

SE252:Lecture 5-6, Jan 22/27

ILO2: *Cloud Virtualization, Abstractions and Enabling Technologies*

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Ongoing Assignments



Reading from Previous Lecture

- Textbook, Sec 3.0 – 3.3
- Understanding Full Virtualization, Paravirtualization and Hardware Assist, *VMWare, Tech Report WP-028-PRD-01-01*, 2007
- Formal Requirements for Virtualizable 3rd Generation Architectures, Popek & Goldberg, CACM, 1974
- Performance Overhead Among Three Hypervisors: An Experimental Study using Hadoop Benchmarks, Jack Li, Qingyang Wang, Deepal Jayasinghe, Junhee Park, Tao Zhu, Calton Pu, IEEE Big Data Congress, 2013



ILO 2: Cloud Virtualization, Abstractions & Enabling Technologies

- *You should be able to*
 - *Explain* virtualization and their role in elastic computing. ✓
 - *Describe* service oriented architectures that are foundational to the WWW. ✓
 - *Characterize* the distinctions between Infrastructure, Platform and Software as a Service (IaaS, PaaS, SaaS) abstractions, and Public and Private Clouds, and
 - *analyse* their advantages and disadvantages.



Lecture 5

Public & Private IaaS Clouds



Cloud Fabrics

- System software & tools to manage Cloud Infrastructure
 - “OS for the Data Center”
 - *Clouds are more than just virtualization*
- Translates external service requests to series of actions
- Manages the health of the system, billing
- Proprietary: Amazon, Microsoft, *VMWare*
- Open source: Eucalyptus, OpenStack



Public & Private Cloud

Who owns the H/W? Who does the management?

- *Public clouds* can be used by anyone willing to pay (“Public” ≠ “free” 😊)
 - Third-party owns, manages and rents *aaS
- Private clouds owned by private orgs.
 - But managed for internal users like a cloud
 - *Ease of management, on-demand/elastic provisioning, SOA access, sandboxing, easy upgrades, billing...secure, ~cheaper*
 - Often run an open source Cloud fabric, or purchase off-the-shelf from vendors



