabled on the web dashboard
- service start requires SLA to be specified

Zuccato's PaaSSOA - Changed monitoring modality

- before ⇒ pull mode:
  - events gathered and queued by Jolie interpreter
  - events request performed by main monitor
  - reply by 2nd level monitor empties internal queues
  - events gathered through polling ⇒ disadvantageous



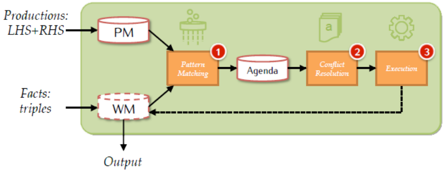
- after ⇒ push mode:
  - event generation remains unchanged
  - Elastic Scheduler receives events
  - 2nd level mon send events automatically upon queuing
  - enable "real-time" events processing



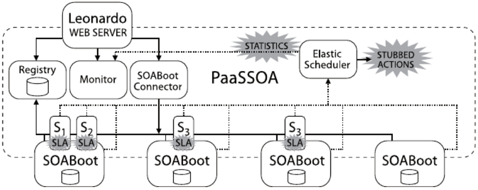
Changes impact also the SOABoot service

Zuccato's PaaSSOA - Drools inference engine integration

- Drools working:
  - Production Memory ⇒ Rules
  - Working Memory ⇒ Facts
  - Facts assertion in WM ⇒ pattern matching with LHS
  - Agenda ⇒ schedule rules execution
  - side effect produced by RHS execution ⇒ forward chaining



- Elastic scheduler integration:
  - ES core service in PaaSSOA
  - Java Drools embedded in a Jolie wrapper (Elastic Scheduler)
  - definition of declarative rules
  - stats and control on services
  - input ⇒ services events
  - output ⇒ stubbed actions



Zuccato's PaaSSOA - Declarative logic implementation

- Events aggregation:
  - Events and Facts = Java objects
  - objects type: Service, Session, Operation
  - rules to match the start event correlated with the received end event
  - based on timestamp attribute
  - calculate and store statistics

```
rule "updateOperation"
salience 1
when
    $e1: PaaSSOAMonitorEvent( $dom: domain, $sid: SessionId,
                              $opname: OperationName,
                              type matches "OperationStarted",
                              $ts: timestamp )
    $e2: PaaSSOAMonitorEvent( domain == $dom,
                              SessionId == $sid,
                              OperationName == $opname,
                              type matches "OperationEnded",
                              timestamp >= $ts )
    $s: Service( name == $dom, $maddr: email_address,
                 $isb: is_soaboot )
    $op: Operation( name == $opname, service == $dom,
                    $sla: response_time_threshold,
                    $rst: stats_reset )
    $js: DroolsJavaService()
then
    long duration = $e2.getTimestamp() - $ts;
```

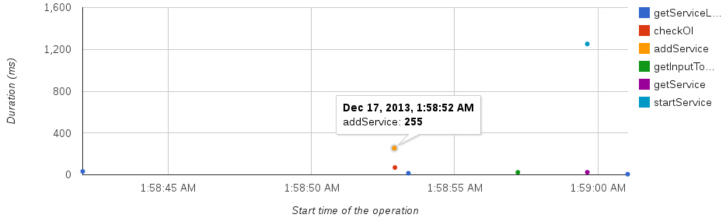
- Enablement of elastic capacity:
  - Drools Fusion ⇒ temporal relationship between events (Allen operators)
  - rule replicates service when the end event doesn't arrive within the SLA threshold
  - replication is only stubbed (test toolkit)

```
rule "breakSLA"
salience 1
when
    $e1: PaaSSOAMonitorEvent( $dom: domain, $sid: SessionId,
                              $opname: OperationName,
                              type matches "OperationStarted" )
    not PaaSSOAMonitorEvent( domain == $dom,
                              SessionId == $sid,
                              OperationName == $opname,
                              type matches "OperationEnded",
                              this after [0ms,500ms] $e1 )
    $op: Operation( name == $opname, service == $dom,
                    $sla: response_time_threshold )
    not ActionEvent( domain == $dom )
    $js: DroolsJavaService()
then
    $js.actionOnPaaSSOA( $dom, "AddInstance" );
```

Zuccato's PaaSSOA - Service Monitor redesign

MONITOR: see monitor details of your services.

