TEST REPORT

Eco4Cloud Proof of Concept Test for

Introduction

Eco4Cloud is a spin-off from the Institute for High-Performance Computing and Networking of Italy's National Research Council (CNR) and has researched/developed/engineered an innovative and effective solution to optimize the consolidation of virtual machines (VM) in highly-virtualized data centers yielding significant reductions of the relevant **energy bills** and related **Carbon emissions**, as well as additional benefits in terms of DC **SLA assurance**, **capacity planning**, **orchestration optimization**, **risk monitoring/mitigation**.

In fact Eco4Cloud's technology is based on an innovative bio-inspired probabilistic algorithm which consolidates the maximum number of virtual machines on the minimum number of physical servers in a data center, enabling the switch-off/hibernation of those freed-up, making them dynamically available as additional capacity for incremental workloads.

The resulting CapEx and OpEx reductions are tangible and this document reports the outcomes of a Proof of Concept test carried out at one of ACME's data centers, in Rome, between Aug. 8th and Aug. 27th 2013.

Executive Summary

The results on the test performed on **22 servers** show that Eco4Cloud yields a **reduction of power consumption of 50%**, by consolidating the workload on only one half of the originally active physical servers.

The following is our estimation of the overall yearly cost savings achievable by ACME with Eco4Cloud on the examined 22 servers:

- it is possible to save 4 kW of consumed power
- this equates to about 8 kW, assuming that PUE = 2.0 and considering the additional savings that can be achieved on the Power & Cooling components
- assuming an average energy cost of 0.14 €/kWh, this would be the annual cost saving:

Annual cost saving = 8 kW x 24 h x 365 days x 0,14 €/kWh = 9.811,2 €/year

This estimate only refers to the test perimeter of the above mentioned 22 servers alone, and is meant to serve as a basis to extrapolate the broader potential and related economics of adopting Eco4Cloud's software across the entire DC operation of ACME.

Test Description

The test has been performed on 22 servers running VMWare's vSphere virtualization platform. The servers are grouped in two clusters of 18 and 8 servers respectively, with the following hardware configurations:

Cluster	# Servers	CPU core	RAM (GB)
Production Cluster SAS	6	12	64
	8	16	192
Rome Cluster SAS	7	12	64
	1	16	192

These servers hosted 105 Virtual Machines which were assigned a number of virtual cores from 1 to 8 and an amount of RAM varying from 1 GB to 32 GB. The test began with the installation of the Eco4Cloud monitoring tool which allowed to collect the traces of all the physical servers and the VMs for 21 consecutive days.

Resources utilization before using Eco4Cloud

Figure 1 reports the CPU utilization of the 22 servers during the monitored period, specifically the percentage of CPU used by each server with respect to the overall CPU capacity of the same server. The figure shows that most servers have **very low CPU utilization**, often lower than 15%. This is an indicator of **remarkable inefficiency** and **excessive energy consumption**: it is known in fact that an

active server with very low CPU utilization consumes about 70% of the power that the same server consumes when the utilization is close to 100%. The Eco4Cloud software can greatly improve efficiency by consolidating the VMs on a lower number of servers and putting some servers in a low power state.

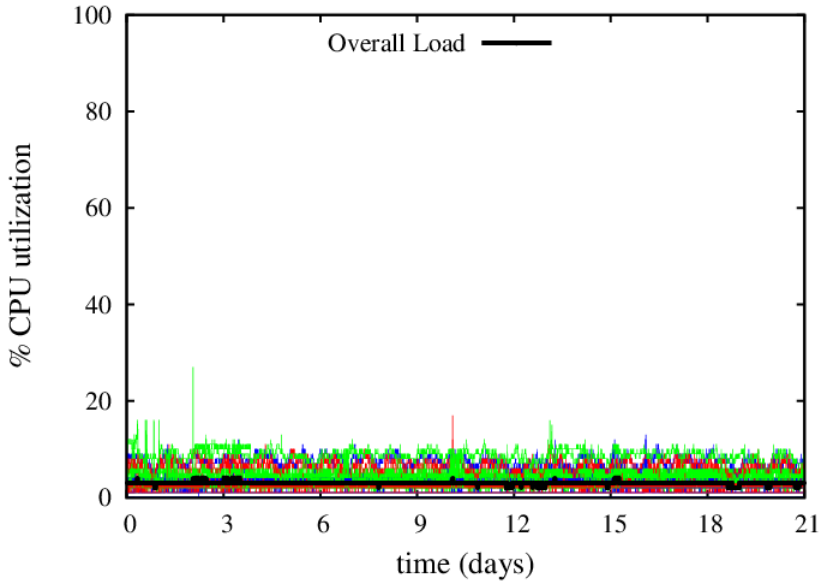

Figure 1 - CPU utilization of the 22 servers before using Eco4Cloud

Figure 2 shows the RAM allocation (again in percentage with respect to the total amount of RAM) of the 22 servers: the **RAM utilization is also quite low**, between 8% and 70%.