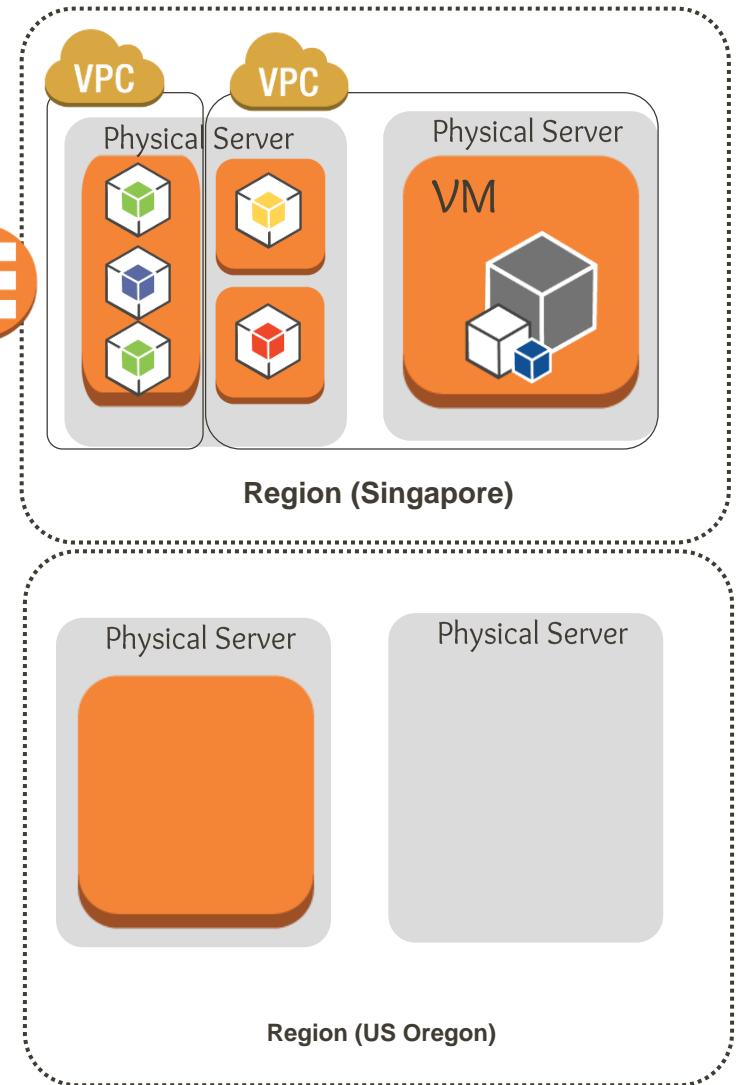


Amazon Web Service Public IaaS Cloud



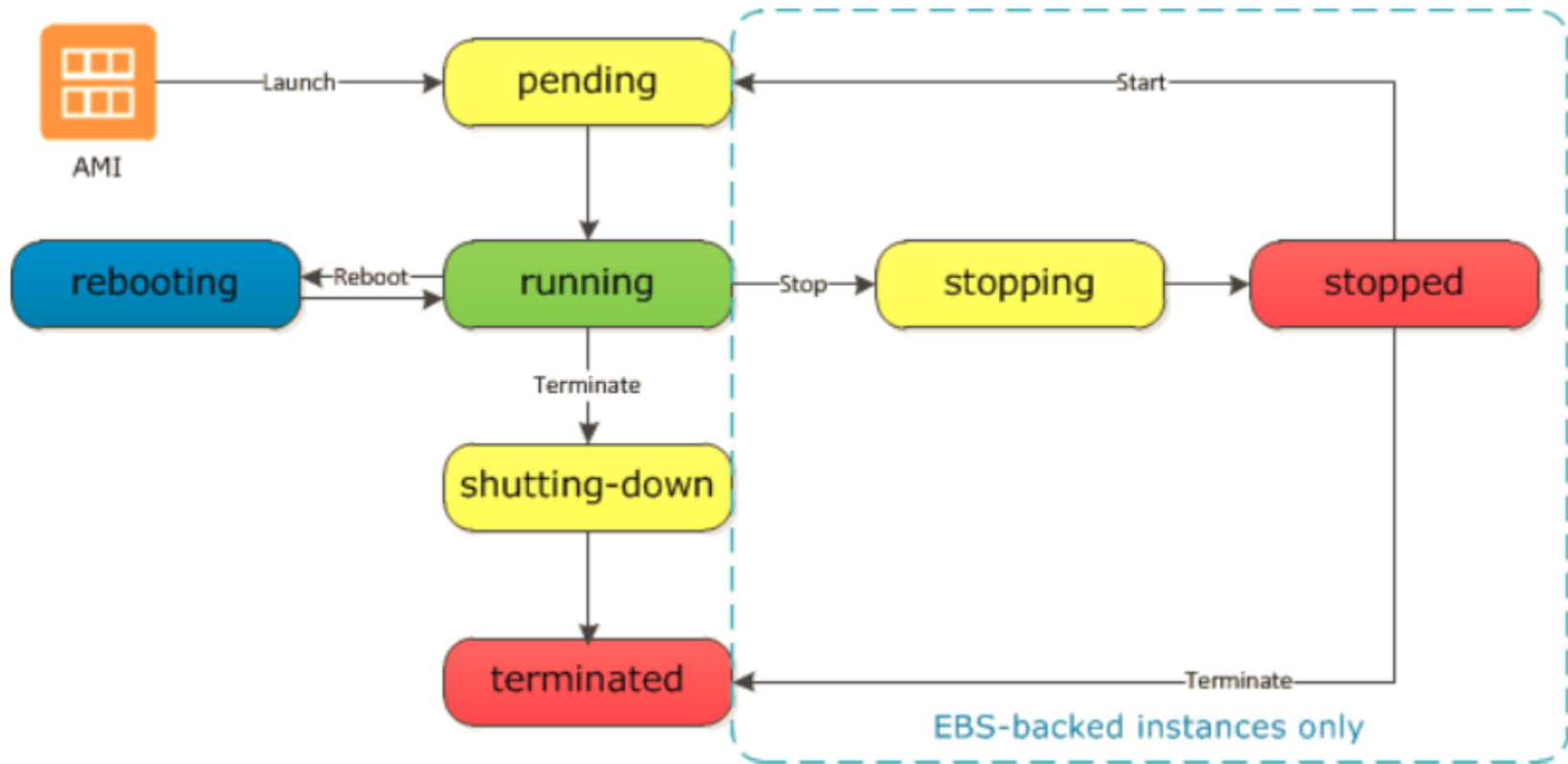
IaaS Computing Services

- Multi Tenancy
 - Pay by VM Hour
- Virtual Private Cloud offer *virtual network*
- Public and/or private Ips
 - Elastic IP for transparent routing
- Availability Zones to increase reliability within data centre (region)
 - Span regions for geo distribution, redundancy





EC2 Instance Life-cycle



“Each time you transition an instance from stopped to running, we charge a full instance hour, even if these transitions happen multiple times within a single hour.”



