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Cloud Computing and Grid Computing 360-Degree Compared

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In collaboration with:

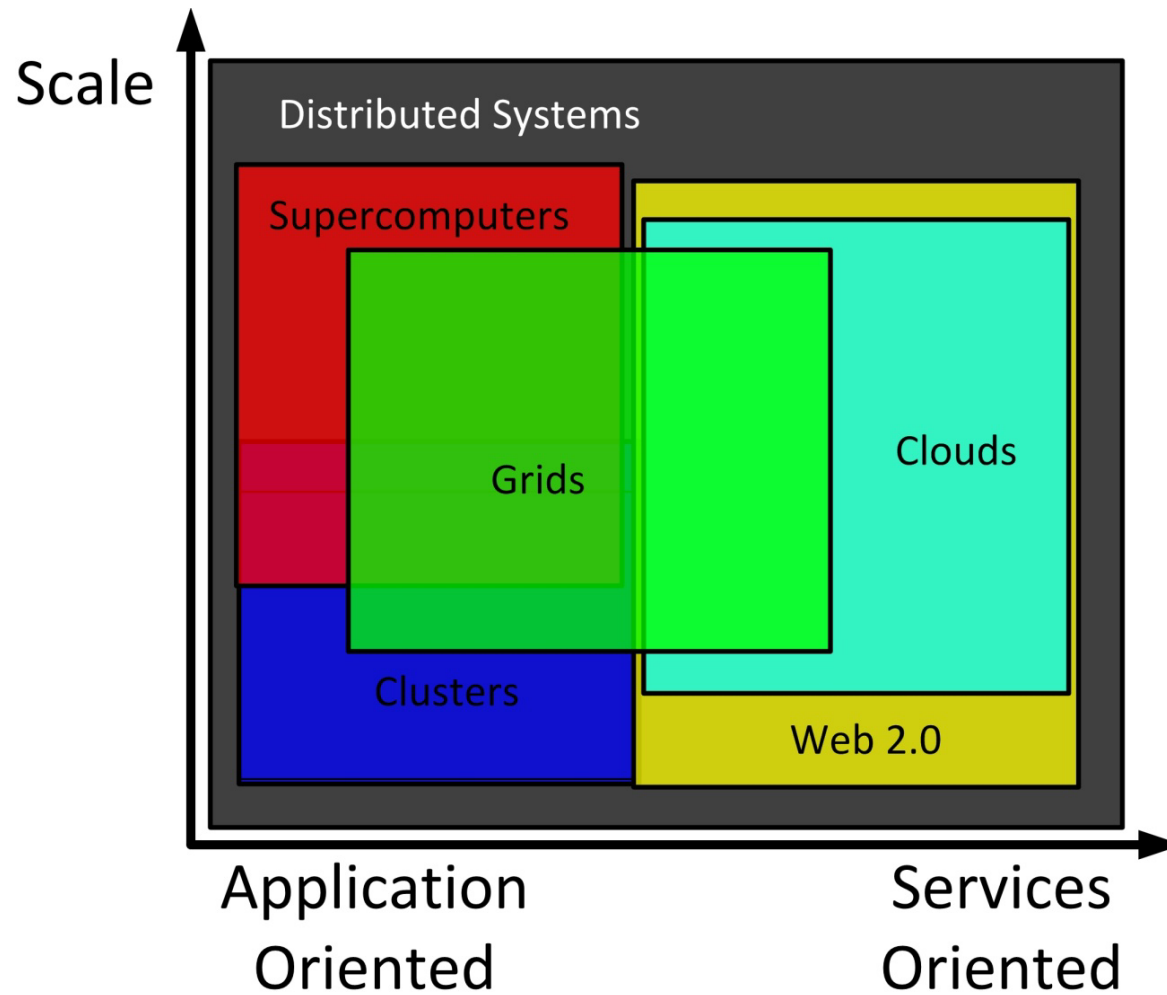
Ian Foster, University of Chicago and Argonne National Laboratory

Yong Zhao, Microsoft Corporation

Shiyong Lu, Wayne State University

University of Chicago, Graduate Seminar
November 10th, 2008

Clusters, Grids, Clouds, ...