Domain	Statistics	Actions
passoa/soaboot/localhost/	Service type: SOABoot service Started on: Tue Dec 17 01:58:26 CET 2013 Memory used by JVM on start: 17.1 MB Total number of sessions executed: 8 Total number of requests executed: 8 Total duration of sessions: 1.688 sec Total duration of operations: 1.68 sec Total memory used by sessions: 8.52 MB Total memory used by operations: 8.16 MB SESSION: getServiceList | Sessions: 3 Duration: (avg 19, max 35, min 8) ms | Memory: (avg 1.1, max 1.45, min 0.77) MB OPERATION: getServiceList | Requests: 3 Duration: (avg 18, max 33, min 6) ms | Memory: (avg 1.1, max 1.45, min 0.77) MB ...	Hide Services



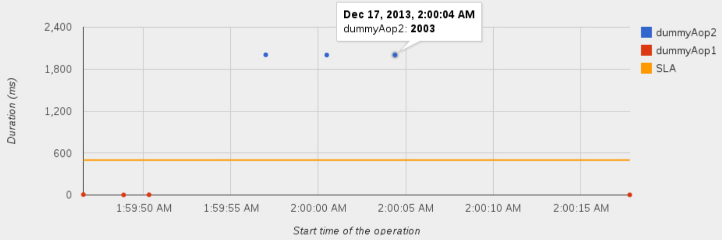
Zuccato's PaaSSOA - Service Monitor redesign

passoa/soaboot/localhost
/Dummy

Service Type: Deployed service
Admin email: zukzuc@gmail.com
Started on: Tue Dec 17 01:59:01 CET 2013
Memory used by JVM on start: 1.21 MB
Started on: Tue Dec 17 01:59:01 CET 2013
Memory used by JVM on start: 1.21 MB
Total number of sessions executed: 7
Total number of requests executed: 7
Total duration of sessions: 6.029 sec
Total duration of operations: 6.022 sec
Total memory used by sessions: 1.51 MB
Total memory used by operations: 1.41 MB
Total number of SLA violations: 3
Total duration of SLA violations: 4.51 sec

SESSION: dummyAop2 | Sessions: 3
Duration: (avg 2004, max 2007, min 2002) ms | Memory: (avg 0.36, max 0.37, min 0.33) MB
OPERATION: dummyAop2 | Requests: 3 | SLA violations: 3
Duration: (avg 2003, max 2005, min 2002) ms | Memory: (avg 0.36, max 0.37, min 0.33) MB | SLA: (limit 0.5, over 4.51) sec

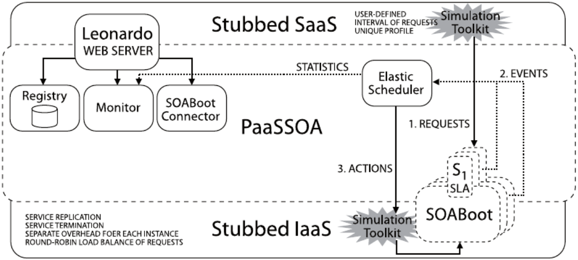
...



Zuccato's PaaSSOA - ES Test Toolkit

Ad-hoc toolkit implemented to test the ES to overcome current limitations

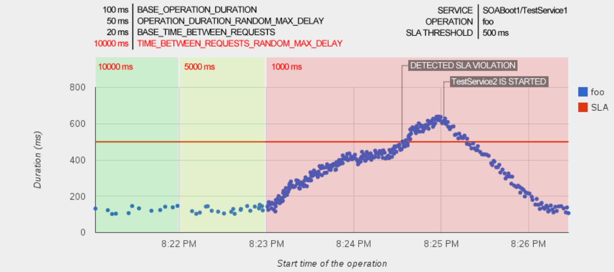
- service simulation
  ⇒ event generation
- use profile
  ⇒ sequential ops
- 1 iter = 1 simulated op
- 4 parameters
  - 2 for op duration
  - 2 for time between ops
- enable overload
- enable effect of actions
  - service replication
  - service termination
- enable load-balancing



