4th Slide Set Cloud Computing

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Agenda for Today

- Amazon Web Services (AWS)
  - Reasons for using the AWS
  - Examples of applications that use the AWS
  - Elastic Compute Cloud (EC2)
  - Elastic Block Store (EBS)
  - Elastic Load Balancing (ELB)
  - Simple Storage Service (S3)
  - Google Cloud Storage and further alternative service offerings
- Solutions for running private cloud infrastructure services
  - Eucalyptus
  - OpenStack

Amazon Web Services (AWS)

- The AWS is a collection of different public cloud services
  - Launched in 2002
  - Billed according to consumption
  - Services of the AWS are among others...

Elastic Compute Cloud (EC2)	$\Longrightarrow$	Infrastructure service for virtual servers
Simple Storage Service (S3)	$\Longrightarrow$	Storage service for web objects
Elastic Block Store (EBS)	$\Longrightarrow$	Storage service for virtual storage volumes
Elastic Load Balancing (ELB)	$\Longrightarrow$	Service for virtual load balancers
CloudWatch	$\Longrightarrow$	Service for monitoring AWS resources
Auto Scaling	$\Longrightarrow$	Service for scaling EC2 capacities
SimpleDB	$\Longrightarrow$	Service for distributed database
Amazon Simple Queue Service (SQS)	$\Longrightarrow$	Service for message queues
Amazon Mechanical Turk	$\Longrightarrow$	HuaaS/Crowdsourcing marketplace

Attention!

- Many screenshots in this slide set are from the years 2012/2013/2014
- The web interfaces of cloud service providers often change
- $\Longrightarrow$ Many screenshots are outdated! Sorry for that!
- The functionality and technical terms are seldom modified

AWS Overview – http://aws.amazon.com

aws | Contact Sales | Products | Solutions | Pricing | Getting Started | Documentation | AWS Marketplace | More | English | My Account | Sign In to

Clou
Amazon V
analytics,
These ser
enterprise
applicatio

Compute
- Amazon EC2
- Amazon EC2 Auto Scaling
- Amazon Elastic Container Service
- Amazon Elastic Container Service for Kubernetes
- Amazon Elastic Container Registry
- Amazon Lightsail
- AWS Batch
- AWS Elastic Beanstalk
- AWS Fargate
- AWS Lambda
- AWS Serverless Application Repository
- Elastic Load Balancing
- VMware Cloud on AWS

Storage
- Amazon Simple Storage Service (S3)
- Amazon Elastic Block Storage (EBS)
- Amazon Elastic File System (EFS)
- Amazon Glacier
- AWS Storage Gateway
- AWS Snowball
- AWS Snowball Edge
- AWS Snowmobile

Database
- Amazon Aurora
- Amazon RDS
- Amazon DynamoDB
- Amazon ElastiCache
- Amazon Redshift
- Amazon Neptune
- AWS Database Migration Service

Migration
- AWS Migration Hub
- AWS Application Discovery Service

Networking & Content Delivery
- Amazon VPC
- Amazon CloudFront
- Amazon Route 53
- Amazon API Gateway
- AWS Direct Connect
- Elastic Load Balancing

Developer Tools
- AWS CodeStar
- AWS CodeCommit
- AWS CodeBuild
- AWS CodeDeploy
- AWS CodePipeline
- AWS Cloud9
- AWS X-Ray
- AWS Tools & SDKs

Management Tools
- Amazon CloudWatch
- AWS Auto Scaling
- AWS CloudFormation
- AWS CloudTrail
- AWS Config
- AWS OpsWorks
- AWS Service Catalog
- AWS Systems Manager
- AWS Trusted Advisor
- AWS Personal Health Dashboard
- AWS Command Line Interface
- AWS Management Console
- AWS Managed Services

Media Services
- Amazon Elastic Transcoder
- Amazon Kinesis Video Streams
- AWS Elemental MediaConvert
- AWS Elemental MediaLive

Machine Learning
- Amazon SageMaker
- Amazon Comprehend
- Amazon Lex
- Amazon Polly
- Amazon Rekognition
- Amazon Machine Learning
- Amazon Translate
- Amazon Transcribe
- AWS DeepLens
- AWS Deep Learning AMIs
- Apache MXNet on AWS
- TensorFlow on AWS

Analytics
- Amazon Athena
- Amazon EMR
- Amazon CloudSearch
- Amazon Elasticsearch Service
- Amazon Kinesis
- Amazon Redshift
- Amazon QuickSight
- AWS Data Pipeline
- AWS Glue

Security, Identity & Compliance
- AWS Identity and Access Management (IAM)
- Amazon Cloud Directory
- Amazon Cognito
- Amazon GuardDuty
- Amazon Inspector
- Amazon Macie
- AWS Certificate Manager
- AWS CloudHSM
- AWS Directory Service
- AWS Firewall Manager
- AWS Key Management Service

AR & VR
- Amazon Sumerian

Application Integration
- Amazon MQ
- Amazon Simple Queue Service (SQS)
- Amazon Simple Notification Service (SNS)
- AWS AppSync
- AWS Step Functions

Customer Engagement
- Amazon Connect
- Amazon Pinpoint
- Amazon Simple Email Service (SES)

Business Productivity
- Alexa for Business
- Amazon Chime
- Amazon WorkDocs
- Amazon WorkMail

Desktop & App Streaming
- Amazon WorkSpaces
- Amazon AppStream 2.0

Internet of Things
- AWS IoT Core
- Amazon FreeRTOS
- AWS Greengrass
- AWS IoT 1-Click
- AWS IoT Analytics
- AWS IoT Button
- AWS IoT Device Defender
- AWS IoT Device Management

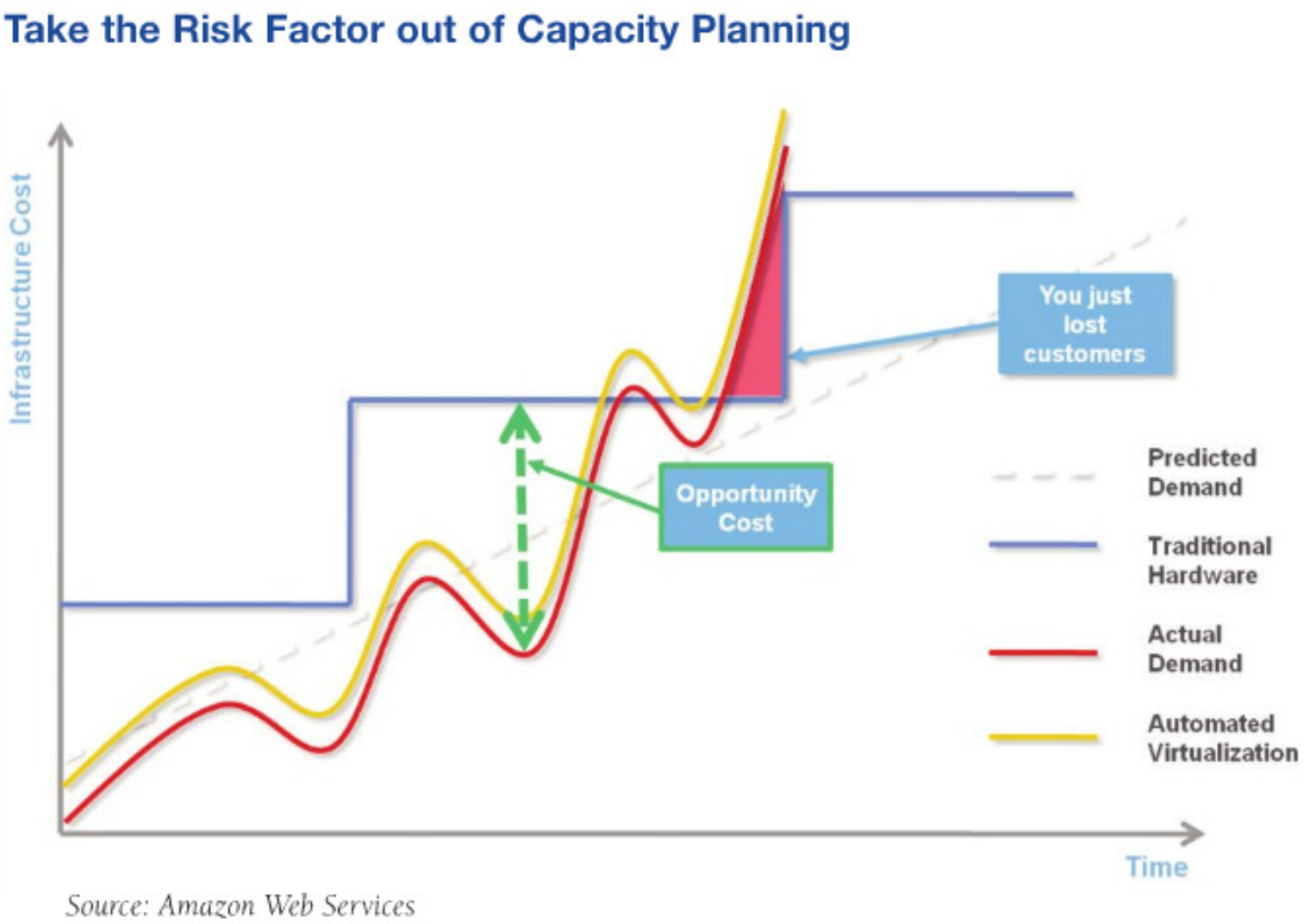
Game Development
- Amazon GameLift
- Amazon Lumberyard

Why AWS?

- Why should a company use the AWS, instead of buying own resources?
- How many resources does the company need in the future?
- Scenario: A web offering of a startup company
  - How many resources will be consumed?
  - What costs will arise?
  - How much time is required to acquire additional resources and include them into the infrastructure?

Without a credit card, the AWS cannot be used

Own physical Infrastructure compared with the Cloud



AWS Customer Success Story: Animoto (1/2)

- Users can create videos from their own pictures and music
  - `http://animoto.com`
- The software analyzes the pictures and the music and generates videos in the style of a trailer or a MTV music video
- Videos can be uploaded to YouTube and exported to various formats

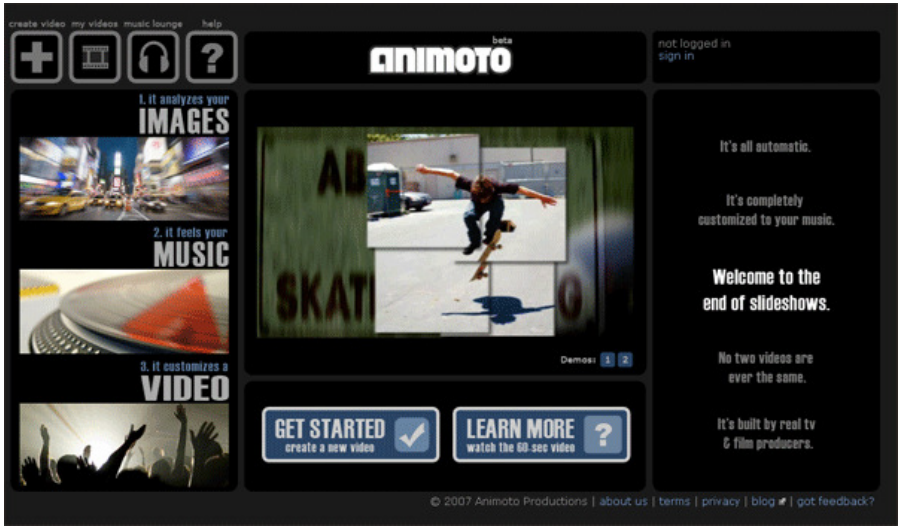
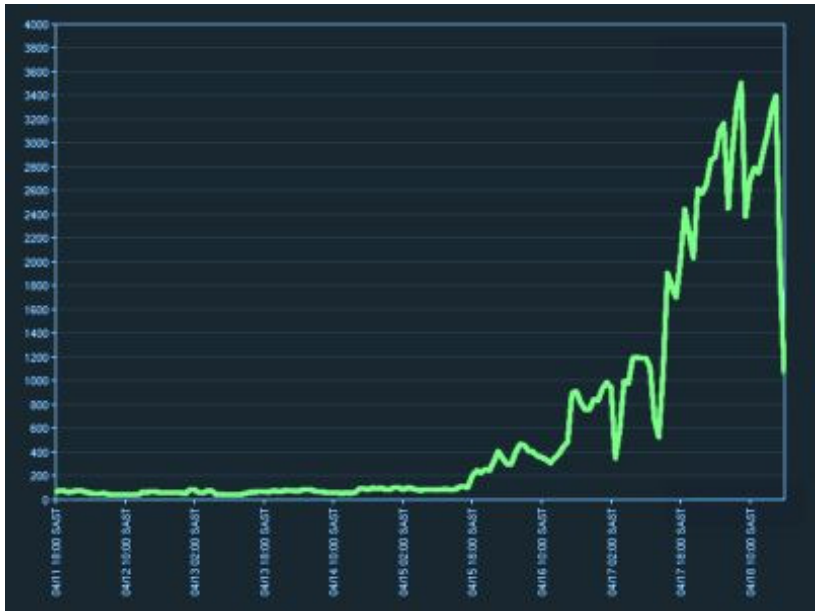


Image source: Google image search

AWS Customer Success Story: Animoto (2/2)

- 2006-2008: Only few users used the service
- April 2008: Facebook application launched
  - 750,000 new users in 3 days
  - At the peak, up to 25,000 people tried to render a video in a single hour
  - Slashdot effect!
  - Automatic adjustment of the instances to render the videos from 2 up to 450



http://www.youtube.com/watch?v=VwDS6MexKEo

Animoto on AWS - Customer Success Story

Slashdot Effect

en.wikipedia.org/wiki/Slashdot_effect

Create account Log in

Article Talk Read Edit source View history Search

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
Donate to Wikipedia

Interaction
Help
About Wikipedia
Community portal
Recent changes
Contact page

Toolbox

Slashdot effect

From Wikipedia, the free encyclopedia

"Flash crowd" redirects here. For the short story by Larry Niven, see Flash Crowd. For the social gathering in the real world, see flash mob.

