Cloud Infrastructure

Existing cloud infrastructure

- The cloud computing infrastructure at Amazon, Google, and Microsoft (as of mid 2012).
  - Amazon is a pioneer in Infrastructure-as-a-Service (IaaS).
  - Google's efforts are focused on Software-as-a-Service (SaaS) and Platform-as-a-Service (PaaS).
  - Microsoft is involved in PaaS.
- Private clouds are an alternative to public clouds. Open-source cloud computing platforms such as:
  - Eucalyptus,
  - OpenNebula,
  - Nimbus,
  - OpenStack

  can be used as a control infrastructure for a private cloud.

Amazon Web Services (AWS)

- AWS → IaaS cloud computing services launched in 2006.
- Businesses in 200 countries used AWS in 2012.
- The infrastructure consists of compute and storage servers interconnected by high-speed networks and supports a set of services.
- An application developer:
  - Installs applications on a platform of his/her choice.
  - Manages resources allocated by Amazon.

AWS regions and availability zones

- Amazon offers cloud services through a network of data centers on several continents.
- In each *region* there are several availability zones interconnected by high-speed networks.
- An *availability zone* is a data center consisting of a large number of servers.

Region	Location	Availability zones	Cost
US West	Oregon	us-west-2a/2b/2c	Low
US West	North California	us-west-1a/1b/1c	High
US East	North Virginia	us-east-1a/2a/3a/4a	Low
Europe	Ireland	eu-west-1a/1b/1c	Medium
South America	Sao Paulo, Brazil	sa-east-1a/1b	Very high
Asia Pacific	Tokyo, Japan	ap-northeast-1a/1b	High
Asia Pacific	Singapore	ap-southeast-1a/1b	Medium

- Regions do not share resources and communicate through the Internet.