When Eco4Cloud migrates the VMs and consolidates the load, it must obviously respect the constraints imposed by both CPU and RAM. The use of disk I/O and bandwidth is not reported in this report as these are not significant constraints for this test.

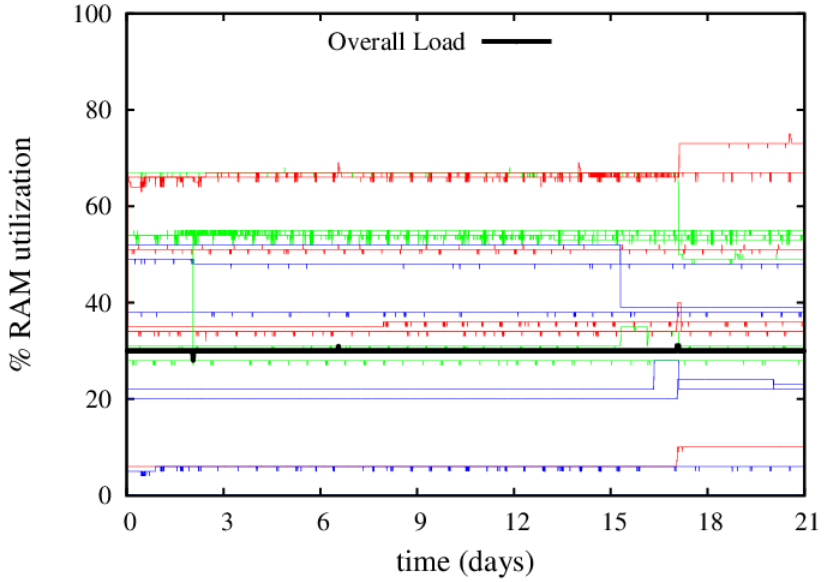

Figure 2. - RAM utilization of the 22 servers before using Eco4Cloud

Resources utilization when using Eco4Cloud

After the monitoring period, Aug. 8th-27th 2013, the Eco4Cloud software was installed. Figures 3 and 4 report, respectively, the CPU and RAM utilization of the test servers. In the specific case of ACME's data center, the main resource bottleneck is the memory, as the VMs are generally memory-bound while they make a light use of CPU. Therefore, the most remarkable benefit achieved with Eco4Cloud is in terms of significantly improved RAM utilization. Figure 4 shows in fact that the RAM utilization increases from the 8%-70% range to the 30%-70% range.