The **Slashdot effect**, also known as **slashdotting**, occurs when a popular website links to a smaller site, causing a massive increase in traffic. This overloads the smaller site, causing it to slow down or even temporarily become unavailable. The name stems from the huge influx of web traffic that would result from the technology news site *Slashdot* linking to websites, although the name is dated since flash crowds from *Slashdot* have been reported in 2005 as diminishing beginning in 2004 due to competition from similar sites.[1] The effect has been associated with other websites or metablogs such as Fark, Digg, *Drudge Report*, Reddit, and Twitter, leading to terms such as being **Farked** or **Drudged**, or being under the **Reddit effect**.[2][3] Google Doodles, which link to search results on the doodle topic, also result in high increases of traffic from the search results page.[4] Typically, less robust sites are unable to cope with the huge increase in traffic and become unavailable – common causes are lack of sufficient data bandwidth, servers that fail to cope with the high number of requests, and traffic quotas. Sites that are maintained on shared hosting services often fail when confronted with the Slashdot effect.

A **flash crowd** is a more generic term without using any specific name that describes a network phenomenon where a network or host suddenly receives a lot of traffic. This is sometimes due to the appearance of a web site on a blog or news column.[5][6][7]

- Linear increase of traffic is unrealistic
- Huge problem for startup companies with own resources

AWS Customer Success Story: New York Times

- 2007: The New York Times wants to create PDF versions from the articles from the years 1851-1980
  - The newspaper planned to make the articles from the years 1851-1922 available online for free
- The raw version of the articles were 11 million scanned images
  - Each article had to be composed of several TIFF files and had to be scaled
- First, 4 TB TIFF files had to be uploaded to S3
- 100 EC2 instances required approximately 24 hours for the calculation
- Result: 1.5 TB of PDF files inside S3
- `https://timesmachine.nytimes.com`

"All the News That's Fit to Print."

The New York Times.

TITANIC SINKS FOUR HOURS AFTER HITTING ICEBERG; 866 RESCUED BY CARPATHIA, PROBABLY 1250 PERISH; ISMAY SAFE, MRS. ASTOR MAYBE, NOTED NAMES MISSING

Col. Astor and Bride, Isidor Straus and Wife, and Maj. Butt Aboard.

"RULE OF SEA" FOLLOWED

Women and Children Put Over in Lifeboats and Are Supposed to be Safe on Carpathia.

PICKED UP AFTER 8 HOURS

Biggest Liner Plunges to the Bottom at 2:20 A. M.

RESCUERS THERE TOO LATE

WOMEN AND CHILDREN FIRST

SEA SEARCH FOR OTHERS

The Lost Titanic Being Towed Out of Belfast Harbor.

PARTIAL LIST OF THE SAVED.

