CS 525
Advanced Distributed Systems
Spring 2016

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Lecture 2

What(’s in) the Cloud?

January 21, 2016

Google App Engine

amazon web services

RIGHTSCALE

ORACLE

GridGain 2.0

Elastic Server

VirtualBox

virtualLogix

vmware

force.com platform as a service

CITRIX

OpenVZ

KVM

10gen

Microsoft

parascale Powering Cloud Storage

hp

Xen

GIGASPACES

Parallels Optimized Computing

RIGHTSCALE

enomaly

elastra

ORACLE

BUNGEEconnect

PowerVM

Virtualiron

The Hype!

- Forrester in 2010 – Cloud computing will go from $40.7 billion in 2010 to $241 billion in 2020.
- Goldman Sachs says cloud computing will grow at annual rate of 30% from 2013-2018
- Hadoop market to reach $20.8 B by by 2018: Transparency Market Research
- Companies and even Federal/state governments using cloud computing now: fbo.gov

Many Cloud Providers

AWS: Amazon Web Services
- EC2: Elastic Compute Cloud
- S3: Simple Storage Service
- EBS: Elastic Block Storage

- Microsoft Azure
- Google Cloud/Compute Engine
- Rightscale, Salesforce, EMC, Gigaspaces, 10gen, Datastax, Oracle, VMWare, Yahoo, Cloudera
- And many many more!

Two Categories of Clouds

- Can be either a (i) public cloud, or (ii) private cloud
- Private clouds are accessible only to company employees
- Public clouds provide service to any paying customer:
  - Amazon S3 (Simple Storage Service): store arbitrary datasets, pay per GB-month stored
  - Amazon EC2 (Elastic Compute Cloud): upload and run arbitrary OS images, pay per CPU hour used
  - Google AppEngine/Compute Engine: develop applications within their appengine framework, upload data that will be imported into their format, and run

Customers Save Time and $$$

- Dave Power, Associate Information Consultant at Eli Lilly and Company: “With AWS, Powers said, a new server can be up and running in **three minutes** (it used to take Eli Lilly **seven and a half weeks** to deploy a server internally) and a 64-node Linux cluster can be online **in five minutes** (compared with three months internally). … It's just shy of instantaneous.”

- Ingo Elfering, Vice President of Information Technology Strategy, GlaxoSmithKline: “With Online Services, we are able to reduce our IT operational costs by roughly **30%** of what we’re spending”

- Jim Swartz, CIO, Sybase: “At Sybase, a private cloud of virtual servers inside its datacenter has saved nearly **$US2 million annually** since 2006, Swartz says, because the company can share computing power and storage resources across servers.”

- 100s of startups in Silicon Valley can harness large computing resources without buying their own machines.

But what exactly IS a cloud?

What is a Cloud?

- It's a cluster!
- It's a supercomputer!
- It's a datastore!
- It's superman!

