



UNIVERSITY of TARTU

INSTITUTE OF COMPUTER SCIENCE



MTAT.08.027

# Basics of Cloud Computing (3 ECTS)

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**Mobile & Cloud Lab**



# Course Purpose

- Introduce cloud computing concepts
- Introduce cloud providers and usage scenarios
- Introduction to distributed computing algorithms like MapReduce
- Glance of research at Mobile & Cloud Lab in cloud computing domain
- <https://courses.cs.ut.ee/2017/cloud/spring/>

# Schedule

- Lecture
  - Tuesday 10:15 – 12:00 (J. Liivi 2 - 402)
- Labs
  - Wed 10:15 - 12:00 (J. Liivi 2 - 205) (1. group)
  - Wed 16:15 - 18:00 (J. Liivi 2 - 205) (2. group)
  - Fri 14:15 - 16:00 (J. Liivi 2 - 205) (3. group)

# Course Logistics

- MTAT.08.011 - Basics of Grid and Cloud Computing
  - Was discontinued from 2014
- MTAT.08.037 Basics of Scientific Computing Infrastructures (3 ECTS)
  - You can take the above course Instead of Grid part
- Consult your curriculum coordinators

# Questions

- Is everyone comfortable with data structures?
- How comfortable you are with algorithms?
- How comfortable you are with programming?
  - Java ?
    - External APIs?
  - Python – I assume you are
  - Web programming

# Grading

- Written exam – 50%
- Labs – 45%
  - 7 lab exercises
- Active participation in the lectures (Max 5%)
  
- To pass the course
  - You need to score at least 50% in each of the above subsections
  - You need to score at least 50% in the total

# Taking the Course

- Got reputation as a tough course
  - People who have stuck with the curriculum have scored good
- Labs will get you easy points
  - Will try to provide bonus points for some of the labs
- Examination is considered to be a bit tough
  - One of the previous year's examination paper is online
- Being a practical course it takes enough time and effort

# Course schedule & Outline

- **07.02** Basics of Cloud Computing
- **14.02** Cloud Providers & SciCloud
- **21.02** Scaling in Cloud
- **28.02** MapReduce
- **07.03** MapReduce Algorithms
- **14.03** Platform as a Service
- **21.03** Other Cloud Services
- **28.03** Examination 1 – Option 2
  - **27.03** Examination 1 – Option 1



# Course schedule - continued

- Labs

**8-10.02** Starting with a cloud

**15-17.02** Working with SciCloud

**22-24.02** Load balancing in cloud

**01-03.03** MapReduce - Basics

**08-10.03** Data analysis with MapReduce

**15-17.03** Google AppEngine

**22-24.03** Other Cloud Services

# Grading of Labs

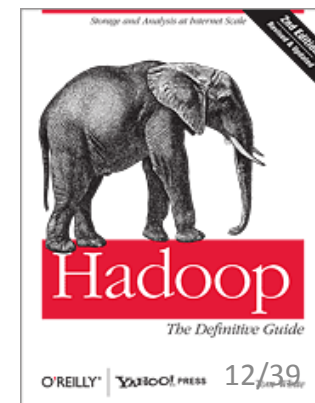
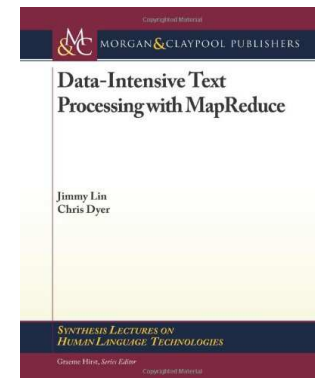
- Strongly suggest you to finish the lab exercises before coming to the next lecture
- Try to submit the results by Tuesday 10:00 next week to be graded for full score
- Late submissions
  - You can submit the results till one day before your scheduled lab (group) for 90% score
    - Bonus points will still put it ~above 100%
  - After that 10% will be deducted per day
  - You can submit exercises for 50% evaluation till 28.03

# Course schedule - continued

- **28.03** Examination 1 – Option 2
- **27.03** Examination 1 – Option 1
- Examination for second attempt – 11<sup>th</sup> April

# Reference Books

- Mastering Cloud Computing: Foundations and Applications Programming  
Authors: Rajkumar Buyya, Christian Vecchiola, S.Thamarai Selvi
- Data-Intensive Text Processing with MapReduce  
Authors: Jimmy Lin and Chris Dyer  
<http://lintool.github.io/MapReduceAlgorithms/MapReduce-book-final.pdf>
- White, Tom. Hadoop: the definitive guide. O'Reilly, 2012.