CAPT. E. J. SMITH.

```
https://aws.amazon.com/de/blogs/aws/new-york-times/
http://open.blogs.nytimes.com/2007/11/01/self-service-prorated-super-computing-fun/
http://open.blogs.nytimes.com/2008/05/21/the-new-york-times-archives-amazon-web-services-timesmachine/
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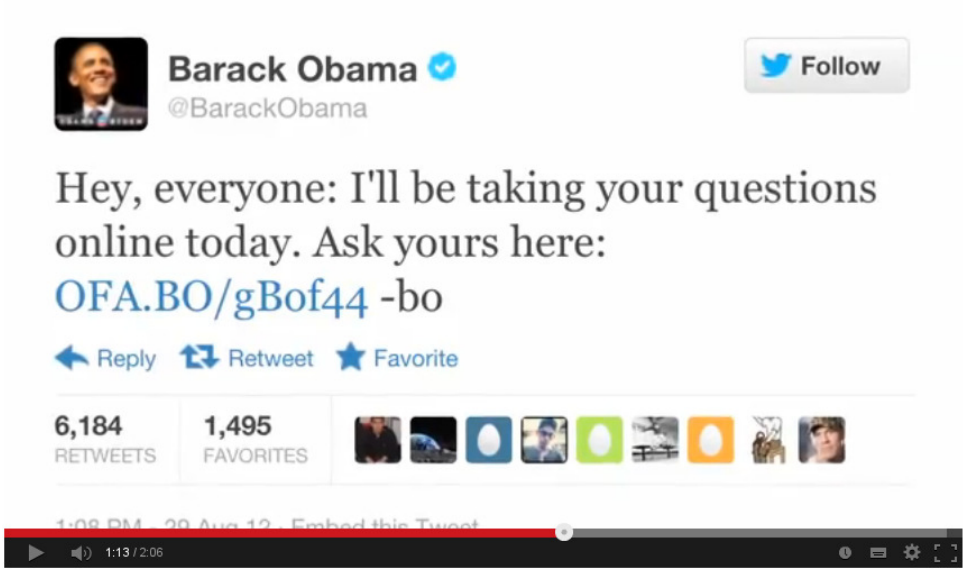
AWS Customer Success Story: reddit

reddit on AWS - Customer Success Story



reddit on AWS - Customer Success Story

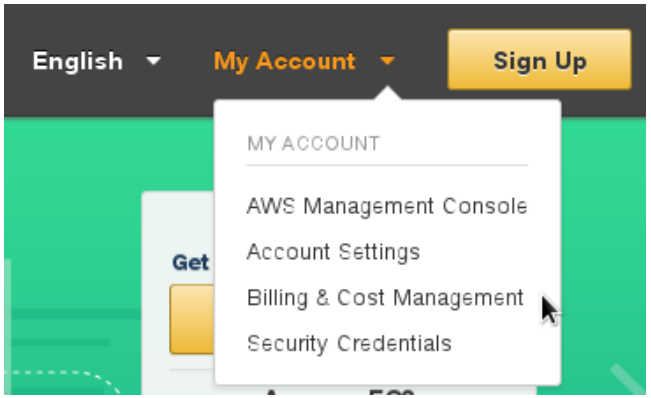
- 2012: reddit has 4 billion page views per month
  - Scalable infrastructure based of AWS
- Server capacity was doubled in minutes for President Obama's live Q&A session in 2012

`http://www.youtube.com/watch?v=BPMNB29zDvk`
Update (May 2018): The video is not online any more. . .

AWS – Check your Account Activity !!!

State: October 2016

- Please regularly check their user account!
  - Login at the AWS page and check the **Billing & Cost Management** page
- Running lots of instances all the time quickly melts together your credit
  - If the credit is spend and resources are still consumed, the credit card will be charged
    - The account holder is responsible for resulting costs
  - You can specify limits and alerts $\Longrightarrow$ do it!



Amazon Elastic Compute Cloud (EC2)

- Users can create, use and control virtual server instances in Amazons data centers
  - Supported operating systems:
    - **Linux**: Amazon Linux, Debian, Ubuntu, SuSE, OpenSuSE, Kali, RedHat Enterprise, CentOS, Mint, Gentoo, Fedora, RancherOS, Alpine,...
    - **Windows Server**: 2003/2008/2012/2016/2019
    - **BSD**: FreeBSD, NetBSD (†), MidnightBSD
    - **Solaris**: OpenSolaris (†)
    - **MacOS X** `https://aws.amazon.com/de/about-aws/whats-new/2020/11/announcing-amazon-ec2-mac-instances-for-macos/`
- Virtual servers are created from Amazon Machine Images (AMI)
  - These are like a blueprint to be used when creating new virtual servers
  - Amazon provides prebuilt images
  - Besides Amazon, many third-party vendors, such as IBM, Oracle and SAP, provide AMIs including proprietary software packages
  - End users as well can create their own images for later reuse
    - End users can publish their AMIs and put them on the market using a product ID (paid instances)

EC2 Terminology

State: October 2016

- EC2 provides 11 sites (**regions**) with resources:
  - Virginia, California, Oregon, Ireland, Frankfurt, Singapore, Sydney, Tokyo, Seoul, Mumbai, Sao Paulo
- Each region contains **availability zones**
  - Each availability zone is a cluster

Region	Availability Zones
Virgina	us-east-1a, us-east-1b, us-east-1c, us-east-1d, us-east-1e
California	us-west-1a, us-west-1b, us-west-1c
Oregon	us-west-2a, us-west-2b, us-west-2c
Ireland	eu-west-1a, eu-west-1b, eu-west-1c
Frankfurt	eu-central-1a, eu-central-1b
Singapore	ap-southeast-1a, ap-southeast-1b
Sydney	ap-southeast-2a, ap-southeast-2b, ap-southeast-2c
Tokyo	ap-northeast-1a, ap-northeast-1b, ap-northeast-1c
Seoul	ap-northeast-2a, ap-northeast-2c
Mumbai	ap-south-1a, ap-south-1b
Sao Paulo	sa-east-1a, sa-east-1b, sa-east-1c

Update June 2019: The list of availability zones did grow: Missing in this slide are Oregon, Canada, Paris, Osaka, Stockholm and Hong Kong

EC2 Instance Types

State: May 2018

Sicher | https://www.ec2instances.info/?region=eu-central-1

Forschugnsförder | MPI | HP MicroServer G | Raspberry Pi | Diverses | Escrima | Haus | Cloud | LaTeX

Region: EU (Frankfurt) | Cost: Hourly | Reserved: 1-year - No Upfront | Columns | Compare Selected | Clear Filters | CSV

Filter: Min Memory (GiB): 0 Min vCPUs: 0 Min Storage (GiB): 0 Search:

Name	API Name	Memory	vCPUs	Instance Storage	Network Performance	Linux On Demand cost	Linux Reserved cost	Windows On Demand cost	Windows Reserved cost
M1 General Purpose Small	m1.small	1.7 GiB	1 vCPUs	160 GiB HDD + 900MB swap	Low	unavailable	unavailable	unavailable	unavailable
M1 General Purpose Medium	m1.medium	3.75 GiB	1 vCPUs	410 GiB HDD	Moderate	unavailable	unavailable	unavailable	unavailable

• • •

T1 Micro	t1.micro	0.613 GiB	1 vCPUs	EBS only	Very Low	unavailable	unavailable	unavailable	unavailable
T2 Nano	t2.nano	0.5 GiB	1 vCPUs for a 1h 12m burst	EBS only	Low	$0.006700 hourly	$0.005000 hourly	$0.009000 hourly	$0.007000 hourly
T2 Micro	t2.micro	1.0 GiB	1 vCPUs for a 2h 24m burst	EBS only	Low to Moderate	$0.013400 hourly	$0.010000 hourly	$0.018000 hourly	$0.014000 hourly
T2 Small	t2.small	2.0 GiB	1 vCPUs for a 4h 48m burst	EBS only	Low to Moderate	$0.026800 hourly	$0.019000 hourly	$0.036000 hourly	$0.028000 hourly
T2 Medium	t2.medium	4.0 GiB	2 vCPUs for a 4h 48m burst	EBS only	Low to Moderate	$0.053600 hourly	$0.038000 hourly	$0.071600 hourly	$0.056000 hourly
T2 Large	t2.large	8.0 GiB	2 vCPUs for a 7h 12m burst	EBS only	Low to Moderate	$0.107200 hourly	$0.076000 hourly	$0.135200 hourly	$0.104000 hourly
T2 Extra Large	t2.xlarge	16.0 GiB	4 vCPUs for a 5h 24m burst	EBS only	Moderate	$0.214400 hourly	$0.153000 hourly	$0.255400 hourly	$0.194000 hourly
T2 Double Extra Large	t2.2xlarge	32.0 GiB	8 vCPUs for a 4h 3m burst	EBS only	Moderate	$0.428800 hourly	$0.306000 hourly	$0.490800 hourly	$0.368000 hourly
M5 General Purpose Large	m5.large	8.0 GiB	2 vCPUs	EBS only	High	$0.115000 hourly	$0.082000 hourly	$0.207000 hourly	$0.174000 hourly
M5 General Purpose Extra Large	m5.xlarge	16.0 GiB	4 vCPUs	EBS only	High	$0.230000 hourly	$0.164000 hourly	$0.414000 hourly	$0.348000 hourly
M5 General Purpose Double Extra Large	m5.2xlarge	32.0 GiB	8 vCPUs	EBS only	High	$0.460000 hourly	$0.328000 hourly	$0.828000 hourly	$0.696000 hourly
M5 General Purpose Quadruple Extra Large	m5.4xlarge	64.0 GiB	16 vCPUs	EBS only	High	$0.920000 hourly	$0.655000 hourly	$1.656000 hourly	$1.391000 hourly

• • •

I3 High I/O Large	i3.large	15.25 GiB	2 vCPUs	475 GiB NVMe SSD	Up to 10 Gigabit	$0.186000 hourly	$0.126000 hourly	$0.278000 hourly	$0.218000 hourly
I3 High I/O Extra Large	i3.xlarge	30.5 GiB	4 vCPUs	950 GiB NVMe SSD	Up to 10 Gigabit	$0.372000 hourly	$0.252000 hourly	$0.556000 hourly	$0.436000 hourly
I3 High I/O Double Extra Large	i3.2xlarge	61.0 GiB	8 vCPUs	1900 GiB NVMe SSD	Up to 10 Gigabit	$0.744000 hourly	$0.504000 hourly	$1.112000 hourly	$0.872000 hourly