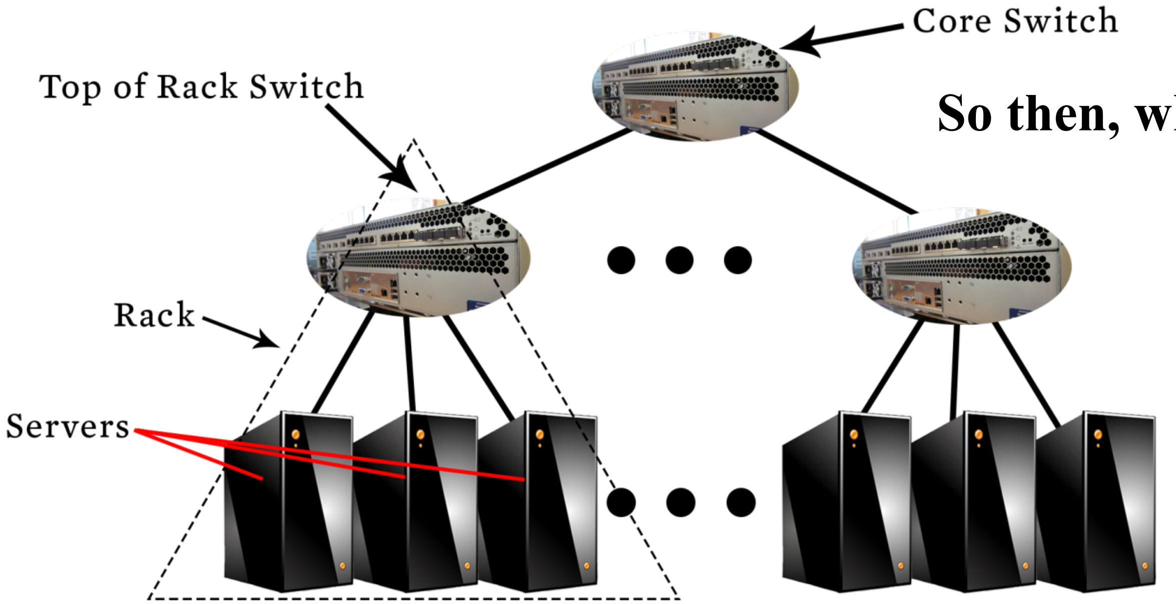
- None of the above
- All of the above

- Cloud = Lots of storage + compute cycles nearby

What is a Cloud?

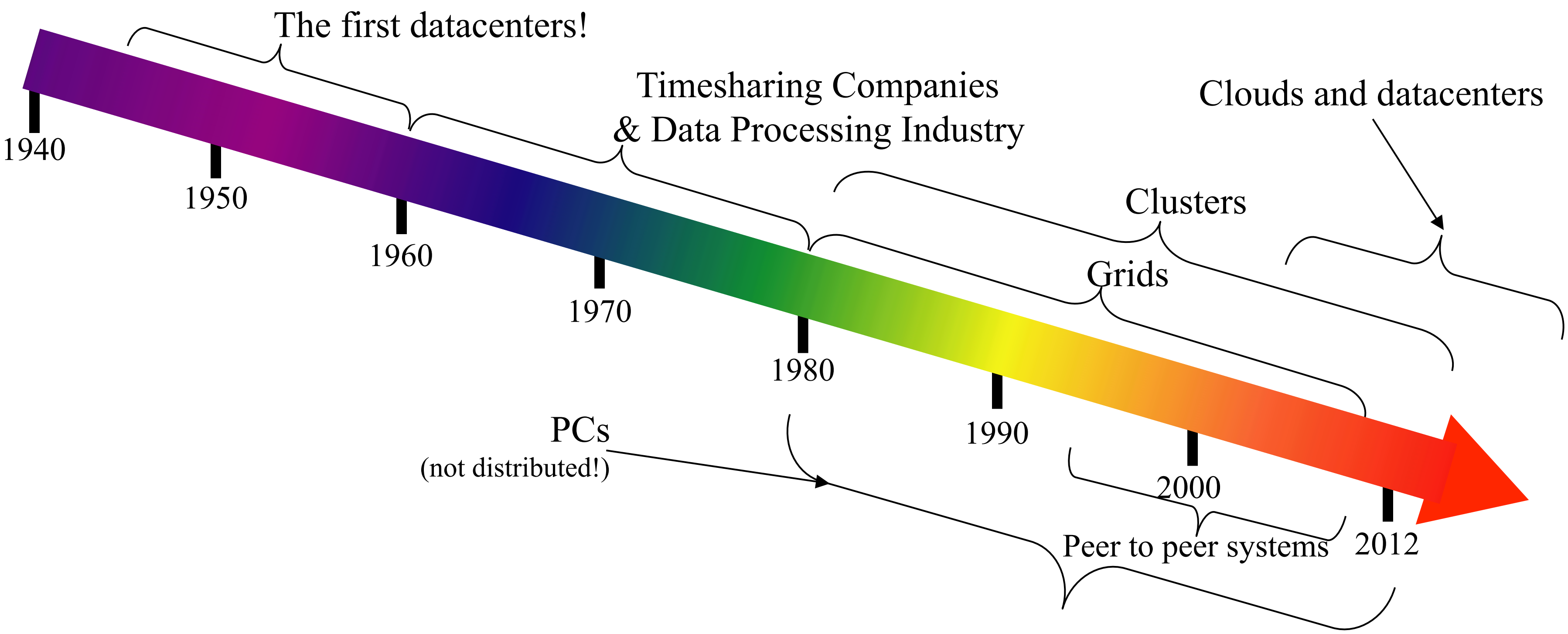
- A single-site cloud (aka "Datacenter") consists of
  - Compute nodes (grouped into racks)
  - Switches, connecting the racks
  - A network topology, e.g., hierarchical
  - Storage (backend) nodes connected to the network
  - Front-end for submitting jobs and receiving client requests
  - (Often called 3-tier architecture)
  - Software Services
- A geographically distributed cloud consists of
  - Multiple such sites
  - Each site perhaps with a different structure and services

A Sample Cloud Topology



So then, what is a cluster?