EC2 under the hood

```
System Log: i-7c2682b0 (simmhan/se252) X
```

```
[ 0.000000] Initializing cgroup subsys cpuset
[ 0.000000] Initializing cgroup subsys cpu
[ 0.000000] Initializing cgroup subsys cpuacct
[ 0.000000] Linux version 3.14.20-20.44.amzn1.x86_64 (mockbuild@gobi-build-60001) (gcc version
[ 0.000000] Command line: root=LABEL=/ console=ttyS0
[ 0.000000] e820: BIOS-provided physical RAM map:
[ 0.000000] BIOS-e820: [mem 0x0000000000000000-0x00000000000009dfff] usable
[ 0.000000] BIOS-e820: [mem 0x00000000000009e000-0x00000000000009ffff] reserved
[ 0.000000] BIOS-e820: [mem 0x0000000000000e0000-0x0000000000000fffff] reserved
[ 0.000000] BIOS-e820: [mem 0x000000000001000000-0x0000000000003ffffff] usable
[ 0.000000] BIOS-e820: [mem 0x000000000fc0000000-0x000000000ffffff] reserved
[ 0.000000] NX (Execute Disable) protection: active
[ 0.000000] SMBIOS 2.4 present.
[ 0.000000] Hypervisor detected: Xen HVM
[ 0.000000] Xen version 4.2.
[ 0.000000] Netfront and the Xen platform PCI driver have been compiled for this kernel: unplug
[ 0.000000] Dixie and the Xen platform PCI driver have been compiled for this kernel: unplug
[ 0.000000] You might have to change the root device
[ 0.000000] from /dev/hd[a-d] to /dev/xvd[a-d]
[ 0.000000] in your root= kernel command line option
[ 0.000000] No AGP bridge found
[ 0.000000] e820: last_pfn = 0x40000 max_arch_pfn = 0x400000000
[ 0.000000] x86 PAT enabled: cpu 0, old 0x7040600070406, new 0x7010600070106
[ 0.000000] found SMP MP-table at [mem 0x000fbb00-0x000fbbaf] mapped at [ffff880000fbb00]
[ 0.000000] init_memory_mapping: [mem 0x00000000-0x000fffff]
[ 0.000000] init_memory_mapping: [mem 0x3fe00000-0x3fffffff]
[ 0.000000] init_memory_mapping: [mem 0x3c000000-0x3fdfffff]
[ 0.000000] init_memory_mapping: [mem 0x00100000-0x3bffffff]
[ 0.000000] RAMDISK: [mem 0x37482000-0x37feffff]
[ 0.000000] ACPI: RSDP 0000000000ea020 000024 (v02 Xen)
[ 0.000000] ACPI: XSDT 00000000fc00f710 00005C (v01 Xen HVM 00000000 HVML 00000000)
[ 0.000000] ACPI: FACP 00000000fc00f260 0000F4 (v04 Xen HVM 00000000 HVML 00000000)
[ 0.000000] ACPI: DSDT 00000000fc0035e0 00BBF6 (v02 Xen HVM 00000000 INTL 20090123)
[ 0.000000] ACPI: FACS 00000000fc0035a0 000040
[ 0.000000] ACPI: APIC 00000000fc00f360 0000D8 (v02 Xen HVM 00000000 HVML 00000000)
[ 0.000000] ACPI: SRAT 00000000fc00f4b0 000170 (v01 Xen HVM 00000000 HVML 00000000)
[ 0.000000] ACPI: HPET 00000000fc00f620 000038 (v01 Xen HVM 00000000 HVML 00000000)
```

Close

Public IP 54.169.170.201



IaaS Computing Services

```
ec2-user@ip-172-31-16-134:~/se252-jan15/project-0
[ec2-user@ip-172-31-16-134 project-0]$ cat /proc/cpuinfo
processor       : 0
vendor_id     : GenuineIntel
cpu family    : 6
model         : 62
model name    : Intel(R) Xeon(R) CPU E5-2670 v2 @ 2.50GHz
stepping     : 4
microcode    : 0x415
cpu MHz      : 2494.048
cache size   : 25600 KB
physical id  : 0
siblings     : 1
core id      : 0
cpu cores    : 1
apicid       : 0
initial apicid : 0
fpu          : yes
fpu_exception : yes
cpuid level  : 13
wp           : yes
flags        : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clf
```



EC2 under the hood@2014

System Log: i-f8cf57ae (calvinandhobbes/1)

```
Xen Minimal OS!  
start_info: 0xae2000 (VA)  
nr_pages: 0x26700  
shared_inf: 0x7e030000 (MA)  
pt_base: 0xae5000 (VA)  
nr_pt_frames: 0x9  
mfn_list: 0x9ae000 (VA)  
mod_start: 0x0 (VA)  
mod_len: 0  
flags: 0x0  
cmd_line: root=/dev/sda1 ro 4  
stack: 0x96d840-0x98d840  
MM: Init  
_text: 0x0 (VA)  
_etext: 0x7dc7d (VA)  
_erodata: 0x9a000 (VA)  
_edata: 0x9fce0 (VA)  
stack_start: 0x96d840 (VA)  
_end: 0x9ade40 (VA)  
start_pfn: afl  
max_pfn: 26700  
Mapping memory range 0xc00000 - 0x26700000  
setting 0x0-0x9a000 readonly  
skipped 0x1000  
MM: Initialise page allocator for c1f000(c1f000)-26700000(26700000)  
MM: done  
Demand map pfns at 26701000-2026701000.  
Heap resides at 2026702000-4026702000.  
Initialising timer interface  
Initialising console ... done.  
gnttab table mapped at 0x26701000.  
Initialising scheduler  
Thread "Idle": pointer: 0x2026702050, stack: 0x26660000  
Thread "xenstore": pointer: 0x2026702800, stack: 0x26670000  
xenbus initialised on irq 1 mfn 0xfc5d4f  
Thread "shutdown": pointer: 0x2026702fb0, stack: 0x26680000  
Dummy main: start info=0x98d940
```



IaaS Computing Services@2014

```
ec2-user@ip-172-31-2-169:~  
  
  _ |  ( _ | _ )  
  _ |  ( _ | _ )  
  _ | \ _ | _ |  
                                     Amazon Linux AMI  
  
https://aws.amazon.com/amazon-linux-ami/2013.09-release-notes/  
7 package(s) needed for security, out of 18 available  
Run "sudo yum update" to apply all updates.  
[ec2-user@ip-172-31-2-169 ~]$ cat /proc/cpuinfo  
processor       : 0  
vendor_id      : GenuineIntel  
cpu family     : 6  
model          : 45  
model name     : Intel(R) Xeon(R) CPU E5-2650 0 @ 2.00GHz  
stepping       : 7  
microcode     : 0x70a  
cpu MHz        : 1800.000  
cache size    : 20480 KB  
physical id   : 0  
siblings      : 1  
core id       : 0  
cpu cores     : 1
```



