MTAT.08.027
Basics of Cloud Computing
(3 ECTS)

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Mobile & Cloud Lab

tiigriülikool

amazon web services

Course Purpose

- Introduce cloud computing concepts
- Introduce cloud providers and usage scenarios
- Introduction to distributed computing algorithms like MapReduce
- Recent developments in the domain such as Serverless computing
- Glance of research at Mobile & Cloud Lab in cloud computing domain

- https://courses.cs.ut.ee/2019/cloud/spring/

Schedule

- Lecture
  - Wednesday 12:15 – 14:00 (J. Liivi 2 - 405)
- Labs
  - Wed 14:15 - 16:00 (J. Liivi 2 - 205) (1. group)
  - Thu 16:15 - 18:00 (J. Liivi 2 - 205) (2. group)

Course Logistics

- Will be replaced by LTAT.06.008 - Cloud Computing
  - 6 ECTS, Spring 2020
- 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

- **13.02** Basics of Cloud Computing
- **20.02** Cloud Providers & SciCloud
- **27.02** Scaling in Cloud
- **06.03** MapReduce
- **13.03** MapReduce Algorithms
- **20.03** Platform as a Service
- **27.03** Other Cloud Services & Serverless computing
- **03.04** Summary and Research on Cloud
- **17.04** Examination 1 – Option 2
  - **16.04** Examination 1 – Option 1

Course schedule - continued

- Labs

  13-14.02 Starting with a cloud

  20-21.02 Working with SciCloud

  27-28.02 Load balancing in cloud

  06-07.03 MapReduce - Basics

  13-14.03 Data analysis with MapReduce

  20-21.03 Google AppEngine

  27-28.03 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 Wednesday 12:00 next week to be graded for full score
- Late submissions
  - 10% will be deducted per day
  - You can submit exercises for 50% evaluation till end of the course (10th April)

Course schedule - continued

- **17.04** Examination 1 – Option 2
- **16.04** Examination 1 – Option 1

- Examination for second attempt – 30th April

Reference Books

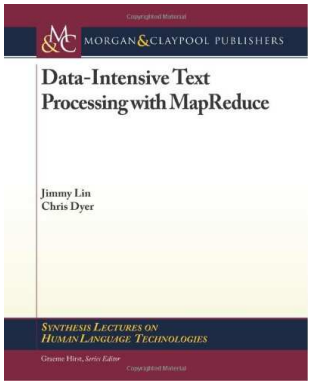
- Mastering Cloud Computing: Foundations and Applications Programming

Authors: Rajkumar Buyya, Christian Vecchiola, S.Thamarai Selvi

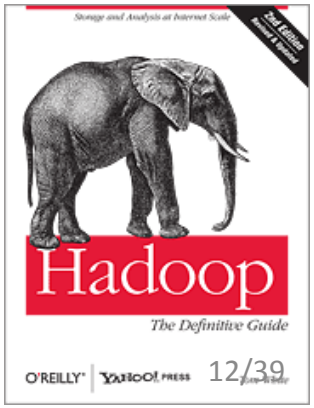
- Data-Intensive Text Processing with MapReduce

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.