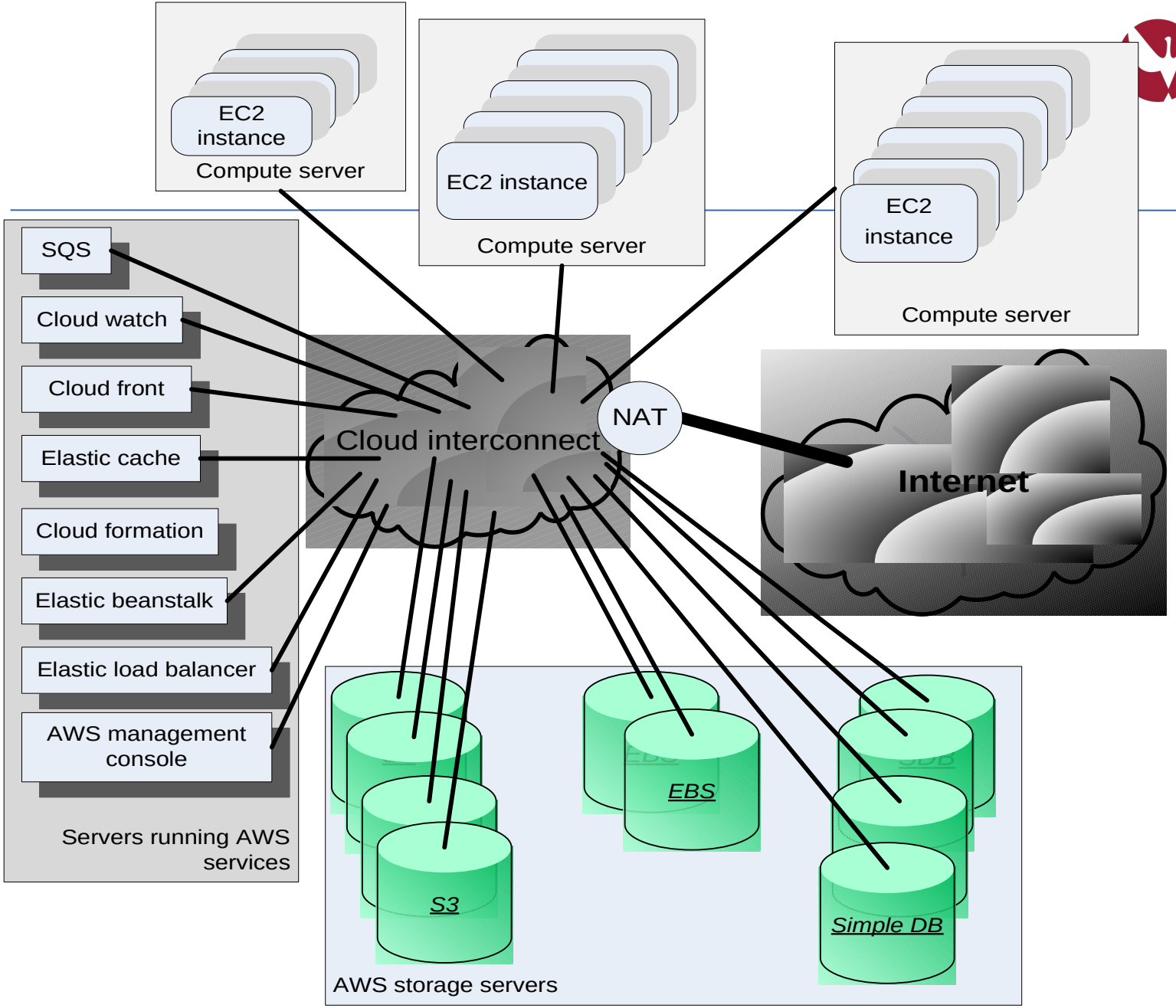

US West
(Oregon)
US West
(N. California)
US East
(N. Virginia)
EU
(Ireland)
Asia Pacific
(Tokyo)
Asia Pacific
(Singapore)
South America
(San Paulo)
Low cost region
Medium cost region
High cost region
Very high cost region

AWS instances

- An instance is a virtual server with a well specified set of resources including: CPU cycles, main memory, secondary storage, communication and I/O bandwidth.
- The user chooses:
  - The region and the availability zone where this virtual server should be placed.
  - An instance type from a limited menu of instance types.
- When launched, an instance is provided with a DNS name; this name maps to a
  - *private IP address* → for internal communication within the internal EC2 communication network.
  - *public IP address* → for communication outside the internal Amazon network, e.g., for communication with the user that launched the instance.

AWS instances (cont'd)

- Network Address Translation (NAT) maps external IP addresses to internal ones.
- The public IP address is assigned for the lifetime of an instance.
- An instance can request an *elastic IP address*, rather than a public IP address. The elastic IP address is a static public IP address allocated to an instance from the available pool of the availability zone.
- An elastic IP address is not released when the instance is stopped or terminated and must be released when no longer needed.


EC2 instance
Compute server
EC2 instance
Compute server
EC2 instance
Compute server
SQS
Cloud watch
Cloud front
Elastic cache
Cloud formation
Elastic beanstalk
Elastic load balancer
AWS management console
Servers running AWS services
Cloud interconnect
NAT
Internet
EBS
S3
Simple DB
AWS storage servers