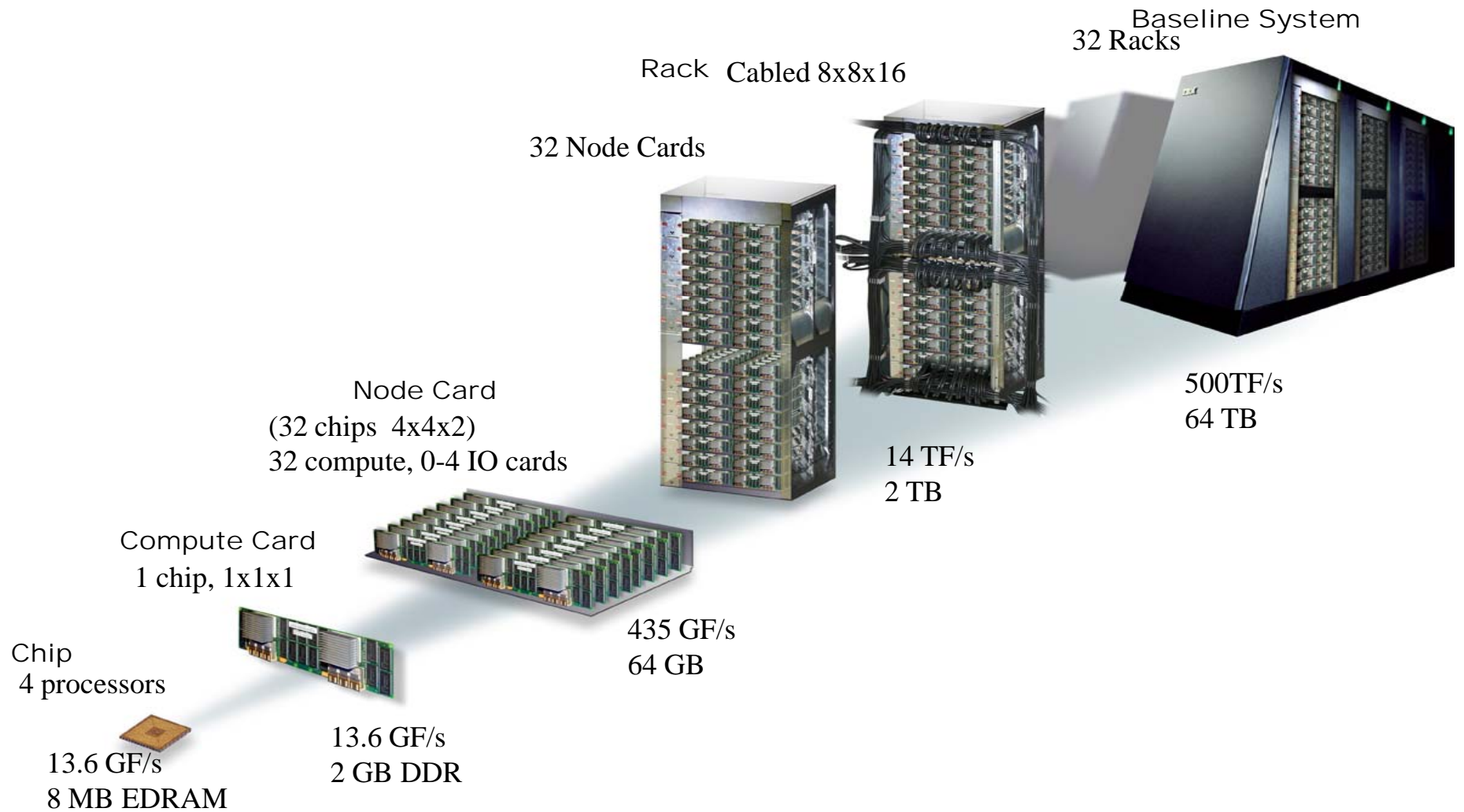
Supercomputing



Highly-tuned computer clusters using commodity processors combined with custom network interconnects and customized operating system