Zuccato's PaaSSOA - ES Test (upward scalability)

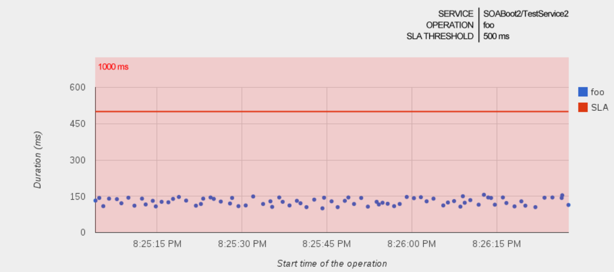
TestService1

- increased frequency ⇒ overload
- detected violation ⇒ replication
- new instance start delay



TestService2 (replicated instance)

- new SOABoot
- new service instance
- load-balancer comes into play



Zuccato's PaaSSOA - ES Test (downward scalability)

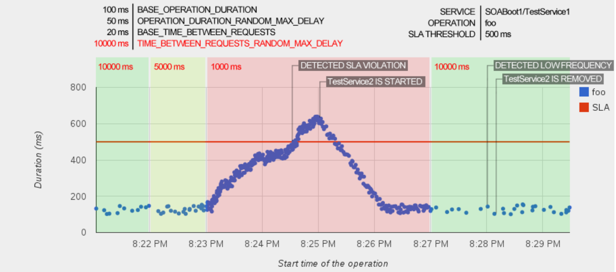
more difficult!

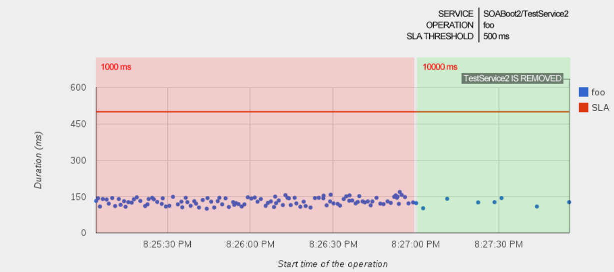
TestService1

- diminished frequency
  ⇒ terminate instances
- optimization
  ⇒ reduce cost!
- instance termination delay

TestService2 (replicated instance)

- instance termination
- SOABoot termination
- effect of rebalancing
- can lead to trashing (now one less cannot be enough)





PaaSSOA post Zuccato - Hurdles and new challenges

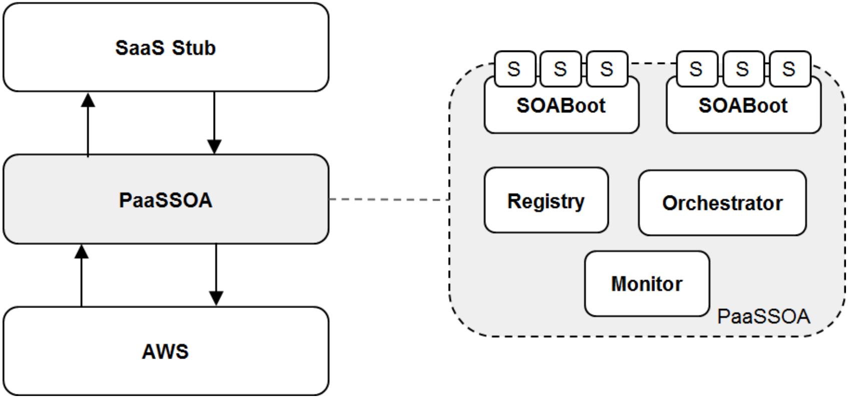
- hurdles in PaaSSOA:
  - no real services to test
  - no real IaaS (tested in a local environment)
  - no implemented PaaSSOA replication and migration feats to manage services

  ⇒ thus the Elastic Scalability test was a mere simulation !!
- another entire master thesis dedicated on the theme of elastic scalability (by Baraldo V.)