"A Cloudy History of Time"



"A Cloudy History of Time"

First large datacenters: ENIAC, ORDVAC, ILLIAC
Many used vacuum tubes and mechanical relays

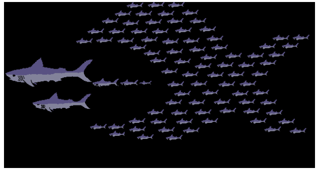
1940

1950

1960

IBM
xerox
Honeywell

1970

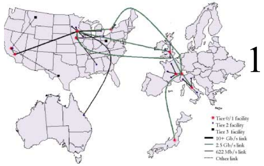


CRAY THE SUPERCOMPUTER COMPANY

Berkeley NOW Project
Supercomputers
Server Farms (e.g., Oceano)

1980

Open Science Grid



1990

P2P Systems (90s-00s)
•Many Millions of users
•Many GB per day

LimeWire

2000

KaZaA

BitTorrent

2012

Clouds

Data Processing Industry
- 1968: $70 M. 1978: $3.15 Billion

Timesharing Industry (1975):
•Market Share: Honeywell 34%, IBM 15%,
•Xerox 10%, CDC 10%, DEC 10%, UNIVAC 10%
•Honeywell 6000 & 635, IBM 370/168,
Xerox 940 & Sigma 9, DEC PDP-10, UNIVAC 1108

Grids (1980s-2000s):
•GriPhyN (1970s-80s)
•Open Science Grid and Lambda Rail (2000s)
•Globus & other standards (1990s-2000s)

Trends: Technology

- Doubling Periods – storage: 12 mos, bandwidth: 9 mos, and (what law is this?) cpu compute capacity: 18 mos
- Then and Now
  - Bandwidth
    - 1985: mostly 56Kbps links nationwide
    - 2014: Tbps links widespread
  - Disk capacity
    - Today's PCs have TBs, far more than a 1990 supercomputer

Trends: Users

- Then and Now

  Biologists:

  - 1990: were running small single-molecule simulations
  - 2012: CERN's Large Hadron Collider producing many PB/year

Prophecies

- In 1965, MIT's Fernando Corbató and the other designers of the Multics operating system envisioned a computer facility operating “like a power company or water company”.

- Plug your thin client into the computing Utility and Play your favorite Intensive Compute & Communicate Application
  - Have today’s clouds brought us closer to this reality? Think about it.

Four Features New in Today's Clouds

I. Massive scale.

II. On-demand access: Pay-as-you-go, no upfront commitment.
   - And anyone can access it

III. Data-intensive Nature: What was MBs has now become TBs, PBs and XBs.
   - Daily logs, forensics, Web data, etc.
   - Humans have data numbness: Wikipedia (large) compressed is only about 10 GB!

IV. New Cloud Programming Paradigms: MapReduce/Hadoop, NoSQL/Cassandra/MongoDB and many others.
   - High in accessibility and ease of programmability
   - Lots of open-source

Combination of one or more of these gives rise to novel and unsolved distributed computing problems in cloud computing.

I. Massive Scale

- Facebook [GigaOm, 2012]
  - 30K in 2009 -> 60K in 2010 -> 180K in 2012
- Microsoft [NYTimes, 2008]
  - 150K machines
  - Growth rate of 10K per month
  - 80K total running Bing
- Yahoo! [2009]:
  - 100K
  - Split into clusters of 4000
- AWS EC2 [Randy Bias, 2009]
  - 40K machines
  - 8 cores/machine
- eBay [2012]: 50K machines
- HP [2012]: 380K in 180 DCs
- Google: A lot

What does a datacenter look like from inside?