e.g. IBM Blue Gene/P

IBM Blue Gene/P at ANL ALCF



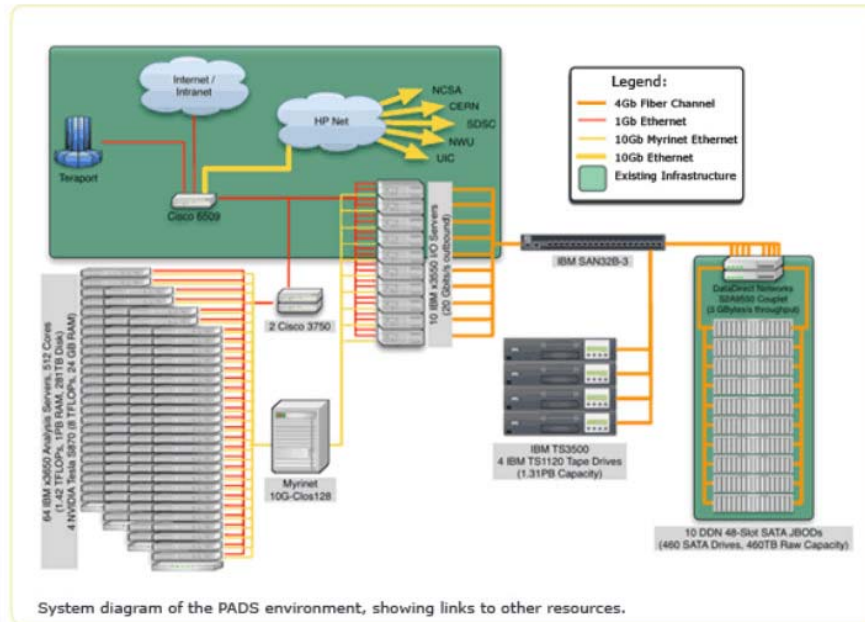
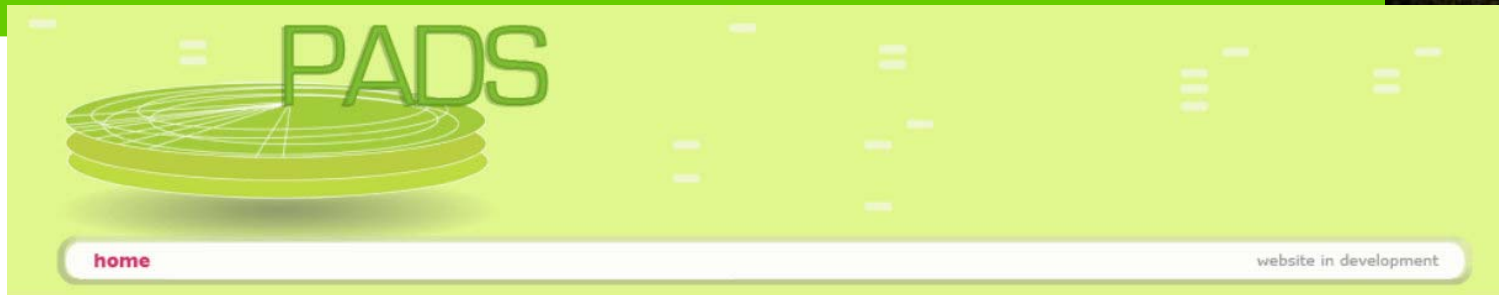
Cluster Computing



Computer clusters using commodity processors, network interconnects, and operating system

e.g. PADS

Petascale Active Data Store (PADS)



PADS is a petabyte (10^{15} -byte)-scale online storage server capable of sustained multi-gigabyte/s I/O performance, tightly integrated with a 9 teraflop/s computing resource and multi-gigabit/s local and wide area networks. Its hardware and associated software enables the reliable storage of, access to, and analysis of massive datasets by both local users and the national scientific community.

The PADS design results from a study of the storage and analysis requirements of participating groups in astrophysics and astronomy, computer science, economics, evolutionary and organismal biology, geosciences, high-energy physics, linguistics, materials science, neuroscience, psychology, and sociology. For these groups, PADS represents a significant opportunity to look at their data in new ways, enabling new scientific insights. The infrastructure also encourages new collaborations across disciplines. PADS is also a vehicle for computer science research into active data store systems, and provides rich data on which to investigate new techniques. Results will be made available as open source software.

The PADS project is supported in part by the National Science Foundation under grant OCI-0821678 and by The University of Chicago.