I3 High I/O Quadruple Extra Large	i3.4xlarge	122.0 GiB	16 vCPUs	3800 GiB (2 * 1900 GiB NVMe SSD)	Up to 10 Gigabit	$1.488000 hourly	$1.008000 hourly	$2.224000 hourly	$1.744000 hourly
I3 High I/O Eight Extra Large	i3.8xlarge	244.0 GiB	32 vCPUs	7600 GiB (4 * 1900 GiB NVMe SSD)	10 Gigabit	$2.976000 hourly	$2.016000 hourly	$4.448000 hourly	$3.488000 hourly
I3 High I/O 16xlarge	i3.16xlarge	488.0 GiB	64 vCPUs	15200 GiB (8 * 1900 GiB NVMe SSD)	25 Gigabit	$5.952000 hourly	$4.032000 hourly	$8.896000 hourly	$6.976000 hourly

EC2 - Required Steps to work with the Service (1/2)

- The user needs a **key pair** to authenticate at its instances
  - Login without password (public key method)
  - Public keys are stored inside the instances
  - Private keys are stored on the users client
  - A new key pair can be created or an existing key pair can be used
- User decides, which ports must be open
  - The fewer ports are opened, the better is the security
  - The user creates for the instance a **security group**, in which the required ports are opened
    - The user can also use an existing security group
- User decides which **operating system (AMI)** and which **instance type** meets his requirements best
- User decides which **region** and **availability zone** he prefers
- The instance is created according to the decisions made before

EC2 - Required Steps to work with the Service (2/2)

- After the virtual server has been created, a **public** and a **private IP address** is dynamically assigned to the instance
  - With the public address the instance can be accessed from the Internet
  - With the private address it can be accessed by other instances inside the Amazon cloud
- Private and public addresses are assigned dynamically each time a new instance is created
  - Dynamically assigned addresses are not suited for the long-term operation of a server
  - Servers need to be restarted from time to time
  - Solution: **elastic IP addresses**
- Users can assign Elastic IPs – once reserved – their own server instances again and again

Persistence of Data in EC2

- At the termination of an instance all changes are lost
- Valuable data must be stored outside the instance
  - Large amounts of structured data can be stored in S3
  - EBS provides block-based storage

EC2 Pricing

$\Longrightarrow$ `https://aws.amazon.com/ec2/pricing/`

- On-Demand instances
- Spot instances
  - Instances have flexible start and end times
- Reserved instances
  - Customers can rent EC2 instances over a 1 or 3 year term to reduce their total costs
- Dedicated Hosts

EC2 Pricing: Internet Data Transfer

State: November 2017

- The import of data to AWS resources is for free
- If data is copied between AWS resources it is for free if these resources are inside the same availability zone

Data Transfer OUT From Amazon EC2 To Internet

First 1 GB / month	$0.000 per GB
Up to 10 TB / month	$0.090 per GB
Next 40 TB / month	$0.085 per GB
Next 100 TB / month	$0.070 per GB
Next 350 TB / month	$0.050 per GB
Next 524 TB / month	Contact Us
Next 4 PB / month	Contact Us
Greater than 5 PB / month	Contact Us

EC2 Pricing: Elastic IP und Load Balancing

State: November 2017

- Elastic IP adresses

Region: EU (Frankfurt)

- $0.00 for one Elastic IP address associated with a running instance
- $0.005 per additional Elastic IP address associated with a running instance per hour on a pro rata basis
- $0.005 per Elastic IP address not associated with a running instance per hour on a pro rata basis
- $0.00 per Elastic IP address remap for the first 100 remaps per month
- $0.10 per Elastic IP address remap for additional remaps over 100 per month

- Elastic Load Balancers

EU (Frankfurt)

$0.0270 per Application Load Balancer-hour (or partial hour)

$0.008 per LCU-hour (or partial hour)

EC2 Pricing: CloudWatch

State: November 2017

Region: EU (Frankfurt)

Amazon CloudWatch Dashboards

- $3.00 per dashboard per month

Detailed Monitoring for Amazon EC2 Instances

- $2.10 down to $0.14 per instance per month at 1-minute frequency******

Amazon CloudWatch Custom Metrics

- $0.30 per metric per month for the first 10,000 metrics
- $0.10 per metric per month for the next 240,000 metrics
- $0.05 per metric per month for the next 750,000 metrics
- $0.02 per metric per month for metrics over 1,000,000

Amazon CloudWatch Alarms

- $0.10 per alarm per month
- $0.30 per high-resolution alarm per month

Amazon CloudWatch API Requests

- $0.01 per 1,000 GetMetricStatistics, ListMetrics, PutMetricData, GetDashboard, ListDashboards, PutDashboard and DeleteDashboards requests

Amazon CloudWatch Logs*

- $0.63 per GB ingested**
- $0.0324 per GB archived per month***
- Data Transfer OUT from CloudWatch Logs is priced equivalent to the "Data Transfer OUT from Amazon EC2 To" and "Data Transfer OUT from Amazon EC2 to Internet" tables on the EC2 Pricing Page.

Amazon CloudWatch Events - Custom Events****

- $1.00 per million custom events generated*****

AWS Simple Monthly Calculator

amazon web services™ SIMPLE MONTHLY CALCULATOR

NEW! - Effective July 1st 2011, Free Inbound Data Transfer, Lower Outbound Data Transfer and New Tiers and Amazon EC2 running Red Hat Enterprise Linux

FREE USAGE TIER: New Customers get free usage tier for first 12 months

Language: English

Services | Estimate of your Monthly Bill ($ 186.28)

Choose region: US-East (Northern Vir

Inbound Data Transfer is Free and Outbound Data Transfer is 1 GB free per region per month

Amazon EC2
Amazon S3
Amazon SQS
Amazon SES
Amazon SNS
Amazon Route 53
Amazon CloudFront
Amazon RDS
Amazon CloudWatch
Amazon SimpleDB
Amazon VPC
Amazon Elastic MapReduce
AWS Import Export
AWS Premium Support

Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides resizable compute capacity in the cloud. It is designed to make web-scale computing easier for developers. Amazon Elastic Block Store (EBS) provides persistent storage to Amazon EC2 instances.

Add To Bill | Clear Form

Compute: Amazon EC2 On-Demand Instances:

	Instances	Description	Operating System	Instance Type	Usage	Detailed Monitoring
	3	Web-Server	Linux/OpenSolaris	Micro	100 Hours/Month	✓
	2	Database	Linux/OpenSolaris	Micro	100 Hours/Month	✓

Compute: Amazon EC2 Reserved Instances:

