Building a Private Cloud with Eucalyptus

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Abstract

Scientists very often have specific requirements regarding the IT services to support their research and very often standardized offerings of their service providers do not fit. At KIT we aim to build a private Cloud to offer flexible infrastructure services that can easily be utilized and managed by end users according to their needs. With Eucalyptus, an open source solution exists that is fully compatible with Amazon EC2, S3 and EBS. This paper compares the performance of a cloud computing infrastructure implemented with Eucalyptus to Amazon EC2/S3/EBS and includes the lessons learned while building up a private cloud with Eucalyptus.

1. Cloud-Computing

The flexibility of cloud computing has its origin in the combination of virtualization technologies with web services. A definition is given in [6]: "Building on compute and storage virtualization, and leveraging the modern Web, Cloud Computing provides scalable, network-centric, abstracted IT infrastructure, platforms, and applications as on-demand services that are billed by consumption."

Cloud computing offers various advantages with respect to the grid paradigm [7]. Where the Grid has to deal with complexity to operate federated and autonomous data centres, Cloud infrastructures implement central control. All resources are traded as a service over the Internet based on a utility model and only the consumed resources are accounted following the pay-as-you-go principle. However, commercial infrastructure cloud providers very often use proprietary middleware systems. With the introduction of Eucalyptus, an open source solution for the construction of a private cloud is available.

Popular public cloud offerings exist from Amazon.com in form of different web services. These web services are called the Amazon Web Services (AWS) and include among others the Elastic Compute Cloud (EC2) [2], Simple Storage Service (S3) [3] and Elastic Block Storage (EBS) [1] EC2 allows to run scalable virtual server instances inside the Amazon server farms using a modified version of the Xen-Hypervisor. S3 provides a web service based storage for applications and EBS provides persistent block level storage volumes for EC2 server instances. The AWS includes many more cloud computing web services but these are not relevant for this paper.

2. Eucalyptus

Eucalyptus [11] is an open source software originally developed at the University of California, Santa Barbara, to implement cloud computing on compute clusters. Eucalyptus implements Infrastructure as a Service (IaaS) while giving the user the ability to run and control virtual machine instances via Xen [4] or KVM [12] deployed across a variety of physical resources [14].

By implementing the same interfaces and protocols, Eucalyptus is able to leverage the same tools known to work with the original Amazon EC2, S3 and EBS. The project has thus the potential to help establish an open cloud computing de facto standard. The main components of Eucalyptus are the Cloud Controller (CLC), Cluster Controller (CC) and Node Controller (NC) [13]. The implementation of the Amazon S3 interface is called Walrus. Eucalyptus also includes a block storage functionality that is similar to EBS.

The NC runs on every node in the cloud as well as a Xen-Hypervisor or KVM. The NC provides information about free resources to the CC. The CC schedules the distribution of virtual machines to the NC and collects resource capacity information. The CLC collects resource information from the CC and operates like a meta-scheduler in the cloud.

Based on Eucalyptus version 1.5.2, a private cloud has been set up at KIT. The installation comprises five dual server blades HP ProLiant BL2x220c with 2x Intel Quad-Core Xeon at 2.33 GHz and 16 GB RAM each. One server runs the CLC, CC and NC. The remaining machines are pure NCs. All servers run Debian 5.0.1 and Xen 3.2. The reason for using Xen instead of KVM is because Xen is used in lots of projects at KIT. The infrastructure is used as a testbed to gain experience with Eucalyptus and at the same time as a development platform for scientists and students to instantiate (virtual) servers without restrictions regarding operating systems, software and firewall issues.

In order to compare the performance measures of our Eucalyptus private cloud with Amazon EC2, S3 and EBS some benchmarking has been done.

2.1 Storage Performance of Eucalyptus

The storage performance of the Amazon EC2 instances (S3) and EBS has been compared with Eucalyptus 1.5.2 using a SATA hard disk with 7200 RPM (rotations per minute) on the basis of the benchmark tool `Bonnie++` [8]. This program measures the rate of sequential output (per character, per block and rewrite) and input (per character and blockwise). Figure 1 and 2 contains the results.

Amazon usees S3 to store the EC2 instaces data. Eucalyptus stores the images in S3 (Walrus) too, but the instance data is stored at the NC locally here.