# Reference Papers

- M. Armbrust et al., “Above the Clouds, A Berkeley View of Cloud Computing”, Technical Report, University of California, Feb, 2009.
- Dean, J., & Ghemawat, S. (2008). MapReduce: simplified data processing on large clusters. *Communications of the ACM*, 51(1), 107-113.

Lecture 1

# **CLOUD COMPUTING**

“It’s nothing new”  
“It’s a trap”

“...we’ve read  
Computing  
that we already  
understand  
different  
the world

“It’s worse than stupidity: it’s  
marketing hype. Somebody is  
saying this is inevitable—and  
whenever you hear that, it’s very  
likely to be a set of businesses  
campaigning to make it true.”

Larry E.  
Street

Richard Stallman, Founder, Free  
Software Foundation (The  
Guardian, Sept. 29, 2008)

Nothing is new!

Anyone thinks it is something else...

# What is Cloud Computing?

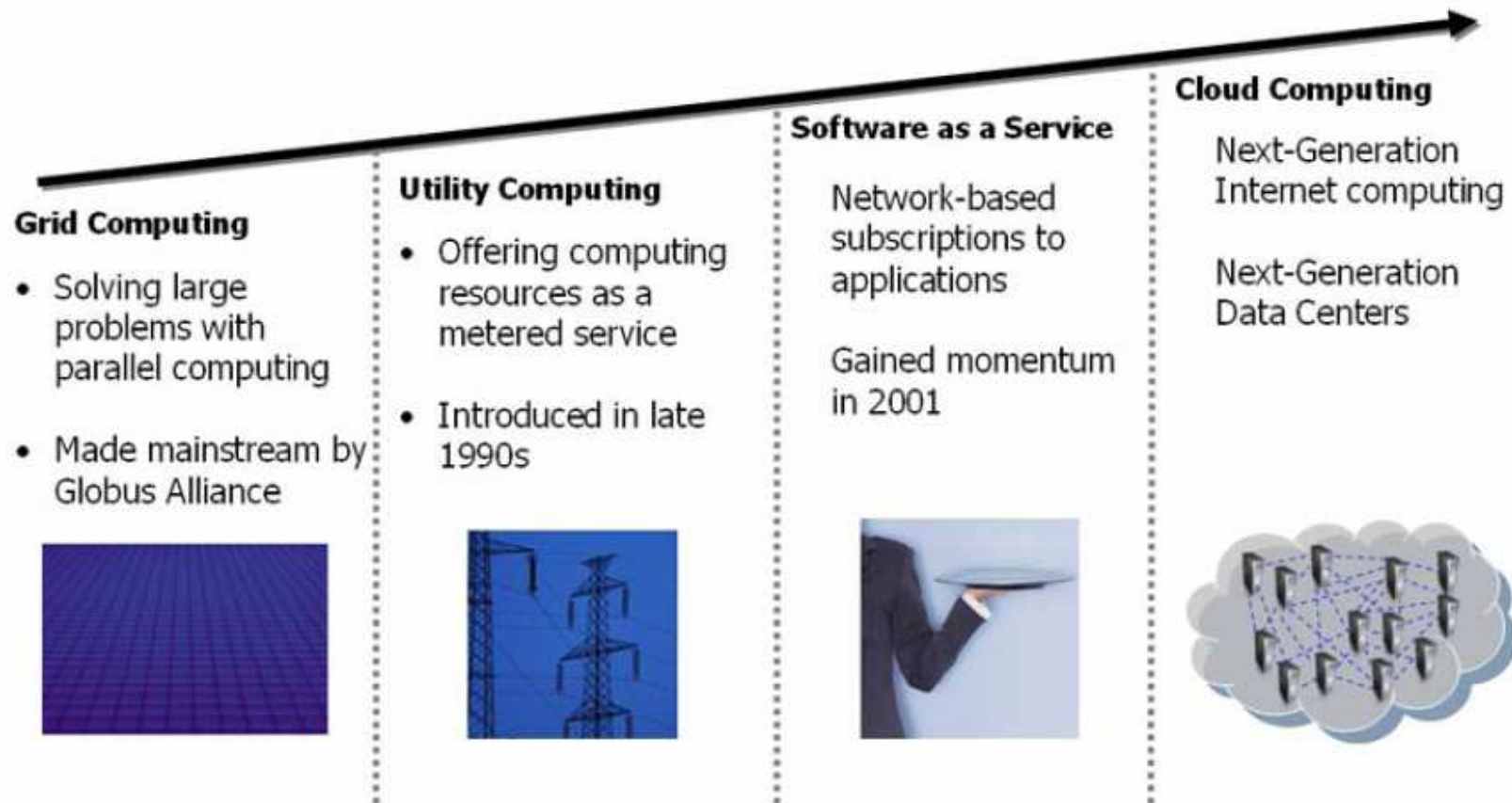
- Computing as a utility
  - Utility services e.g. water, electricity, gas etc
  - Consumers pay based on their usage

