Data Centers and Cloud Computing

Slides courtesy of Tim Wood

Data Centers

- Large server and storage farms
  - 1000s of servers
  - Many TBs or PBs of data
- Used by
  - Enterprises for server applications
  - Internet companies
    - Some of the biggest DCs are owned by Google, Facebook, etc
- Used for
  - Data processing
  - Web sites
  - Business apps

Traditional vs "Modern"

- Data Center architecture and uses have been changing

- Traditional - static
  - Applications run on physical servers
  - System administrators monitor and manually manage servers
  - Use Storage Array Networks (SAN) or Network Attached Storage (NAS) to hold data

- Modern - dynamic, larger scale
  - Run applications inside virtual machines
  - Flexible mapping from virtual to physical resources
  - Increased automation allows larger scale

Inside a Data Center

- Giant warehouse filled with:
- Racks of servers
- Storage arrays

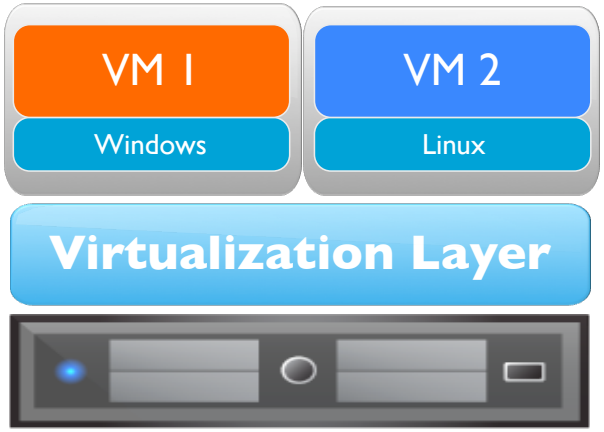
- Cooling infrastructure
- Power converters
- Backup generators

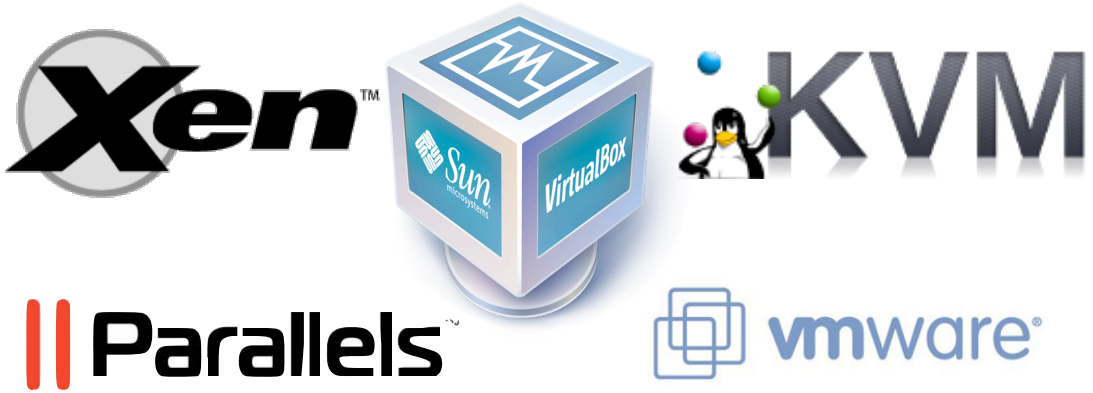
Modular Data Center

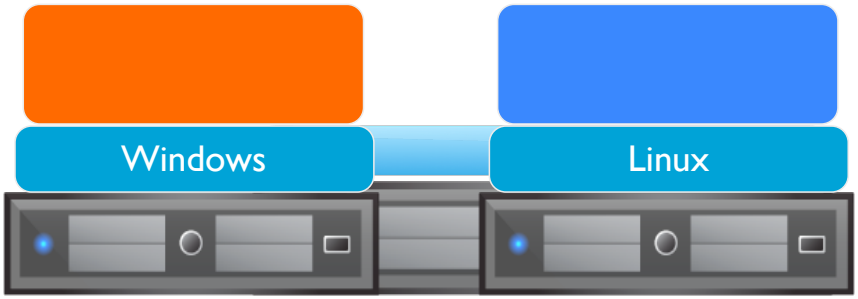
- ...or use shipping containers
- Each container filled with thousands of servers
- Can easily add new containers
  - "Plug and play"
  - Just add electricity
- Allows data center to be easily expanded
- Pre-assembled, cheaper

Server Virtualization

- Allows a server to be "sliced" into Virtual Machines
- VM has own OS/applications
- Rapidly adjust resource allocations
- VM migration within a LAN