[PADSstatus](#)

[myPADS](#)

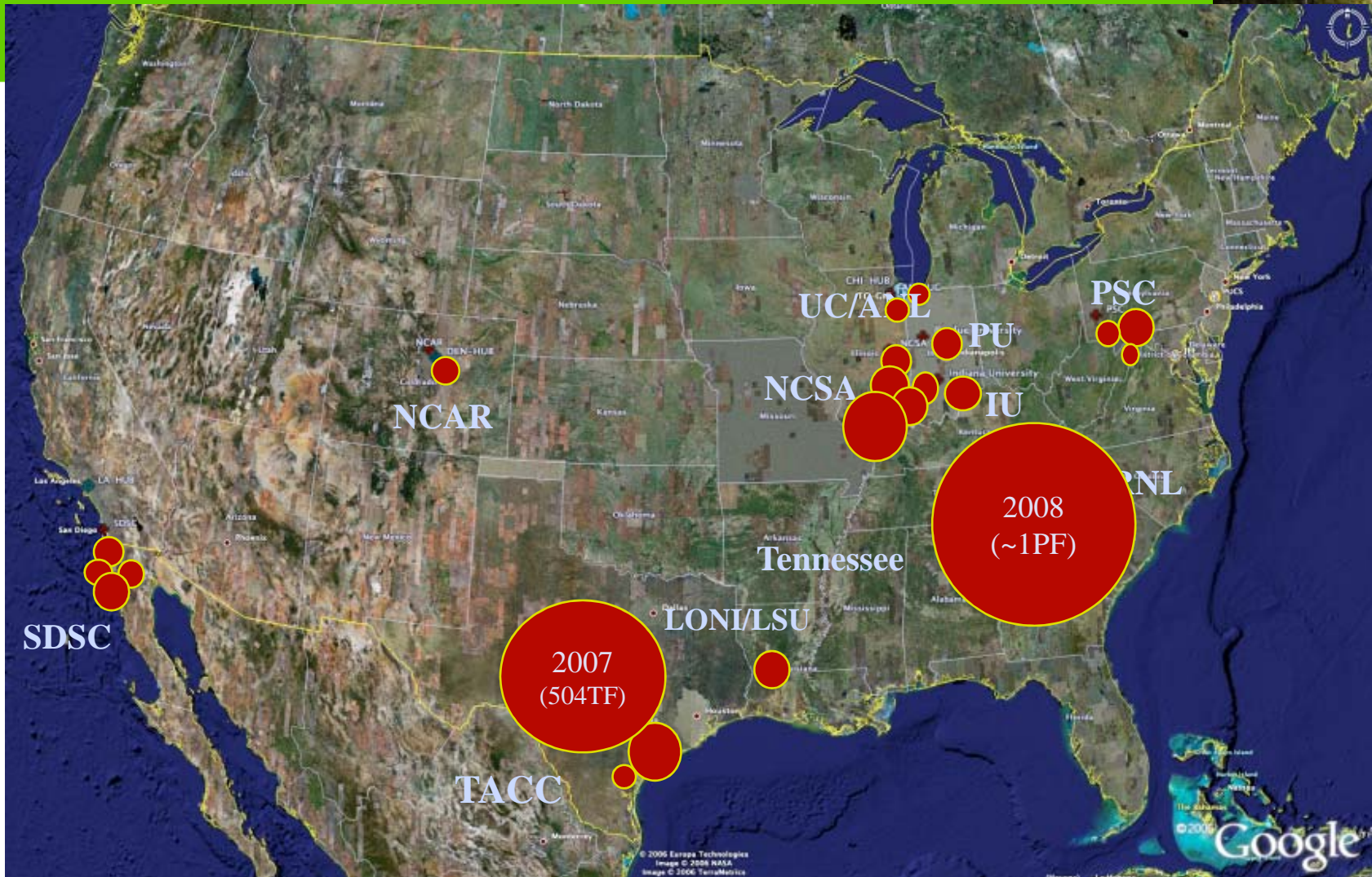
Grid Computing



*Grids tend to be composed of multiple clusters,
and are typically loosely coupled,
heterogeneous, and geographically dispersed*

e.g. TeraGrid

TeraGrid High Performance Computing Systems 2007-8



● Computational Resources
(size approximate - not to scale)

What is the TeraGrid?