## 1969 – Leonard Kleinrock, ARPANET project

- “As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of ‘computer utilities’, which, like present electric and telephone utilities, will service individual homes and offices across the country”



# Timeline

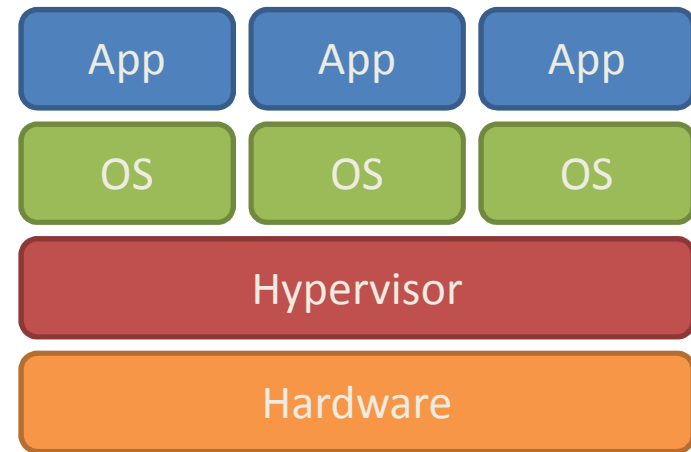


# Clouds - Why Now (not then)?

- Experience with very large datacenters
  - Unprecedented economies of scale
  - Transfer of risk
- Technology factors
  - Pervasive broadband Internet
  - Maturity in Virtualization Technology
- Business factors
  - Minimal capital expenditure
  - Pay-as-you-go billing model

# Virtualization

- Virtualization techniques are the basis of the cloud computing
- Virtualization technologies partition hardware and thus provide flexible and scalable computing platforms
- Virtual machine techniques
  - VMware and Xen
  - OpenNebula
  - Amazon EC2