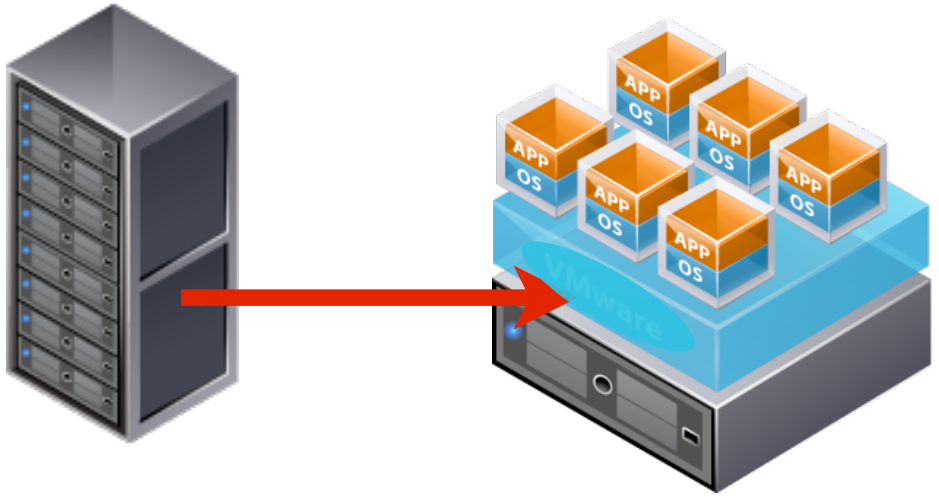




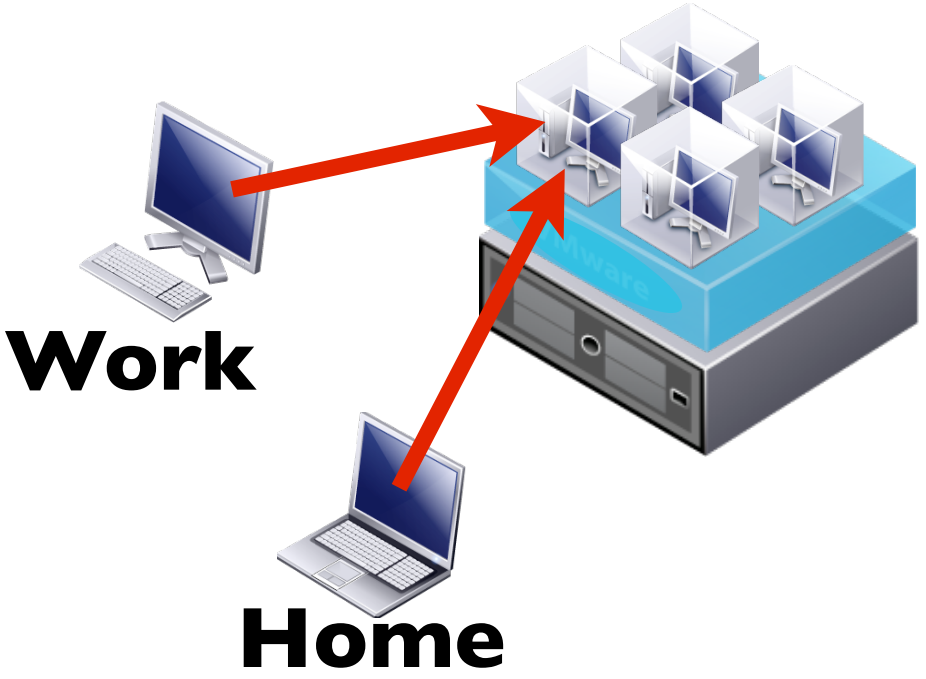


Virtualization in Data Centers

- Virtual Servers
  - Consolidate servers
  - Faster deployment
  - Easier maintenance



- Virtual Desktops
  - Host employee desktops in VMs
  - Remote access with thin clients
  - Desktop is available anywhere
  - Easier to manage and maintain



Data Center Challenges

- Resource management
  - How to efficiently use server and storage resources?
  - Many apps have variable, unpredictable workloads
  - Want high performance **and** low cost
  - Automated resource management
  - Performance profiling and prediction

- Energy Efficiency
  - Servers consume huge amounts of energy
  - Want to be "green"
  - Want to save money