Steps to run an application

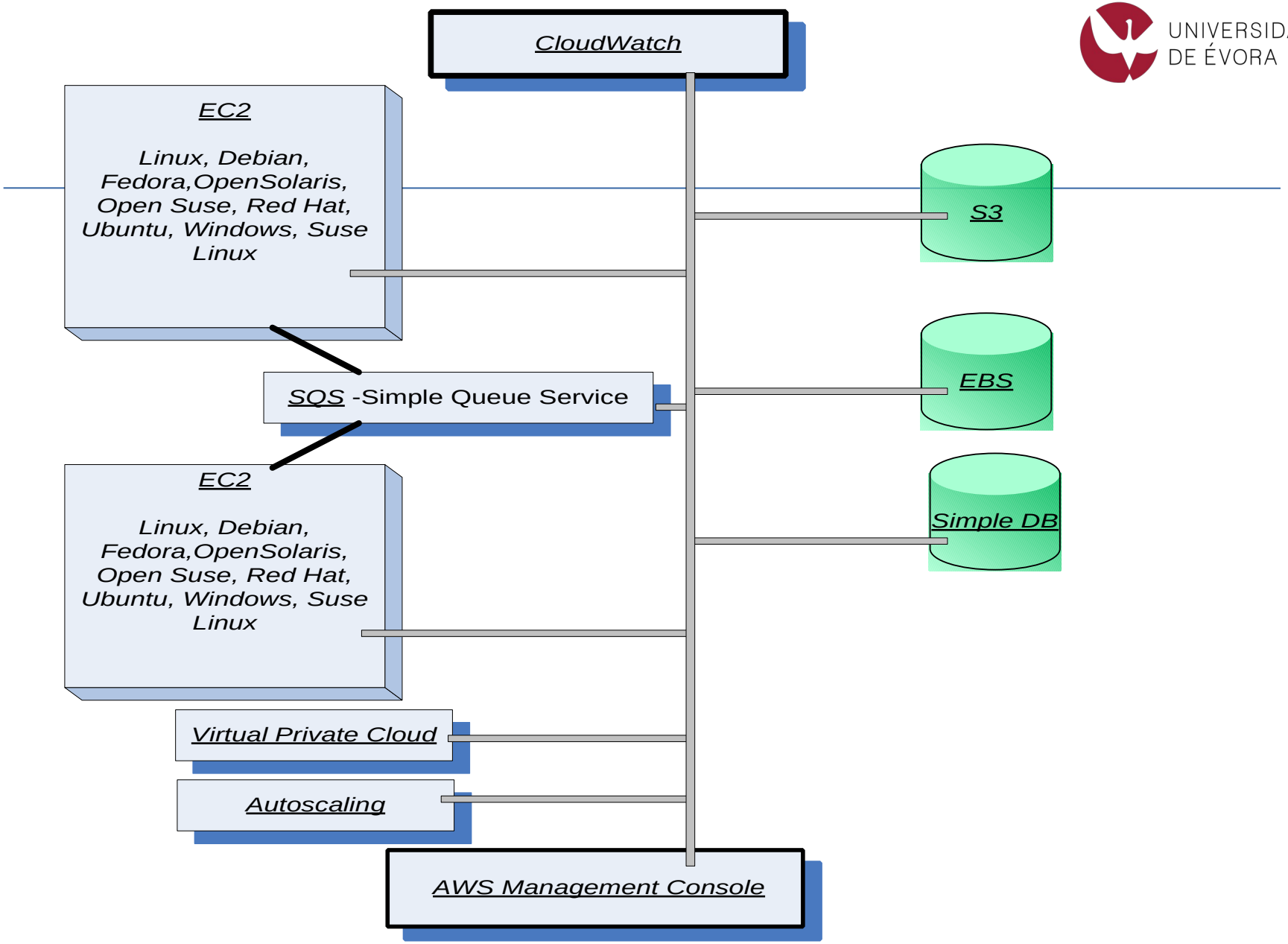
- Retrieve the user input from the front-end.
- Retrieve the disk image of a VM (Virtual Machine) from a repository.
- Locate a system and requests the VMM (Virtual Machine Monitor) running on that system to setup a VM.
- Invoke the Dynamic Host Configuration Protocol (DHCP) and the IP bridging software to set up MAC and IP addresses for the VM.

User interactions with AWS

- The AWS Management Console. The easiest way to access all services, but not all options may be available.
- AWS SDK libraries and toolkits are provided for several programming languages including Java, PHP, C#, and Objective-C.
- Raw REST requests.

Examples of Amazon Web Services

- *AWS Management Console* - allows users to access the services offered by AWS .
- *Elastic Cloud Computing (EC2)* - allows a user to launch a variety of operating systems.
- *Simple Queuing Service (SQS)* - allows multiple *EC2* instances to communicate with one another.
- *Simple Storage Service (S3)*, *Simple DB*, and *Elastic Block Storage (EBS)* - storage services.
- *Cloud Watch* - supports performance monitoring.
- *Auto Scaling* - supports elastic resource management.
- *Virtual Private Cloud* - allows direct migration of parallel applications.