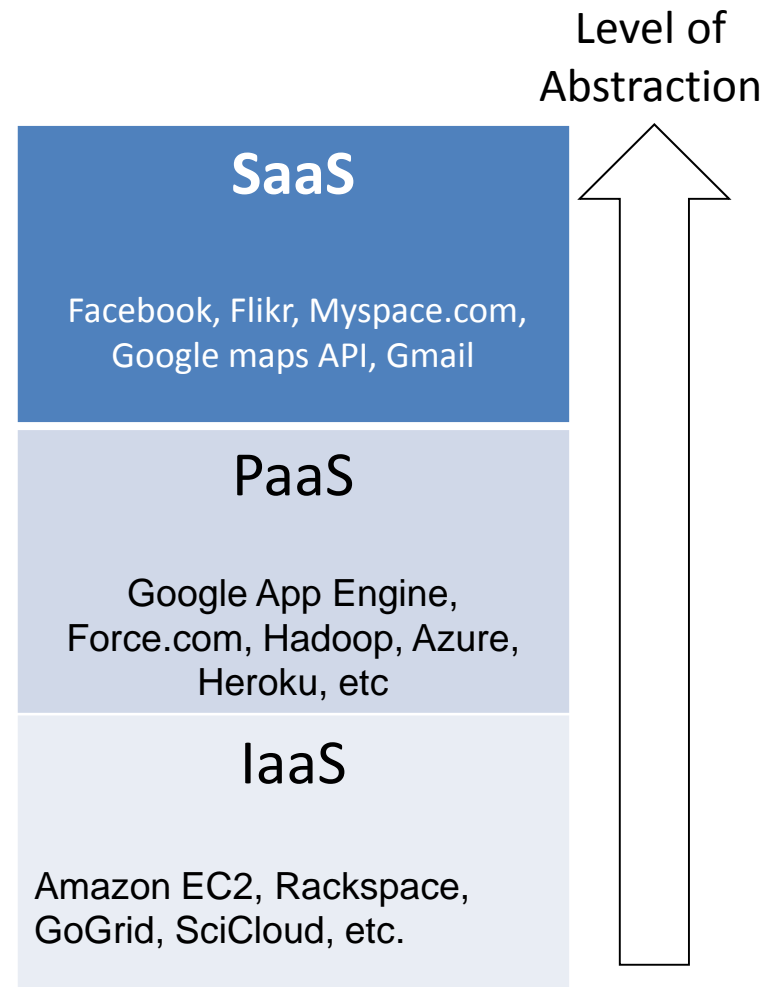
Virtualized Stack

# Cloud Computing - Characteristics

- Illusion of infinite resources
- No up-front cost
- Fine-grained billing (e.g. hourly)
- **Gartner:** “Cloud computing is a style of computing where massively scalable IT-related capabilities are provided ‘as a service’ across the Internet to multiple external customers”

# Cloud Computing - Services

- Software as a Service – SaaS
  - A way to access applications hosted on the web through your web browser
- Platform as a Service – PaaS
  - Provides a computing platform and a solution stack (e.g. LAMP) as a service
- Infrastructure as a Service – IaaS
  - Use of commodity computers, distributed across Internet, to perform parallel processing, distributed storage, indexing and mining of data
  - Virtualization



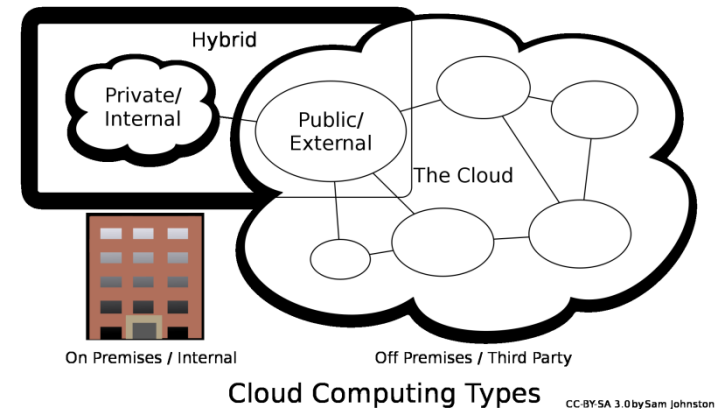
# Cloud Computing - Themes

- Massively scalable
- On-demand & dynamic
- Only use what you need - Elastic
  - No upfront commitments, use on short term basis
- Accessible via Internet, location independent
- Transparent
  - Complexity concealed from users, virtualized, abstracted
- Service oriented
  - Easy to use SLAs

SLA – Service Level Agreement

# Cloud Models

- Internal (private) cloud
  - Cloud with in an organization
- Community cloud
  - Cloud infrastructure jointly owned by several organizations
- Public cloud
  - Cloud infrastructure owned by an organization, provided to general public as service
- Hybrid cloud
  - Composition of two or more cloud models



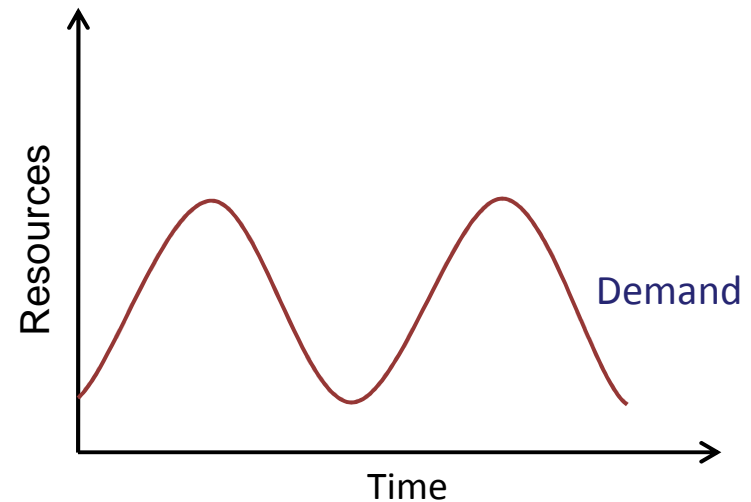
# Short Term Implications of Clouds

- Startups and prototyping
  - Minimize infrastructure risk
  - Lower cost of entry
- Batch jobs
- One-off tasks
  - Washington post, NY Times
- Cost associatively for scientific applications
- Research at scale