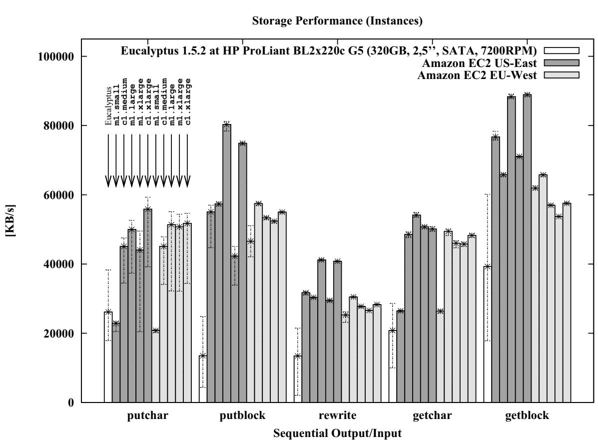

Figure 1. Amazon EC2 instances (S3) and Eucalyptus instances

For all storage performance benchmarks presented in this paper, all instance types were tested for EC2 because the instances of different instance types at Amazon are run on physical servers with different performance capabilities and storage subsystems. For Eucalyptus, just a single instance type was tested as all instance types perform on the same hardware.

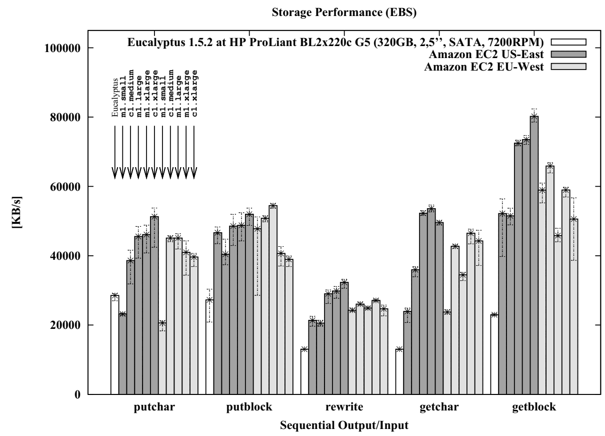

Figure 2. Amazon EBS and Eucalyptus

The read and write performance of Eucalyptus is weaker in all tests compared to Amazon EC2/S3 and EBS. If more performance is needed, we could improve the storage system of the private cloud: Possible solution are the use of faster hard disks, the use of storage subsystems with Redundant Array of Independent Disks (RAID) or implementation of a distributed file system like the Oracle Cluster File System (OCFS2) over a storage area network.

`Bonnie++` also measures the performance for random seeks and especially file creation.

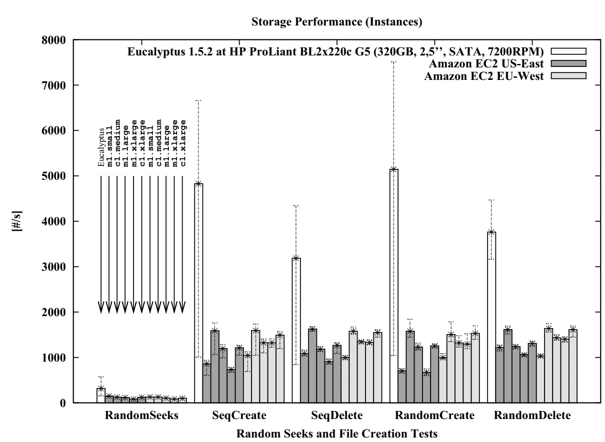

Figure 3. Random Seeks and File Creation/ Deletion for Amazon EC2 instances (S3) and Eucalyptus

In this case the Eucalyptus' performance inside the instances is superior to Amazon EC2/S3 (Figure 3) because Amazon stores the instances in S3 buckets possibly distant from the EC2 machines. In an Eucalyptus infrastructure,

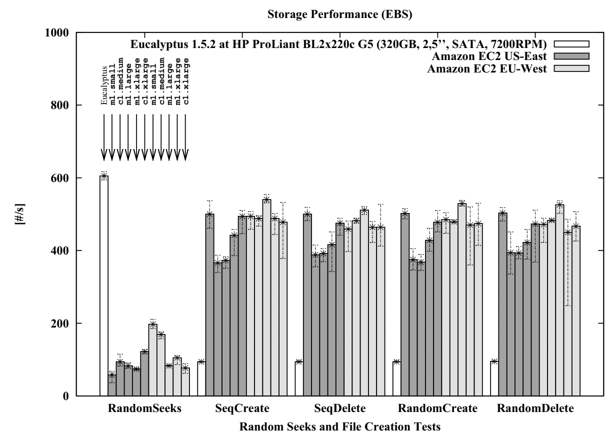

Figure 4. Random Seeks and File Creation/ Deletion for Amazon EBS and Eucalyptus

the images of the instances running are stored locally at the NC. The caching behaviour of the Linux Kernel and the fact, that the Eucalyptus instances made exclusive use of the blade servers to avoid interferences may also play a significant role. The instance images have typically a size of 1-10 GB. Depending on the physical servers load and the RAM equipped, the instances can benefit a lot from the Linux kernel caching behaviour.