CloudWatch
EC2
Linux, Debian, Fedora,OpenSolaris, Open Suse, Red Hat, Ubuntu, Windows, Suse Linux
S3
EBS
SQS -Simple Queue Service
EC2
Linux, Debian, Fedora,OpenSolaris, Open Suse, Red Hat, Ubuntu, Windows, Suse Linux
Simple DB
Virtual Private Cloud
Autoscaling
AWS Management Console

EC2 – Elastic Cloud Computing

- *EC2* - web service for launching instances of an application under several operating systems, such as:
  - Several Linux distributions.
  - Microsoft Windows Server 2003 and 2008.
  - OpenSolaris.
  - FreeBSD.
  - NetBSD.
- A user can
  - Load an *EC2* instance with a custom application environment.
  - Manage network's access permissions.
  - Run the image using as many or as few systems as desired.

EC2 (cont'd)

- Import virtual machine (VM) images from the user environment to an instance through *VM import*.
- *EC2* instances boot from an AMI (Amazon Machine Image) digitally signed and stored in *S3*.
- Users can access:
  - Images provided by Amazon.
  - Customize an image and store it in *S3*.
- An *EC2* instance is characterized by the resources it provides:
  - VC (Virtual Computers) – virtual systems running the instance.
  - CU (Compute Units) – measure computing power of each system.
  - Memory.
  - I/O capabilities.

Instance types

- Standard instances: micro (StdM), small (StdS), large (StdL), extra large (StdXL); small is the default.
- High memory instances: high-memory extra large (HmXL), high-memory double extra large (Hm2XL), and high-memory quadruple extra large (Hm4XL).
- High CPU instances: high-CPU extra large (HcpuXL).
- Cluster computing: cluster computing quadruple extra large (Cl4XL).

Instance name	API name	Platform (32/64-bit)	Memory (GB)	Max EC2 compute units	I-memory (GB)	I/O (M/H)
StdM		32 and 64	0. 633	1 VC; 2 CUs		
StdS	`m1.small`	32	1.7	1 VC; 1 CU	160	M
StdL	`m1.large`	64	7.5	2 VCs; 2×2 CUs	85	H
StdXL	`m1.xlarge`	64	15	4 VCs; 4×2 CUs	1,690	H
HmXL	`m2.xlarge`	64	17.1	2 VCs; 2×3.25 CUs	420	M
Hm2XL	`m2.2xlarge`	64	34.2	4 VCs; 4×3.25 CUs	850	H
Hm4XL	`m2.4xlarge`	64	68.4	8 VCs; 8×3.25 CUs	1,690	H
HcpuXL	`c1.xlarge`	64	7	8 VCs; 8×2.5 CUs	1,690	H
Cl4XL	`cc1.4xlarge`	64	18	33.5 CUs	1,690	H

S3 – Simple Storage System

- Service designed to store large objects; an application can handle an unlimited number of objects ranging in size from 1 byte to 5 TB.
- An object is stored in a bucket and retrieved via a unique, developer-assigned key; a bucket can be stored in a Region selected by the user.
- Supports a minimal set of functions: write, read, and delete; it does not support primitives to copy, to rename, or to move an object from one bucket to another.
- The object names are global.
- S3 maintains for each object: the name, modification time, an access control list, and up to 4 KB of user-defined metadata.

S3 (cont'd)

- Authentication mechanisms ensure that data is kept secure.
- Objects can be made public, and rights can be granted to other users.
- *S3* computes the MD5 of every object written and returns it in a field called ETag.
- A user is expected to compute the MD5 of an object stored or written and compare this with the ETag; if the two values do not match, then the object was corrupted during transmission or storage.

Elastic Block Store (EBS)

- Provides persistent block level storage volumes for use with *EC2* instances; suitable for database applications, file systems, and applications using raw data devices.
- A volume appears to an application as a raw, unformatted and reliable physical disk; the range 1 GB -1 TB.
- An *EC2* instance may mount multiple volumes, but a volume cannot be shared among multiple instances.
- EBS supports the creation of snapshots of the volumes attached to an instance and then uses them to restart the instance.
- The volumes are grouped together in Availability Zones and are automatically replicated in each zone.