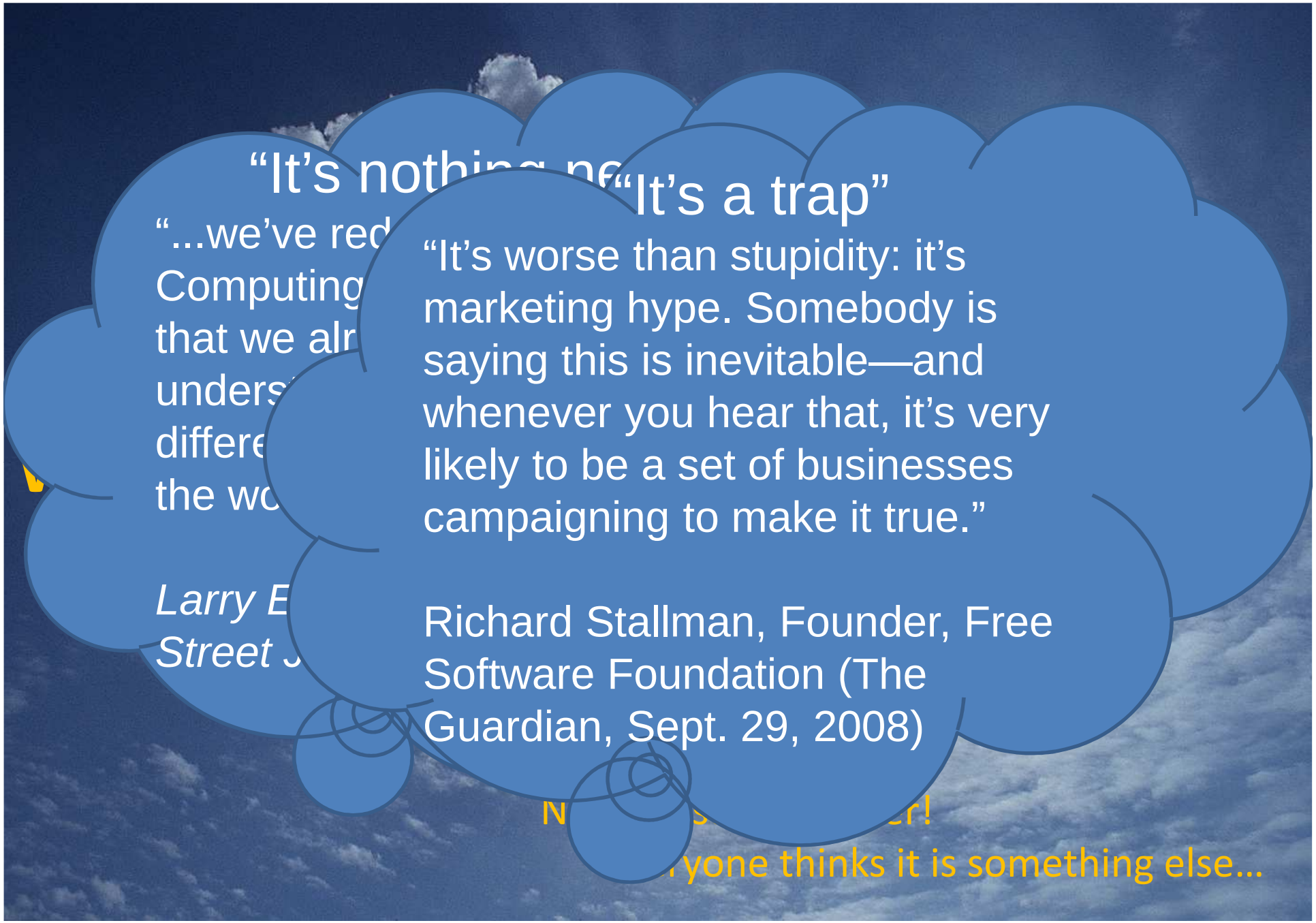
- Dean, J., & Ghemawat, S. (2008). MapReduce: simplified data processing on large clusters. Communications of the ACM, 51(1), 107-113.

- R. Buyya, S. N. Srirama, G. Casale et al: A Manifesto for Future Generation Cloud Computing: Research Directions for the Next Decade, ACM Computing Surveys, ISSN 0360-0300, 51(5):105, 38 pages, 2018.

- Relevant papers will be mentioned in respective lectures

Lecture 1

CLOUD COMPUTING



Slide taken from Professor Anthony D. Joseph's lecture at RWTH Aachen

What is Cloud Computing?

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

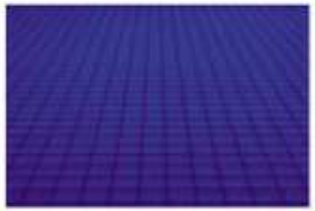
1969 – Leonard Kleinrock, ARPANET project

- "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

Grid Computing

- Solving large problems with parallel computing
- Made mainstream by Globus Alliance