# Cloud Application Demand

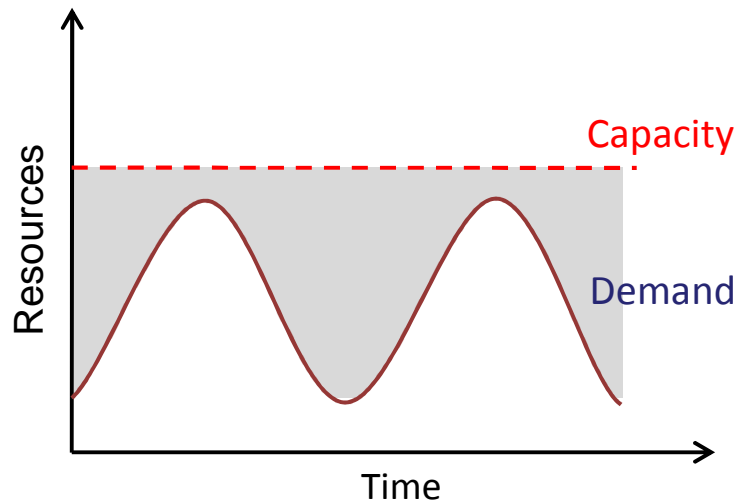
- Many cloud applications have cyclical demand curves
  - Daily, weekly, monthly, ...



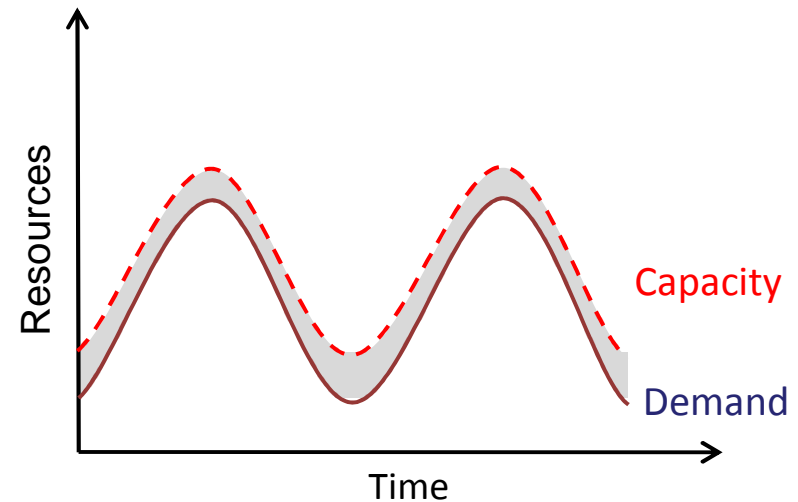
- Workload spikes are more frequent and significant
  - When some event happens like a pop star has expired:
    - More # tweets, Wikipedia traffic increases
    - 22% of tweets, 20% of Wikipedia traffic when Michael Jackson expired in 2009
      - Google thought they are under attack