SimpleDB

- Non-relational data store. Supports store and query functions traditionally provided only by relational databases.
- Supports high performance Web applications; users can store and query data items via Web services requests.
- Creates multiple geographically distributed copies of each data item.
- It manages automatically:
  - The infrastructure provisioning.
  - Hardware and software maintenance.
  - Replication and indexing of data items.
  - Performance tuning.

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SQS - Simple Queue Service

- Hosted message queues are accessed through standard SOAP and Query interfaces.
- Supports automated workflows - *EC2* instances can coordinate by sending and receiving SQS messages.
- Applications using SQS can run independently and asynchronously, and do not need to be developed with the same technologies.
- A received message is “locked" during processing; if processing fails, the lock expires and the message is available again.
- Queue sharing can be restricted by IP address and time-of-day.

CloudWatch

- Monitoring infrastructure used by application developers, users, and system administrators to collect and track metrics important for optimizing the performance of applications and for increasing the efficiency of resource utilization.
- Without installing any software a user can monitor either seven or eight pre-selected metrics and then view graphs and statistics for these metrics.
- When launching an Amazon Machine Image (AMI) the user can start the CloudWatch and specify the type of monitoring:
  - Basic Monitoring - free of charge; collects data at five-minute intervals for up to seven metrics.
  - Detailed Monitoring - subject to charge; collects data at one minute interval.

AWS services introduced in 2012

- *Route 53* - low-latency DNS service used to manage user's DNS public records.
- *Elastic MapReduce (EMR)* - supports processing of large amounts of data using a hosted Hadoop running on *EC2*.
- *Simple Workflow Service (SWF)* - supports workflow management; allows scheduling, management of dependencies, and coordination of multiple *EC2* instances.
- *ElastiCache* - enables web applications to retrieve data from a managed in-memory caching system rather than a much slower disk-based database.
- *DynamoDB* - scalable and low-latency fully managed NoSQL database service.

AWS services introduced in 2012 (cont'd)

- *CloudFront* - web service for content delivery.
- *Elastic Load Balancer* - automatically distributes the incoming requests across multiple instances of the application.
- *Elastic Beanstalk* - handles automatically deployment, capacity provisioning, load balancing, auto-scaling, and application monitoring functions.
- *CloudFormation* - allows the creation of a stack describing the infrastructure for an application.

Elastic Beanstalk

- Handles automatically the deployment, capacity provisioning, load balancing, auto-scaling, and monitoring functions.
- Interacts with other services including *EC2*, *S3*, SNS, Elastic Load Balance and AutoScaling.
- The management functions provided by the service are:
  - Deploy a new application version (or rollback to a previous version).
  - Access to the results reported by CloudWatch monitoring service.
  - Email notifications when application status changes or application servers are added or removed.
  - Access to server log files without needing to login to the application servers.
- The service is available using: a Java platform, the PHP server-side description language, or the .NET framework.

SaaS services offered by Google

- *Gmail* - hosts Emails on Google servers and provides a web interface to access the Email.
- *Google docs* - a web-based software for building text documents, spreadsheets and presentations.
- *Google Calendar* - a browser-based scheduler; supports multiple user calendars, calendar sharing, event search, display of daily/ weekly/monthly views, and so on.
- *Google Groups* - allows users to host discussion forums to create messages online or via Email.
- *Picasa* - a tool to upload, share, and edit images.
- *Google Maps* - web mapping service; offers street maps, a route planner, and an urban business locator for numerous countries around the world

PaaS services offered by Google

- *AppEngine* - a developer platform hosted on the cloud.
  - Initially supported Python, Java was added later.
  - The database for code development can be accessed with GQL (Google Query Language) with a SQL-like syntax.
- *Google Co-op* - allows users to create customized search engines based on a set of facets/categories.
- *Google Drive* - an online service for data storage.
- *Google Base* - allows users to load structured data from different sources to a central repository, a very large, self-describing, semi-structured, heterogeneous database.

