Cloud Computing
Learning Goals

• To have a general understanding of what falls under the nebulous definition of Cloud Computing
  – Not to be confused with nebulous clouds nor the cloud nebula.
• To be familiar with the concepts of SaaS, IaaS, PaaS, (and HuaaS).
• To understand the benefits and risks of using cloud computing
• To be aware of the breadth of services that are available as XaaS
  – Including business models and software development support
What is Cloud Computing?

• Cloud computing is a model for enabling
  – convenient, on-demand network access
  – to a shared pool of configurable computing resources
    • (e.g., networks, servers, storage, applications, and services)
  – that can be rapidly provisioned and released
    • with minimal management effort
    • or service provider interaction

Source: US National Institute of Standards and Technology, 2009
Example Use Cases

- Payroll company – monthly variation
  - Has peak loads on its web applications on the last working day of the month
  - Traffic tails off the rest of the month

- Weather company – special events
  - Fairly steady state load most of the time
  - Extreme peak loads when there is a weather event (hurricane, ice storm, etc.)
Example Use Cases

• Short-Term Campaign
  – You have a campaign (e.g. Superbowl commercial) that needs a short-term increased capacity to manage.
Problem:

- Simulate the interaction of each of millions of compounds with a cancer-related protein.
- Estimated 341,700 hours of computing
  - I.e. 39 years!

Solution:

- Used 10,600 cloud-based compute instances

Physical equivalent:

- 12,000 sq feet data center
- Would cost $44 million

Result

- 2 hour setup
- 9 hours use
- Peak cost $549.72/hour
- Total cost $4,362!

Example Use Cases

• Startup company - scalability
  – Minimal capital available for equipment
  – Minimal capital available to hire tech support staff
  – No way to predict when their new service will go viral.
• Animoto made its service available via Facebook
• Resource needs doubled every 12 hours for three days.
• Demand surged from 50 servers to 3,500 servers
• After the peak subsided, traffic fell to a lower level.

Source: Michael Armbrust et al.
» http://doi.acm.org/10.1145/1721654.1721672
Over / Under Provisioning

Figure 2. (a) Even if peak load can be correctly anticipated, without elasticity we waste resources (shaded area) during nonpeak times. (b) Underprovisioning case 1: potential revenue from users not served (shaded area) is sacrificed. (c) Underprovisioning case 2: some users desert the site permanently after experiencing poor service; this attrition and possible negative press result in a permanent loss of a portion of the revenue stream.

– Source: Michael Armbrust et al.
  » http://doi.acm.org/10.1145/1721654.1721672
Infrastructure is Not Your Core Business

• You have a need for an extensible software application that scales indefinitely (from your perspective) and is available 24/7 worldwide.
• And your core business is not distributed software development.
Essential Characteristics

• On-demand self-service
• Broad network access
• Resource pooling
• Rapid elasticity
• Measured service

— US National Institute of Standards and Technology, 2009
On-demand self-service

- Consumer can unilaterally:
  - Provision computing capabilities,
    - E.g. server time and network storage,
  - As needed
  - Automatically
  - Without requiring human interaction
• Capabilities are available
  – Over the network
  – Accessed through standard, published APIs
Resource pooling

• Provider’s computing resources are pooled
  – Serving multiple consumers using a multi-tenant model
  – With different physical and virtual resources dynamically assigned and reassigned according to consumer demand.

• Customer generally has no control or knowledge over the exact location of the provided resources
  – But may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).

• Examples of resources include
  – storage
  – processing
  – memory
  – network bandwidth
  – virtual machines.
Resource Pooling - Business model

• Resource pooling is key to the business model
  – Large scale data centers
  – In low-cost geographic locations
    • Real estate
    • Power
    • Labor
  – Statistical multiplexing to increase utilization
  – Resulted in significant decrease in costs
    • Decrease factor of 5 to 7- Armbrust et al

• Therefore, cloud computing could was able provide better software and computing services cheaper than medium and small sized data centers.
Rapid elasticity

• Capabilities can be rapidly and elastically provisioned
  – In some cases automatically
  – To quickly scale out and rapidly released to quickly scale in.