# Economics of Cloud Users

- Pay by use instead of provisioning for peak



Static data center

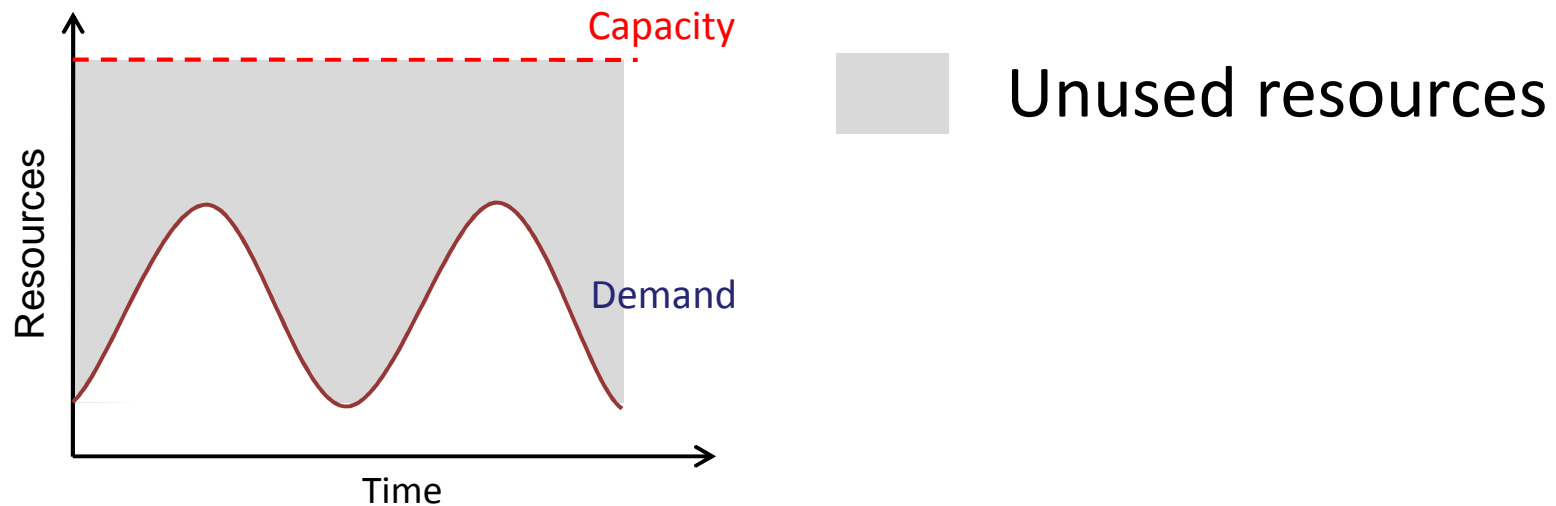


Data center in the cloud

■ Unused resources

# Economics of Cloud Users - continued

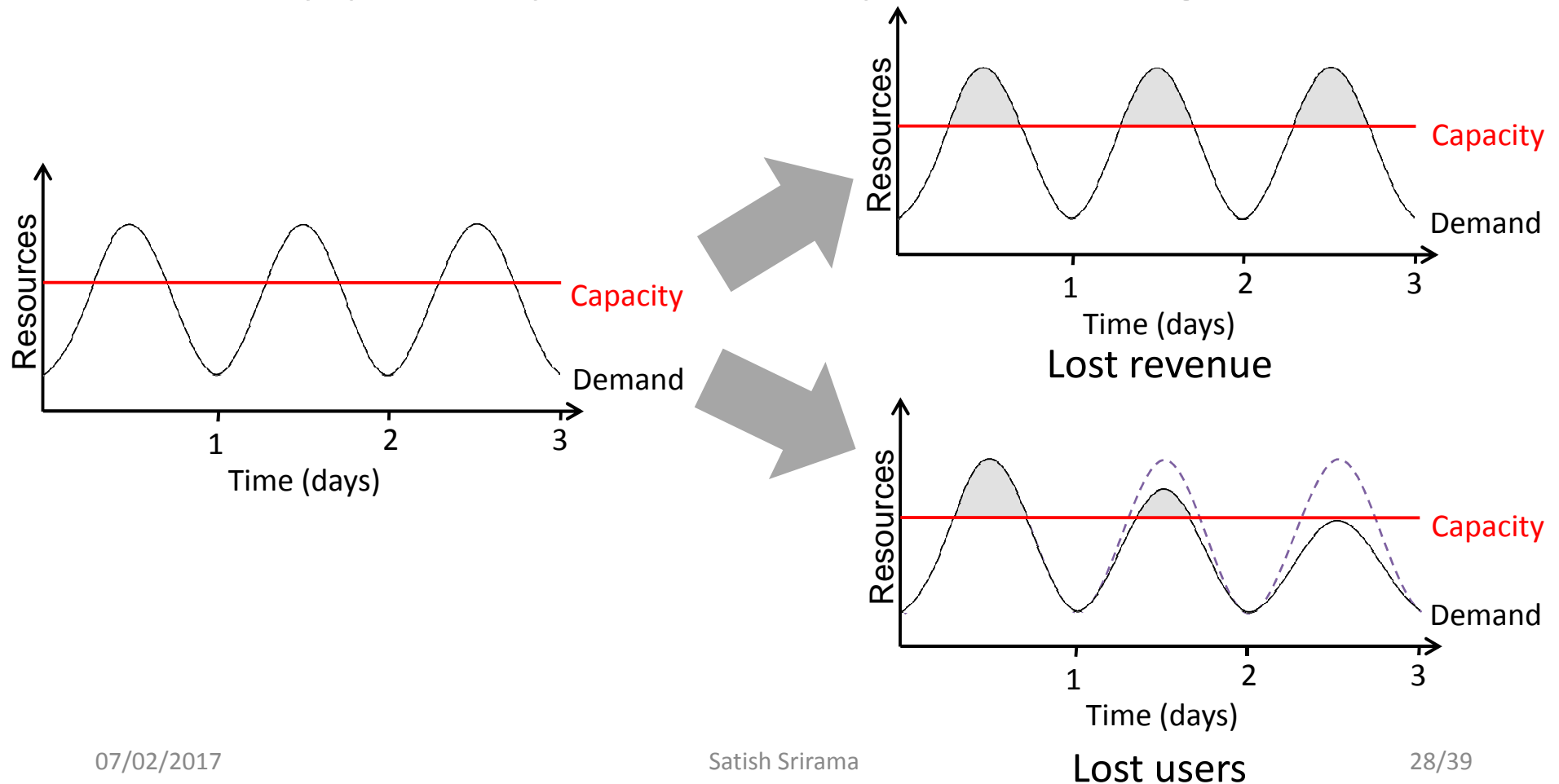
- Risk of over-provisioning: underutilization
  - Huge sunk cost in infrastructure