Utility Computing

- Offering computing resources as a metered service
- Introduced in late 1990s

Software as a Service

Network-based subscriptions to applications

Gained momentum in 2001

Cloud Computing

Next-Generation Internet computing

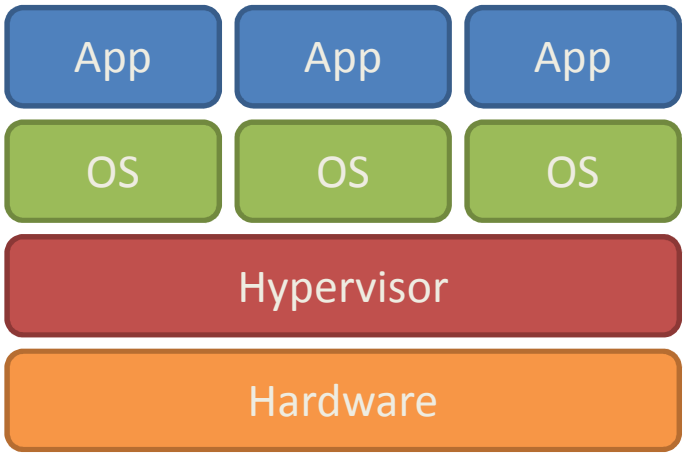
Next-Generation Data Centers

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

Containers

- Use kernel of the host operating system instead of a hypervisor
  - Linux namespace
- Lightweight
  - No hypervisor overhead
  - Each Container acquires only required resources
- Fast start-up/ Bootup
  - Starting a container is faster than booting new OS or spinning up a new VM
- Performance
  - Near native performance
- Different container frameworks
  - LXC, Docker, Linux VServer, OpenVZ
  - Docker is an Open platform [https://www.docker.com/]

