ISTC for Cloud Computing: Center Overview

Greg Ganger & Phil Gibbons
ISTC-CC Retreat 2014
September 4, 2014

http://www.istc-cc.cmu.edu/
ISTC-CC’s Research Pillars

Underlying Infrastructure enabling the future of cloud computing

www.istc-cc.cmu.edu
Specialization is fundamental to efficiency
- No single platform best for all application types
- Called **division of labor** in sociology

Cloud computing must embrace specialization
- As well as consequent heterogeneity and change-over-time
- Stark contrast to common cloud thinking

New approaches needed to enable...
- Effective mixes of targeted and general platform types
- Nimble incorporation of new technologies and accelerators
Specialization Projects

• **S1: Specialized Platforms of Wimpy Nodes**
  - exploring + extending range of apps that run (most) efficiently on such platforms by overcoming OS limits, memory limits, and scalability issues

• **S2: Specialized Platforms of Heterogeneous Multi-Cores**
  - exploring best ways to devise and use heterogeneity on multi-core nodes, considering core types, accelerators, and DRAM/NVM memory, with a focus on cloud’s virtualized, multi-tenancy workloads
Specialization Highlights at Retreat 2014

- “Hardware-Software Interface Issues in Heterogeneous Systems: Design, Verification, and Programming” – Margaret Martonosi (Princeton)

- “Cuckoo Hashing: From ISTC-CC to Intel’s DPDK” – Dong Zhou (CMU) & Ren Wang (Intel Labs)

- “Some New Ideas in Memory System Design for Data-Intensive Computing” – Onur Mutlu (CMU)

- “Using RDMA Efficiently for Key-Value Services” – Dave Andersen (CMU)

- “Optimizing Performance and Productivity on Heterogeneous Processors” – Sudha Yalamanchili (Georgia Tech)

+ 17 posters
• Automation is crucial to cloud reaching potential
  ▫ We suspect that no one here needs to be convinced of this...

• Management is very hard, but cloud makes it worse
  ▫ Much larger scale
  ▫ Much more varied mix of applications/activities
  ▫ Much less pre-knowledge of applications
  ▫ And, we’re adding in platform specialization 😊

• Leaps forward needed on many fronts...
  ▫ Diagnosis, scheduling, instrumentation, isolation, tuning, ...
Automation Projects

• **A1: Resource Scheduling for Heterogeneous Cloud Infrastructures**
  - maximizing the effectiveness of a cloud composed of diverse specialized platforms servicing diverse app types
  - enabling software framework specialization via hierarchical scheduling

• **A2: Problem Diagnosis and Mitigation**
  - new tools and techniques for rapid, robust diagnosis of failures and performance problems
  - automated mitigation based on “quick and dirty” online diagnoses

Specialization | Automation | Big Data | To the Edge
“Scheduling Heterogeneous Resources in Cloud Datacenters” – Alexey Tumanov (CMU)

Posters:

• **PriorityMeister:** Tail Latency QoS for Shared Networked Storage

• **SpringFS:** Bridging Agility and Performance in Elastic Distributed Storage

• **Tetrisched:** Space-Time Scheduling for Heterogeneous Datacenters

• **The Power of Choice in Data-aware Cluster Scheduling**
Big Data Pillar

- Extracting insights from large datasets
  - “Analytics” or “Data-intensive computing”
  - Becoming critical in nearly every domain
    - likely to dominate future cloud data centers

- Need right programming/execution models
  - For productivity, efficiency, and agility
  - Resource efficient operation on shared, specialized infrastructures
Big Data Projects

• **B1: Big Learning Systems**
  - new programming abstractions and execution frameworks enabling efficiency and productivity for large-scale Machine Learning on Big Data

• **B2: Big Data Storage**
  - exploring trade-offs and new approaches in Big Data storage, including support for high ingress and multi-framework sharing of data
“Tachyon: A Reliable Memory Centric Storage for Big Data Analytics” – Haoyuan Li (UC Berkeley)

“What’s New with GraphLab” – Yucheng Low (GraphLab)

“Spark: What’s New and What’s Next”
– Ion Stoica (UC Berkeley)

“Scaling Distributed Machine Learning with the Parameter Server” – Alex Smola (CMU)

“GraphX: Unifying Data-Parallel and Graph-Parallel Analytics” – Joey Gonzalez (UC Berkeley)

“Exploiting Bounded Staleness to Speed Up Big Data Analytics” – Garth Gibson (CMU)

+ 15 posters
To the Edge Pillar

- **Edge devices will participate in cloud activities**
  - Serving as bridge to physical world (sense/actuate)
  - Enhancing interactivity despite location / connectivity

- **Need new programming/ execution models**
  - For adaptive cloud + edge cooperation

Cloudlet demo
To the Edge Projects

• **E1: Cloud-Assisted Mobile Client Computations**
  - new abstractions and system architectures for dynamic exploitation of edge-local cloud resources to enable rich edge device experiences