- An instrument (cyberinfrastructure) that delivers high-end IT resources - storage, computation, visualization, and data/service hosting - almost all of which are UNIX-based under the covers; some hidden by Web interfaces
 - 20 Petabytes of storage (disk and tape)
 - over 100 scientific data collections
 - 750 TFLOPS (161K-cores) in parallel computing systems and growing
 - Support for Science Gateways
- The largest individual cyberinfrastructure facility funded by the NSF, which supports the national science and engineering research community
- Something you can use without financial cost - allocated via peer review (and without double jeopardy)

Major Grids



- TeraGrid (TG)
- Open Science Grid (OSG)
- Enabling Grids for E-scienceE (EGEE)
- LHC Computing Grid from CERN
- Grid Middleware
 - Globus Toolkit
 - Unicore

Cloud Computing



*A large-scale distributed computing paradigm that is driven by **economies of scale**, in which a pool of abstracted, **virtualized, dynamically-scalable, managed computing power, storage, platforms, and services** are delivered on demand to external customers over the **Internet**.*

e.g. Amazon EC2

Major Cloud Computing Middleware



- Google App Engine
 - Engine, Datastore, memcache
- Amazon
 - EC2, S3, SQS, SimpleDB
- Microsoft Azure
- Nimbus
- Eucalyptus
- Salesforce

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powered by **HYPERIC**
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Updated 17:28:05 CST. Updates in 6

Outage Dashboard

Amazon Service Summary

- Elastic Compute Cloud (EC2)
- Simple Storage Service (S3)
- Simple Queue Service (SQS)
- Simple DB (SDB)
- Flexible Payment Service (FPS)

Google App Engine Summary

- Engine
- Datastore
- memcache
- URLFetch

[Service alerts on Twitter](#)
[Hyperic is hiring!](#)


[Sign-up](#) for CloudStatus Updates.

Outage Dashboard

This dashboard displays the last week of health status for selected remote computing services. This view is dynamic. For services with recent outages, a health bar is shown. Given no recent outages in a provider's services, key indicator charts are shown. Click a Service in the left panel for detailed service health status, metrics, and more history.

Google App Engine

Health



11/2 17:27 CST 11/9 17:27 CST

Datastore Delete Time



Datastore Read Time



memcache Get Time




Amazon Web Services

Health

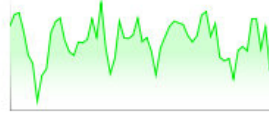


11/2 17:27 CST 11/9 17:27 CST

EC2 Deployment Latency



S3 Read Throughput



SQS Lag Time



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So is “Cloud Computing” just a new name for Grid?



- IT reinvents itself every five years
- The answer is complicated...
- **YES:** the vision is the same
 - to reduce the cost of computing
 - increase reliability
 - increase flexibility by transitioning from self operation to third party

So is “Cloud Computing” just a new name for Grid?



- **NO:** things are different than they were 10 years ago
 - New needs to analyze massive data, increased demand for computing
 - Commodity clusters are expensive to operate
 - We have low-cost virtualization
 - Billions of dollars being spent by Amazon, Google, and Microsoft to create real commercial large-scale systems with hundreds of thousands of computers
 - The prospect of needing only a credit card to get on-demand access to *infinite computers is exciting; *infinite $<O(1000)$

So is “Cloud Computing” just a new name for Grid?



- **YES:** the problems are mostly the same
 - How to manage large facilities
 - Define methods to discover, request, and use resources
 - How to implement and execute parallel computations
 - Details differ, but issues are similar

Outline



- Business model
- Architecture
- Resource management
- Programming model
- Application model
- Security model

Business Model



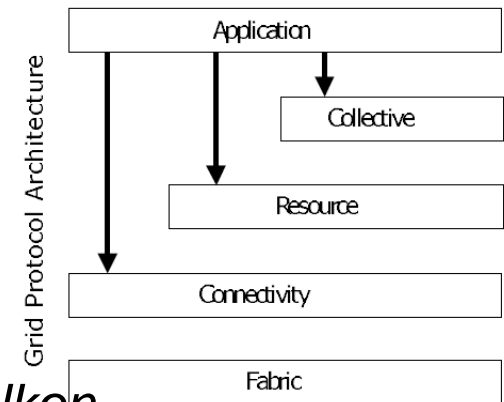
- Grids:
 - Largest Grids funded by government
 - Largest user-base in academia and government labs to drive scientific computing
 - Project-oriented: service units
- Clouds:
 - Industry (i.e. Amazon) funded the initial Clouds
 - Large user base in common people, small businesses, large businesses, and a bit of open science research
 - Utility computing: real money