Storage: Amazon EBS Volumes:

	Volumes	Description	Provisioned Storage	Average IOPS in volume	Snapshot Storage*
	5	Images	10 GB-month	50	25 GB-month of Storage
	10	Data	50 GB-month	10	0 GB-month of Storage

Elastic IP:

Number of Elastic IPs: 1

Elastic IP Non-attached Time: 0 Hours/Month

Number of Elastic IP Remaps: 5 Times/Month

Amazon EC2 Data Transfer:

Data Transfer In: 5 GB/Month

Data Transfer Out: 60 GB/Month

Regional Data Transfer: 10 GB/Month

Public IP/Elastic IP Data Transfer: 35 GB/Month

Common Customer Samples

Free Website on AWS
AWS Elastic Beanstalk Default
Marketing Web Site
Web Application
Media Application
HPC Cluster
Disaster Recovery and Backup
European Web Application

Reset All

Amazon Elastic Block Store (EBS)

- EBS is a part of EC2
- Inside each availability zone, the users can create EBS volumes
  - Size: Up to 16 TB
- An EBS volume implements persistent storage
- A new EBS volume behaves just like an unformatted block device
- an EBS volume can only be mounted to one single instance
  - Volume and instance must be located in the same availability zone
- A volume can contain any filesystem
- The way of using a volume is equal to using an USB flash drive
- Note: EBS is storage for people and S3 is storage for applications
- Volume snapshots can be created (and stored in S3) any time

Pricing of EBS

State: December 2020

Region: Europe (Frankfurt)

Amazon EBS Volumes

With Amazon EBS, you pay only for what you use. The pricing for Amazon EBS volumes is listed below

Volume Type	Price
General Purpose SSD (gp3) - Storage	$0.0952/GB-month
General Purpose SSD (gp3) - IOPS	3,000 IOPS free and $0.006/provisioned IOPS-month over 3,000
General Purpose SSD (gp3) - Throughput	125 MB/s free and $0.0476/provisioned MB/s-month over 125
General Purpose SSD (gp2) Volumes	$0.119 per GB-month of provisioned storage
Provisioned IOPS SSD (io2) - Storage	$0.149/GB-month
Provisioned IOPS SSD (io2) - IOPS	$0.078/provisioned IOPS-month up to 32,000 IOPS
	$0.055/provisioned IOPS-month from 32,001 to 64,000 IOPS
	$0.038/provisioned IOPS-month for greater than 64,000 IOPS†
Provisioned IOPS SSD (io1) Volumes	$0.149 per GB-month of provisioned storage AND $0.078 per provisioned IOPS-month
Throughput Optimized HDD (st1) Volumes	$0.054 per GB-month of provisioned storage
Cold HDD (sc1) Volumes	$0.018 per GB-month of provisioned storage

AWS Management Console (EBS Volumes)

https://console.aws.amazon.com/ec2/home?region=eu-west-1#s=Volumes

Services | Edit | Christian Baun | Ireland | Help

EC2 Dashboard
Events
Tags

INSTANCES
Instances
Spot Requests
Reserved Instances

IMAGES
AMIs
Bundle Tasks

ELASTIC BLOCK STORE
Volumes
Snapshots

NETWORK & SECURITY
Security Groups
Elastic IPs
Placement Groups
Load Balancers
Key Pairs
Network Interfaces

Create Volume | Actions

Viewing: All Volumes | Search | 1 to 5 of 5 Items

Name	Volume ID	Capacity	Volume Type	Snapshot	Created	Zone	State	Alarm Status	Attachment Information
empty	vol-15003940	100 GiB	standard	--	2013-09-27T13:36:11	eu-west-1c	creating	none	
empty	vol-c0117995	8 GiB	standard	snap-6c4e2747	2013-09-27T13:31:51	eu-west-1b	in-use	none	i-cd95ed82:/dev/sda1 (attac
empty	vol-31127a64	200 GiB	standard	--	2013-09-27T13:35:10	eu-west-1b	available	none	
empty	vol-908552c5	8 GiB	standard	snap-d8adacf2	2013-09-27T13:13:15	eu-west-1a	in-use	none	i-1308e65c:/dev/sda1 (attac
empty	vol-ad8354f8	8 GiB	standard	snap-b7aa979c	2013-09-27T13:31:17	eu-west-1a	in-use	none	i-883284c4:/dev/sda1 (attac

1 Volume selected

Volume: vol-15003940

Details | Status Checks | Monitoring | Tags

Volume ID:	vol-15003940	Alarm Status:	none
Capacity:	100 GiB	Snapshot:	
Created:	2013-09-27 15:36 GMT+0200	Zone:	eu-west-1c

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Feedback

Amazon Elastic Load Balancing (ELB)

State: November 2017

- ELB is a part of EC2
- Users can create elastic load balancers inside each availability zone
- The user assigns each of its load balancers a pool of instances
- An elastic load balancer automatically distributes incoming requests to the EC2 instances of its pool
- A ELB identified failed instances inside its pool and distributes the requests automatically to the working instances of the pool

EU (Frankfurt)

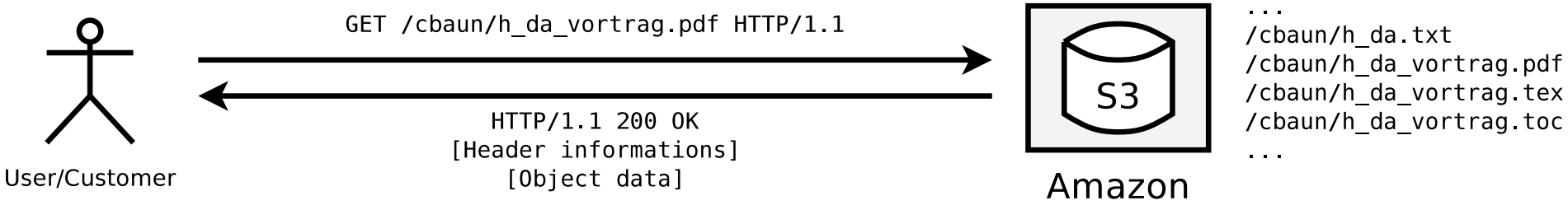
$0.0270 per Application Load Balancer-hour (or partial hour)
$0.008 per LCU-hour (or partial hour)

Amazon Simple Storage Service – S3 (1/2)

- Data is stored as **(web-)objects**
- No files or folders exist, but only **objects**
  - The size of each object can be 1 Byte to 5 TB
  - For each object, 2 KB metadata is stored
  - Each user can store an unlimited number of objects
- Each object is assigned to a **bucket**
  - Buckets have unique names and contain no other buckets
    $\Longrightarrow$ Directories are impossible
  - The name of an object is also called **key**

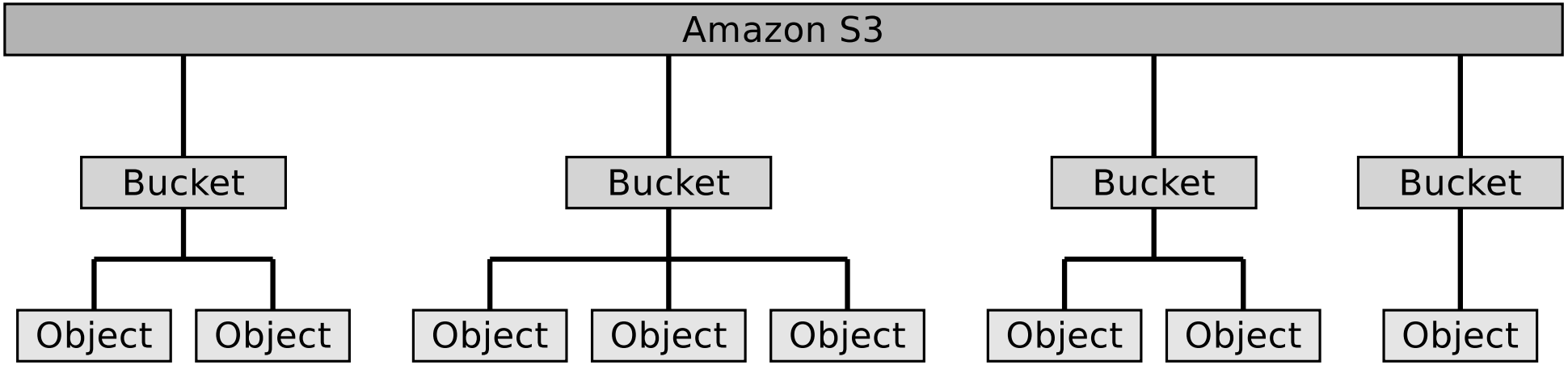
Amazon Simple Storage Service – S3 (2/2)

- Objects are accessible online
  - `http://s3.amazonaws.com/bucket/object`
  - `http://bucket.s3.amazonaws.com/object`
- Access to buckets and objects is done via REST or SOAP (deprecated)
  - Objects can also be downloaded via BitTorrent



- Users can specify for all their objects and buckets the access privileges
  - Access Control List (ACL)

Flat Name Space of S3



- S3 does not support folders
  - Only buckets and objects can be created
  - But folders can be simulated
    - S3Fox, Google and KOALA simulate folder by attaching `_$folder$` at the end of an objects key
    - Objects, which are assigned to such a *folder*, have a key with the naming scheme `folder/subfolder/object`

S3 Pricing (Storage)

November 2017

Region: EU (Frankfurt)

	Standard Storage	Standard - Infrequent Access Storage †	Glacier Storage
First 50 TB / month	$0.0245 per GB	$0.0135 per GB	$0.0045 per GB
Next 450 TB / month	$0.0235 per GB	$0.0135 per GB	$0.0045 per GB
Over 500 TB / month	$0.0225 per GB	$0.0135 per GB	$0.0045 per GB

- **Standard Storage** is designed for 99.999999999% durability and 99.99% availability of objects over a given year
- **Reduced Redundancy Storage** (RRS) is designed to provide 99.99% durability and 99.99% availability of objects over a given year