• To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.
Measured Service

• Providers use a metering capability at some level of abstraction appropriate to the type of service – (e.g., storage, processing, bandwidth, and active user accounts).

• Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

• 1000 processors for 1 hour is no more expensive than 1 processor for 1000 hours
These are worth knowing...

• Essential characteristics of cloud computing
  – On-demand self-service
  – Broad network access
  – Resource pooling
  – Rapid elasticity
  – Measured service
    – US National Institute of Standards and Technology, 2009
Service Models

- IaaS - Infrastructure as a Service
- PaaS - Platform as a Service
- SaaS - Software as a Service
- HuaaS - Humans as a Service
Infrastructure as a Service (IaaS)

• Processing, storage, networks, and other fundamental computing resources
• The consumer can run arbitrary software
  – Including operating systems and applications
Amazon Elastic Compute Cloud (EC2)

- IaaS example
- Multiple instance types, ranging from
  - Micro Instance
    - 613 MB memory
    - up to 2 ECUs
    - Network storage
  - Extra Large Instance
    - 15 GB memory
    - 8 ECUs
    - 1690 GB local storage
    - Higher network performance
Simple Storage Service (S3)

- Web-based storage
- Web Services interface
  - SOAP and REST
    (Two varieties of machine-to-machine communication)
Platform as a Service (PaaS)

- Programming languages, tools, and/or software systems provide a platform upon which a customer can build an applications.
- The consumer does not manage or control the underlying computing infrastructure, but has control over the deployed applications.
Force.com - PaaS

- Force.com development platform
- Apex programming language
- API
- Eclipse IDE integration
- Database, security, workflow, and user interface tools
- Free for developers
Google App Engine – PaaS

• Run web apps on Google infrastructure
  – Automatic scaling and load balancing
• Security and Authentication
• Work queues for scheduled tasks
• Messaging
Google App Engine

• Provides Java, Python, Go, and PHP platforms
• Eclipse IDE integration
• Persistent storage via:
  – Cloud Datastore – NOSQL
  – Cloud SQL – based on MySQL
  – Cloud Storage – objects & files up to 1TB
**Software as a Service (SaaS)**

- Provides the capability to use software applications running on cloud infrastructure.
- Applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email).
While with IaaS and PaaS, the consumer is an application developer, with SaaS, the consumer can be an end user (or application developer).

E.g.

- Companies can use the SaaS named CakeHR
  - Human resources software
- CakeHR uses the PaaS from CenturyLink/AppFog
  - PHP platform as a service
- AppFog uses the IaaS from Amazon Web Services
  - EC2, S3
Example SaaS

- SalesForce.com – CRM
- Flickr – Photo Management
- YouTube, Vimeo – Video Streaming
- Piazza – Course forums
- Others you use?
Human as a Service (HuaaS)

• Less common association with cloud computing
• E.g.
  – YouTube crowdsourcing of “newsworthy” videos
  – Amazon product reviews
  – Amazon Mechanical Turk
  – ReCAPTCHA
  – duoLingo
  – Uber
  – Burpy
  – Thumbtack
  – Favor Delivery
  – HomeAdvisor
Public & Private Clouds

• Public cloud:
  – Cloud computing provided to public customers
  – Service aka *utility computing*

• Private cloud:
  – Cloud computing only within a firm
  – Only sensible when economies of scale are big enough to justify
    • Else you just have a "data center".
Where can we run Node.js apps?

- **Laptop**
  - No static IP address
  - Laptop not awake when TA wants to test
- **Andrew.cmu.edu**
  - Only static web pages
- **Traditional web hosting (e.g. DreamHost, BlueHost)**
  - Do not allow continuous processes
  - Node.js is a running process, not something a web server invokes
- **IaaS** – E.g. AWS
  - Possible, but need to create OS stack to run Node on.
  - More work than is needed
- **PaaS**
  - Best alternative for what we need.
Node.js PaaS Options

- Zeit Now
  - Free
  - Amazingly easy CLI to deploy
- Heroku
- Redhat OpenShift
- Microsoft Azure
- IBM Bluemix
- Modulus
- Nodejitsu
- AppFog
- EngineYard

And others...