File/Object Storage Service:S3

- Resilient object (file) storage, large capacity
 - ~3 copies within same data-centre region
- Eventually consistent model
 - Stale reads, low latency
- Pay as you go
 - *TB-months* for storage, *GB* for transfer out to Internet
 - Free transfer in, or transfer out *within* region
- Flat file structure
 - Buckets, Objects
 - Metadata: ACL, Tags
- Bucket names *globally* unique
- Object names simulate folder structure

<http://se252j15-calvinandhobbes.s3.amazonaws.com/foo.txt>

<http://se252j15-calvinandhobbes.s3.amazonaws.com/mydir/ch.jpg>



File/Object Storage Service:S3

- REST Web Service API to perform actions
 - Amazon SDK wraps REST call in prog. lang.
 - ***com.amazonaws.services.s3.AmazonS3Client***+
 - Cmd line*

```
[ec2-user@ip-172-31-2-169 ~]$ aws s3 ls s3://se252j14-calvinandhobbes
PRE mydir/
2014-01-21 04:30:34      3770 foo.bar
2014-01-21 04:43:23       475 foo.bar.bar.bar
2014-01-21 04:55:01       108 foo.txt
```

- HTTP **Operation**, **Header**, **Resource Name**, **Authorization** (*as header*)
 - **GET, PUT, DELETE, HEAD**
 - **Host, Date, Content-Length, Authorization,...**
 - **Bucket, Object, Tag, ...**



PUT Bucket

Sample Request

This request creates a bucket named `colorpictures`.

Resource

Operation

Headers

Bucket

```
PUT / HTTP/1.1
Host: colorpictures.s3.amazonaws.com
Content-Length: 0
Date: Wed, 01 Mar 2006 12:00:00 GMT
Authorization: AWS AKIAIOSFODNN7EXAMPLE:xQE0diMbLRepdf3YB+FIEXAMPLE=
```

Auth.

Sample Response

Op Status

Headers

```
HTTP/1.1 200 OK
x-amz-id-2: YgIPIfBiKa2bj0KMg95r/0zo3emzU4dzsD4rcKCHQUAdQkf3ShJTOOpXUueF6QKo
x-amz-request-id: 236A8905248E5A01
Date: Wed, 01 Mar 2006 12:00:00 GMT

Location: /colorpictures
Content-Length: 0
Connection: close
Server: AmazonS3
```

<http://docs.aws.amazon.com/AmazonS3/latest/API/RESTBucketPUT.html>



Resource

Operation

Sample Request

This request returns the objects in *BucketName*.

```
GET / HTTP/1.1
Host: BucketName.s3.amazonaws.com
Date: Wed, 12 Oct 2009 17:50:00 GMT
Authorization: AWS AKIAIOSFODNN7EXAMPLE:xQE0diMbLRepdf3YB+FIEXAMPLE=
Content-Type: text/plain
```

Bucket

Sample Response

```
<?xml version="1.0" encoding="UTF-8"?>
<ListBucketResult xmlns="http://s3.amazonaws.com/doc/2006-03-01/">
  <Name>bucket</Name>
  <Prefix/>
  <Marker/>
  <MaxKeys>1000</MaxKeys>
  <IsTruncated>>false</IsTruncated>
  <Contents>
    <Key>my-image.jpg</Key>
    <LastModified>2009-10-12T17:50:30.000Z</LastModified>
    <ETag>"fba9dede5f27731c9771645a39863328"</ETag>
    <Size>434234</Size>
    <StorageClass>STANDARD</StorageClass>
    <Owner>
      <ID>75aa57f09aa0c8caeab4f8c24e99d10f8e7faeebf76c078efc7c6caea54ba06a</ID>
      <DisplayName>mtd@amazon.com</DisplayName>
    </Owner>
  </Contents>
  <Contents>
    <Key>my-third-image.jpg</Key>
    <LastModified>2009-10-12T17:50:30.000Z</LastModified>
    <ETag>"lb2cf535f27731c974343645a3985328"</ETag>
    <Size>64994</Size>
    <StorageClass>STANDARD</StorageClass>
    <Owner>
      <ID>75aa57f09aa0c8caeab4f8c24e99d10f8e7faeebf76c078efc7c6caea54ba06a</ID>
      <DisplayName>mtd@amazon.com</DisplayName>
    </Owner>
  </Contents>
</ListBucketResult>
```

Body



Put Object

Sample Request

Resource

The following request stores the image `my-image.jpg` in the bucket `myBucket`.

Operation

```
PUT /my-image.jpg HTTP/1.1
```

Bucket

```
Host: myBucket.s3.amazonaws.com
```

```
Date: Wed, 12 Oct 2009 17:50:00 GMT
```

Length
Header

```
Authorization: AWS AKIAIOSFODNN7EXAMPLE:xQE0diMbLRepdf3YB+FIEXAMPLE=
```

```
Content-Type: text/plain
```

```
Content-Length: 11434
```

```
Expect: 100-continue
```

Body

```
[11434 bytes of object data]
```

Sample Response With Versioning Suspended

```
HTTP/1.1 100 Continue
```

```
HTTP/1.1 200 OK
```

```
x-amz-id-2: LriYPLdmOdAiIfgSm/F1YsViT1LW94/xUQxMsF7xiEbla0wiIOIxl+zbwZ163pt7
```

```
x-amz-request-id: 0A49CE4060975EAC
```

```
Date: Wed, 12 Oct 2009 17:50:00 GMT
```

```
ETag: "1b2cf535f27731c974343645a3985328"
```