  - This durability level corresponds to an average annual expected loss of 0.01% of the objects

S3 Pricing (Storage)

Region: EU (Frankfurt)

	Standard Storage	Standard - Infrequent Access Storage †	Glacier Storage
First 50 TB / month	$0.0245 per GB	$0.0135 per GB	$0.0045 per GB
Next 450 TB / month	$0.0235 per GB	$0.0135 per GB	$0.0045 per GB
Over 500 TB / month	$0.0225 per GB	$0.0135 per GB	$0.0045 per GB

- **Glacier** is designed for 99.999999999% durability and 99.99% availability of objects over a given year
  - Extremely low-cost storage service option for data archival
  - Stores data for as little as $0,0045 (in EU-Frankfurt) per GB per month
  - Optimized for data that is infrequently accessed and for which retrieval times of several hours are suitable

S3 Pricing (Requests)

November 2017

Request Pricing

Amazon S3 request costs are based on the request type, and are charged on the quantity of requests or the volume of data retrieved as listed in the table below.

Region: EU (Frankfurt)

	Pricing
For Requests Not Otherwise Specified Below	
PUT, COPY, POST, or LIST Requests	$0.0054 per 1,000 requests
GET and all other Requests	$0.0043 per 10,000 requests
Delete Requests	Free †
For Standard – Infrequent Access Requests	
PUT, COPY, or POST Requests	$0.01 per 1,000 requests
GET and all other Requests	$0.01 per 10,000 requests
Lifecycle Transition Requests into Standard – Infrequent Access	$0.01 per 1,000 requests
Data Retrievals	$0.01 per GB

S3 Pricing (Data Transfer)

November 2017

Data Transfer Pricing

The pricing below is based on data transferred "in" to and "out" of Amazon S3 (over the public Internet). AWS Direct Connect pricing can be found here. Transfers between S3 buckets or from S3 to any service(s) within the same region are free.

Region: EU (Frankfurt)

	Pricing
Data Transfer IN To Amazon S3	
All data transfer in	$0.000 per GB
Data Transfer OUT From Amazon S3 To	
Another AWS Region	$0.020 per GB
Amazon CloudFront	$0.000 per GB
Data Transfer OUT From Amazon S3 To Internet	
First 1 GB / month	$0.000 per GB
Up to 10 TB / month	$0.090 per GB
Next 40 TB / month	$0.085 per GB
Next 100 TB / month	$0.070 per GB
Next 350 TB / month	$0.050 per GB
Next 524 TB / month	Contact Us
Next 4 PB / month	Contact Us
Greater than 5 PB / month	Contact Us

AWS Import/Export Disk

- Helps to transfer large amounts of data into or out from the cloud

Available Internet Connection	Theoretical Min. Number of Days to Transfer 1TB at 80% Network Utilization	When to Consider AWS Import/Export Disk?
T1 (1.544Mbps)	82 days	100GB or more
10Mbps	13 days	600GB or more
T3 (44.736Mbps)	3 days	2TB or more
100Mbps	1 to 2 days	5TB or more
1000Mbps	Less than 1 day	60TB or more

- The customers sends a storage device (HDD) to Amazon
- The device concent is copied by Amazon employees into a S3 bucket
  - File systems: NTFS, ext2, ext3 and FAT32 with a mximum size of 16 TB
- Pricing per storage device: $80
- Pricing for the transfer at Amazon site per hour: $2.49
- `https://aws.amazon.com/snowball/disk/`

AWS Import/Export Snowball

Image Source: Amazon

- Amazon offers the Snowball Appliances for importing data into S3
- `https://aws.amazon.com/snowball/`

- Capacity: 50 TB or 80 TB
- 10 Gbit Ethernet interface
- AES 256-bit encryption
- Price: $200 or $250 per device for 10 days
- Each additional day costs $15

Similar offering – Cloud Mass Data Migration

Image Source: IBM

- IBM offers a similar import service for its own IaaS offerings
- **Cloud Mass Data Migration**
- Capacity: 120 TB
- AES 256-bit encryption
- RAID-6
- 10 Gbit Ethernet interface
- Price: $395 per device for 10 days
- Each additional day: +$30

- Customers can migrate 120 TB of data in seven days, with round-trip use of UPS Next Day Air included in the overall service

AWS Snowmobile

Image Source: AWS

- Helps to transfer very large amounts of data into the cloud
  - Customers can transfer up to 100 PB per Snowmobile
    - Data is copied by Amazon employees into a S3 bucket or into Glacier
- Snowmobile is a 45-foot long shipping container, pulled by a truck
  - Includes security personnel, GPS tracking, alarm monitoring, 24/7 video surveillance, and an optional escort security vehicle while in transit
  - All data is encrypted with 256-bit encryption keys
- `https://aws.amazon.com/snowmobile/`

Using S3 with s3cmd

- s3cmd is a simple to use command line tool for uploading, retrieving and managing data in Amazon S3
  - http://s3tools.org/s3cmd

Configure login information	`s3cmd -configure`
List own buckets	`s3cmd ls`
Create bucket	`s3cmd mb s3://Bucket`
Upload object	`s3cmd put LocalFile s3://Bucket/DistantObjekt`
List content of a bucket	`s3cmd ls s3://Bucket`
Download object	`s3cmd get s3://Bucket/DistantObjekt LocalFile`
Erase objekt	`s3cmd del s3://Bucket/DistantObjekt`
Erase (empty) bucket	`s3cmd rb s3://Bucket`

S3 Alternatives: Google Cloud Storage

https://cloud.google.com/storage/

- Storage service for web objects
  - Interface is compatible with S3
  - Functionality is (almost) identical to S3
- Objects are accessible online
  - `https://storage.googleapis.com/bucket/object`
  - `https://bucket.storage.googleapis.com/object`
- Access to buckets and objects is done via REST or SOAP
- Users can specify for all their objects and buckets the access privileges
  - Access Control List (ACL)
- Provides the command line tool GSutil and the software service (SaaS) Google Storage Manager
  - GSutil can interact with Google Cloud Storage and S3
    - GSutil is based on the Python library boto

Some further S3-compatible Service Offerings

This list from November 2017 is not complete! Many more S3-compatible service offerings exist

Service Offering	URL/Status
Aruba Object Storage service	`https://www.arubacloud.com`
BetterServers Object Storage	`https://www.betterservers.com`
e24cloud	`https://www.e24cloud.com/en/cloud-features/`
Rackspace Cloud Files	`https://www.rackspace.com/de/cloud/files`
Caringo Cloud Storage	`https://www.caringo.com`
Cloudian	`http://www.cloudian.com`
DreamHost DreamObjects	`https://www.dreamhost.com/cloud/storage/`
Dunkel S3	`https://www.dunkel.de/s3`
S3FOR.ME	`http://www.s3for.me`
