http://www.cs.columbia.edu/~roxana/teaching/COMS-E6998-7-Fall-2011/

Challenges in Cloud Computing and Mobile Devices

COMS-6998-7 (Fall 2011)

Instructor: Roxana Geambasu
Presenters: Avner May and Yang Tang

9/14/11: Intro to Cloud Computing and Its Challenges

Announcement: Choice Between Reviews & Project

- You can choose to either:
  1. Do the paper reviews and class presentations, OR
  2. Do a research project, for which you can also get extra credit

- Reading the papers and participating in class discussions are mandatory for both cases

- Updates reflecting this change will appear on the class web page later today

Outline

- A history of cloud computing (Roxana)
  - Slides were inspired by Armando Fox' presentation on cloud computing history for the UC Berkeley's CS-10 course
- General challenges (Avner)
  - Above the clouds: A Berkeley view of cloud computing. M. Armbrust, A. Fox, R. Griffith, A.D. Joseph, R.H. Katz, A. Konwinski, G. Lee, D.A. Patterson, A. Rabkin, I. Stoica, M. Zaharia. Technical Report UCB/EECS-2009-28, 2009.
- Specific challenge: Side-channel information leakage (Yang)
  - Hey, you, get off of my cloud: Exploring information leakage in third-party compute clouds. T. Ristenpart, E. Tromer, H. Shacham, and S. Savage. In *Proceedings of the ACM Conference on Computing Communications Security (CCS)*, 2009.
- Further challenges (Roxana)

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What Is Cloud Computing?

- Computing technology in which data and/or computation are outsourced to a massive-scale, multi-user infrastructure that is managed by a third-party.

- Appeared gradually due to two important challenges facing the Web:
  - Scaling
  - Management

Around 1995: The Scaling Challenge

- The Web and e-commerce were gaining traction

- Their challenge: how to scale?
  - 1996 to 1997: eBay grew from 41,000 to 341,000 users!

Pre-1995 Answer: Big, Expensive Computers

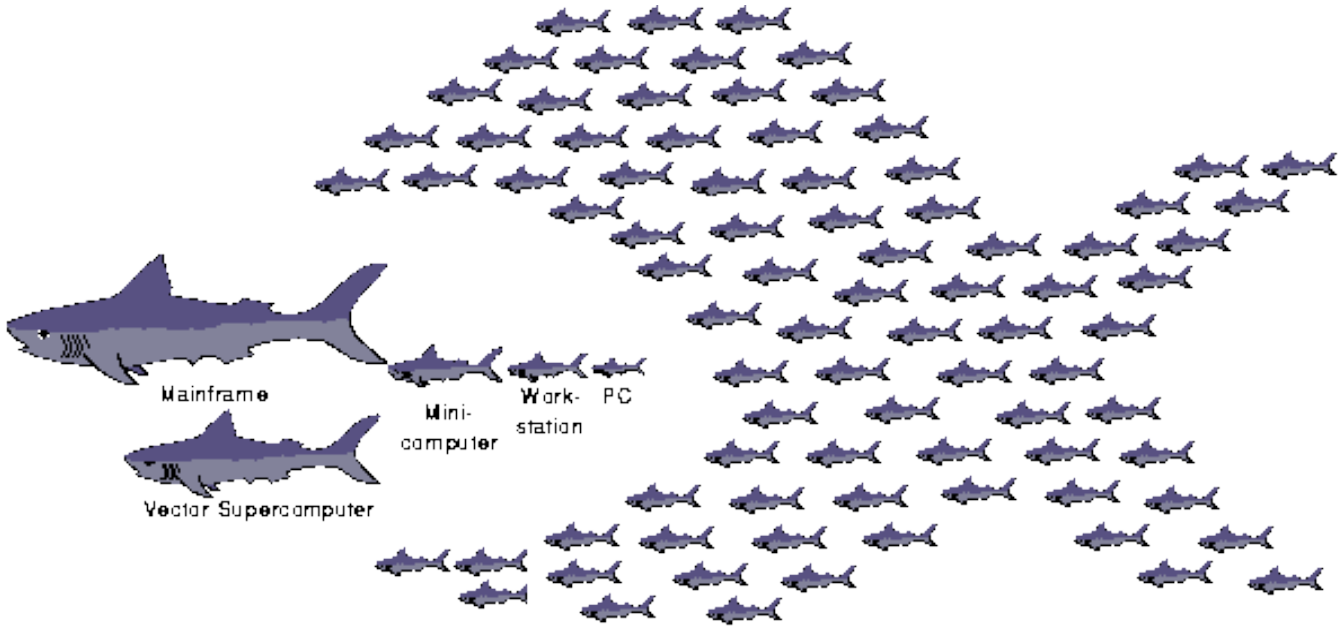
- Example: eBay used Sun E-10000 “supermini”
  - 64 processors @250MHz, 64GB RAM, 20TB disk, ~$1M
- The good:
  - Easy to manage
  - Easy to program
  - Simple failure mode
- The bad:
  - Q: Any ideas?