Checksum

```
Content-Length: 0
```

```
Connection: close
```

```
Server: AmazonS3
```

<http://docs.aws.amazon.com/AmazonS3/latest/API/RESTObjectPUT.html>



GET Object

Sample Request

The following request returns the object, `my-image.jpg`.

```
GET /my-image.jpg HTTP/1.1
Host: bucket.s3.amazonaws.com
Date: Wed, 28 Oct 2009 22:32:00 GMT
Authorization: AWS AKIAIOSFODNN7EXAMPLE:0RQf4/cRonhpaBX5sCYVf1bNRuU=
```

Sample Response

```
HTTP/1.1 200 OK
x-amz-id-2: eftixk72aD6Ap51TnqcoF8eFidJG9Z/2mkiDFu8yU9AS1ed4OpIszj7UDNEHGran
x-amz-request-id: 318BC8BC148832E5
Date: Wed, 28 Oct 2009 22:32:00 GMT
Last-Modified: Wed, 12 Oct 2009 17:50:00 GMT
ETag: "fba9dede5f27731c9771645a39863328"
Content-Length: 434234
Content-Type: text/plain
Connection: close
Server: AmazonS3
[434234 bytes of object data]
```

Checksum

Body

<http://docs.aws.amazon.com/AmazonS3/latest/API/RESTObjectGET.html>



S3 Bucket Names

- `se252j15-calvinandhobbes.s3.amazonaws.com`
- You can create “folders” within the bucket using “/” separated object names
 - E.g. `http://se252j15-calvinandhobbes.s3.amazonaws.com/mydir/ch.jpg`
- Objects are private by default
 - Make them public if they need to be displayed in browser. E.g. `CannedAccessControlList.PublicRead`



S3 from your AWS Console

The screenshot shows the AWS S3 Management Console interface. The browser address bar displays "https://console.aws.amaz...". The navigation bar includes "Services", "EC2", "S3", "SQS", "IAM", and "VPC". The user is logged in as "CalvinAndHobbes @ dream-lab". The main content area shows a "Create Bucket" button and an "Actions" dropdown. Below this, there are tabs for "None", "Properties", and "Transfers". The "All Buckets" section contains a table with the following data:

Name
<input type="checkbox"/> se252-jan14-billing-reports
<input type="checkbox"/> se252j14
<input checked="" type="checkbox"/> se252j14-calvinandhobbes

The screenshot shows the AWS S3 Management Console interface for a specific bucket. The browser address bar displays "https://console.aws.amaz...". The navigation bar includes "Services", "EC2", "S3", "SQS", "IAM", and "VPC". The user is logged in as "CalvinAndHobbes @ dream-lab". The main content area shows "Upload", "Create Folder", and "Actions" buttons. Below these are tabs for "None", "Properties", and "Transfers". The "All Buckets / se252j14-calvinandhobbes" section contains a table with the following data:

Name	Storage Class	Size	Last Modified
<input type="checkbox"/> foo.bar	Standard	3.6 KB	Tue Jan 21 10:00:34 GMT+530 2014
<input type="checkbox"/> foo.bar.bar.bar	Standard	475 bytes	Tue Jan 21 10:13:23 GMT+530 2014
<input type="checkbox"/> foo.txt	Standard	108 bytes	Tue Jan 21 10:25:01 GMT+530 2014
<input checked="" type="checkbox"/> input	--	--	--
<input type="checkbox"/> mydir	--	--	--
<input type="checkbox"/> output	--	--	--
<input type="checkbox"/> syncOne42396458972090181268234645c-d16d-485c-b057-58290ffa48d7.html	Standard	1.9 KB	Sun Jan 26 11:58:17 GMT+530 2014
<input type="checkbox"/> syncOne75528249354856390652dc1b615-52a1-4ef1-8c23-42f0a4955f3e.html	Standard	2.4 KB	Sun Jan 26 15:58:59 GMT+530 2014

A context menu is open over the "input" folder, showing the following options: Open, Make Public, Delete, Initiate Restore, Cut, and Copy.



Authorization

- *Authorization* is a hash signature
 - **SecretAccessKey**(Op, Time, Param)=**Signature**
 - Authorization Header=AWS **AccessKeyID:Signature**

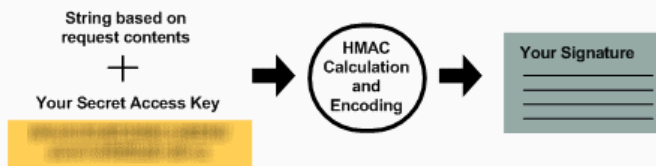
You

AWS

1 Create a request:

Request
AccessKeyId = ...
Action = ...
Timestamp = ...
ParameterA = ...

2 Create an HMAC-SHA1 signature:



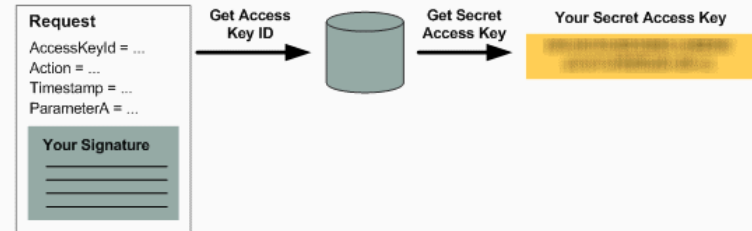
3 Send the request and signature to AWS:

Request
AccessKeyId = ...
Action = ...
Timestamp = ...
ParameterA = ...