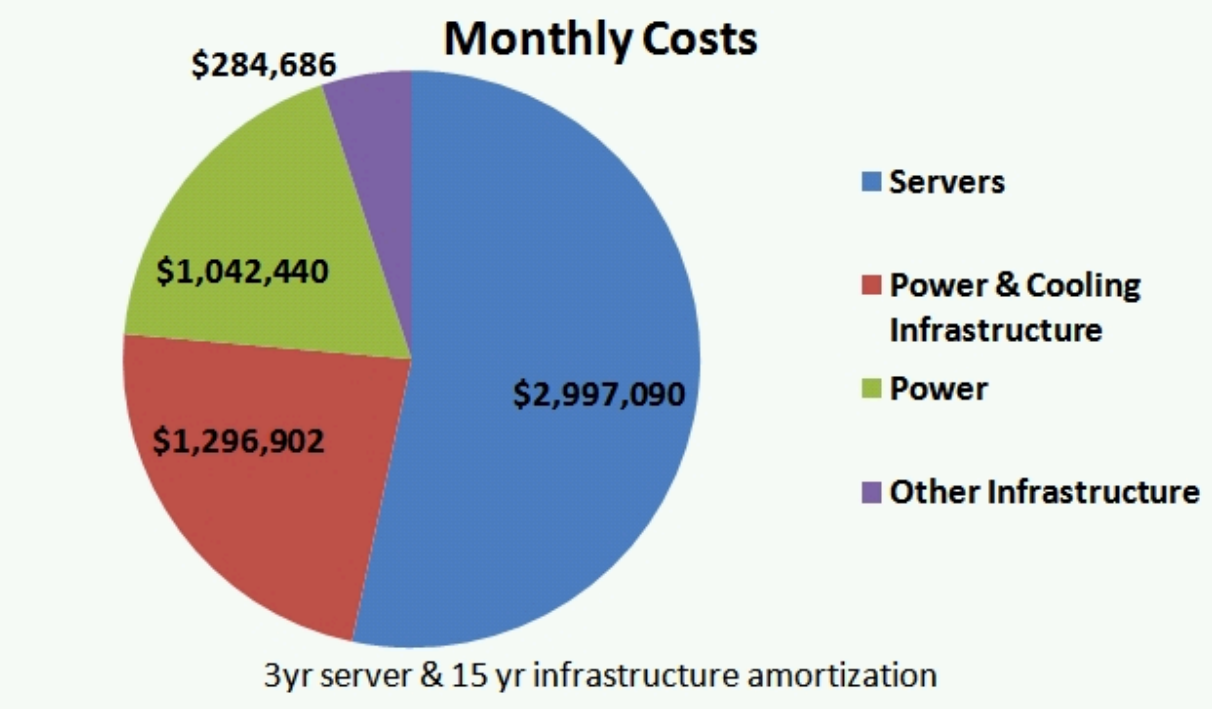
Reliability Challenges

- Typical failures in first year of a google data center:
  - 0.5% overheat (power down most machines in under five minutes, expect 1-2 days to recover)
  - 1 PDU (Power Distribution Unit) failure (about 500-1000 machines suddenly disappear, budget 6 hours to come back)
  - 1 rack-move (You have plenty of warning: 500-1000 machines powered down, about 6 hours)
  - 1 network rewiring (rolling 5% of machines down over 2-day span)
  - 20 rack failures (40-80 machines instantly disappear, 1-6 hours to get back) 5 racks go wonky (40-80 machines see 50% packet loss)
  - 8 network maintenances (4 might cause ~30-minute random connectivity losses)
  - 12 router reloads (takes out DNS and external virtual IP address (VIPS) for a couple minutes)
  - 3 router failures (have to immediately pull traffic for an hour)
  - dozens of minor 30-second blips for DNS
  - 1000 individual machine failures
  - thousands of hard drive failures

http://static.googleusercontent.com/external_content/untrusted_dlcp/research.google.com/en/us/people/jeff/stanford-295-talk.pdf

Data Center Costs

- Running a data center is expensive
- Efficiency captured as PUE (Power Usage Effectiveness)
  - Ratio of IT Power / Total Power (typical: 1.7, Google PUE ~ 1.1)