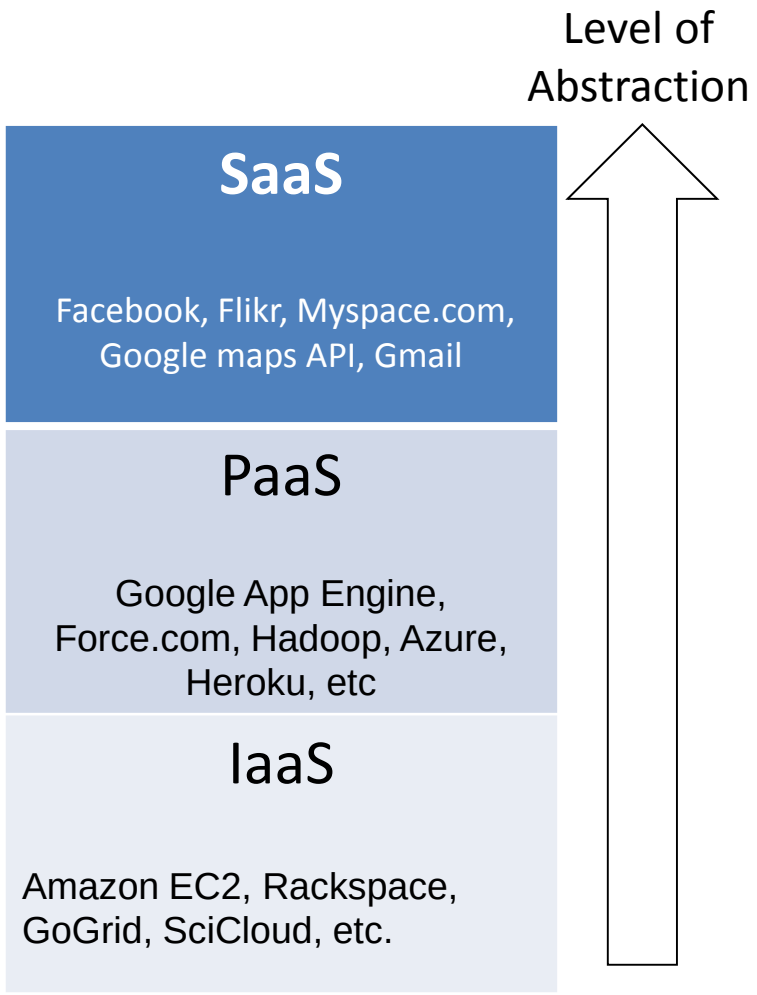
Cloud Computing - Characteristics

- 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



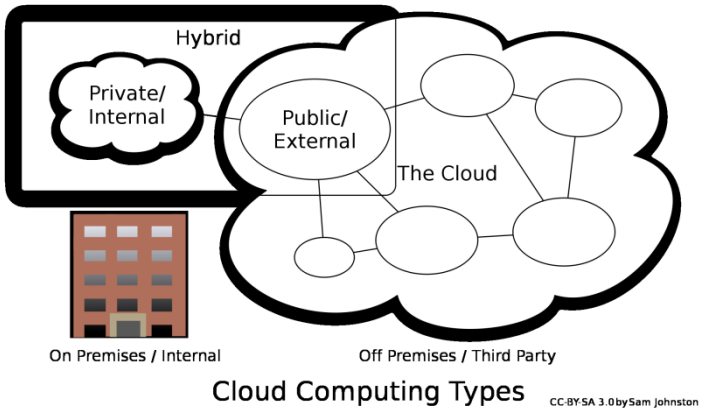
Cloud Computing - Themes

- 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

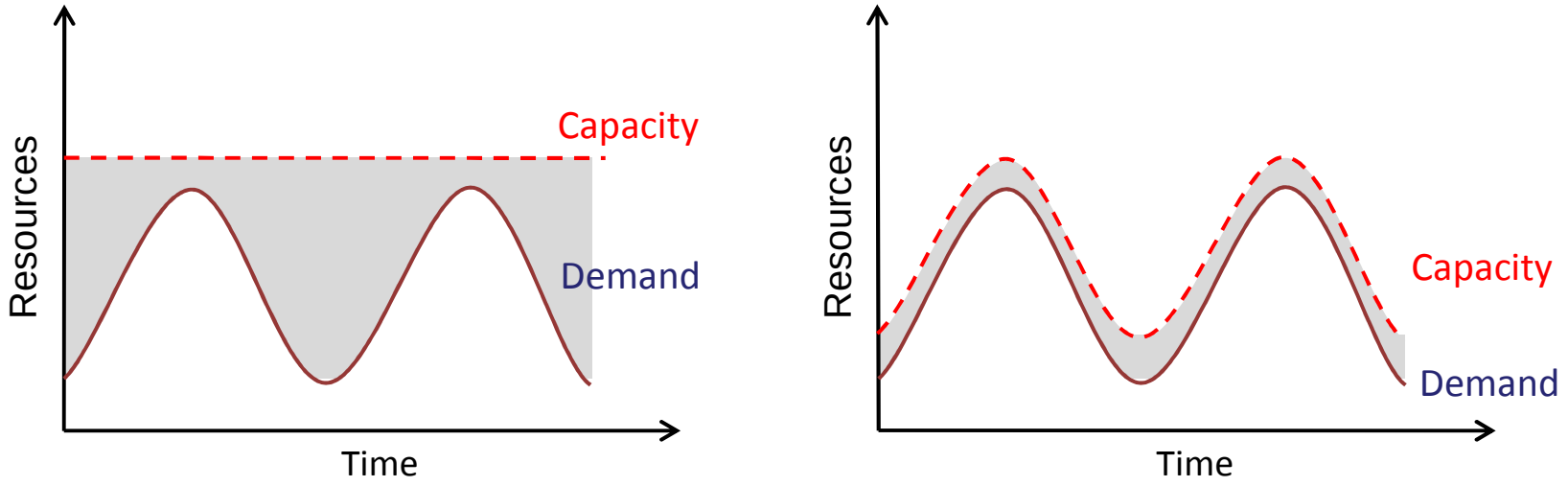


Short Term Implications of Clouds

- 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

Economics of Cloud Users

- Many cloud applications have cyclical demand curves
  - Daily, weekly, monthly, …
- Pay by use instead of provisioning for peak