⇒ this time the research involves the integration of PaaSSOA with a real IaaS

- with a partial redesign, PaaSSOA can reside on a real state-of-the-art IaaS such AWS
- abstraction layer that helps to decouple logic service from real service instances

Baraldo's PaaSSOA - High-level architecture

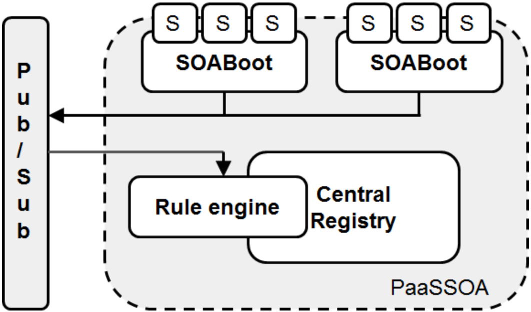


Baraldo's PaaSSOA - Key components

- A SOABoot is a PaaS representation of a VM provided by the IaaS
  - Every SOABoot can contain multiple services
- The registry keeps trace of deployed services and SOABoots mapping
- The monitor collects and present data received from SOABoots
- The orchestrator helps to manage services (automatically and manually)

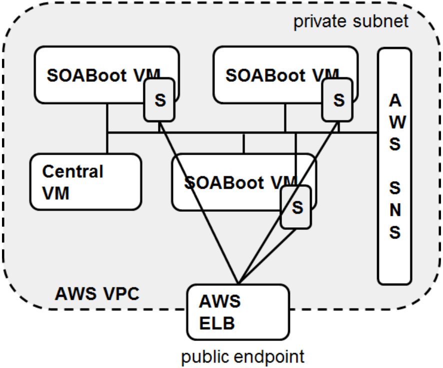
Baraldo's PaaSSOA - Publish/subscribe

- We need to obtain loose coupling
- A publish/subcribe broker is a possible solution
- It helps to obtain scalability and elasticity



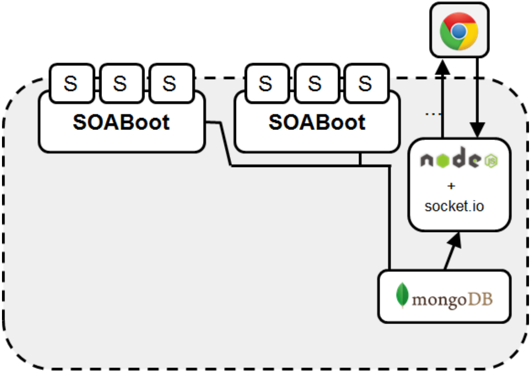
Baraldo's PaaSSOA - AWS Architecture

- Environment boundaries
  - VPC
  - Private subnets (scalable resource group)
- Load balancing
  - AWS ELB (2-levels dispaching)



Baraldo's PaaSSOA - Dashboard and monitor

- A new dashboard that becomes a simple orchestrator
- A scalable logging system where every entity can push log events
- Information could be available as soon as possible
  - Full-push architecture



Baraldo's PaaSSOA - Current status and Future Prospects

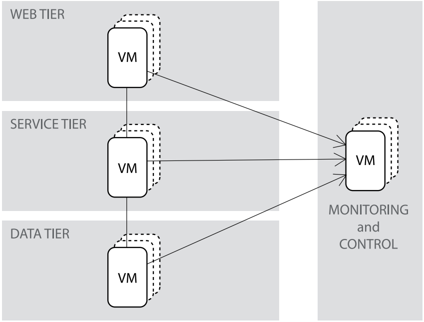
- This is a prototype: it shows the potential of the SOA principles injected in a real cloud stack
- It needs reengineering based on the experimental results
  - What are the key system components?
  - What components should be decomposed?
- Outlook:
  - Improve the elasticity mechanisms
  - Improve SOA components' implementation
  - Explore other technology stacks