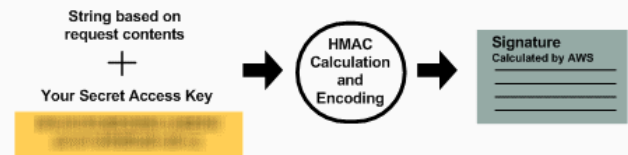
Your Signature

AWS

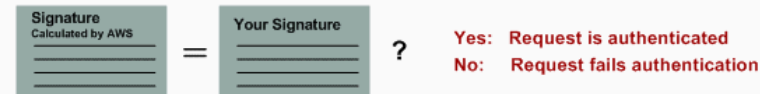
4 Retrieve your Secret Access Key:



5 Create an HMAC-SHA1 signature:



6 Compare the two signatures:





File/Object Storage Service:EBS

- Store blocks on disk volume
 - Unformatted block device. You install F/S
 - Attach to *one* VM instance
- Durable, resilient storage
 - Replicated
- Higher performance, random access
- Create snapshots to S3
 - (Incremental) Backup, expand/shrink



AWS Simple Queue Service (SQS)

- Guaranteed delivery
 - Write once, Read *at least* once
 - Idempotent tasks, or remove duplicates
- FIFO not Guaranteed
 - Message order may change
 - Use sequence numbers for ordering
- Up to 256KB per message
 - Message payloads are opaque to SQS
- Message retention for 4 days max



SQS API

- `CreateQueue`, `ListQueue`, `DeleteQueue`
- `GetQueueAttribute`
 - *ApproximateNumberOfMessages*
 - *ApproximateNumberOfMessagesNotVisible*
- `MessageID` is unique ID
- `ReceiptHandle` for received message
 - Token used update/delete message



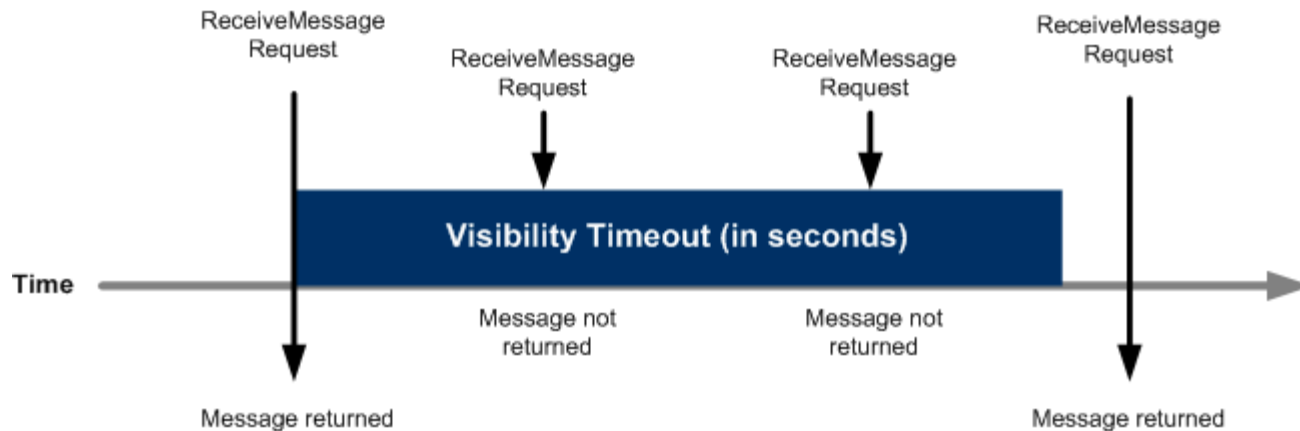
Short/Long Polling

- `SendMessage` & `ReceiveMessage`
 - `Batch` operation possible
- *Short polling* “samples” distributed queues & returns a few messages (*default*)
 - Returns *immediately*, even with 0 messages
 - May not return messages even if present (*Starvation?*)
- *Long polling* returns any available message
 - But only after a *timeout polling* period
 - Guaranteed to return any available messages
 - Reduces frequent *polling*, *empty message* responses