PaaS and SaaS services from Microsoft

- *Windows Azure* - an operating system; has 3 components:
  - Compute - provides a computation environment.
  - Storage - for scalable storage.
  - Fabric Controller - deploys, manages, and monitors applications.
- *SQL Azure* - a cloud-based version of the SQL Server.
- *Azure AppFabric*, formerly .NET Services - a collection of services for cloud applications.

Open-source platforms for private clouds

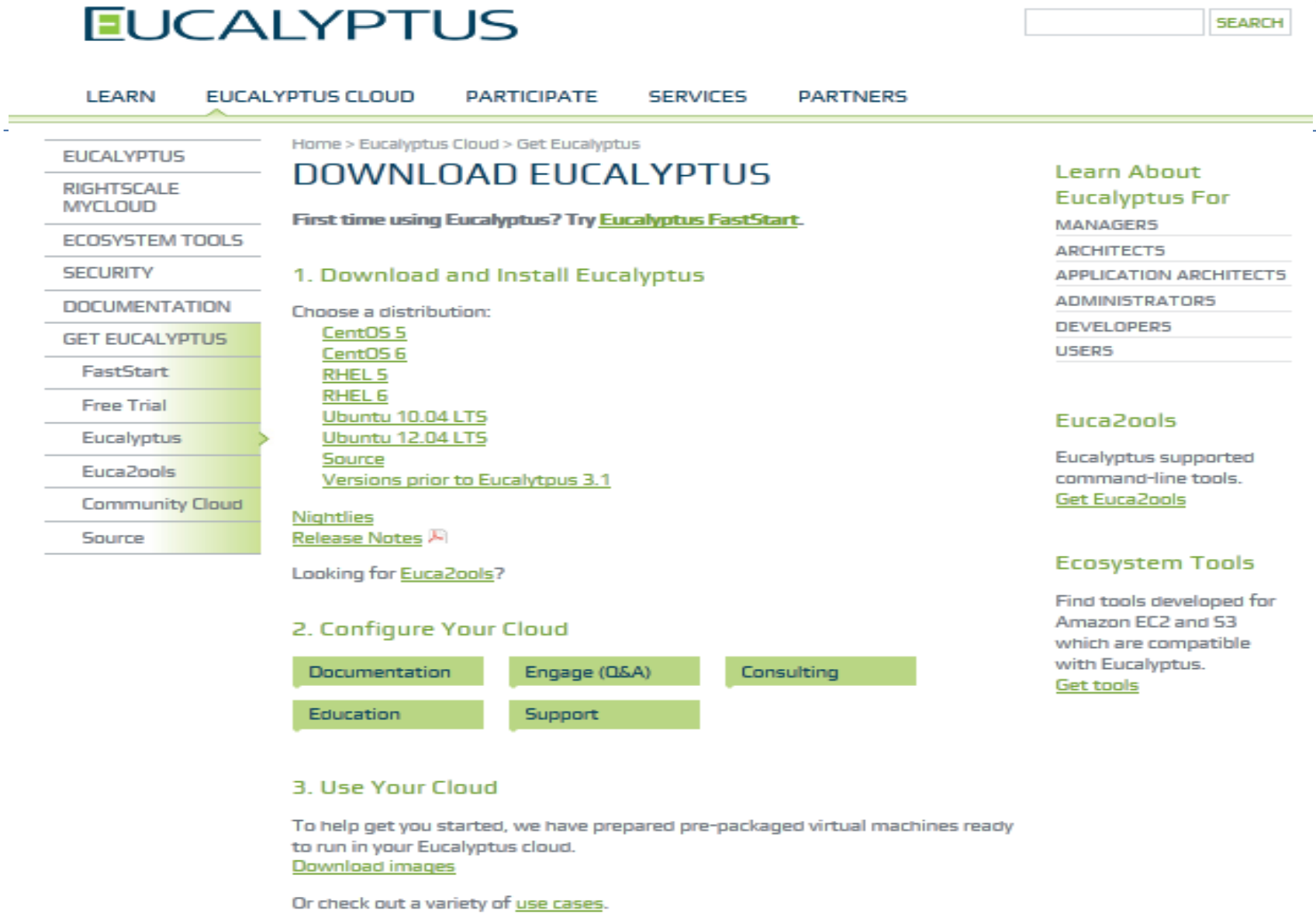
- *Eucalyptus* - can be regarded as an open-source counterpart of Amazon's EC2.