Architecture



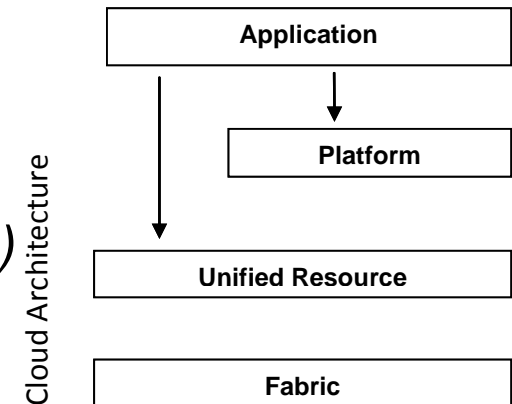
- Grids:

- Application: *Swift, Grid portals (NVO)*
- Collective layer: *MDS, Condor-G, Nimrod-G*
- Resource layer: *GRAM, Falkon, GridFTP*
- Connectivity layer: *Grid Security Infrastructure*
- Fabric layer: *GRAM, PBS, SGE, LSF, Condor, Falkon*



- Clouds:

- Application Layer: *Software as a Service (SaaS)*
- Platform Layer: *Platform as a Service (PaaS)*
- Unified Resource: *Infrastructure as a Service (IaaS)*
- Fabric: *IaaS*