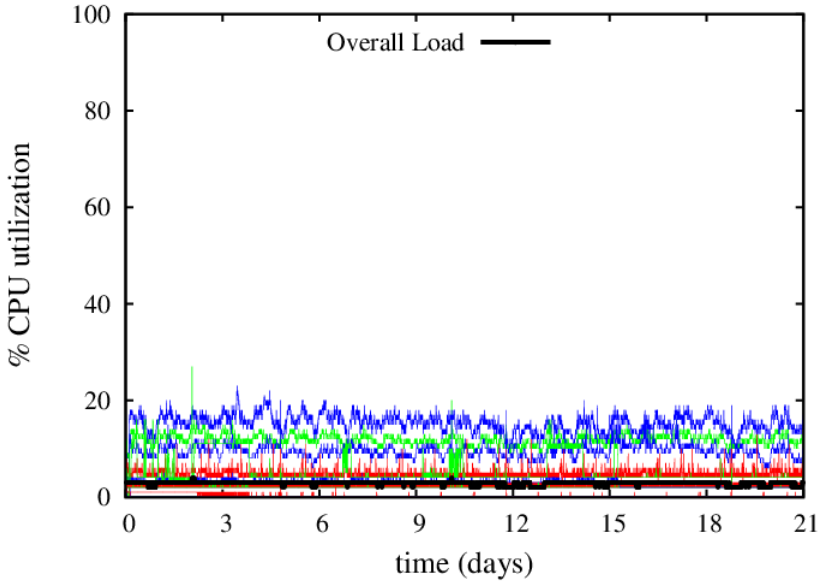

Figure 3. - CPU utilization of the 22 servers when using Eco4Cloud

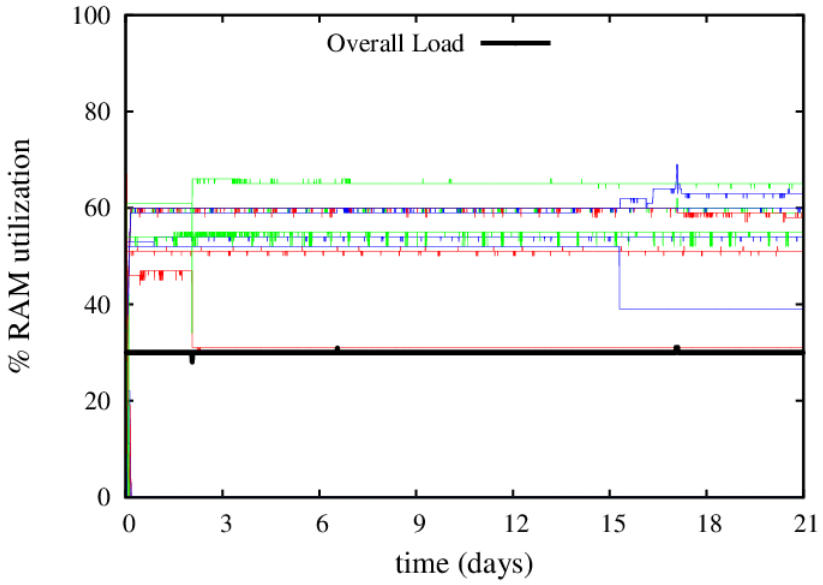

Figure 4. - RAM utilization of the 22 servers when using Eco4Cloud

Figure 5 reports the number of active servers, with and without the use of Eco4Cloud:

- before installing Eco4Cloud the load is distributed across 22 active servers
- with Eco4Cloud, VM migrations allow this number to decrease from 22 to 11

The resulting reduction in power consumption is shown in Figure 6 and **the energy saving achieved with Eco4Cloud is about 50%**. The figure shows only the power directly consumed by servers. It should be considered that additional energy saving is obtained thanks to the lower use of Power & Cooling systems, as several servers have been hibernated. For example, assuming a PUE (Power Usage Effectiveness) equal to 2.0, a comparable energy saving is achieved in the cooling and supplying components of the data center hence doubling the overall benefit.

Figure 7 reports the number of migrations per hour in the whole data center during the first day of Eco4Cloud operation. It is noticed that several low migrations[1] are performed in the first hours of operation in order to unload some servers and then put them in a low power state. No high migration is required in the examined period, meaning the Eco4Cloud consolidates the load without causing any overload event on single servers. Figure 8 reports the number of migrations for the entire 3 weeks: remarkably, no migration (whether "low" or "high") occurred at steady state, i.e. since the second day onwards.

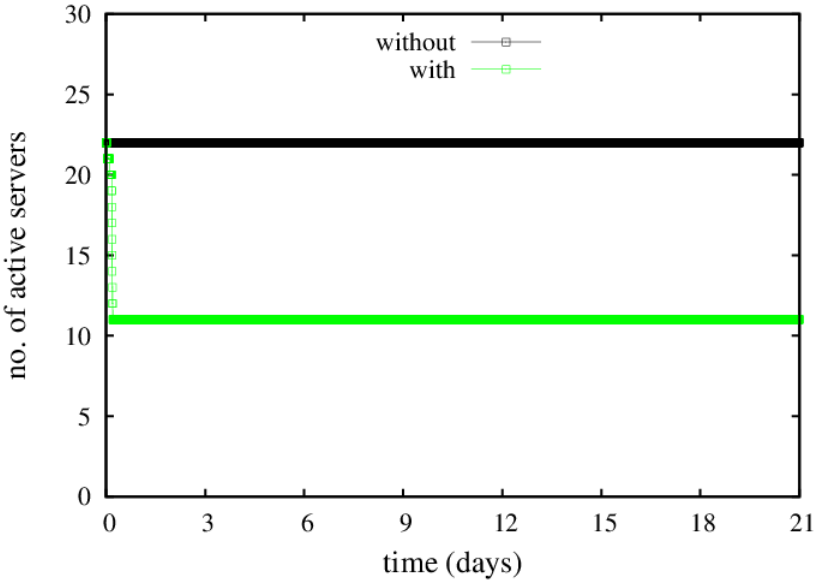

Figure 5. - Number of active servers with and without Eco4Cloud.

[1] It may be useful to recall that "high migrations" of VMs are performed when the CPU utilization or RAM allocation exceed the respective thresholds - in order to prevent QoS degradation - while "low migrations" are performed to unload under-utilized servers and possibly hibernate such servers.