Connectria Cloud Storage	It is unclear if this service is still available
HP Helion Public cloud	Defunct since January 2016
Host Europe Cloud Storage	Defunct since end 2014
Nirvanix	Defunct since September 2013

Never forget...

a Cloud Service Providers may modify of service offering (functionality) or even go out of business at any time

Solutions for running Private Cloud Infrastructure Services

- Several free solutions exist run infrastructure services

CloudStack	`http://cloudstack.apache.org`
Eucalyptus	`https://www.eucalyptus.cloud`
Nimbus	`http://www.nimbusproject.org` (†)
OpenNebula	`http://www.opennebula.org`
OpenStack	`http://www.openstack.org`

This is not a complete list!

- These solutions are used mainly for the construction of private clouds
- Some solutions can also be used for the construction of public cloud services

Eucalyptus

- EUCALYPTUS – Elastic Utility Computing Architecture for Linking Your Programs To Useful Systems
- Allows execution and control of virtual instances (Xen or KVM) on different physical resources
- Developed at UC Santa Barbara
  - Further development by Eucalyptus Systems, Inc.
- Interface compatible to AWS
  - EC2 + EBS + ELB + AutoScaling and S3
- Use of poplar AWS-compatible tools is possible:
  - e.g.: S3 Curl, Elasticfox, s3cmd,...
- Free software: GPLv3 (until 11/2017). Now BSD

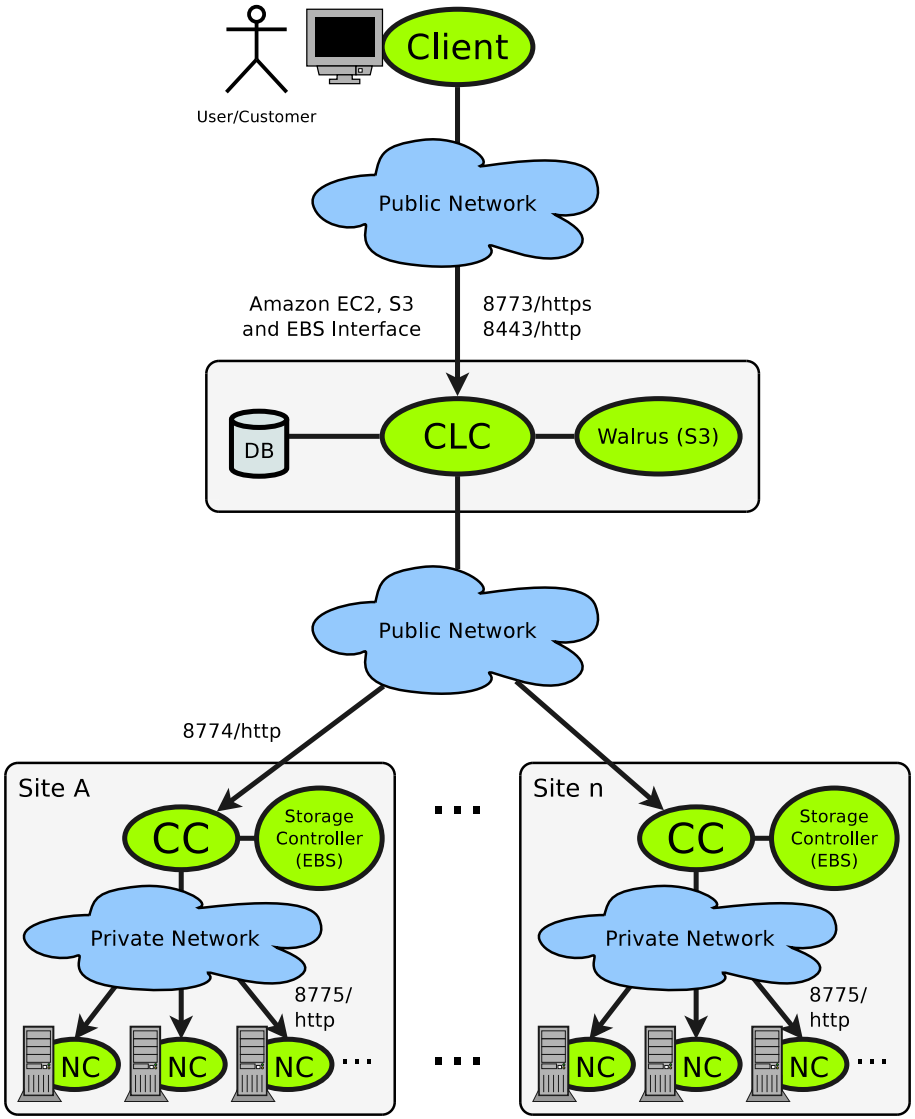
In 2008 + 2009, Eucalytus was a major step forward in establishing an API standard for cloud infrastructure services

Eucalyptus Services

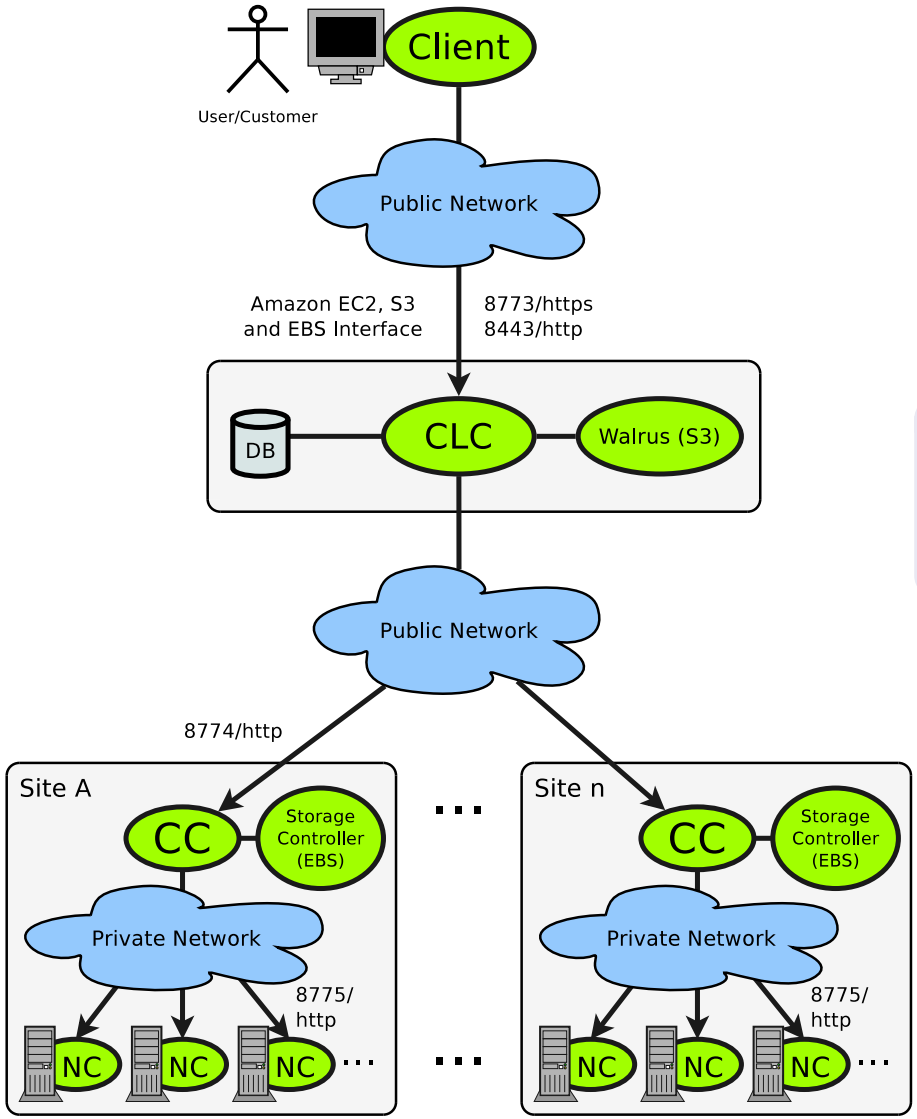
- Eucalyptus consists of several UNIX services
  - Cloud Controller (CLC)
  - Cluster Controller (CC)
  - Node Controller (NC)
  - Walrus
  - Storage Controller (SC)
- The services communicate via web services (SOAP+REST)
- Eucalyptus infrastructures consist of one or more sites

Redundant operation of the services CLC, CC, Storage Controller and Walrus became a feature with Eucalyptus v3.0 in 2011

This feature was removed with v4.2 in 2015



Node Controller (NC)

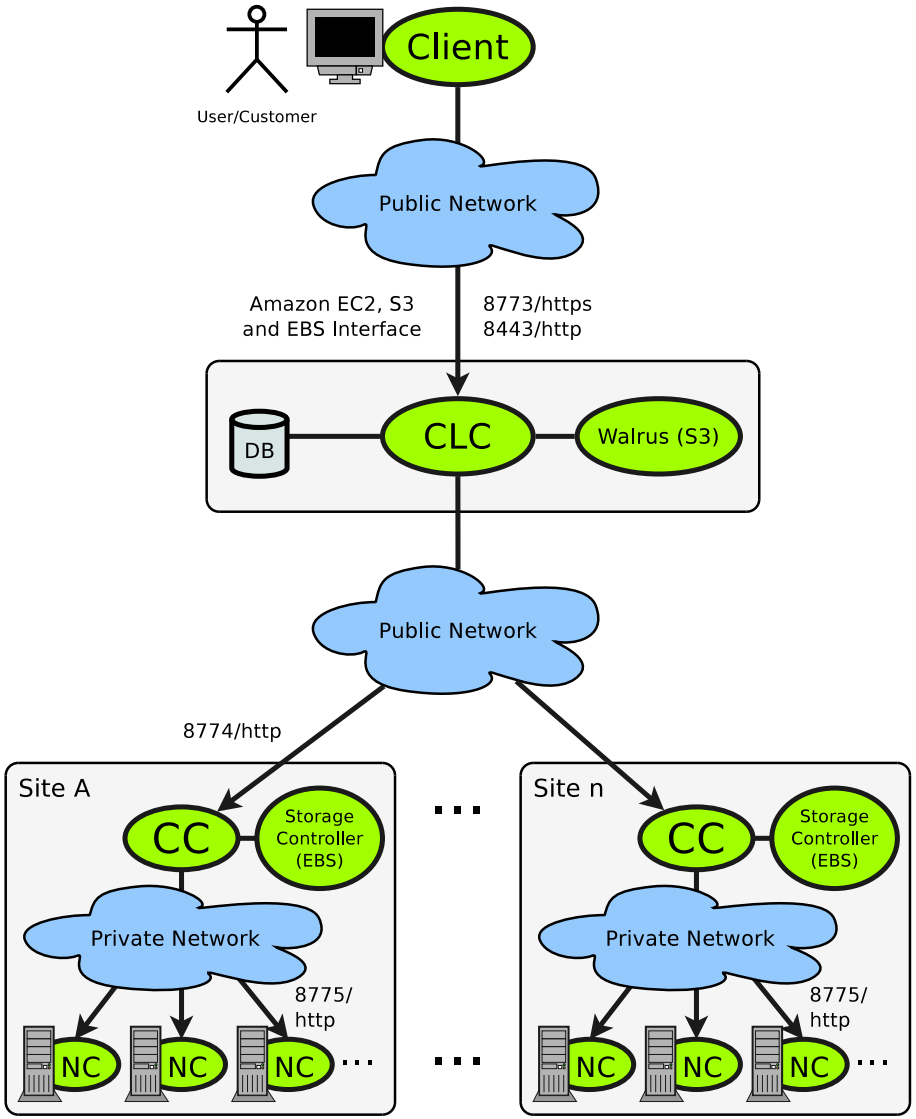


- Runs on every physical node, where instances are planned to run
- Controls the KVM hypervisor

- Xen is not supported any longer since v4.0
- VMware ESX(i) is not supported any longer since v4.1

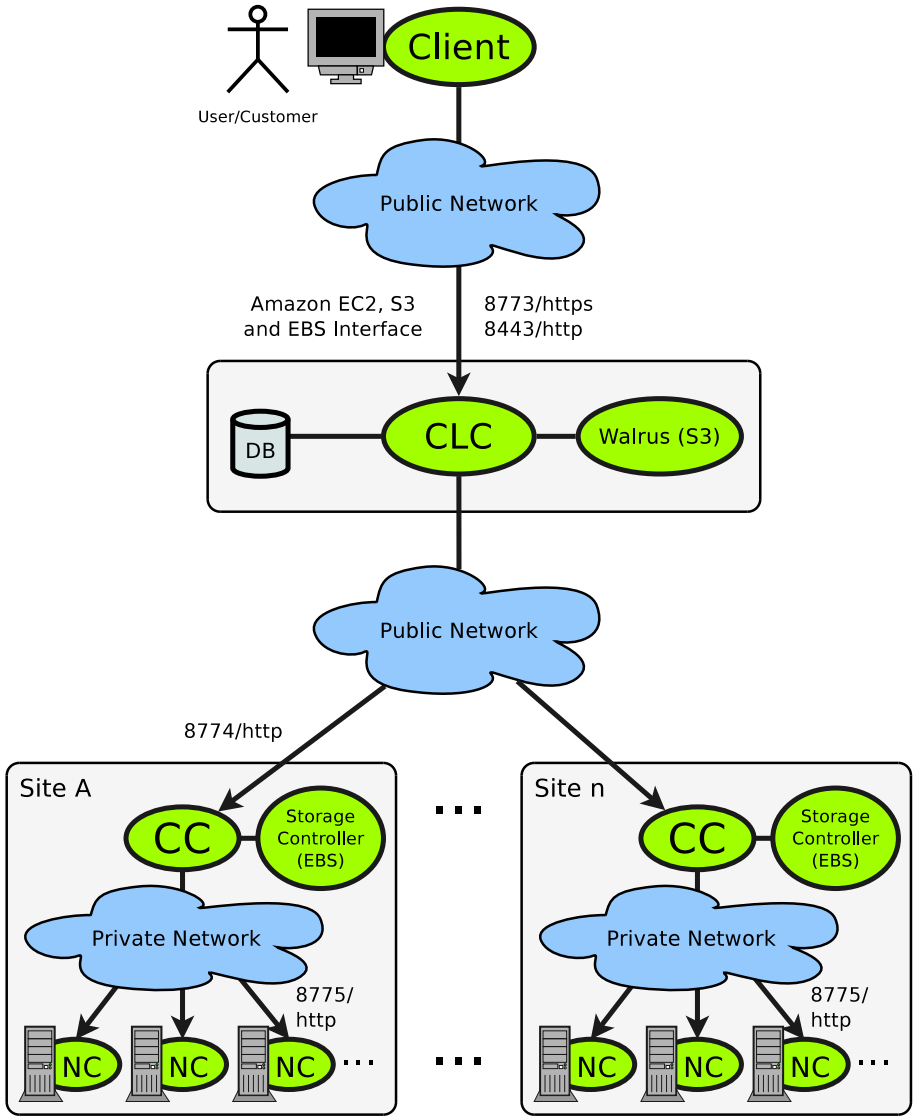
- Each NC transmits information about the utilization of their own resources to the CC of the site
  - Number of virtual processors
  - Free memory
  - Free storage

Cluster Controller (CC)



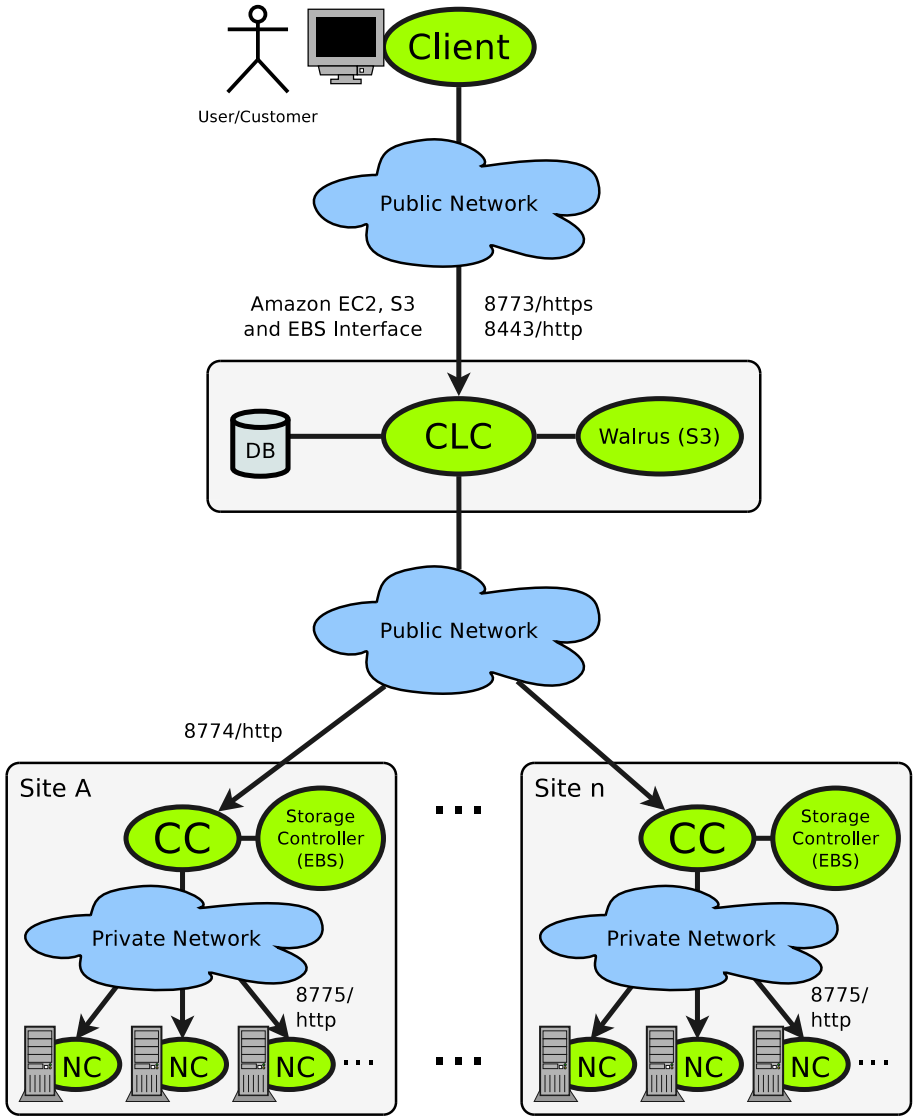
- Exactly a single CC per site is required
- Controls the distribution of the virtual machines to the NCs
- Collects free resource information from the NCs
- In small infrastructures CLC and CC usually run on the same physical server
- In each site, the NCs communicate with the CC via a virtual network (VLAN)
  - The VLAN ensures that all instances within a site share the same subnet

Cloud Controller (CLC)



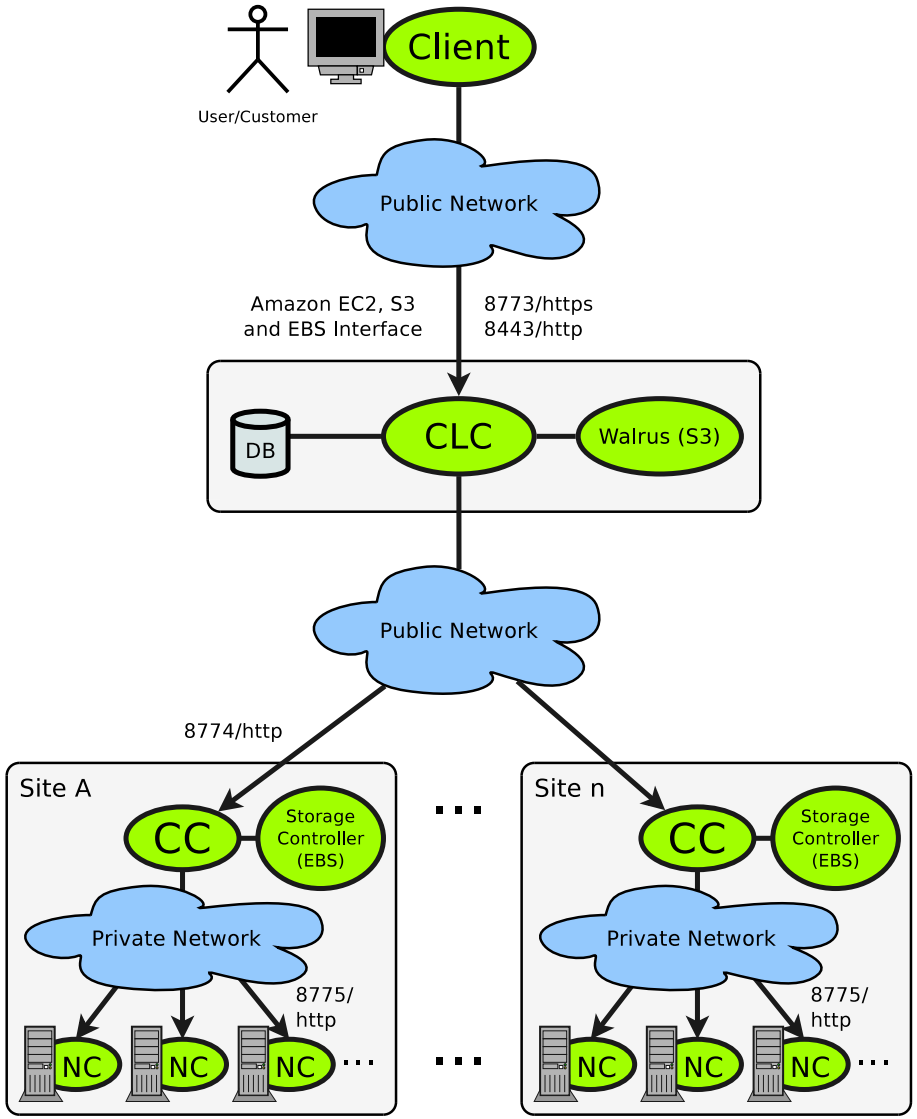
- Exactly a single CLC per Eucalyptus infrastructure is required
- Acts as a meta-scheduler in the cloud infrastructure
- Collects resource information from the CCs
- Runs per default on the same physical server as the storage services Walrus and Storage Controller

Walrus



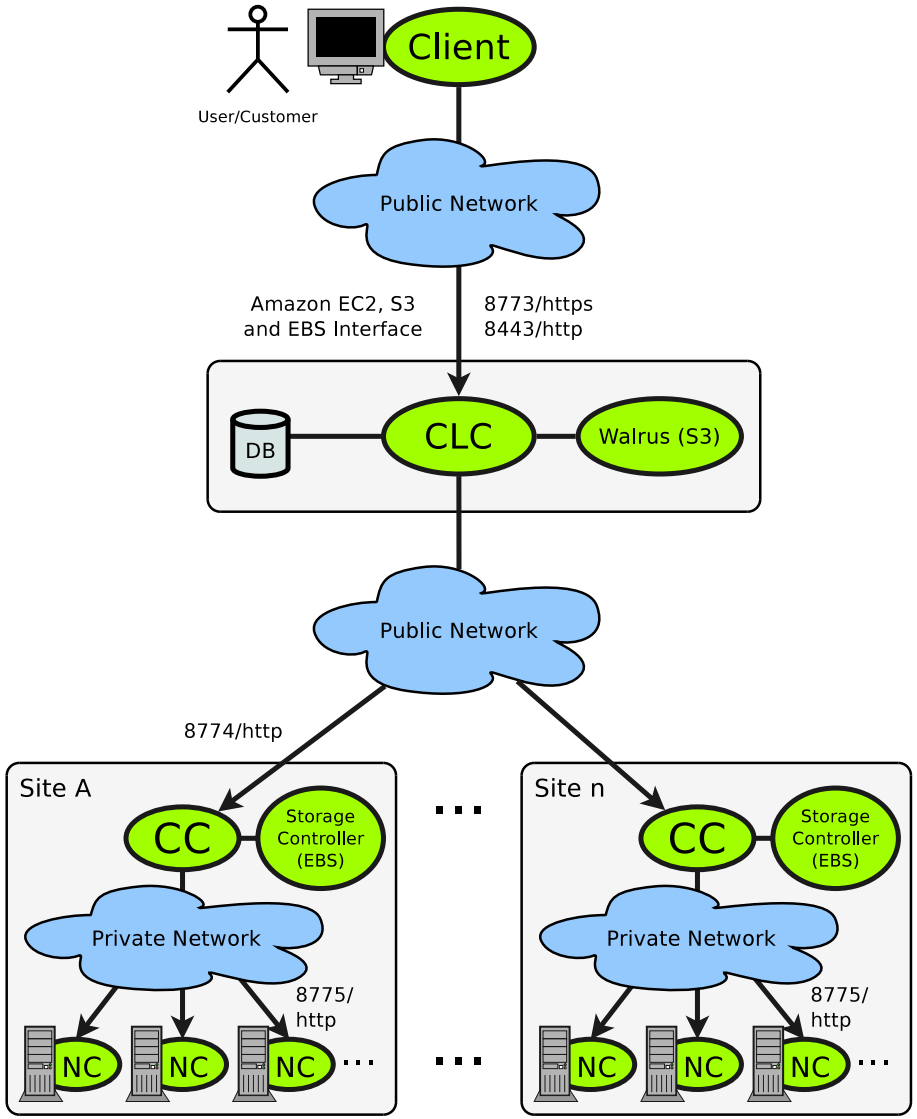
- Storage service, which implements the S3 REST API
- Eucalyptus stores here the images
- Usually runs on the physical server which hosts the CLC/CC
  - Can be outsourced from the CLC since v1.6
- Walrus is not a distributing service
  - Operates only in single-node mode
- In order to improve the read/write performance of the object-based storage, Walrus can be replaced by a Riak Cloud Storage (Cluster)

Storage Controller



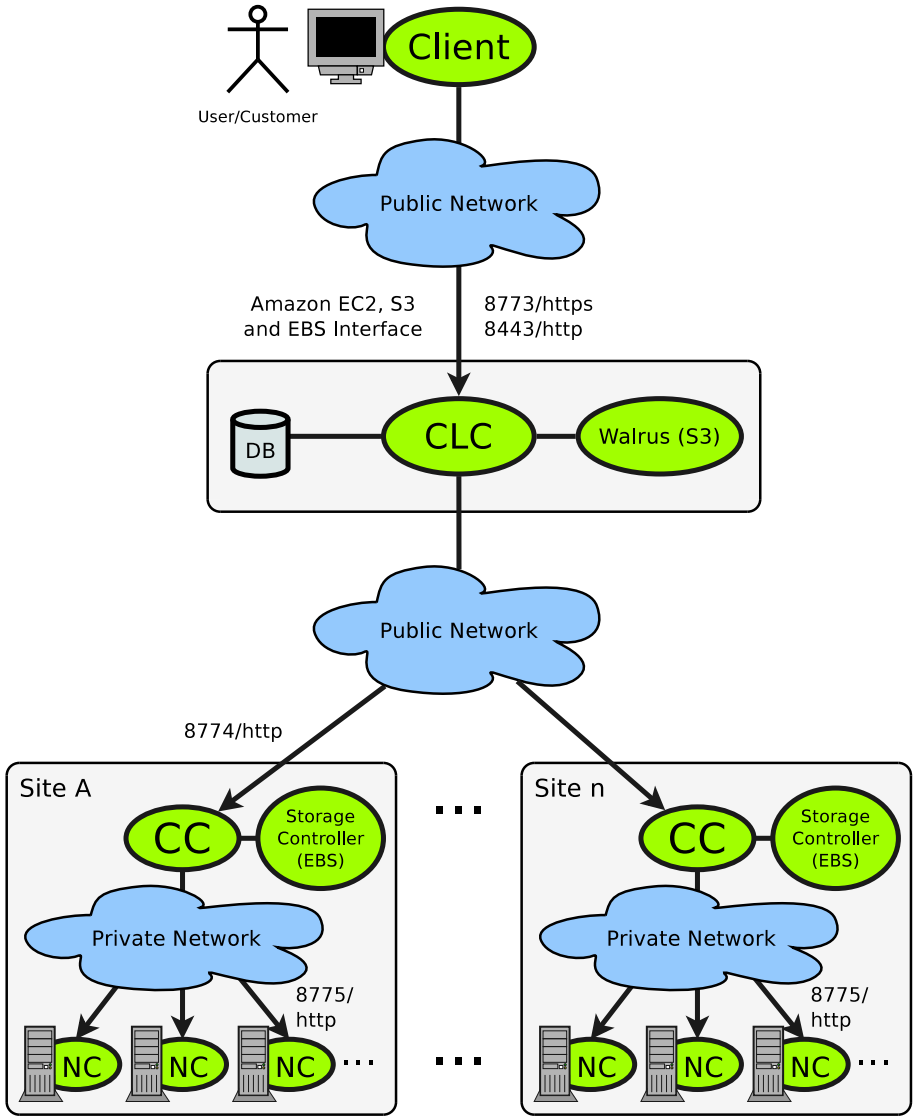
- Storage service, which implements the EBS API
- In infrastructures with only a single site, the Storage Controller usually runs on the physical server which hosts the CLC/CC
  - Can be outsourced from the CLC since v1.6
- If the infrastructure contains multiple sites, each site has its own storage controller

Launch of an Instance in Eucalyptus (1/2)



1. A user or applications, which tries to start instances, provides the CLC these parameters:
   - Image
   - linstance type
   - Number of instances
2. CLC selects a CC with enough free resources in its cluster
3. CC selects in the local cluster one (or more) NC(s), with enough free resources and commands the start of the instance(s)

Launch of an Instance in Eucalyptus (2/2)



4. If the required image is not available on the NC, the NC requests the image from the CLC
5. CLC transmits the image from Walrus via an encrypted transmission via Secure Copy (SCP) to the NC
6. The transmission duration for images from Walrus to the NCs depends of:
   - Network technology used
   - Number of required transmissions
   - Size of the images

Some Facts about Eucalyptus

- The Installation of Eucalyptus is simple when CentOS is used
  - and it is horror when other Linux distributions are used
- Stable operation of an Eucalyptus infrastructure is possible
  - If administrators are willing to invest some time...
  - Single services need to reboot from time to time
  - Commercial support is available
- Extensions and modifications in the source code are difficult
  - Source code of services appears obscure
- Some history...
  - HP acquired Eucalyptus systems in 9/2014
  - 2015: Eucalpytus became a part of HPE, which separated from HP
  - 2017: Eucalpytus became a part of DXC Technology $\Longrightarrow$ † (?!)

A new Hope for Eucalpytus?

- DXC stopped developing the product in late 2017
- AppScale Systems forked the code in 2018 and started supporting the product and continued the development
  $\Longrightarrow$ AppScale ATS
- `https://www.eucalyptus.cloud`
- Latest versions:
  - 5.0 from December 2020
  - 4.4.6 from November 2020
  - 4.4.5 from December 2018
- `https://github.com/corymbia/eucalyptus/`

Eucalyptus Installation (the simple way on a single node)

- Check the installation tutorial `https://docs.eucalyptus.cloud/eucalyptus/4.4.6/index.html#shared/install_section.html`
- Create a virtual machine with CentOS 7.3 minimal
- Execute:

```
bash <(curl -Ls https://eucalyptus.cloud/install)
```

- The script will ask a few questions (e.g. about spare IP addresses)
- Hope the best

Eucalyptus 5

`https://docs.eucalyptus.cloud/eucalyptus/5/install_guide/automated_install/`

- A faststart iso image „Cloud in a Box“ existed until 2015/2016
- The last revision came with Eucalyptus 3.4.2 and CentOS 6
- It was the most simple way to install an Eucalyptus IaaS on a single node or a cluster mode
- It is not available any more

Review of NASA regarding Eucalyptus

NASA drops Ubuntu's Koala food for (real) open source

Open core is not open source: a cautionary tale

By **Cade Metz in San Francisco** • **Get more from this author**

Posted in Software, 20th July 2010 05:09 GMT

Free whitepaper – Hosted apps

NASA is dropping Eucalyptus from its Nebula infrastructure cloud not only because its engineers believe the open source platform can't achieve the sort of scale they require, but also because it isn't entirely open source.

NASA chief technology officer Chris Kemp tells *The Reg* that as his engineers attempted to contribute additional Eucalyptus code to improve its ability to scale, they were unable to do so because some of the platform's code is open and some isn't. Their attempted contributions conflicted with code that was only available in a partially closed version of platform maintained by Eucalyptus Systems Inc., the commercial outfit run by the project's founders.

Instead, Kemp's team built their own compute engine and fabric controller from scratch. The new platform — dubbed Nova — has been open sourced under the Apache 2.0 license and is now part of the OpenStack project announced today by Rackspace.

Source: `http://www.theregister.co.uk/2010/07/20/why_nasa_is_dropping_eucalyptus_from_its_nebula_cloud/`

2011: Ubuntu switches from Eucalpytus to OpenStack

Ubuntu Cloud: OpenStack Wins, Eucalyptus Loses

Joe Panettieri | *Talkin' Cloud* *May 10, 2011*

Stated politely, Canonical is transitioning the Ubuntu Cloud to OpenStack -- an open source cloud standard -- as a foundation technology. Stated bluntly, Ubuntu is de-emphasizing Eucalyptus, another open source cloud standard. The obvious question: Is the open source cloud industry's balance of power shifting from Eucalyptus to OpenStack?

According to an official statement from Canonical:

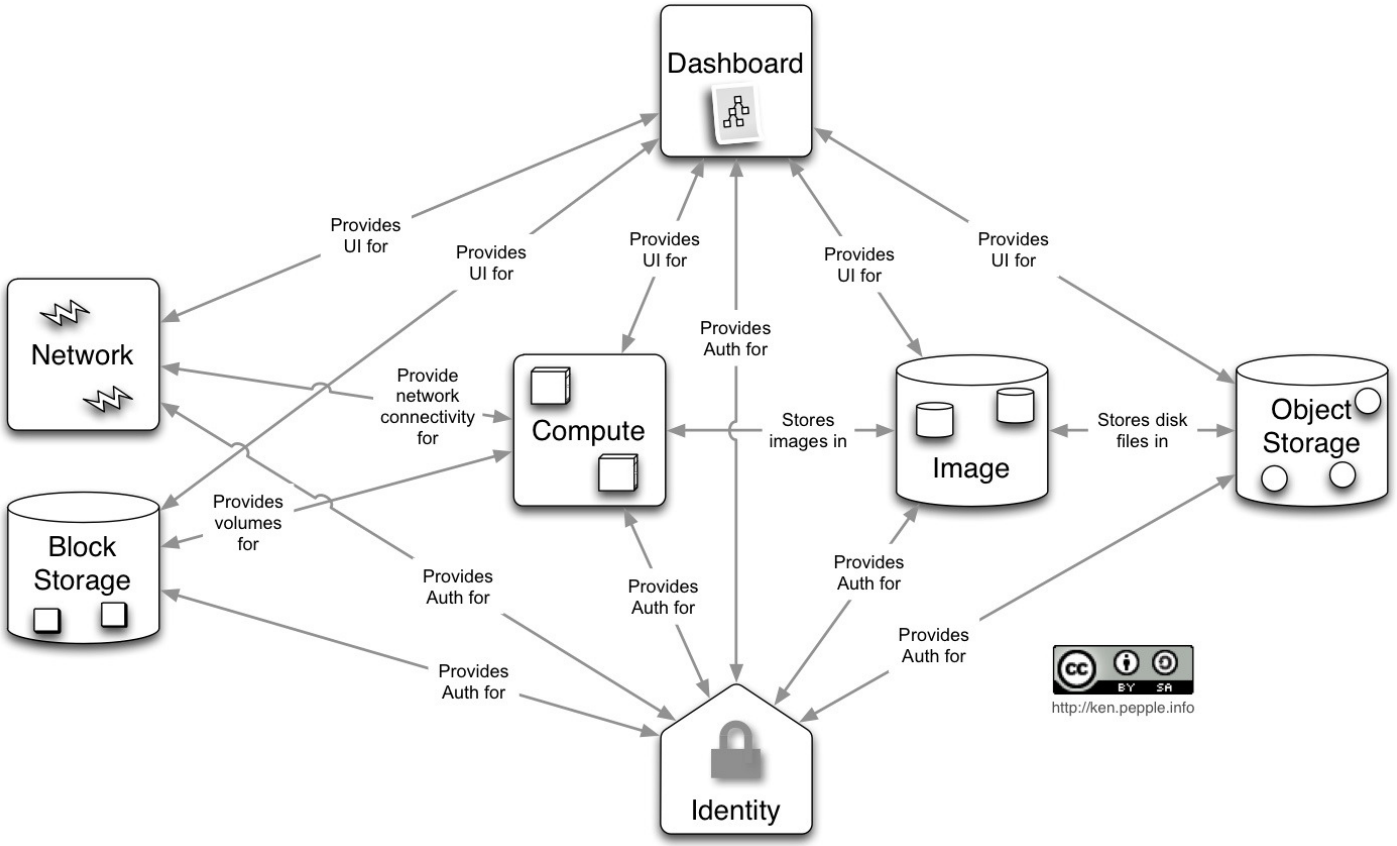
> "Today, the Ubuntu project announced that future versions of the Ubuntu Cloud will use OpenStack as a foundation technology. OpenStack, the rapidly growing, open-source, cloud platform effort founded by Rackspace and NASA in 2010, has secured more than 53 commercial companies including Dell, Internap, Intel and Cisco to join the IaaS cloud computing initiative since launching. Ubuntu officially joined the OpenStack initiative in February of this year, but it is not currently providing commercial services for it as part of the releases of its most recent Linux-based operating system, Ubuntu Server and Ubuntu Enterprise Cloud. However, with this announcement, OpenStack will become a core part of future releases. While no longer the foundation technology for the Ubuntu Cloud, Eucalyptus will remain within Ubuntu and will be available for users who prefer this technology."

Source: `http://talkincloud.com/ubuntu-cloud-openstack-wins-eucalyptus-loses`

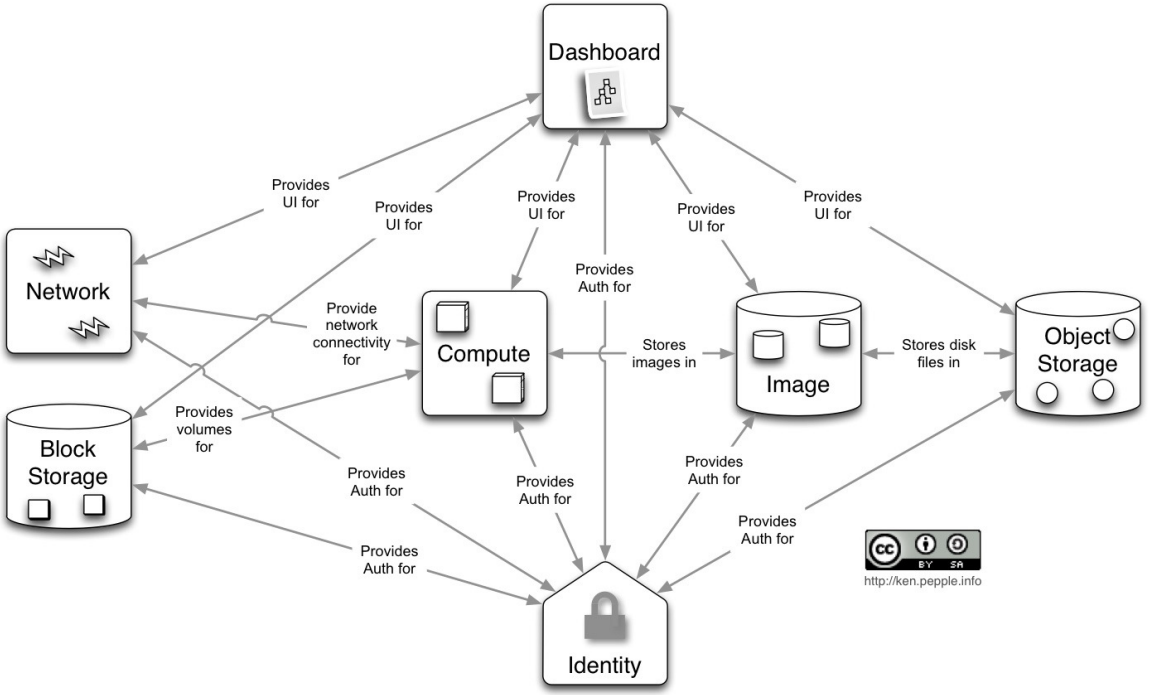
OpenStack

Image Source: OpenStack

- Initiated by NASA and Rackspace Cloud
  - Supported by AMD, Dell, IBM, Intel, Red Hat, SuSE, Yahoo and more
- Free software (Apache License v2.0)
- Contains several services which communicate via REST



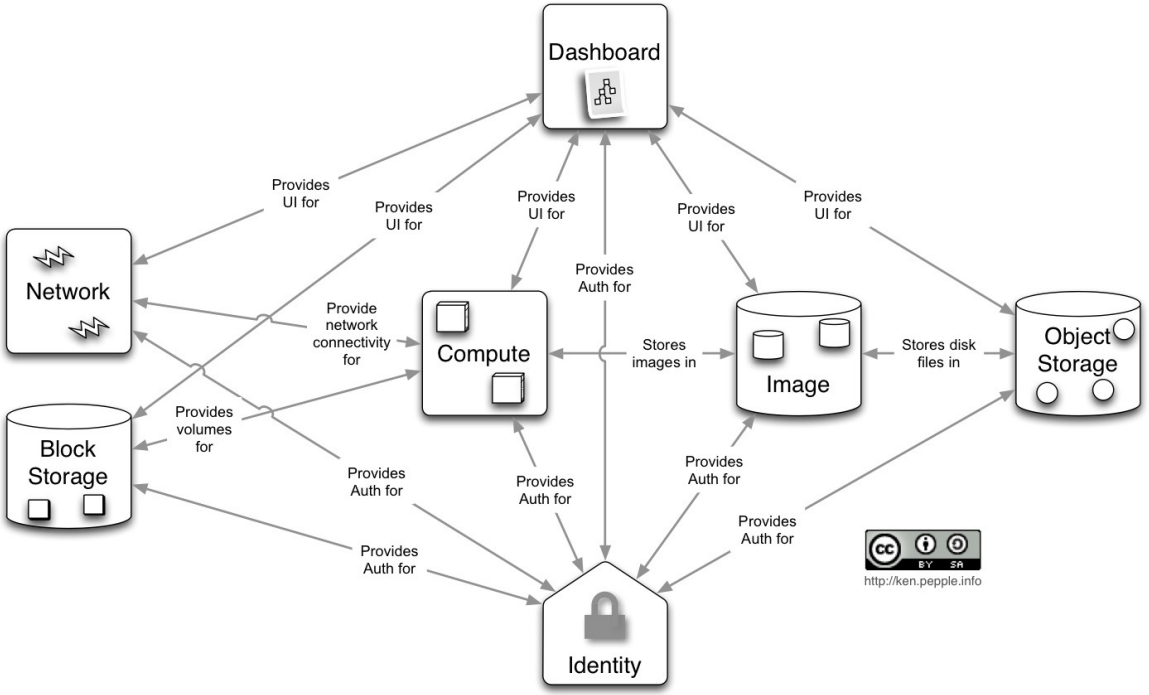
OpenStack – Services (1/3)



- **Compute** (*Nova*)
  - Infrastructure service
  - Implements the EC2 API
  - Highly scalable (up to tens of thousands of nodes)

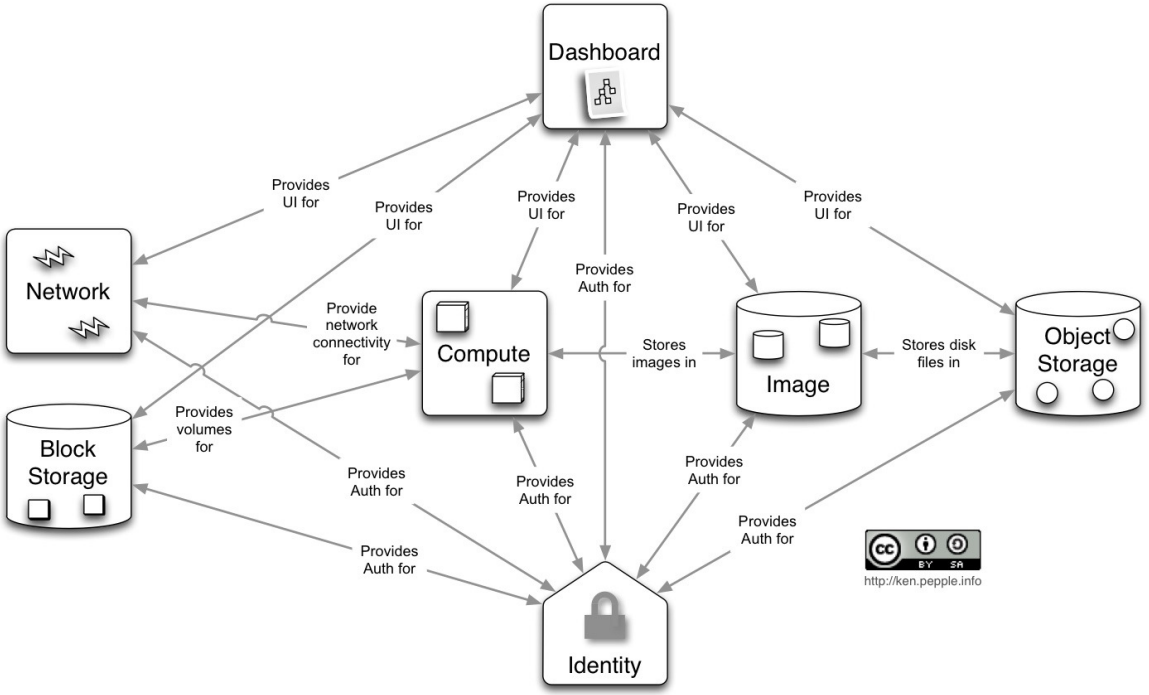
- **Object Storage** (*Swift*)
  - Redundant, highly scalable (petabyte range), object-based storage service
  - Objects are stored on multiple hardware
  - Automatic replication when nodes fail or are added
  - Implements the S3 API

OpenStack – Services (2/3)



- **Image Service** (*Glance*)
  - Service for the search, register and request of images
  - Supported image formats: Raw, AMI, VHD (Hyper-V), VDI (VirtualBox), qcow2 (Qemu/KVM), VMDK and OVF (VMWare)
- **Block Storage** (*Cinder*)
  - Storage service for persistent block-based storage devices
  - Virtual storage devices can be created, erased, attached to and detached from instances
  - Implements the EBS API

OpenStack – Services (3/3)



- **Identity Service** (*Keystone*)
  - Central directory of users for the other OpenStack services
  - Provides user authentication
  - Can interact (query) existing user directory services (e.g. LDAP)

- **Dashboard** (*Horizon*)
  - Provides a graphical web-interface for administrators and users
- **Networking** (*Neutron*)
  - Service for managing IP addresses and distributing them to instances
  - Administrators specify, if all instances are connected to the same network, or if they are separated from each other via VLAN

Infrastructure Services and their Compatibility to the AWS

	AWS APIs implemented		
Project/Solution	EC2	S3	EBS (EC2)
CloudStack	partly	—	—
Eucalyptus	partly	partly (Walrus)	partly (SC)
Nimbus	partly	partly (Cumulus)	—
OpenNebula	partly	—	partly
OpenStack	partly (Nova)	partly (Swift)	partly (Cinder)

- Many free private cloud solutions exist, which implement an object-based storage service and provide the S3 API
  - MinIO, Ceph-RGW, Fake S3, Riak CS, S3ninja, S3rver, Scality S3 Server,. . .

Freie Objektspeichersoftware mit S3-API, *Christian Baun*. iX 9/2017, P.76-79
`https://www.heise.de/ix/heft/Eimerweise-3807215.html`