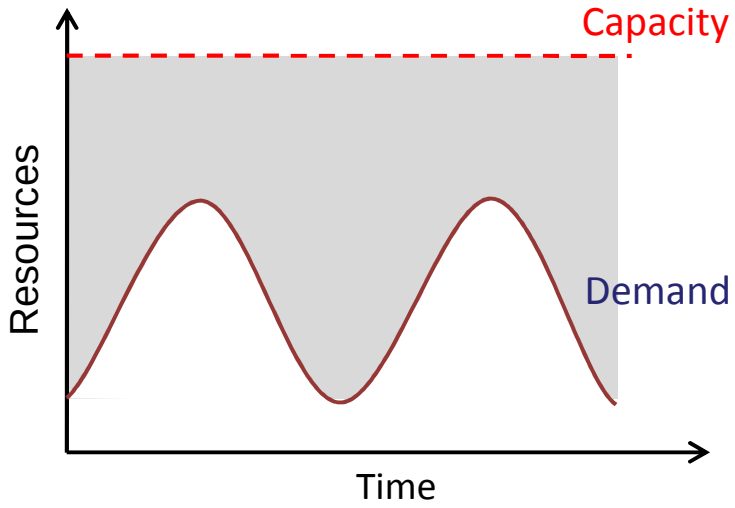
Static data center

Data center in the cloud

Unused resources

Economics of Cloud Users - continued

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

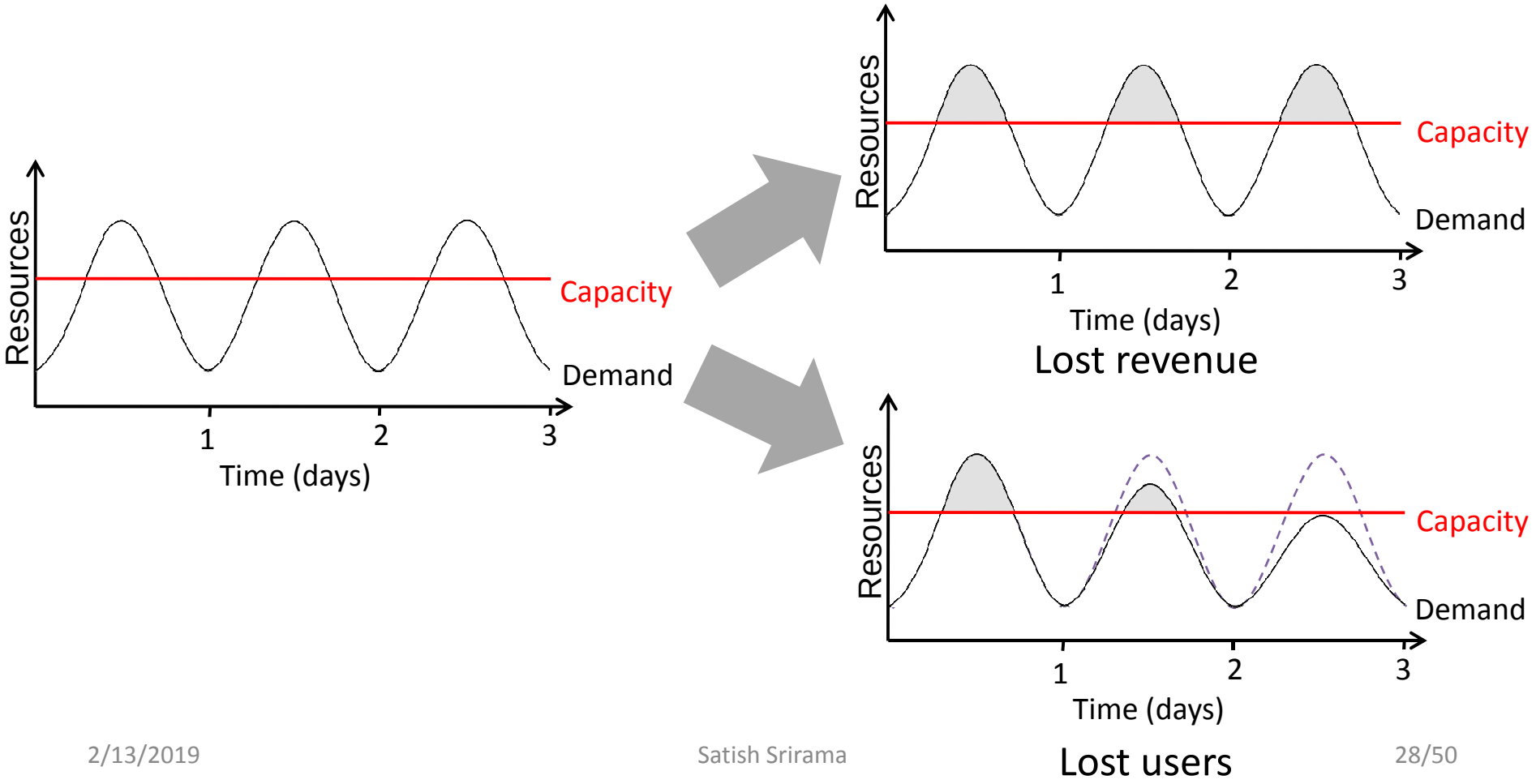


Unused resources

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]