Pre-1995 Answer: Big, Expensive Computers

- Example: eBay used Sun E-10000 “supermini”
  - 64 processors @250MHz, 64GB RAM, 20TB disk, ~$1M
- The good:
  - Easy to manage
  - Easy to program
  - Simple failure mode
- The bad:
  - Expensive
  - Single point of failure
  - No incremental scalability

1995: Berkeley Network of Workstations (NOW)

- Idea: Leverage many interconnected small, cheap, general-purpose machines for incremental scalability and reliability
  - Typical PC: 200 MHz CPU, 32MB RAM, 4GB disk



A Case for Networks of Workstations: NOW. *IEEE Micro*, 1995. Tom Anderson, Dave Culler, Dave Patterson, el.al.

NOW-0

- 1994: NOW had 4 HP-735's

NOW-1

- 1995: NOW had 32 Sun SPARC stations

NOW-2

- 1997: 60 Sun SPARC-2's
- Build Inktomi app

Companies Adopt NOW

- Everybody builds their own clusters and grows them to handle more and more load
  - Examples: eBay, Amazon, Google, all .com bubble companies
- Similar to early days of electricity when everyone built their own generator

Q: What do you think happened next?

Late 1990s: The Manageability Challenge

- Hard to manage and program large clusters
  - How to write scalable distributed programs?
  - How to debug large-scale programs?
  - How to make services reliable?
  - How to architect the network infrastructure?
  - How to provision a cluster to handle peak load?
  - How to administer a huge number of computers?
  - …
- Each company had to build their own complex software
  - Like each of us building an OS from scratch!

Early 2000s: Scalable Cluster Primitives

- Very few technically strong companies create powerful scalable and reliable primitives for cluster management and programming
- Examples:
  - Google's Map/Reduce
  - The Google File System (GFS)
  - Google's Bigtable
  - Amazon's Dynamo
  - Distributed debugging and tracing tools
  - Datacenter temperature regulators
  - Scalable distributed communication mechanisms
  - …

Mid 2000s: Three Valuable Commodities

- Giant-scale clusters with enormous excess capacity
  - Everybody provisioned for peak

Q: How big was a typical Google datacenter around 2005?

a. 1,000 machines

b. 5,000 machines

c. 10,000 machines

d. 50,000 machines

e. 100,000 machines

Mid 2000s: Three Valuable Commodities

- Giant-scale clusters with enormous excess capacity
  - Everybody provisioned for peak
- Expertise for managing and operating clusters at low cost
  - "Economies of scale"
- Complex software to help program/manage clusters
  - Even full applications (e.g., Gmail, Google Calendar, etc.)

Q: What do you think happened next?