Monitoring and Control - Overview

- Cloud application monitoring problem ⇒ 3 dimensions:
  - physical (hosts)
  - logical (services)
  - time
- Need to consider two sides:
  - events collection side (input)
  - actions execution side (output)
- Then we need to put logic in-between ⇒ how
  - collection side ⇒ event processors = collect, parse, filter, transform, transfer events
  - actions execution side ⇒ configuration tools = streamline the task of configuring & maintaining servers
  - in-between current state or knowledge ⇒ production rule system = execute productions in order to achieve some goal for the system

Monitoring and Control - Architecture

- VMs on each tier are equipped differently:
  - web tier: web servers, application servers (front-ends)
  - service tier: interpreters and compilers, services (back-ends)
  - data tier: DBMS relational, NoSQL, storage volumes (back-ends)
- monitoring and control tier is the "brain"
- the first step is to equip each VM with an active agent
  - gathering of system and service performance
  - fixed footprint ⇒ round robin DB
  - agents send statistics and events to monitoring nodes (async)



Monitoring and Control - Current status

- gathering basic and general system performance statistics with Collectd
- graph visualization with Graphite

Monitoring and Control - Next step

- test a minimal application simulating the presence of users
  - differentiate VMs, equip VMs with the real tools
  - specialize configuration of plugin to match tier
  - automate the provisioning of new VMs

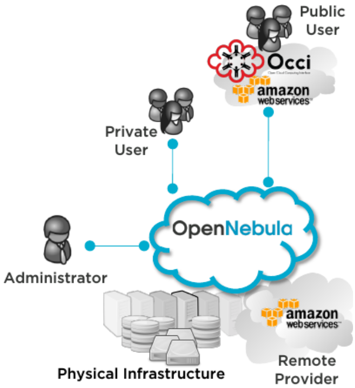
Private and Hybrid cloud - Overview

- investigate the use of open-source cloud managers to build private and hybrid cloud
- challenges of IaaS clouds:
  - How do I provision a new VM?
    Image Management & Context
  - Where do I store the disks?
    Storage
  - How do I set up networking for a multitier service?
    Network & VLANs
  - Where do I put my web server VM?
    Monitoring & Scheduling
  - How do I manage any hypervisor?
    Virtualization
  - Who has access to the Cloud's resources?
    User & Role Management
  - How do I manage my distributed infrastructure
    Interfaces & APIs?

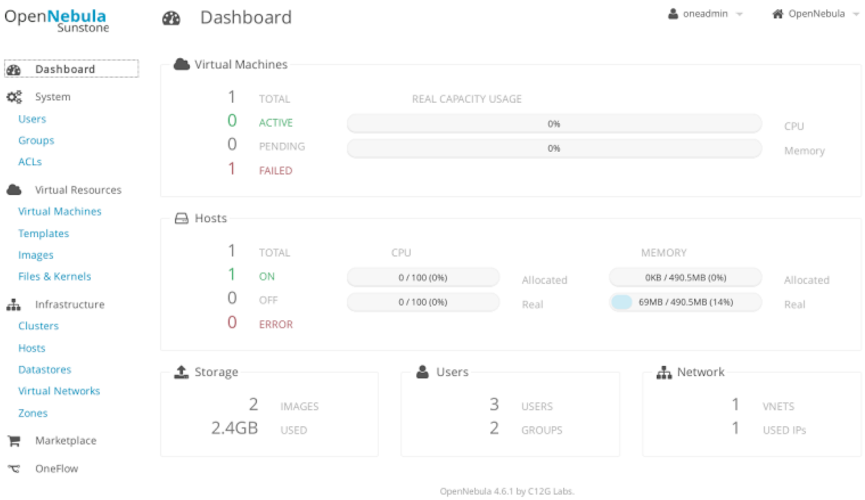
Private and Hybrid cloud - OpenNebula

OpenNebula = uniform management layer that orchestrate multiple technologies

- Data Center Virtualization Manager
  - Open-source Apache license
  - Interoperable, based on standards
  - Adaptable
- Private Clouds ⇒ virtualize your on-premise infrastructure
- Pubic Clouds ⇒ expose standard cloud interfaces
- Hybrid Clouds ⇒ extend your private cloud with resources from a remote cloud provider
- Ready for end-users
  - Advanced user management
  - CLI and Web Interface