- *Open-Nebula* - a private cloud with users actually logging into the head node to access cloud functions. The system is centralized and its default configuration uses the NFS file system.

- *Nimbus* - a cloud solution for scientific applications based on Globus software; inherits from Globus:
  - The image storage.
  - The credentials for user authentication.
  - The requirement that a running Nimbus process can **ssh** into all compute nodes.

Eucalyptus

- *Virtual Machines* - run under several VMMs including Xen, KVM, and VMware.
- *Node Controller* - runs on server nodes hosting a VM and controls the activities of the node.
- *Cluster Controller* - controls a number of servers.
- *Cloud Controller* - provides the cloud access to end-users, developers, and administrators.
- *Storage Controller* - provides persistent virtual hard drives to applications. It is the correspondent of EBS.
- *Storage Service (Walrus)* - provides persistent storage; similar to S3, it allows users to store objects in buckets.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CentOS 6
RHEL 5
RHEL 6
Ubuntu 10.04 LTS
Ubuntu 12.04 LTS
Source
Versions prior to Eucalytpus 3.1
Nightlies
Release Notes
Looking for Euca2ools?
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Ecosystem Tools
Find tools developed for Amazon EC2 and S3 which are compatible with Eucalyptus.
Get tools

Cloud storage diversity and vendor lock-in

- Risks when a large organization relies on a single cloud service provider:
  - Cloud services may be unavailable for a short or an extended period of time.
  - Permanent data loss in case of a catastrophic system failure.
  - The provider may increase the prices for service.
- Switching to another provider could be very costly due to the large volume of data to be transferred from the old to the new provider.
- A solution is to replicate the data to multiple cloud service providers, similar to data replication in RAID.

Energy use and ecological impact

- The energy consumption of large-scale data centers and their costs for energy and for cooling are significant.
- In 2006, the 6,000 data centers in the U.S consumed 61×10^9 KWh of energy, 1.5% of all electricity consumption, at a cost of $4.5 billion.
- The energy consumed by the data centers was expected to double from 2006 to 2011 and peak instantaneous demand to increase from 7 GW to 12 GW.
- The greenhouse gas emission due to the data centers is estimated to increase from 116×10^9 tones of CO_2 in 2007 to 257 tones in 2020 due to increased consumer demand.
- The effort to reduce energy use is focused on computing, networking, and storage activities of a data center.