Static data center

# Economics of Cloud Users - continued

- Heavy penalty for under-provisioning



# Economics of Cloud Providers

- Building a very large-scale datacenter is very expensive
  - \$100+ Million (Minimum)
- Large Internet Companies Already Building Huge DCs
  - Google, Amazon, Microsoft...
- 5-7x economies of scale [Hamilton 2008]

<b>Resource</b>	<b>Cost in Medium DC</b>	<b>Cost in Very Large DC</b>	<b>Ratio</b>
Network	\$95 / Mbps / month	\$13 / Mbps / month	7.3x
Storage	\$2.20 / GB / month	\$0.40 / GB / month	5.5x
Administration	≈140 servers/admin	>1000 servers/admin	7.1x

# Economics of Cloud Providers - continued

- Power

Price per KWH	Where	Possible Reasons Why
3.6¢	Idaho	Hydroelectric power; not sent long distance
10.0¢	California	Electricity transmitted long distance over the grid; limited transmission lines in Bay Area; no coal fired electricity allowed in California.
18.0¢	Hawaii	Must ship fuel to generate electricity

- Cooling is also expensive
  - Build data centers near rivers
- Extra benefits
  - Amazon: utilize off-peak capacity
  - Microsoft: sell .NET tools
  - Google: reuse existing infrastructure

# Economics of Cloud Providers - Failures

- Cloud Computing providers bring a shift from high reliability/availability servers to commodity servers
  - At least one failure per day in large datacenter
- Why?
  - Significant economic incentives – much lower per-server cost
- Caveat: User software has to adapt to failures
  - Very hard problem!
- Solution: Replicate data and computation
  - MapReduce & Distributed File System (Will discuss later in Lecture 4)

# Adoption Challenges

<b>Challenge</b>	<b>Opportunity</b>
Availability	Multiple providers & Use elasticity to prevent DDoS attacks
Data lock-in	Standardization
Data Confidentiality and Auditability	Encryption, VLANs, Firewalls; Geographical Data Storage



# Growth Challenges

<b>Challenge</b>	<b>Opportunity</b>
Data transfer bottlenecks	FedEx-ing disks, Data Backup/Archival
Performance unpredictability	Improved VM support, flash memory, scheduling VMs
Scalable storage	Invent scalable store
Bugs in large distributed systems	Invent Debugger that relies on Distributed VMs
Scaling quickly	Invent Auto-Scaler; Snapshots for conservation