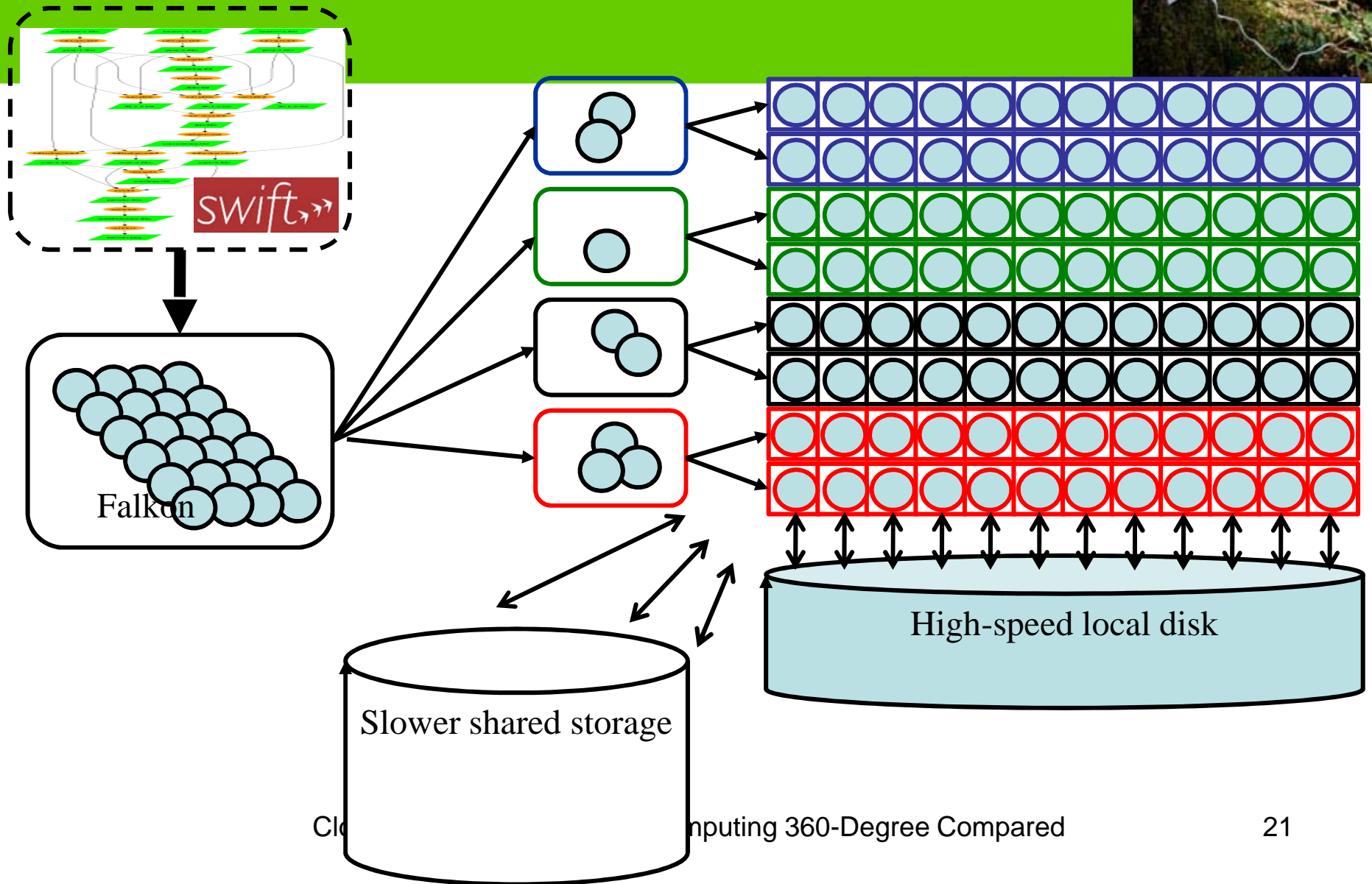


Resource Management



- Compute Model
 - batch-scheduled vs. time-shared
- Data Model
 - Data Locality
 - Combining compute and data management
- Virtualization
 - Slow adoption vs. central component
- Monitoring
- Provenance

Managing 160K CPUs



Resource Management

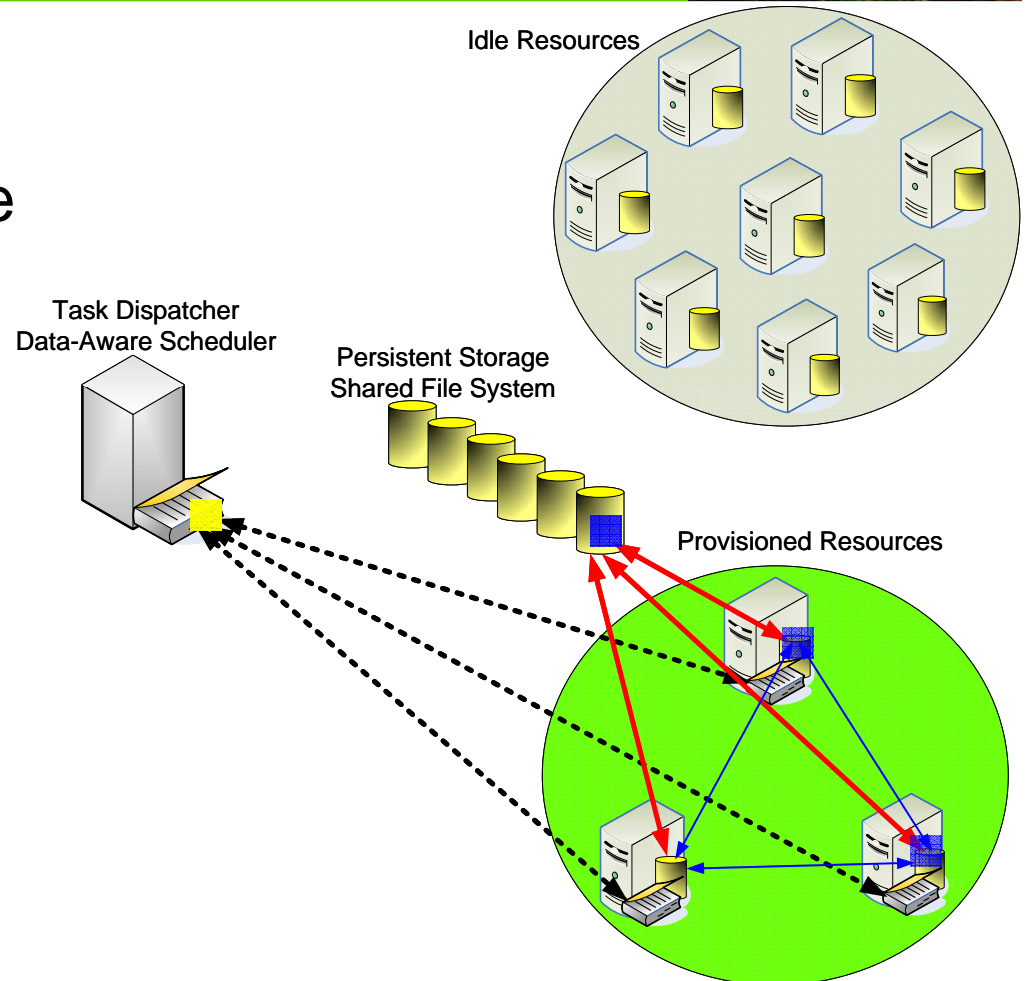


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Data Diffusion



- Resource acquired in response to demand
- Data and applications diffuse from archival storage to newly acquired resources
- Resource “caching” allows faster responses to subsequent requests
 - Cache Eviction Strategies: RANDOM, FIFO, LRU, LFU
- Resources are released when demand drops