• **E2: Geographically Distributed Data Storage**
  - new techniques for geographically distributed data storage/caching that reduce both access latency & reliance on expensive WAN-uplink bandwidth, while providing the desired scalability, fault tolerance, consistency & findability
To the Edge Highlights at Retreat 2014

• “Personal Clouds: Sharing and Integrating Networked Resources to Enhance End User Experiences”
  – Ada Gavrilovska (Georgia Tech)

• “Towards Wearable Cognitive Assistance”
  – Satya (CMU)

• Plus Friday Keynote:

Toward ISTC-CC Capstones

**Capstone #1: Big Learning Systems**
- We’re creating the leading frameworks for big learning
  - e.g., GraphLab, Spark, and Parameter Server systems
- Ideal: given an ML app + system, use best mechanisms
  - requires mapping the space and understanding tradeoffs

**Capstone #2: Resource mgmt for specialization**
- We’ve asserted need for mixes of specialized platforms
  - Significant progress on both exploiting & scheduling fronts
- Putting it together: Flexible apps on heterogeneous clouds

**Capstone #3: Edge-Cloud Resources**
- We’ve asserted need for cloudlets near edge
- Working with IL & BUs to create demo and pilots
ISTC-CC: Intel Oversight & BoA

• Intel oversight
  ▫ Rich Uhlig (Executive Sponsor)
  ▫ Scott Hahn (Managing Director)
  ▫ Chris Ramming (Director of UCO)
  ▫ Jeff Parkhurst (Program Director)

• Board of Advisors (including Rich and Scott)
  ▫ Randy Bryant (Dean of School of CS, CMU)
  ▫ Jeff Chase (Professor of CS, Duke)
  ▫ Balint Fleischer (Gen. Mgr. Data Center Grp Arch., Intel)
  ▫ Frans Kaashoek (Professor of CS&Eng, MIT)
  ▫ Pradeep Khosla (Chancellor, UC San Diego)
  ▫ Jason Waxman (Gen. Mgr. Cloud Platform Group, Intel)
ISTC-CC: Institutions & Faculty

- Carnegie Mellon University
  - Greg Ganger (PI), Dave Andersen, Guy Blelloch, Garth Gibson, Mor Harchol-Balter, Todd Mowry, Onur Mutlu, Priya Narasimhan, M. Satyanarayanan, Dan Siewiorek, Alex Smola, Eric Xing

- Georgia Tech
  - Greg Eisenhower, Ada Gavrilovska, Ling Liu, Calton Pu, Karsten Schwan, Matthew Wolf, Sudha Yalamanchili

- Princeton University
  - Mike Freedman, Margaret Martonosi

- University of California at Berkeley
  - Anthony Joseph, Randy Katz, Ion Stoica

- University of Washington
  - Carlos Guestrin

- Intel Labs
  - Phil Gibbons (PI), Michael Kaminsky, Mike Kozuch, Babu Pillai
## ISTC-CC: Cross-Institution Collaboration

<table>
<thead>
<tr>
<th>Project</th>
<th>Personnel</th>
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<tbody>
<tr>
<td>S1 Specialized Platforms of Wimpy Nodes</td>
<td>Andersen[C], Schwan[G], Freedman[P], Kaminsky[I], Kozuch[I], Pillai[I]</td>
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<tr>
<td>S2 Specialized Platforms of Heterogeneous Many-Cores</td>
<td>Mowry[C], Mutlu[C], Gavrilovska[G], Schwan[G], Yalamanchili[G], Martonosi[P], Gibbons[I], Kozuch[I]</td>
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<tr>
<td>A1 Resource Scheduling for Heterogeneous Cloud Infrastructures</td>
<td>Joseph[B], Katz[B], Stoica[B], Ganger[C], Harchol-Balter[C], Kozuch[I]</td>
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<td>A2 Problem Diagnosis and Mitigation</td>
<td>Ganger[C], Narasimhan[C], Eisenhauer[G], Liu[G], Schwan[G], Wolf[G]</td>
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<tr>
<td>B1 Big Learning Systems</td>
<td>Stoica[B], Andersen[C], Blelloch[C], Ganger[C], Gibson[C], Smola[C], Xing[C], Guestrin[W], Gibbons[I]</td>
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<td>B2 Big Data Storage</td>
<td>Stoica[B], Andersen[C], Ganger[C], Gibson[C], Xing[C], Pu[G], Schwan[G]</td>
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<td>E1 Cloud-Assisted Mobile Client Computations</td>
<td>Satya[C], Siewiorek[C], Gavrilovska[G], Liu[G], Schwan[G], Martonosi[P], Pillai[I]</td>
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<td>E2 Geographically Distributed Data Storage</td>
<td>Andersen[C], Satya[C], Siewiorek[C], Freedman[P], Kaminsky[I], Pillai[I]</td>
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<td>Conference</td>
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<td>ICCD (Sep’13)</td>
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<td>SOCC (Oct’13)</td>
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<td>SOSP (Nov’13)</td>
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<td>MICRO (Dec’13)</td>
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<td>HPCA (Feb’14)</td>
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<td>FAST (Feb’14)</td>
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<td>NSDI (Apr’14)</td>
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<td>EuroSys (Apr’14)</td>
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<td>CCGrid (May’14)</td>
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<td>SIGMETRICS (Jun’14)</td>
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<td>SIGCOMM (Aug’14)</td>
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<td>PACT (Aug’14)</td>
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To appear:
- OSDI (Oct’14) – 3
- SC (Nov’14) – 2