- A virtual walk through a datacenter
- Reference: http://gigaom.com/cleantech/a-rare-look-inside-facebooks-oregon-data-center-photos-video/

Servers

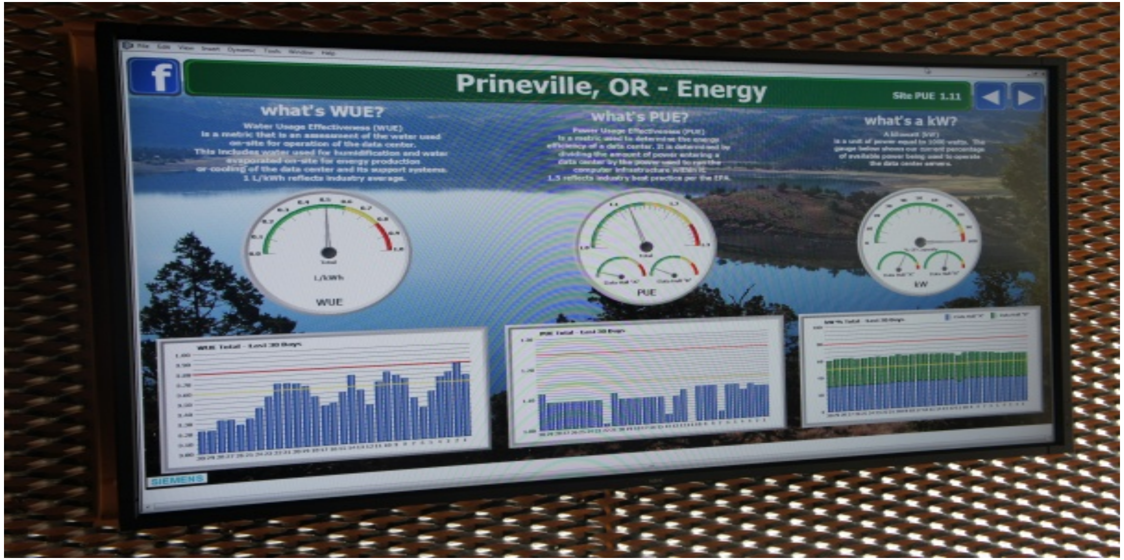
Front

Back

In

Some highly secure (e.g., financial info)

Power



Off-site

On-site

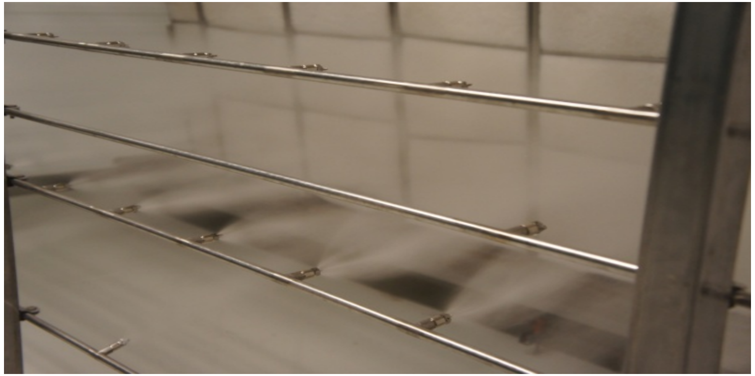
•WUE = Annual Water Usage / IT Equipment Energy (L/kWh) – low is good

•PUE = Total facility Power / IT Equipment Power – low is good (e.g., Google~1.11)

Cooling

Air sucked in from top (also, Bugzappers)

Water purified



Water sprayed into air

15 motors per server bank

Extra - Fun Videos to Watch

- [Microsoft GFS Datacenter Tour (Youtube)](http://www.youtube.com/watch?v=hOxA1l1pQIw)
  - http://www.youtube.com/watch?v=hOxA1l1pQIw

- [Timelapse of a Datacenter Construction on the Inside (Fortune 500 company)](http://www.youtube.com/watch?v=ujO-xNvXj3g)
  - http://www.youtube.com/watch?v=ujO-xNvXj3g

II. On-demand access: *aaS Classification

On-demand: renting a cab vs. (previously) renting a car, or buying one. E.g.:

- AWS Elastic Compute Cloud (EC2): a few cents to a few $ per CPU hour
- AWS Simple Storage Service (S3): a few cents per GB-month

- HaaS: Hardware as a Service
  - You get access to barebones hardware machines, do whatever you want with them, Ex: Your own cluster
  - Not always a good idea because of security risks
- IaaS: Infrastructure as a Service
  - You get access to flexible computing and storage infrastructure. Virtualization is one way of achieving this (cgroups, Kubernetes, Dockers, VMs,…). Often said to subsume HaaS.
  - Ex: Amazon Web Services (AWS: EC2 and S3), Eucalyptus, Rightscale, Microsoft Azure, Google Cloud.