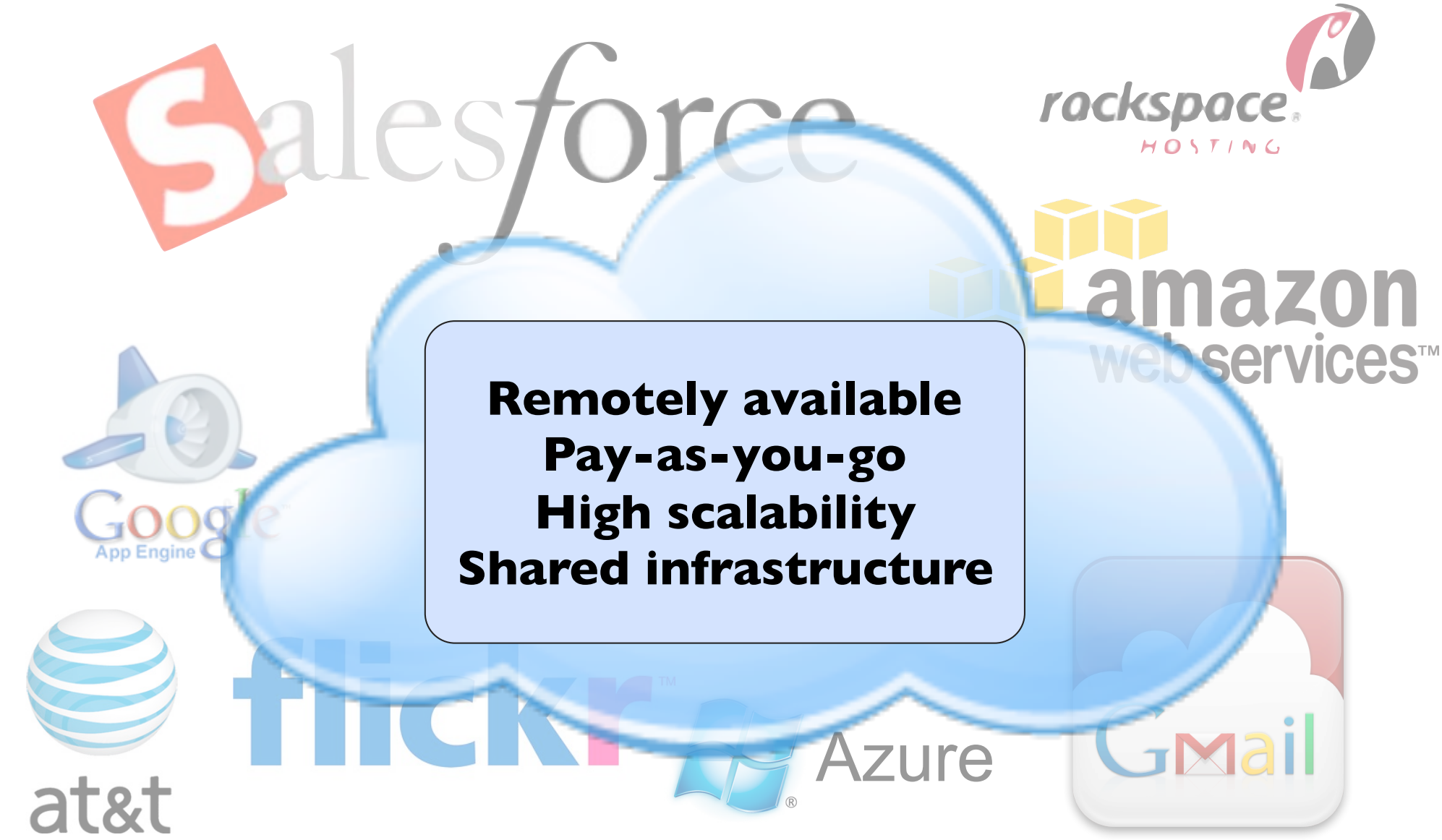


http://perspectives.mvdirona.com/2008/11/28/CostOfPowerInLargeScaleDataCenters.aspx

Economy of Scale

- Larger data centers can be cheaper to buy and run than smaller ones
  - Lower prices for buying equipment in bulk
  - Cheaper energy rates
- Automation allows small number of sys admins to manage thousands of servers
- General trend is towards larger mega data centers
  - 100,000s of servers
- Has helped grow the popularity of **cloud computing**

What is the cloud?



