Cloud Computing – Lecture 1

Introduction to Cloud Computing

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Course Purpose

• Introduce cloud computing concepts
• Introduce cloud services and providers
• Introduction to distributed data processing in the cloud
• Recent developments in the domain
  – E.g., Serverless computing, fog computing etc.
  – Cloud computing challenges

• Course website:
  – https://courses.cs.ut.ee/2021/cloud/spring/

• Course Slack: invitation sent through email
Schedule

• Lecture
  – Tuesday 10.15 - 14.00

• Labs
  – Wednesday 16:15 - 18:00 (1. group, Souvik, Pelle)
  – Thursday 10:15 - 12:00 (2. group, Jakob Mass)
  – Thursday 16:15 - 18:00 (3. group, Shivananda Poojara)
Expectations to students

• Should be comfortable with data structures
• Should be comfortable with algorithms
• Should be comfortable with programming in different languages
  – Python
  – Java
    • External APIs
  – Web programming:
    • REST
  – May touch JavaScript and PHP
Grading

• Written exam – 50%
• Labs – 50%
  – ~14 lab exercises
• To pass the course
  – Must submit 80% of lab solutions to qualify for the Exam!
  – Must collect at least 40% from exam!
  – You need to score at least 51% in total!
Taking the Course

• Completing all the labs will contribute half the grade
  – Some labs have bonus exercises for extra points
• Examination is considered to be fairly tough
• One of the previous year’s examination paper is available on the course website
• Being a practical course, it requires sufficient investment of time and effort
Lecture outline

1. Introduction to Cloud Computing
2. Infrastructure as a Service and Virtualization
3. Platform as a service
4. Serverless computing
5. Cloud storage services
6. Scaling enterprise applications on Cloud
7. Big Data processing in cloud
8. MapReduce Algorithms
9. Beyond MapReduce: Higher level Data Analytics
10. Deployment models in cloud
11. Private and Hybrid clouds
12. Data streams, data flow pipeline management
13. Internet of Things and Fog computing
14. Cloud computing challenges
Practice session outline

• Labs follow the lectures lecture topics 1:1
Grading lab submissions

• Strongly suggest finishing the lab exercises before coming to the next lecture

• Submit the results by Wednesday 16:00 next week to be graded for 100%

• Late submissions
  – 10% will be deducted for every missed day
  – You can submit exercises for 50% evaluation till the end of the week after
Plagiarism policy

• The practical session tasks are meant to be solved alone
• If you need help, write to the Slack channel or ask from TA's
• You can discuss the main ideas with other students,
  – but you must solve the tasks by yourself, it shouldn't be a team effort
  – Otherwise, you will not acquire all the knowledge yourself
• **In principle:**
  – Do your work yourself
  – Do not share your work with others
    • if they need help, give them hints or guidelines
  – If you get a lot of help from some online source, cite it!
Exam schedule

• Provisional examination times
  – Examination 1 – Option 1 – 25th of May
  – Examination 1 – Option 2 – 1st of June

  – Examination for second attempt - 15th of June
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

  Authors: Tom White
Reference Papers


• Other relevant papers will be mentioned in respective lectures
Emergence of Cloud computing

• **Larry Ellison, Oracle, 2008:**
  – "The interesting thing about cloud computing is that we’ve redefined cloud computing to include everything that we already do"
  – "... I don’t understand what we would do differently in the light of cloud computing, other than market ... you know, change the wording on some of our ads."

• **Richard Stallmann**, founder of the **Free Software Foundation**, 2008:
  – cloud computing is simply a trap aimed at forcing more people to buy into locked, proprietary systems that would cost them more and more over time
  – "It's stupidity. It's worse than stupidity: it's a marketing hype campaign,"
  – "Somebody is saying this is inevitable – and whenever you hear somebody saying that, it's very likely to be a set of businesses campaigning to make it true."
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

1990s

- 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 not earlier?

• Experience with very large datacenters
  – Unprecedented scale
  – Transfer of risk

• Technological factors
  – Pervasive broadband Internet
  – Maturity in Virtualization Technology

• Business factors
  – More demand for computational power
  – High cost
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
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 service models

- **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 Model management complexity

- **Own Hardware**
  - Applications
  - Data
  - Runtime
  - Middleware
  - Operating System
  - Virtualization
  - Servers
  - Storage
  - Networking

- **IaaS**
  - Applications
  - Data
  - Runtime
  - Middleware
  - Operating System
  - Virtualization
  - Servers
  - Storage
  - Networking

- **PaaS**
  - Applications
  - Data
  - Runtime
  - Middleware
  - Operating System
  - Virtualization
  - Servers
  - Storage
  - Networking