II. On-demand access: *aaS Classification

- PaaS: Platform as a Service
  - You get access to flexible computing and storage infrastructure, coupled with a software platform (often tightly coupled)
  - Ex: Google's AppEngine (Python, Java, Go)
- SaaS: Software as a Service
  - You get access to software services, when you need them. Often said to subsume SOA (Service Oriented Architectures).
  - Ex: Google docs, MS Office on demand

III. Data-intensive Computing

- Computation-Intensive Computing
  - Example areas: MPI-based, High-performance computing, Grids
  - Typically run on supercomputers (e.g., NCSA Blue Waters)
- Data-Intensive
  - Typically store data at datacenters
  - Use compute nodes nearby
  - Compute nodes run computation services
- In data-intensive computing, the focus shifts from computation to the data: CPU utilization no longer the most important resource metric, instead I/O is (disk and/or network)

IV. New Cloud Programming Paradigms

- Easy to write and run highly parallel programs in new cloud programming paradigms:
  - Google: MapReduce and Sawzall
  - Amazon: Elastic MapReduce service (pay-as-you-go)
  - Google (MapReduce)
    - Indexing: a chain of 24 MapReduce jobs
    - ~200K jobs processing 50PB/month (in 2006)
  - Yahoo! (Hadoop + Pig)
    - WebMap: a chain of several MapReduce jobs
    - 300 TB of data, 10K cores, many tens of hours
  - Facebook (Hadoop + Hive)
    - ~300TB total, adding 2TB/day (in 2008)
    - 3K jobs processing 55TB/day
  - Similar numbers from other companies, e.g., Yieldex, eharmony.com, etc.
  - NoSQL: MySQL is an industry standard, but Cassandra is 2400 times faster!

Two Categories of Clouds

- Can be either a (i) public cloud, or (ii) private cloud
- Private clouds are accessible only to company employees
- Public clouds provide service to any paying customer

- You’re starting a new service/company: should you use a public cloud or purchase your own private cloud?

Single site Cloud: to Outsource or Own?

- Medium-sized organization: wishes to run a service for *M* months
  - Service requires 128 servers (1024 cores) and 524 TB
  - Same as UIUC CCT (Cloud Computing Testbed) cloud site
- All costs circa 2009
- Outsource (e.g., via AWS): *monthly* cost
  - S3 costs: \$0.12 per GB month. EC2 costs: \$0.10 per CPU hour (costs from 2009)
  - Storage = \$ 0.12 X 524 X 1000 ~ \$62 K
  - Total = Storage + CPUs = \$62 K + \$0.10 X 1024 X 24 X 30 ~ \$136 K
- Own: monthly cost
  - Storage ~ \$349 K / *M*
  - Total ~ \$ 1555 K / *M* + 7.5 K (includes 1 sysadmin / 100 nodes)
    - using 0.45:0.4:0.15 split for hardware:power:network and 3 year lifetime of hardware

Single site Cloud: to Outsource or Own?

- Breakeven analysis: more preferable to own if:
  - $\$349\text{ K} / M < \$62\text{ K}$ (storage)
  - $\$ 1555\text{ K} / M + 7.5\text{ K} < \$136\text{ K}$ (overall)

  Breakeven points
  - $M > 5.55$ months (storage)
  - $M > 12$ months (overall)

- As a result
  - Startups use clouds a lot
  - Cloud providers benefit monetarily most from storage