The EBS performance of Eucalyptus is weak (Figure 4) because Eucalyptus stores the EBS files at the CLC centrally. Every access to EBS data has to go over the network.

The performance peak of Eucalyptus for random seeks (Figure 4) is obviously caused by the Linux kernel caching behaviour of the host operating system due to low load at the CLC.

While testing the storage performance of Eucalyptus, the instances were running exclusively on the blade servers to avoid interferences. We cannot make any assertion about the workload of the Amazon S3 system and the load of the physical hosts at Amazon during our testing.

2.2 CPU Performance

A widely accepted test to compare the CPU performance on Linux is the compilation of the Linux kernel. All available Amazon EC2 instance types (see Table 1) were tested.

Amazon points out the estimated performance of the instance types via so called Elastic Compute Units (ECU). One ECU provides the CPU capacity equivalent to a 1.0-1.2 GHz 2007 AMD Opteron or Intel Xeon processor resp. an early 2006 1.7 GHz Intel Xeon processor. For `m1.small` instances the single virtual core is equivalent to one ECU. The virtual cores of the `m1.large`

Table 1. Amazon EC2 Instance Types

Instance Type	Archi-tecture	RAM [GB]	virtual Cores	Compute Units
`m1.small`	32-bit	1.7	1	1
`c1.medium`	32-bit	1.7	2	5
`m1.large`	64-bit	7.5	2	4
`m1.xlarge`	64-bit	15	4	8
`c1.xlarge`	64-bit	7	8	20

and `m1.xlarge` instances are equivalent to two ECUs each. The virtual cores of the high-CPU instance types `c1.medium` and `c1.xlarge` are equivalent to 2.5 ECUs each.

Eucalyptus provides five instance types following the identical naming scheme of EC2. Per default, the Eucalyptus and Amazon EC2 instance types are different with respect to their CPU and memory capability. For this benchmark the Eucalyptus instance types were adapted to the size of the Amazon EC2 instance types.

The time needed to compile Linux Kernel 2.6.29.3 with 1, 2, 4 and 8 threads was measured. The results in Figure 5 show that additional RAM and CPUs are leading to a significant performance boost when using more threads.

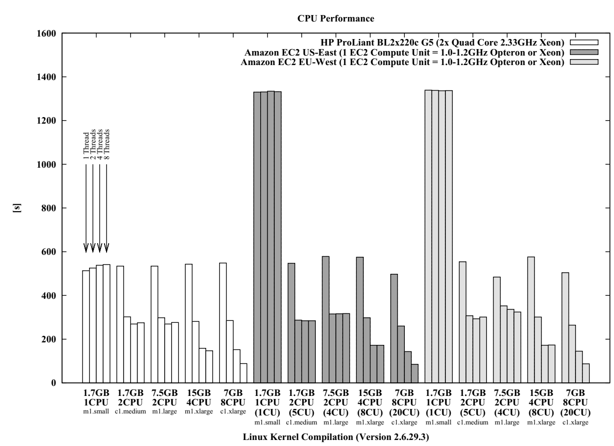

Figure 5. CPU Performance measurement via Linux Kernel compilation

The measurements indicate that our Eucalyptus infrastructure performs substantially better for `m1.small` instances as compared to Amazon EC2. This is not surprising because the CPU differs and the Eucalyptus instances were running separately on the blade servers to avoid interferences. We cannot make any assertion about the load of the physical hosts at Amazon during our CPU testing. It is likely that the Amazon servers storing `m1.small` instances have to share their resources between lots of instances thus drastically reducing the CPU performance.

Using more threads than virtual/physical CPUs/cores available is not advisable due to the thread context switching overhead.

2.3 Network Transfer Rate

The network transfer rate between Amazon EC2 and Eucalyptus was measured with `iperf`. The strong in-house network transfer rate (Figure 6) is not surprising because of the 1000 Mbit/s Ethernet bandwidth between the blade servers. But it is evident that the network transfer rate to the Eucalyptus infrastructure is much more constant in contrast to the situation observed at Amazon EC2.