The Cloud Stack

Software as a Service

Hosted applications
Managed by provider

Platform as a Service

Platform to let you run
your own apps
Provider handles scalability

Infrastructure as a Service

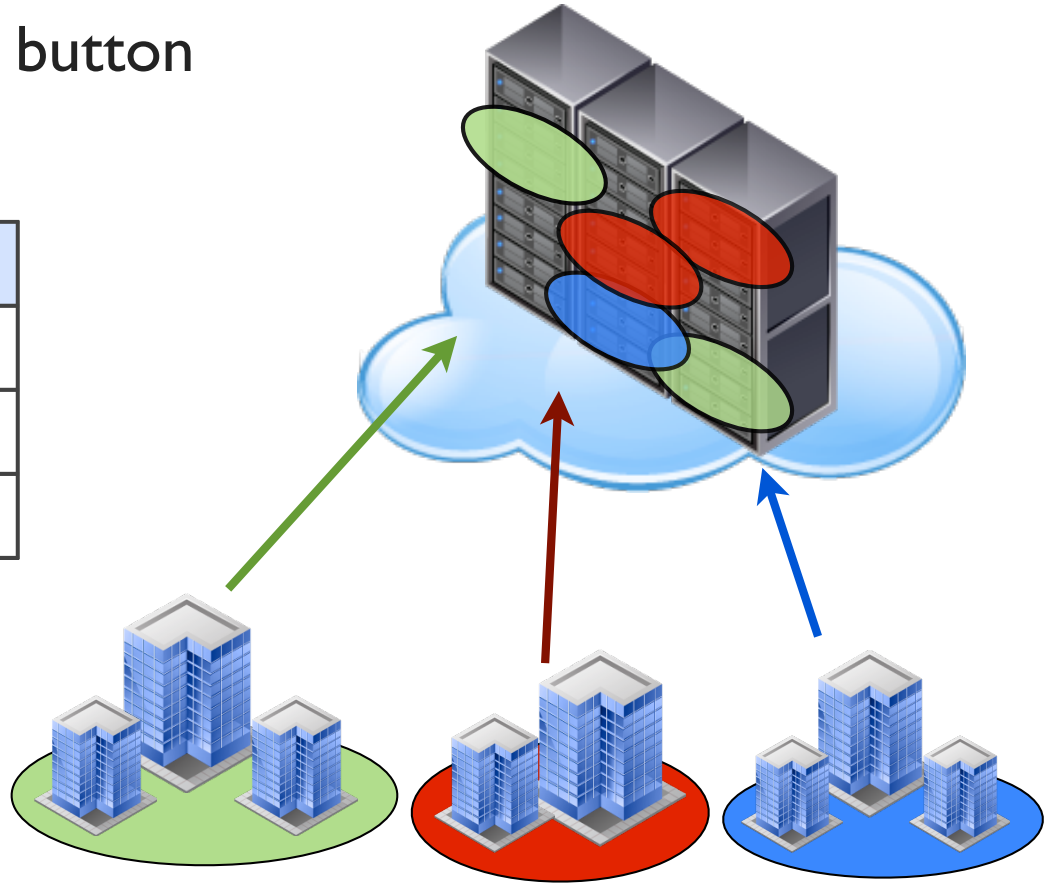
Raw infrastructure
Can do whatever you
want with it

IaaS: Amazon EC2

- Rents servers and storage to customers
  - Uses virtualization to share each server for multiple customers
  - Economy of scale lowers prices
  - Can create VM with push of a button

	Smallest	Medium	Largest
VCPUs	1	5	33.5
RAM	613MB	1.7GB	68.4GB
Price	$0.02/hr	$0.17/hr	$2.10/hr

Storage	$0.10/GB per month
Bandwidth	$0.10 per GB



PaaS: Google App Engine

- Provides highly scalable execution platform
  - Must write application to meet App Engine API
  - App Engine will autoscale your application
  - Strict requirements on application state
    - "Stateless" applications much easier to scale

- Not based on virtualization
  - Multiple users' threads running in same OS
  - Allows google to quickly increase number of "worker threads" running each client's application

- Simple scalability, but limited control
  - Only supports Java and Python

Public or Private

- Not all enterprises are comfortable with using **public cloud** services
  - Don't want to share CPU cycles or disks with competitors
  - Privacy and regulatory concerns
- Private Cloud
  - Use cloud computing concepts in a private data center
    - Automate VM management and deployment
    - Provides same convenience as public cloud
    - May have higher cost
- Hybrid Model
  - Move resources between private and public depending on load
  - Cloud Bursting

Programming Models

- Client/Server
  - Web servers, databases, CDNs, etc
- Batch processing
  - Business processing apps, payroll, etc
- Map Reduce
  - Data intensive computing
  - Scalability concepts built into programming model

Cloud Challenges

- Privacy / Security
  - How to guarantee isolation between client resources?
- Extreme Scalability
  - How to efficiently manage 1,000,000 servers?
- Programming models
  - How to effectively use 1,000,000 servers?

Further Resources

- "Above the Clouds" - cloud computing survey paper from Berkeley

- Workshops & Conferences
  - Hot Topics in Cloud Computing (HotCloud)
  - Symposium on Cloud Computing (SOCC)
  - lots of other small workshops
  - most recent systems conferences (NSDI, USENIX ATC, OSDI, SOSP)

- Other
  - Google App Engine / Amazon EC2 blogs
  - James Hamilton's Perspectives: http://perspectives.mvdirona.com/