Motivation for the Cloud

- **Self-service configuration**
  - Provision the servers, storage, and network connectivity they need

- **Hosting**
  - Don’t worry about hosting and maintenance

- **Elastic growth & metered service**
  - Users can add more to their environment as needed
  - Pay for what you use

- **CAPEX → OPEX**
  - No capital purchases, depreciation

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XaaS

- **Software as a Service (SaaS)**
  - Ability to use software in the cloud
  - Users
    - Web-based email, Google apps, Microsoft Office Online, Apple iWork for iCloud

- **Platform as a Service (PaaS)**
  - Ability to deploy apps in the cloud
  - Programmers
    - Java/Eclipse programming platform as a network service, Google App Engine: Python, Java, PGP, Go

- **Infrastructure as a Service (IaaS)**
  - Create a computing environment in the cloud
  - IT
    - Create a web service with several load-balanced web servers, app servers, and a back-end database

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Public vs. Private

- **Private cloud**
  - Dedicated to one organization; hosted on premises

- **Public cloud**
  - **Hosted Enterprise Cloud**
    - Set of infrastructure dedicated to one organization
    - Hosted and operated by a third party (e.g., Rackspace)
  - **Multi-tenant Public Cloud**
    - Shared and dedicated resources
    - Elastic scaling
    - Services accessible by multiple customers over the Internet

- **Hybrid Cloud**
  - Services provided with a combination of private and public cloud

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Vendors

- Many vendors: frameworks & providers
- Popular open efforts: CloudStack, Openstack, & Eucalyptus
  - Share some of the same components
  - Enable the use of a variety of VMs, network controllers, and storage systems
- Also:
  - Google Compute Engine (GCE)
  - Amazon EC2 ( Elastic Compute Cloud)
    - Amazon S3 (storage) + Amazon RDS (relational DB) + ...
    - Microsoft Azure

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CloudStack

- [Initially Citrix]
- Mostly written in Java
- >100 production clouds
- Up to 30K physical hosts
- Supports lots of hypervisors
- Multiple datacenters
- Amazon EC2 compatible

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OpenStack

- [Initially Rackspace]
- Mostly written in Python
- Not widely used commercially
- Supports lots of hypervisors
- Network is a point of failure
- Partial support for Amazon EC2
- Difficult to install

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Eucalyptus

- Mostly written in Java
- Focus on private cloud
- KVM & Xen hypervisor support
- Amazon EC2 and S3 compatible
The following examples will focus on CloudStack

Cloud infrastructure hierarchy

- Managed collection of hosts, networks, storage: may span data centers
- Collection of hosts, networks, storage: one or more zones per data center
- A rack
- Group of hosts & associated primary storage

Core Components

- Dashboard
- Management
- Identity
- Compute
- Network
- Storage

Virtual Machines

- Each physical machine runs a hypervisor
  - Allows running of multiple operating systems
  - Provides virtual interfaces to hardware (storage, NIC, MMU, ...)
  - Management server interacts with hypervisor
- Setup: user actions
  - Select OS
  - Number of CPUs and RAM
  - Disk size, number of volumes
  - Network
- Provisioning
  - Primary storage volume(s) allocated on a cluster
  - VM configured from template & configuration data
  - Instance of VM copied from secondary storage to primary storage

Compute

Network
The Network

• Administrator actions
  – Define networks (local addresses)
  – Attach VMs to networks
  – Acquire public address(es) for NAT
  – Configure firewall rules for access and load balancing

The Network: keeping things separated

• Physical hosts share a physical network
• Virtual network (VLAN)
  – Tag on ethernet frame identifies virtual network
  – Traffic from multiple hosts multiplexed on the same physical network
  – Management traffic is untagged
• Hypervisor involvement
  – Traffic labels defined by management interface and configured on hypervisor
  – Hypervisor provides virtual LAN interface
  – Filters traffic to VM

The Network: connecting networks

• Virtual router
  – DHCP: assign internal addresses
  – DNS: domain name lookup
  – Load balancing: define a pool of internal servers
  – VPN: secure channel between internal & remote networks/machines
• Virtual routers manage connectivity between
  – Internal subnets
  – Internal & external networks
• May deploy a combination of virtual and physical network hardware
  – E.g., dedicated firewalls and load balancers, virtual router for DHCP & DNS

Storage

• Primary Storage
  – The VM’s “disks”
  – Presented as a block device (looks like a raw disk)
  – The VM writes a file system on it
  – Accessible from on VM host or a cluster within a pod
  – Uses local disk, iSCSI, Fibre Channel, or NFS
• Secondary Storage
  – Zone-level configuration
  – Stores templates, snapshots, ISO images
  – Uses NFS or OpenStack Swift object store
• Other (beyond IaaS)
  – Access other storage servers
  – Distributed file systems, Bigtable, Amazon S3, Databases

Snapshots

• Backup images of a VM
  – Allows restoring state of a machine to the latest snapshot
  – Administrator configures frequency of snapshots
  – Hypervisor writes them
• Initially written to primary storage (fast)
• Then moved to secondary storage
• Backup network traffic can be segregated to lower impact
High Availability

- Poll VMs for liveness (heartbeats)
- Fencing
  - Disallow dead/unknown VM from accessing storage
- Restart VM
- Use snapshots for restoring VM state
- Other mechanisms for HA (beyond IaaS)
  - Active/active, active/passive redundancy
  - Application-level heartbeats
  - Paxos/Virtual synchrony

The End