The Potential of Cloud Computing: Challenges, Opportunities, Impact

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NAE Frontiers of Engineering, September 2010

Image: John Curley http://www.flickr.com/photos/jay_que/1834540/
Get Your Own Supercomputer

- 41.88 Teraflops on LINPACK benchmark
  - Faster than #145 entry on current Top500 list
- No batch queues—start your job in minutes
- No grantwriting—just a credit card ($1400/hour, 1 hour minimum purchase)
- No need to predict usage in advance—pay only for what you use, get more on demand
- Lease several simultaneously
- MPI and Matlab available, among other packages
Warehouse Scale Computers

• Built to support consumer demand of Web services (email, social networking, etc.)
  – “Private clouds” of Google, Microsoft, Amazon, ....

• “Warehouse scale” buying power = 5-7x cheaper hardware, networking, administration cost

photos: Cnet News, Sun Microsystems, datacenterknowledge.com
2008: Public Cloud Computing Arrives

- Unlike Grid, computing on-demand *for the public*
- Virtual machines from $0.085 to $1.60/hr
  - Pay as you go with credit card, 1 hr. minimum
  - Cheaper if willing to share or risk getting kicked off
  - Machines provisioned & booted in a few minutes

1,000 machines for 1 hr = 1 machine $\times$ 1,000 hrs

* 2x quad-core Intel Xeon (Nehalem)
What’s In It For You?

Cloud Computing progress 2008-2010

- Scientific & high-performance computing (HPC)
- Educators
- Enterprise apps, eg email
- CS researchers
- Web startups

Scientific & high-performance computing (HPC)
What’s in it for you?

• **What:** Low cost + on-demand + cost-associativity = Democratization of Supercomputing

• **How:** Sophisticated software & operational expertise mask unreliability of commodity components

• **Example:** MapReduce
  – LISP language construct (~1960) for elegantly expressing *data parallel* operations w/sequential code
  – MapReduce (Google) and Hadoop (open source) provide failure masking & resource management for performing this on commodity clusters

“Warehouse scale” software engineering issues hidden from application programmer
MapReduce in Practice

• Example: spam classification
  – training: $10^7$ URLs x 64KB data each = 640GB data
  – One heavy-duty server: ~270 hours
  – 100 servers in cloud: ~3 hours (= ~$255)

• Rapid uptake in other scientific research
  – Large-population genetic risk analysis & simulation (Harvard Medical School)
  – Genome sequencing (UNC Chapel Hill Cancer Ctr)
  – Information retrieval research (U. Glasgow – Terrier)
  – Compact Muon Solenoid Expt. (U. Nebraska Lincoln)

• What’s the downside?
Challenge: Cloud Programming

- **Challenge:** exposing parallelism
  - MapReduce relies on “embarrassing parallelism”

- Programmers must (re)write problems to expose this parallelism, if it’s there to be found

- Tools still primitive, though progressing rapidly
  - MapReduce—early success story
  - Pig (Yahoo! Research) & Hive (Apache Foundation) – write database-like queries to run as Hadoop jobs
  - Mesos—share cluster among Hadoop, MPI, interactive jobs (UC Berkeley)

- **Challenge for tool authors:** parallel software hard to debug and operate reliably (YY Zhou)
### Challenge: Big Data

<table>
<thead>
<tr>
<th>Application</th>
<th>Data generated per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA Sequencing (Illumina HiSeq machine)</td>
<td>1 TB</td>
</tr>
<tr>
<td>Large Synoptic Survey Telescope</td>
<td>30 TB; 400 Mbps sustained data rate between Chile and NCSA</td>
</tr>
<tr>
<td>Large Hadron Collider</td>
<td>60 TB</td>
</tr>
</tbody>
</table>

- **Challenge:** Long-haul networking is most expensive cloud resource, and improving most slowly
- Copy 8 TB to Amazon over ~20 Mbps network
  => ~35 days, ~$800 in transfer fees
- How about shipping 8TB drive to Amazon instead?
  => 1 day, ~$150 (shipping + transfer fees)

Challenge: “non-cloudy” scientific codes

- Challenge: scientific and HPC codes designed around “supercomputer-centric” assumptions
  - reliability, static configuration, exclusive resource use...
- Opportunity: resource management frameworks
- Time-to-answer may still be faster, since no wait!
- Cloud vendors are listening to HPC customers
  - July 2010: cluster of 880 EC2 “cluster compute” instances achieve 41.82 Tflops on LINPACK
  - MathWorks supporting “cloud MATLAB” on these
Better Education

- Capacity on demand is perfect for university courses
- Students can run new kinds of experiments at scale
- Unburdens system administrators, so provisioning is faster
- Students get access to state-of-the-art hardware
- Berkeley now using cloud computing from entry-level to graduate EECS courses
An Analogy: Clusters of Commodity PC’s, c.1995

• Clusters of Commodity PC’s vs. symmetric multiprocessors

• *Potential* advantages: incremental scaling, absolute capacity, economy of using commodity HW & SW

• 1995: SaaS on SMPs; software architecture SMP-centric

• 2010: Berkeley undergrads prototype SaaS in 6-8 weeks and deploy on cloud computing
Conclusion

• Democratization of supercomputing capability
  – Time to answer may be faster even if hardware isn’t
  – Writing a grant proposal around a supercomputer?

• Software & hardware rapidly improving as vendors listen to scientific/HPC customers

• HPC opportunity to influence design of commodity equipment

Impact: Potential democratizing effect comparable to microprocessor
Acknowledgments

• Colleagues at UC Berkeley RAD Lab
  – Co-authors of *Above The Clouds*: Michael Armbrust, Rean Griffith, Anthony D. Joseph, Randy Katz, Andy Konwinski, Gunho Lee, David Patterson, Ariel Rabkin, Ion Stoica, Matei Zaharia
  – And everyone else in the RAD Lab

• Colleagues at our industrial collaborators
Thank you!