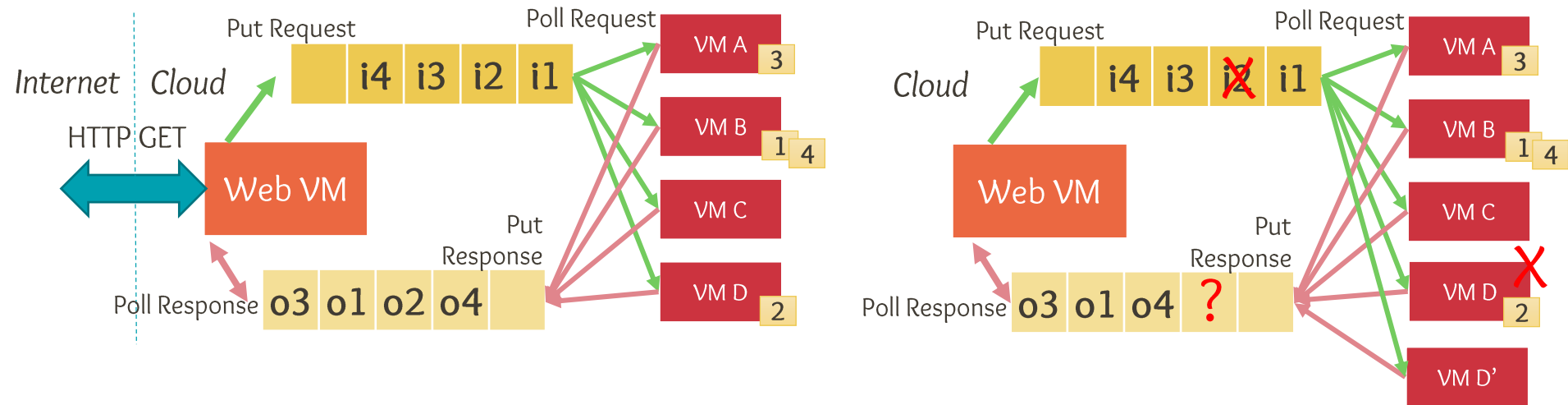
Message Lifetime/Visibility

- “Received” Messages need to be “Deleted” before they are removed
- Received messages can reappear automatically after a timeout
- APIs: `SetQueueAttributes`, `ReceiveMessage`, `ChangeMessageVisibility`





Using Message Visibility APIs



- Typical Queue
 - `Get(and delete)Message(i)`
 - `DoTask(i)`
 - `PutMessage(o)`
- SQS (and other Cloud queue services)
- `ReceiveMessage(i) → DoTask(i) → SendMessage(o) → DeleteMessage(i)`
 - *Optionally, keep extending visibility during DoTask(i)*
 - `ChangeMessageVisibility`



SQS from your AWS Console

The screenshot shows the AWS Management Console interface for SQS. At the top, there's a navigation bar with 'Services' and 'Edit' menus, and user information 'CalvinAndHobbes @ dream-lab' in Singapore. The main content area is titled 'Queues' and includes a 'Create New Queue' button and a 'Queue Actions' dropdown. A table lists three queues, with the third one selected. Below the table, a context menu is open over the selected queue, showing options like 'Send a Message', 'View/Delete Messages', 'Configure Queue', 'Add a Permission', 'Delete Queue', and 'Subscribe Queue to SNS Topic'. The details for the selected queue are shown below, including its name, URL, ARN, creation and update times, and various configuration parameters like visibility timeout, retention period, and message size.

URL: <https://console.aws.amazon.com/sqs/home?region=ap-southeast-1#queue-browser:selected=https://sqs.ap-southeast-1.amazonaws.com/503310696788/se252j14-calvinandhobbes-boink>

Name	Messages Available	Messages in Flight	Created
<input type="checkbox"/> cloud-test-fubar	0	0	2013-10-06 22:55:12 GMT+05:30
<input type="checkbox"/> cloud-test-pramodh	0	0	2013-11-17 09:21:41 GMT+05:30
<input checked="" type="checkbox"/> se252j14-calvinandhobbes-boink	1	0	2014-01-28 06:42:21 GMT+05:30

1 SQS Queue selected.

Details | Permissions

Name: se252j14-calvinandhobbes-boink
URL: <https://sqs.ap-southeast-1.amazonaws.com/503310696788/se252j14-calvinandhobbes-boink>
ARN: arn:aws:sqs:ap-southeast-1:503310696788:se252j14-calvinandhobbes-boink
Created: 2014-01-28 06:42:21 GMT+05:30
Last Updated: 2014-01-28 06:42:21 GMT+05:30
Delivery Delay: 0 seconds

Default Visibility Timeout: 30 seconds
Message Retention Period: 4 days
Maximum Message Size: 256 KB
Receive Message Wait Time: 0 seconds
Messages Available (Visible): 1
Messages in Flight (Not Visible): 0
Messages Delayed: 0

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Gotchas!