- **SaaS**
  - Applications
  - Data
  - Runtime
  - Middleware
  - Operating System
  - Virtualization
  - Servers
  - Storage
  - Networking
Cloud Computing characteristics

• Illusion of infinite resources
• No up-front cost
• Fine-grained billing
  – (e.g. hourly, by minute, second, ms)

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 characteristics

• 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
Types of clouds

• **Internal (private) cloud**
  – Cloud within 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 cloud computing

• Startups and prototyping
  – Minimize initial infrastructure risk
  – Lower cost of entry

• Batch jobs

• Scaling up one-off tasks
  – New York times had to convert 11 mil articles to PDF
    • IT department estimation: 7 weeks
    • Managed to do it in 24 hours using 100 EC2 instances instead

• Research at scale
Economics of Cloud usage

- Many applications have cyclical demand curves
  - Daily, weekly, monthly, ...
- Pay by use instead of provisioning for peak
Economics of Cloud Users - continued

• Risk of over-provisioning: underutilization
  – Huge sunk cost in infrastructure
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 have built huge data centers
  – Google, Amazon, Microsoft...
• 5-7x economies of scale [Hamilton 2008]

<table>
<thead>
<tr>
<th>Resource</th>
<th>Cost in Medium DC</th>
<th>Cost in Very Large DC</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network</td>
<td>$95 / Mbps / month</td>
<td>$13 / Mbps / month</td>
<td>7.3x</td>
</tr>
<tr>
<td>Storage</td>
<td>$2.20 / GB / month</td>
<td>$0.40 / GB / month</td>
<td>5.5x</td>
</tr>
<tr>
<td>Administration</td>
<td>≈140 servers/admin</td>
<td>&gt;1000 servers/admin</td>
<td>7.1x</td>
</tr>
</tbody>
</table>
Economics of Cloud Providers - continued

• Power

<table>
<thead>
<tr>
<th>Price per KWH</th>
<th>Where</th>
<th>Possible Reasons Why</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6¢</td>
<td>Idaho</td>
<td>Hydroelectric power; not sent long distance</td>
</tr>
<tr>
<td>10.0¢</td>
<td>California</td>
<td>Electricity transmitted long distance over the grid; limited transmission lines in Bay Area; no coal fired electricity allowed in California.</td>
</tr>
<tr>
<td>18.0¢</td>
<td>Hawaii</td>
<td>Must ship fuel to generate electricity</td>
</tr>
</tbody>
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• 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 must adapt to failures
  – Can be very difficult!

• Solution: Replicate data and computation
  – MapReduce & Distributed File System (Will discuss later MapReduce Lecture)
## Adoption Challenges

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Opportunity</th>
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</thead>
<tbody>
<tr>
<td>Availability</td>
<td>Multiple providers &amp; Use elasticity to prevent DDoS attacks</td>
</tr>
<tr>
<td>Data lock-in</td>
<td>Standardization</td>
</tr>
<tr>
<td>Data Confidentiality and Auditability</td>
<td>Encryption, VLANs, Firewalls; Geographical Data Storage</td>
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## Growth Challenges

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transfer bottlenecks</td>
<td>FedEx-ing disks, Data Backup/Archival</td>
</tr>
<tr>
<td>Performance unpredictability</td>
<td>Improved VM support, flash memory, scheduling VMs</td>
</tr>
<tr>
<td>Scalable storage</td>
<td>Invent scalable store</td>
</tr>
<tr>
<td>Bugs in large distributed systems</td>
<td>Invent Debugger that relies on Distributed VMs</td>
</tr>
<tr>
<td>Scaling quickly</td>
<td>Invent Auto-Scaler; Snapshots for conservation</td>
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## Policy and Business Challenges

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputation Fate Sharing</td>
<td>Offer reputation-guarding services like those for email</td>
</tr>
<tr>
<td>Software Licensing</td>
<td>Pay-for-use licenses; Bulk use sales</td>
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Long-Term Implications of cloud computing

• Systems and applications have had to adapt to cloud computing

• Application software:
  – Cloud & client parts, disconnection tolerance

• Infrastructure software:
  – Resource accounting, VM awareness

• Hardware systems:
  – Containers, energy proportionality
This week in Lab

• Introduction to IaaS
  – OpenStack private cloud
  – Getting access
  – Work with Virtual Machines

• **NB!** If you joined the course later than Friday, 5th February at **11:00**,  
  – contact Pelle Jakovits on Slack about getting access to UT OpenStack Cloud
Next lecture

• Infrastructure as a Service and Virtualization
References

• **Papers to read at home**