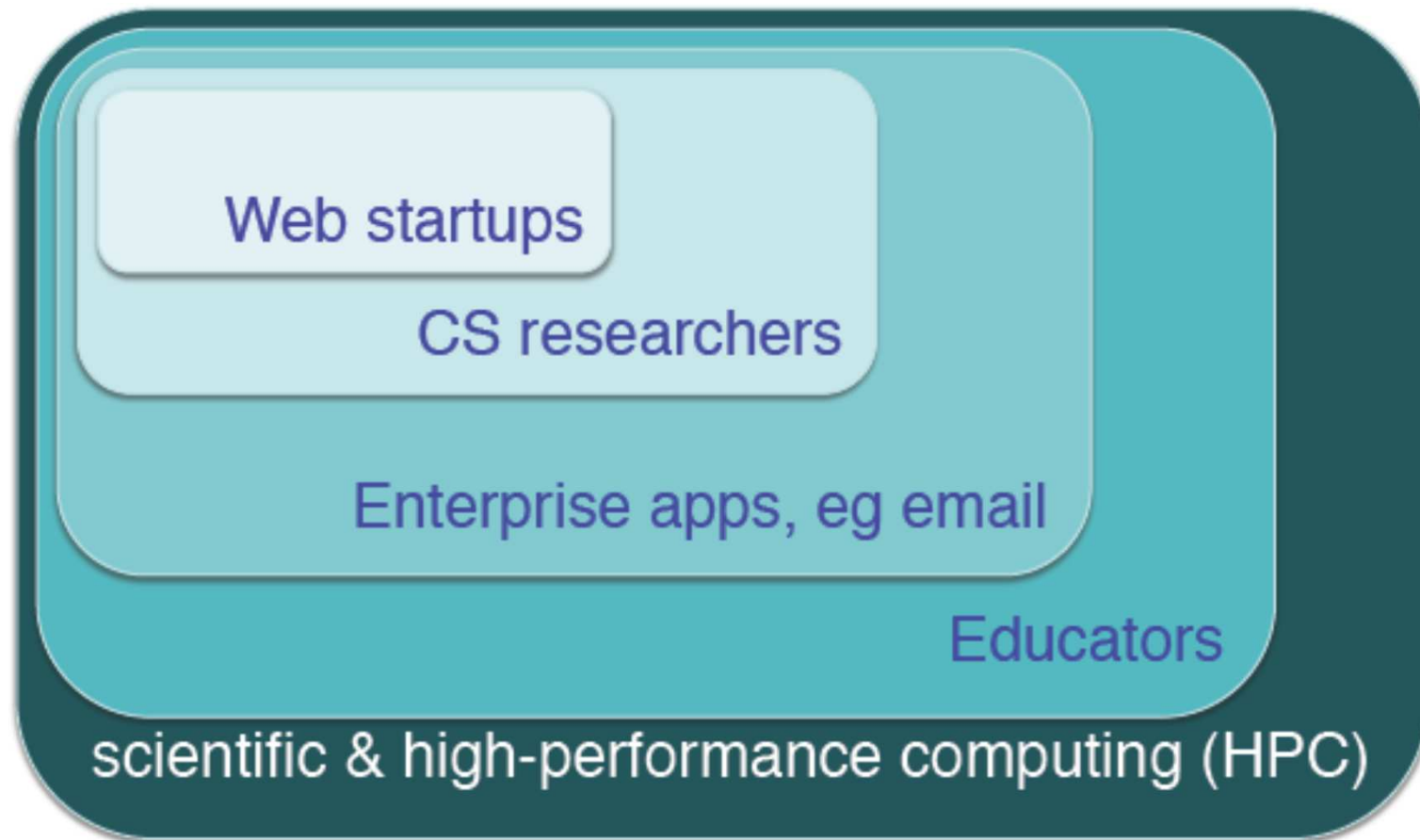
# Policy and Business Challenges

<b>Challenge</b>	<b>Opportunity</b>
Reputation Fate Sharing	Offer reputation-guarding services like those for email
Software Licensing	Pay-for-use licenses; Bulk use sales

# Long Term Implications of clouds

- Application software:
  - Cloud & client parts, disconnection tolerance
- Infrastructure software:
  - Resource accounting, VM awareness
- Hardware systems:
  - Containers, energy proportionality

# Cloud Computing Progress



Armando Fox, 2010

# This week in Lab (Homework)

- Registration to the cloud & keys
  - Firefox plugin & working with Eucatools and API
- Study the following paper
  - M. Armbrust et al., “Above the Clouds, A Berkeley View of Cloud Computing”, Technical Report, University of California, Feb, 2009.

# Next lecture

- Cloud providers
  - Amazon EC2, S3, EBS
- Eucalyptus
- OpenStack

# References

- Several of the slides are taken from Prof. Anthony D. Joseph's lecture at RWTH Aachen (March 2010)
- Papers to read
  - M. Armbrust et al., "Above the Clouds, A Berkeley View of Cloud Computing", Technical Report, University of California, Feb, 2009.
- The Cloud: Battle of the Tech Titans
  - Cover story in Businessweek
  - [http://www.businessweek.com/magazine/content/11\\_11/b4219052599182.htm](http://www.businessweek.com/magazine/content/11_11/b4219052599182.htm)