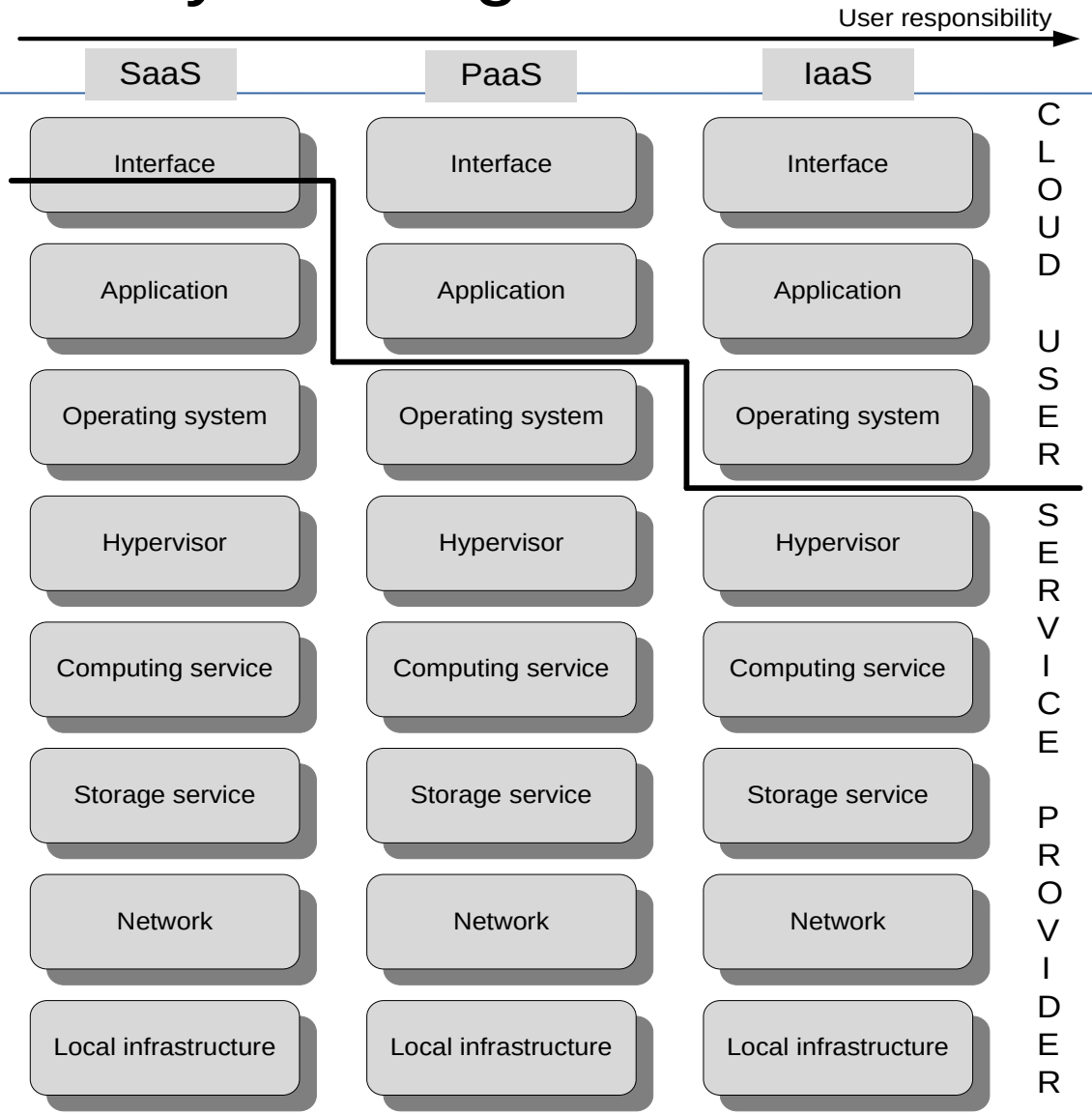
Energy use and ecological impact (cont'd)

- Operating efficiency of a system is captured by the *performance per Watt of power*.
- The performance of supercomputers has increased 3.5 times faster than their operating efficiency – 7,000% versus 2,000% during the period 1998 – 2007.
- A typical Google cluster spends most of its time within the 10-50% CPU utilization range; there is a mismatch between server workload profile and server energy efficiency.

Service Level Agreement (SLA)

- SLA - a negotiated contract between the customer and CSP; can be legally binding or informal. Objectives:
  - Identify and define the customer's needs and constraints including the level of resources, security, timing, and QoS.
  - Provide a framework for understanding; a critical aspect of this framework is a clear definition of classes of service and the costs.
  - Simplify complex issues; clarify the boundaries between the responsibilities of clients and CSP in case of failures.
  - Reduce areas of conflict.
  - Encourage dialog in the event of disputes.
  - Eliminate unrealistic expectations.
- Specifies the services that the customer receives, rather than how the cloud service provider delivers the services.

Responsibility sharing between user and CSP



User security concerns

- Potential loss of control/ownership of data.
- Data integration, privacy enforcement, data encryption.
- Data remanence after de-provisioning.
- Multi tenant data isolation.
- Data location requirements within national borders.
- Hypervisor security.
- Audit data integrity protection.
- Verification of subscriber policies through provider controls.
- Certification/Accreditation requirements for a given cloud service.

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Credits, references and reading material

- *Cloud Computing: Theory and Practice*

  Dan C. Marinescu

  Chapter 3

- *Distributed and Cloud Computing*

  K. Hwang, G. Fox and J. Dongarra

  Morgan Kaufmann, 2012