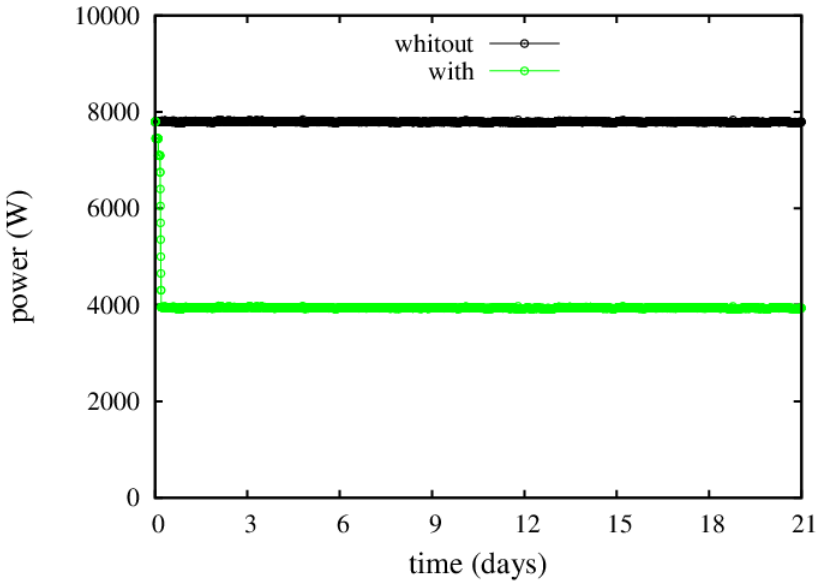

Figure 6. Consumed power with and without Eco4Cloud.

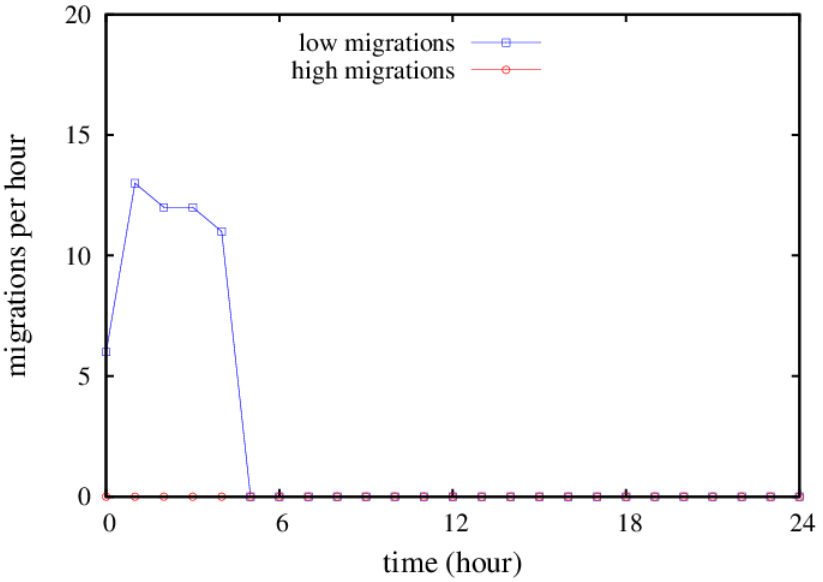

Figure 7. -Number of high and low migrations per hour during the first day of Eco4Cloud operation.

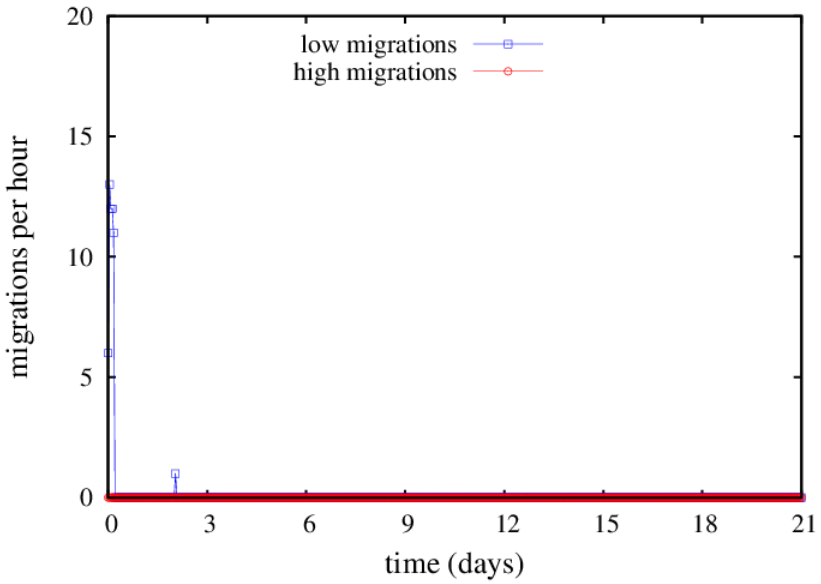

Figure 8. - Number of high and low migrations per hour for all the 21 days.