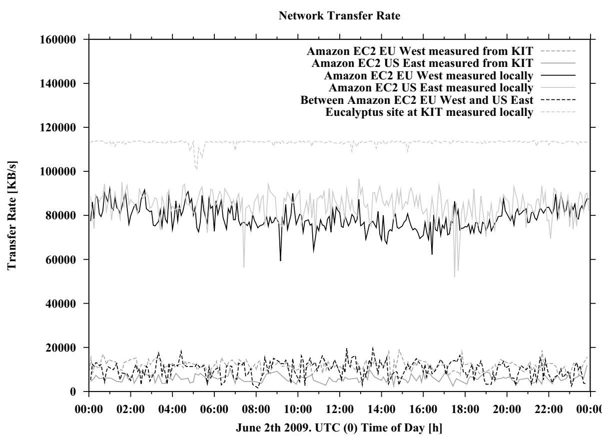

Figure 6. Network Transfer Rate

The network transfer rates inside the EC2 US East and EU West regions imply that there is 1000 Mbit/s Ethernet used as well, but with a higher workload. The network transfer rate from KIT to the EU West region is much better compared to Amazon EC2 in US East, which is not surprising.

2.4 Network Latency

In order to examine the potential for HPC applications using private Eucalyptus clouds and public cloud infrastructures, the network latency, more exact the round-trip time (RTT) was measured. The results in show that HPC in the cloud over the Internet is problematic when using resources that are not physically located inside the same site respectively zone.

The RTT inside the Eucalyptus cluster is under 0.5 ms and constant over the time. (Figure 7) This is because all resources are stored inside the same BladeCenter. The RTT the EC2 sites in Europe and the United States is constant

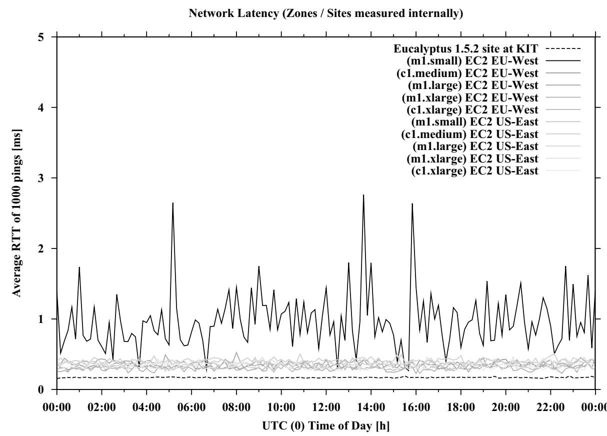

Figure 7. RTT inside the Eucalyptus cluster and both EC2 sites

in the range of 0.3-0.5 ms over the time. One single exception is the RTT of the m1.small instances in EU2 EU-West. Their RTT is significant worse compared to the other instace types. Obviously the physical machines, running instances from the instance type m1.small face a high workload or their network access is underprivileged by the network switches. For all test cases in Figure 7, instances from the identical instance types and inside the same zones were tested.

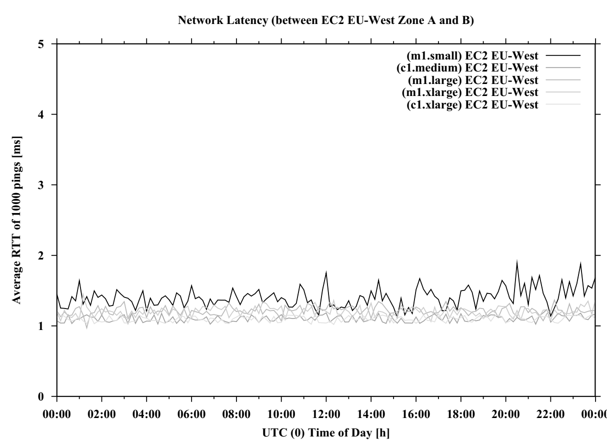

Figure 8. RTT between both zones of EC2 in Europe

While the Eucalyptus infrastructure at KIT consist of just a single site, the EC2 site in Europe contains of two zones. These are `eu-west-1a` and `eu-west-1b`. The EC2 site in the United States contains of the four zones `us-east-1a`, `us-east-1b`, `us-east-1c` and us-east-1d. Like inside the zones, the RTT between the two EC2 zones in Europe is very constant and performs circa 1 ms slower (Figure 8) which is still a very good RTT and indicates that the zones inside a EC2 site are physically located next to each other and linked together via strong network connections.