- Transient vs Persistent Data
 - Local VM store vs. EBS/S3

- Resiliency vs Availability of Compute
 - Availability zones

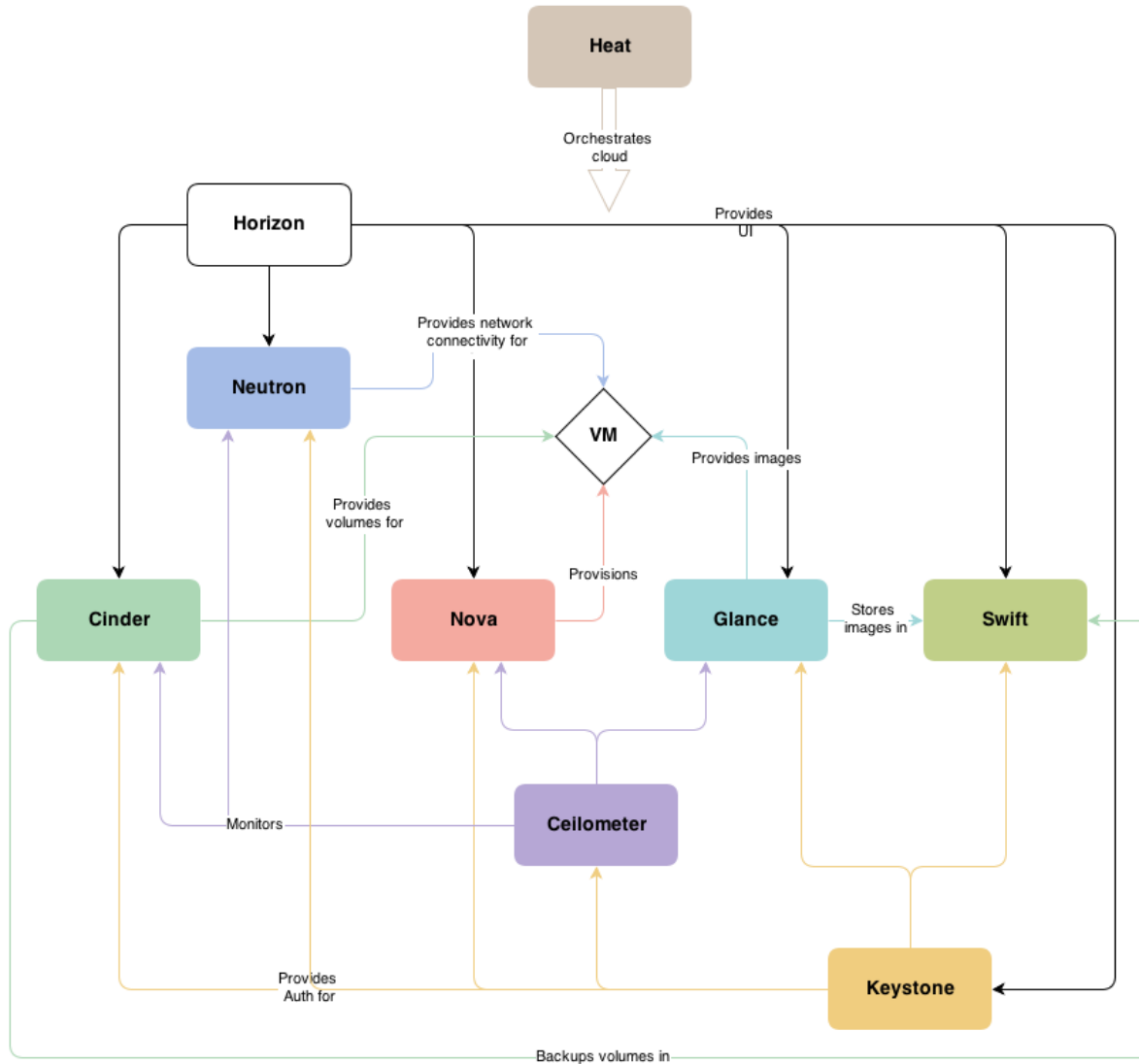
- Resiliency vs Availability of Data
 - Local & Global replication



OpenStack Private Cloud Fabric



OpenStack Private Fabric: Conceptual



<http://docs.openstack.org/admin-guide-cloud/content/conceptual-architecture.html>



Commercial & “Free” Clouds

Do you pay for it?

- Clouds as a “utility” computing model
 - There is no free power/water...*or is there?*
- Amazon AWS, Microsoft Azure, Salesforce
 - Google AppEngine, Rackspace, Citrix, iCloud
- NSF’s FutureGrid, DropBox
 - Sample teasers from commercial providers
 - Education/Research grants



Hybrid, Multi, Mobile, Spot Clouds...

- Many nuanced distinctions, vague terminologies, hyped concepts...
- *Do you run exclusively on the Cloud? Or “Cloud Burst” from local machines?*
- *Do you use multiple Cloud providers?*
- *Are smart phones collectively a Cloud?*
- *Can we sell spare capacity in auctions?*



Tentative Project Topics

Type	Title
App-aaS	IISc Campus Map using OpenStreetMaps, build higher order services
Analytics-aaS	Launch, Perf Model & Viz of GoFFish Graphs, e.g. NScale
IaaS	VM scheduling algos on OpenStack
PaaS	Edge+Cloud CEP Processing for IoT
SaaS	Activiti Workflow for On-Demand Provisioning of Wordpress as a Service
IaaS	Docker containers & VMs for Big Data deployments
IaaS/PaaS	Perf benchmarking & Viz of Cloud and Bare Metal for Hadoop {K-Means, WC}, Storm {LRB} Platforms, HPL
IaaS	Cloud on a USB-CloudSim to run AWS from a USB drive.
PaaS	Online Analytics & Viz of Storm Streams+Hive Data
PaaS	Bibtex & PDF text analytics Pipeline, K-Means Clustering
Analytics-aaS	Time-series graph algorithms, e.g., using NELL



Test AWS VM

- t2.medium instances
- Setup SSH Client
 - Private key, IISc proxy (*corkscrew*), **ec2user@**
- 1. **ec2-54-169-172-211.ap-southeast-1.compute.amazonaws.com**
- 2. **ec2-54-169-77-100.ap-southeast-1.compute.amazonaws.com**



Reading from Today's Lecture

- Textbook, Sec 4.1 – 4.4
- Amazon AWS API documentation (EC2, S3, SQS)
- OpenStack Juno documentation

Ongoing Assignment

- Project 0 due tonight (Jan 22)
- Login to AWS EC2 and try out Project 0
- Homework A available by Jan 27, Due Tue, Feb 3
- Discuss project topics, teams. Due Thu, Feb 5
 - ME/MTech Final year projects

Makeup Class, Project Discussion:
Fri 4-530P