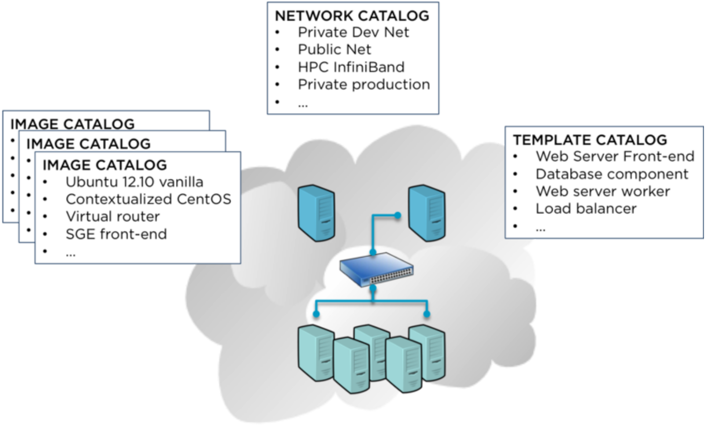


OpenNebula - Quick tour of main features



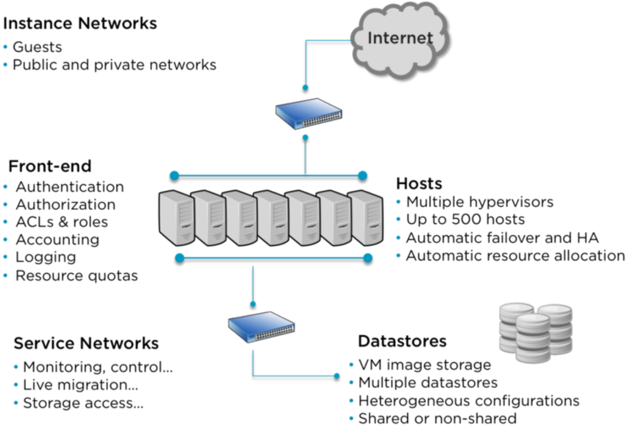
OpenNebula - What does it offer to Cloud Consumers?

- Image Catalogs
- Network Catalogs
- VM Template Catalog
- Virtual Resource Control and Monitoring
- Multi-tier Cloud Applicaion Control and Monitoring



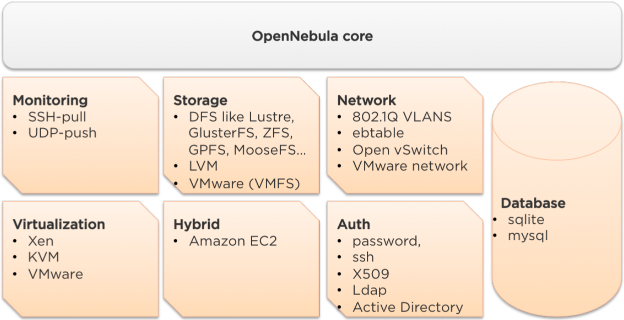
OpenNebula - What does it offer to Cloud Operators?

- Users and Groups
- Virtualization
- Hosts
- Monitoring
- Accounting
- Networking
- Storage
- Security
- High Availability
- Clusters
- Multiple Zones
- VDCs
- Cloud Bursting
- App market



OpenNebula - What does it offer to Cloud Builders?