2006: Monetization of Cloud Infrastructure

- AWS sells resources, expertise, and access to cloud primitives in a pay-for-what-you-use model
  - Resources: CPU, network bandwidth, persistent storage
  - Cloud primitives: Amazon S3, EC2, SQS, Map/Reduce, etc.
- Google launches Google Apps for Your Domain
  - Customizable Gmail, Google Docs, Google Calendar under a custom domain (e.g., **`gmail.cs.columbia.edu`**)
- Google then launches the App Engine
  - Web hosting infrastructure (such infrastructures existed before, but never enjoyed popularity)
- Microsoft launches Azure in 2009

Great Advantages of Cloud Computing

- Low barrier of market entry for startups
- Cheaper, low-management email, calendars, CRM solutions
- New mobile applications
- Faster batch processing via parallelization
- … Avner will discuss …

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Avner

- (Other PPT)

Discussion Topics

- What other challenges does cloud computing raise?
- Do you agree with this quote: "There are no fundamental obstacles to making a cloud-computing environment as secure as the vast majority of in-house IT environments?"
- What is the cloud economics equation missing?

$$\text{UserHours}_{\text{cloud}} \times (\text{revenue} - \text{Cost}_{\text{cloud}}) \geq \text{UserHours}_{\text{datacenter}} \times \left(\text{revenue} - \frac{\text{Cost}_{\text{datacenter}}}{\text{Utilization}}\right)$$

Discussion Topics

- What other challenges does cloud computing raise?
  - Global energy consumption: is it better to run in optimized cloud and transfer data back and forth OR run locally on less optimized devices?
- Do you agree with this quote: "There are no fundamental obstacles to making a cloud-computing environment as secure as the vast majority of in-house IT environments?"
  - Lack of trust in cloud providers changes game fundamentally
- What is the cloud economics equation missing?

$$\text{UserHours}_{\text{cloud}} \times (\text{revenue} - \text{Cost}_{\text{cloud}}) \geq \text{UserHours}_{\text{datacenter}} \times \left(\text{revenue} - \frac{\text{Cost}_{\text{datacenter}}}{\text{Utilization}}\right)$$

  - Quality of service: availability, reliability, etc. – how to put a value on those?

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Yang

- (PDF)

Discussion Topics

- A *weakness* is only a *vulnerability* if it's worth exploiting. Does this paper prove the existence of a *vulnerability*?
- Why did Amazon have these "vulnerabilities"?
- Would allowing users to specify where to run their instances be better or worse for security?
- What are the disadvantages of a random placement policy?

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Additional Data-related Challenges

- Both of today's papers assume trust in the cloud provider
- But should the provider always be trusted?

Additional Data-related Challenges

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- But should the provider always be trusted?
  - Weak and dynamic contractual agreements (ToS) result in weak assurances by the cloud
  - Provider could respond to subpoenas without client's knowledge or control
  - Provider may have monetary incentives to reveal your data to unintended parties (ad companies, insurance companies)
  - Provider may want to lower replication factors for your long-unused data to save on storage costs
  - Provider may want to keep your data even after you request its deletion to be able to mine it
  - …

Our Definition of Cloud Computing

- Computing technology in which data and/or computation are outsourced to a massive-scale, multi-user infrastructure that is managed by a third-party.

- Includes both:
  - Software as a service (e.g., Gmail, Google Docs, Mozy, etc.)
  - Infrastructure/platform as a service (e.g., Amazon AWS, Google AppEngine, Microsoft Azure, etc.)

Next Class: Cryptographic Solutions

- **Public key encryption with keyword search.** D. Boneh, G. D. Crescenzo, R. Ostrovsky, and G. Persiano. In *Proceedings of the IACR Annual Eurocrypt Conference*, 2004.
- **Computing arbitrary functions of encrypted data.** C. Gentry. In *Communications of the ACM*, 2008.

Assignments:

- Those with projects: schedule meeting with me
- Those without projects: sign up to present assigned papers or to create presentations for Optional papers
- Everyone:
  - Send me your project/no project choice by Friday, Sept 14, 8pm
  - Read papers and prepare to discuss them in class!