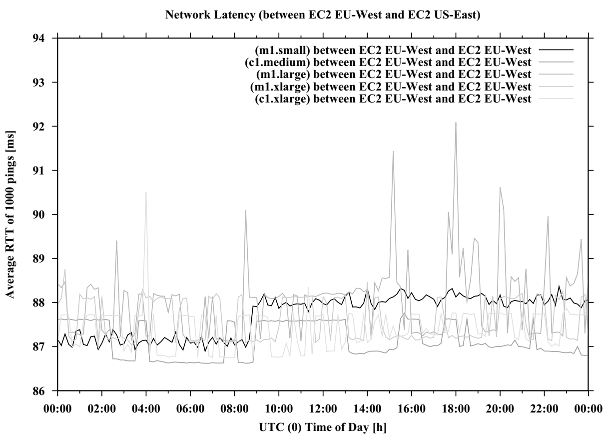

Figure 9. RTT between EC2 in Europe and the USA

The RTT between the EC2 site in Europe and the EC2 site in the United States performs surprisingly constant over the time. The measurements in Figure 9 cover a szenario where instances from the identical instance class inside EU-West and US-East are linked together in an cloud infrastructure to increase the level of availability.

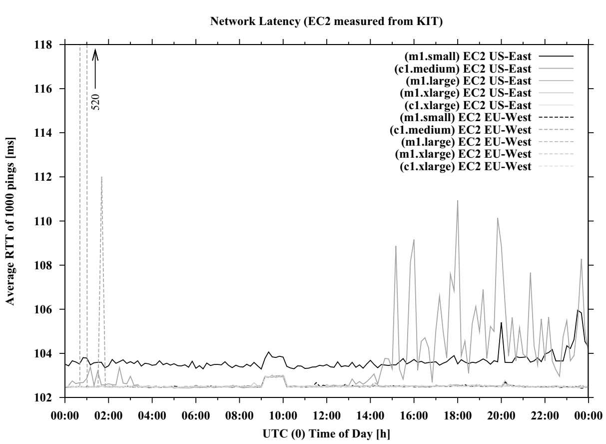

Figure 10. RTT between EC2 and the KIT

From all test cases the RTT measurements between the KIT and the EC2 sites are worst. It is amazing how constant the RTT is over the time and that for most instance types the RTT between the KIT and EC2 is equal for both sites (Figure 10). It would be comprehensible when the RTT between the KIT and EC2 EU-West is better compared to the RTT between the KIT and EC2 US-East, but no significant gap exists.

For MPI jobs where loosely coupled tasks compute a few seconds it seems possible to use cloud infrastructures. However, the network latency inside Amazon EC2 is poor and a surprising outcome is that the network latency inside the Amazon regions is not significantly better than the network latency between Amazon EC2 EU West and EC2 US East.

3. Lessons learned from building up a Private Cloud

As a result of our testing we conclude that Eucalyptus is a suitable solution for IaaS and we are operating several Eucalyptus installations. It is our observation that each new version of the system improves the compatibility with the original Amazon EC2, S3 and EBS and the existing tools [9] [10] [15] [16] [17]. The installation of Eucalyptus is well documented and manageable.

Several performance measurements [5] with Eucalyptus compared to the original AWS have been made. The result of these measurements is that a private cloud can provide almost the same functionality and possibly better performance compared to the AWS. The performance can be easily improved with storage area networks (SAN) for storing the data in the S3/EBS directories (e.g. image files) in a better performing environment. This approach also helps a lot to reduce the time, needed to start the virtual server instances. On the other hand, AWS offers unlimited scalability and thus it would be beneficial to combine both, private and public resources in a hybrid cloud.

The robustness of our Eucalyptus installations is still not as good as the AWS. But this is not surprising: Cloud computing is still a fresh technology and Eucalyptus as well as other open source cloud projects are under heavy development.

4. Conclusion

Eucalyptus is an interesting product to build private cloud infrastructures for R&D. The performance of such an installation with commodity hardware is satisfying for most common scientific applications. Already now a large number of open source tools exists for cloud management. As also other cloud software providers start to implement Amazon AWS as a cloud computing interface AWS has the potential to become a de facto standard for cloud computing infrastructure services.

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