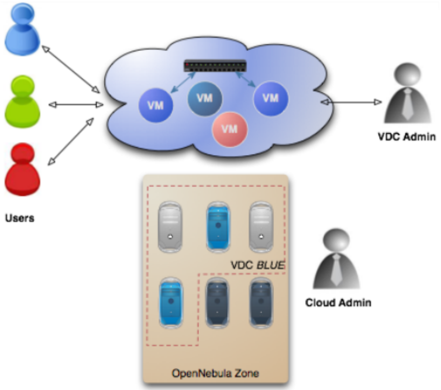
- User Management
- Virtualization
- Monitoring
- Networking
- Storage
- Databases
- Cloud Bursting



OpenNebula - Current status and Use Cases

Virtual private Cloud Computing

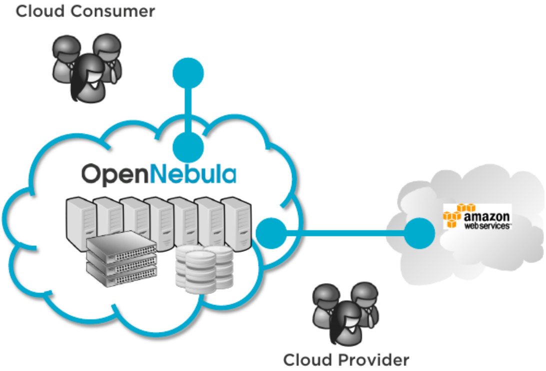
- Typical scenario in large organizations and cloud providers
- On-demand provision of fully-configurable and isolated Virtual Data Center (VCD) with full control and capacity to administer its users and resources



OpenNebula - Current status and Use Cases

Hybrid Cloud Computing

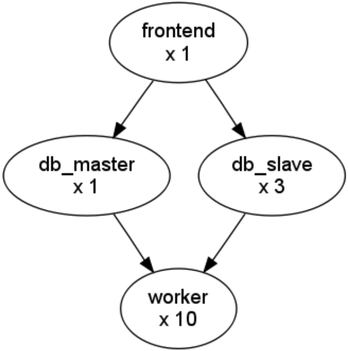
- Extension of the local private infrastructure with resources from remote clouds
- Cloud bursting to meet peak or fluctuating demands



OpenNebula - Current status and Use Cases

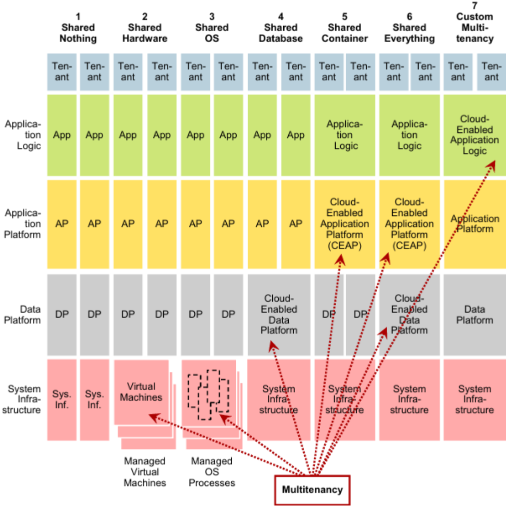
Managing Multi-tier Applications

- define, execute and manage multi-tiered applications
- interconnected Virtual Machines (roles, cardinality)
- each group of Virtual Machines is deployed and managed as a single entity



Multitenant data and app - Overview

Investigate how to design and to build multitenant data and apps



Focus on:

- 3 - Shared OS
  ⇒ with Docker
- 4 - Shared Database
  ⇒ separate schema for each tenant
  ⇒ with PostgreSQL

Multitenant data and app - Current status

A solution for multitenancy data $\Rightarrow$ migrate the schema and the data of a tenant across VMs on data tier

- identical schema for each tenant
- logical separation
  $\Rightarrow$ more physical integration = more difficult to ensure logical isolation
- performance management
  $\Rightarrow$ common startegy is to deploy resource-hungry tenants alongside tenants with low resource demands

Building a very minimal application that use the underlying data tier
$\Rightarrow$ moving schemas around

Multitenant data and app - Next steps

Add pieces to the stack ⇒ complement the PoC with the monitoring solution (collectd + graphite).

We will need also the logic !!

- The ultimate goal is to achieve a prototype cloud platform:
  - continuously monitoring
  - reorganizing (moving tenants around)
  - horizontally scaling service instances

  ⇒ it's all done transparently

References

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