98 published papers highlighted in ISTC-CC Newsletter for Year 3
Open Source Code Releases in Year 3

Open Source page: www.istc-cc.cmu.edu/research/ossr/

• GraphBuilder 1.0 released open source in Jun’13
• GraphLab 2.2 released open source in Jul’13

• Spark 0.9 release Feb’14 – Apache incubator
• Tachyon 0.5 released open source in Jul’14

• Mesos 0.14 released Oct’13 – Apache

• Cuckoo hashing in Intel DPDK (internal)
  ▫ Intel plans to release in DPDK v1.8 end of this year

• Other open source releases include: CBT, MICA, Concurrent Cuckoo, two Parameter Server systems, Eiger, EPaxos, Parrot, Cloudlet OpenStack++, CuckooFilter, RankSelect, MemC3, NVMalloc, etc.

Also Benchmarks page:  www.istc-cc.cmu.edu/research/benchmarks/
Highlights of Year 3 Honors

- **New IEEE Fellows** – Gibbons, Gibson, Yalamanchili
  - ISTC-CC: 8 ACM Fellows, 8 IEEE Fellows, 2 NAE members
- **2 IEEE Design & Automation Conf. Awards** – Siewiorek
- **Steven J. Fenves Award** – Ganger
- **Program Chairs** – Gibson (ATC), Kozuch (HotCloud), Schwan (Middleware & MBDS), Stoica (NSDI)
- **Conference Chair** – Kaminsky (SOSP)
- **Best Paper Awards** – Multu in HPCA’14 & RTAS’14, Satya in IC2E’14, Smola in KDD’14
- **Fellowships** – Chang (Intel), Meza & Subramanian (Bertucci)
- **2013 SPEC Distinguished Dissertation Award** – Gandhi
- **CMU SCS Outstanding Dissertation Award** – Gonzalez
- **Many grants awarded: Amplifying funding**
  - Intel support for 25 students, yet working with 63
Blue Badge Employees:
• Ameya Ambardekar – CMU
• Parag Dixit – CMU
• Soila Kavulya – CMU
• Min Lee – GA Tech

Intel Fellowship winners:
• Kevin Chang – CMU
• Dan Lustig – Princeton
• Yoongu Kim – CMU
• Priyanka Tembey – GA Tech
• Michelle Goodstein - CMU

Interns @ Intel:
• Hrishikesh Amur (2012) – GA Tech
• Nanley Cherry (2014) – GA Tech
• Chris Fallin (2012) – CMU
• Naila Farooqi (2014) – GA Tech
• Prasun Gera (2014) – GA Tech
• Liting Hu (2013) – GA Tech
• Sudarsun Kannan (2013) – GA Tech
• Yoongu Kim (2012) – CMU
• Xiaozhou Li (2013) – Princeton
• Jamie Liu (2012) – CMU
• Dan Lustig (2013) – Princeton
• Alex Merritt (2012,2013) – GA Tech
• Dipanjan Sengupta (2013) – GA Tech
• Vivek Seshadri (2012) – CMU
• Priyanka Tembey (2012) – GA Tech
• Nandita Vijaykumar (2014) – CMU
• Dong Zhou (2014) – CMU
[10:00-11:15] Research Talks session #1
  - Margaret Martonosi (Princeton), Ada Gavrilovska (GA Tech), Dong Zhou (CMU) / Ren Wang (Intel Labs)


[11:40-12:30] Research Talks session #2
  - M. Satyanarayanan (CMU), Haoyuan Li (Berkeley)

[12:30-12:45] Poster session #1 Previews - Babu Pillai (Intel Labs)

[12:45-2:00] Lunch /Poster session #1

[2:00-2:15] Break

[2:15-3:30] Research Talks session #3
  - Yucheng Low (GraphLab), Ion Stoica (Berkeley), Alex Smola (CMU)

[3:30-4:00] Break / Group Photo

[4:00-4:50] Research Talks session #4
  - Onur Mutlu (CMU), Alexey Tumanov (CMU)

[4:50-5:05] Poster session #2 Previews – Michael Kaminsky (Intel Labs)

[5:15-8:30] Reception w/Poster session #2 & Dinner [JF5 Café/Patio]
Retreat Goal:

Benefit the research projects (direction & impact)

- Community building
- Brainstorming/feedback (but not ARs 😊) on:
  - ideas & approaches for tackling the research challenges
  - jump-start collaborations
  - synergies, connections & tech transfer opportunities
- Learn, share & have fun

Who to see about...
- Poster Previews/Sessions: Babu Pillai or Michael Kaminsky
- Logistics questions/issues: Tanya McCutchen