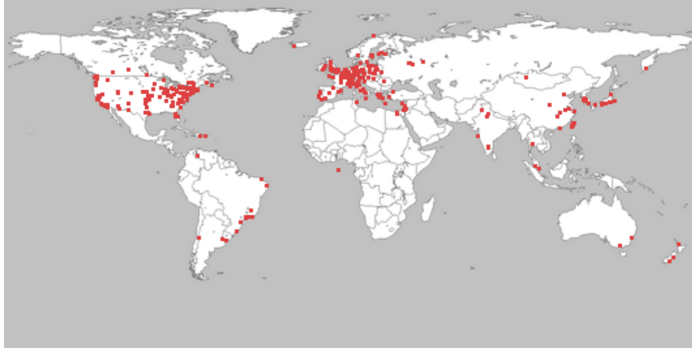
ACADEMIC CLOUDS: EMULAB

- A community resource open to researchers in academia and industry. Very widely used by researchers everywhere today.
- https://www.emulab.net/
- A cluster, with currently ~500 servers
- Founded and owned by University of Utah (led by Late Prof. Jay Lepreau)

- As a user, you can:
  - Grab a set of machines for your experiment
  - You get root-level (sudo) access to these machines
  - You can specify a network topology for your cluster
  - You can emulate any topology

PLANETLAB

An open platform for developing, deploying, and accessing planetary-scale services



- A community resource open to researchers in academia and industry
- http://www.planet-lab.org/
- Currently, ~ 1077 nodes at ~500 sites across the world
- Founded at Princeton University (led by Prof. Larry Peterson), but owned in a federated manner by the sites

- Node: Dedicated server that runs components of PlanetLab services.
- Site: A location, e.g., UIUC, that hosts a number of nodes.
- Sliver: Virtual division of each node. Currently, uses VMs, but it could also other technology. Needed for timesharing across users.
- Slice: A spatial cut-up of the PL nodes. Per user. A slice is a way of giving each user (Unix-shell like) access to a subset of PL machines, selected by the user. A slice consists of multiple slivers, one at each component node.
- Thus, PlanetLab allows you to run real world-wide experiments.
- Many services and projects have been deployed atop it, used by millions (not just researchers): Application-level DNS services, Monitoring services, CoralCDN, etc.

Speaking of Projects…

- For now, it's important to start thinking of who's going to be on your project team…

Projects

- Groups of 2-3.
- We'll start detailed discussions "soon" (early Feb), but start discussing ideas now (start by browsing the Course Schedule)
  - Read ahead, especially the "More papers" in sections later in the course (and sections not covered in the course, i.e., marked "Leftover")

Selecting your Team is Important

- Selecting your partner is important: select someone with a complementary personality to yours!
  - Apple: Wozniak loved being an engineer and hated interacting with people, Jobs loved making calls, doing sales and preferred engineering much less
  - Flickr: Stewart was improvisational, Fake was goal-driven
  - Paypal: Levchin loved to program and break things, Thiel talked to VCs and did sales.
  - RoR: Hansson says that development of Ruby on Rails benefited from having a small team and a small budget that kept them focused – this is why the big giants could not beat them.
- The upshot is that you have to select a team with complementary characteristics
- Selecting your team – 1) DIY or 2) use Piazza or 3) just hang back after class today
- Piazza is up (link from course website)

Presentations and Scribes

Student-led paper presentations (see instructions on website)

- **Start from February 11th**
- **Groups of up to 2 students present** each class, responsible for a set of 2 "Main Papers" on a topic
  - 45 minute presentations (total) followed by discussion
  - ***Email me slides at least 24 hours before the presentation time***
  - **Select your topic by Jan 28th - visit me in OH to sign up**
- **Plus one Scribe**
  - summarize Piazza, lead discussion at end of class, and post a scribe summary after class
  - **Sign up by Jan 28th**
- **Everyone in the class must participate as a presenter or scribe for at least one session**
- List of papers is up on the website

Administrative Announcements (2)

- Each of the *other* students (non-presenters/scribers) expected to **read the papers before class** and turn in a one to two page **review** of the **two** main papers (summary, comments, criticisms and possible future directions)
  - Post review on Piazza **before noon** on day of class
  - Reviews are not due until student presentations start
- You must review all sessions on+after 2/11 (except the one your present/scribe in)
- We highly recommend doing a presentation – you learn more and it's overall less work
  - But sign up early before the slots are gone!

Summary

- Clouds build on many previous generations of distributed systems
- Especially the timesharing and data processing industry of the 1960-70s.
- Need to identify unique aspects of a problem to classify it as a new cloud computing problem
  - Scale, On-demand access, data-intensive, new programming
- Otherwise, the solutions to your problem may already exist!