Resource	Cost in Medium DC	Cost in Very Large DC	Ratio
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

Challenge	Opportunity
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

Challenge	Opportunity
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

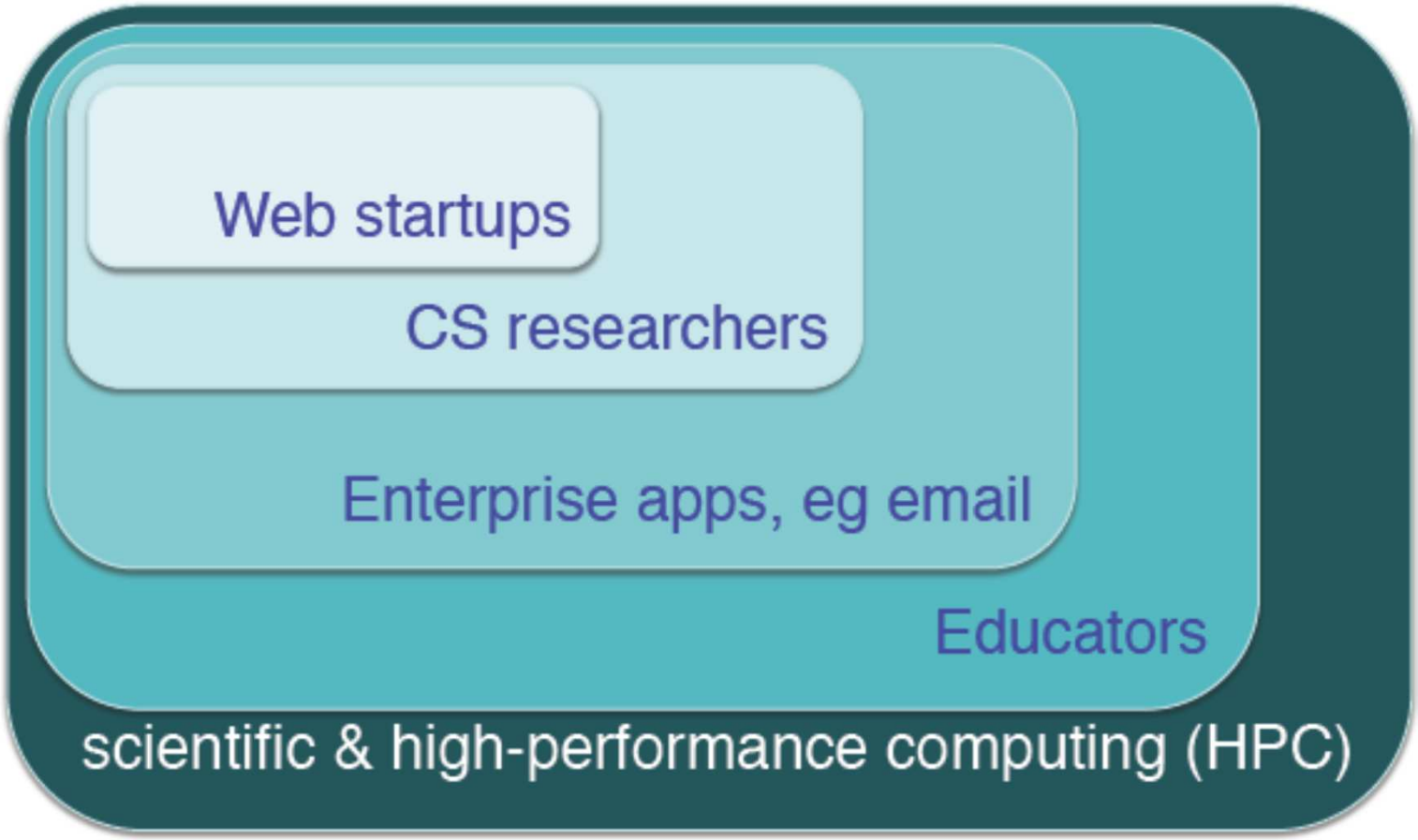
Policy and Business Challenges

Challenge	Opportunity
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)

- Introduction to IaaS & Getting keys
  - Work with Virtual Machines
- 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.