Resource Management



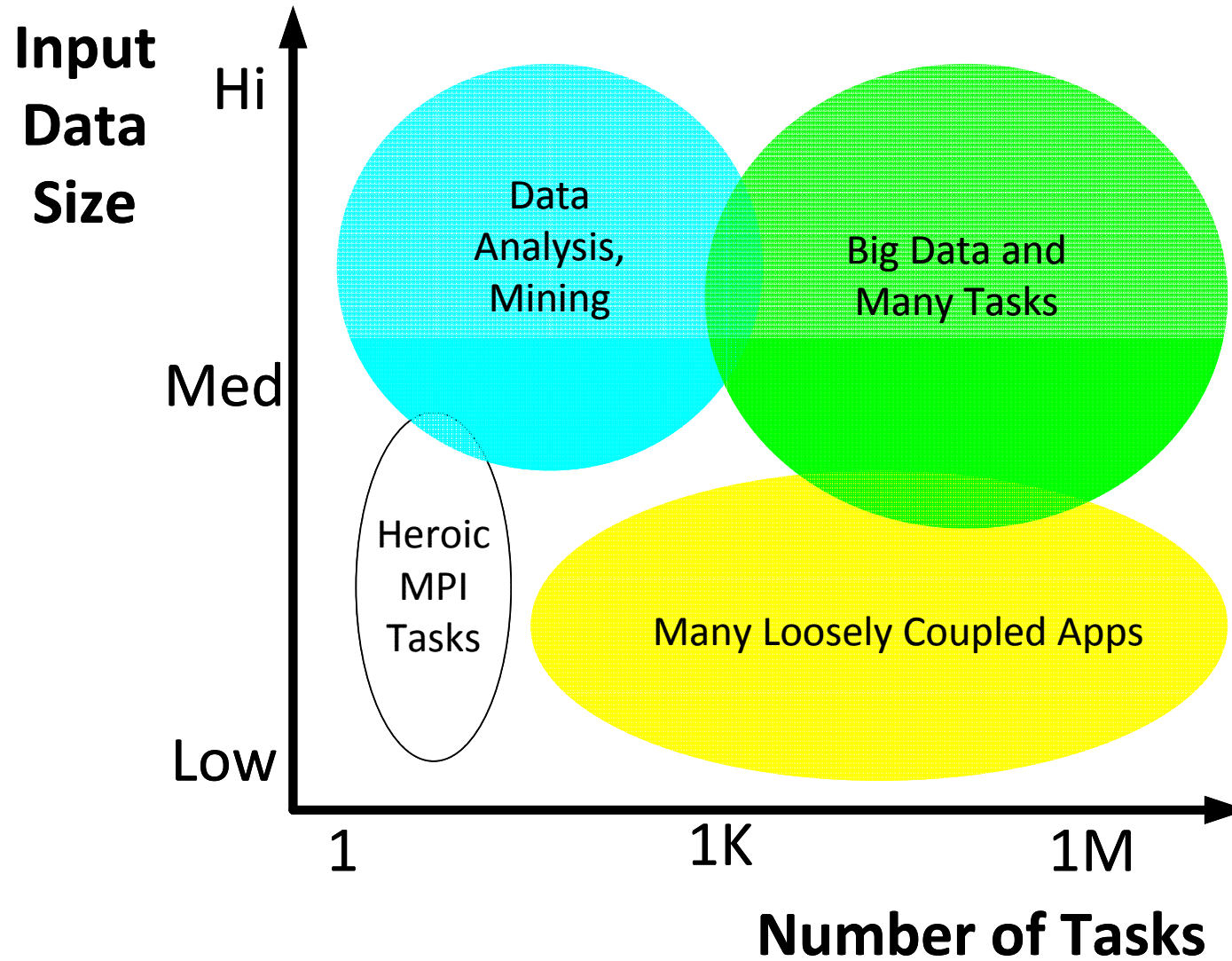
- Compute Model
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Programming and Application Model

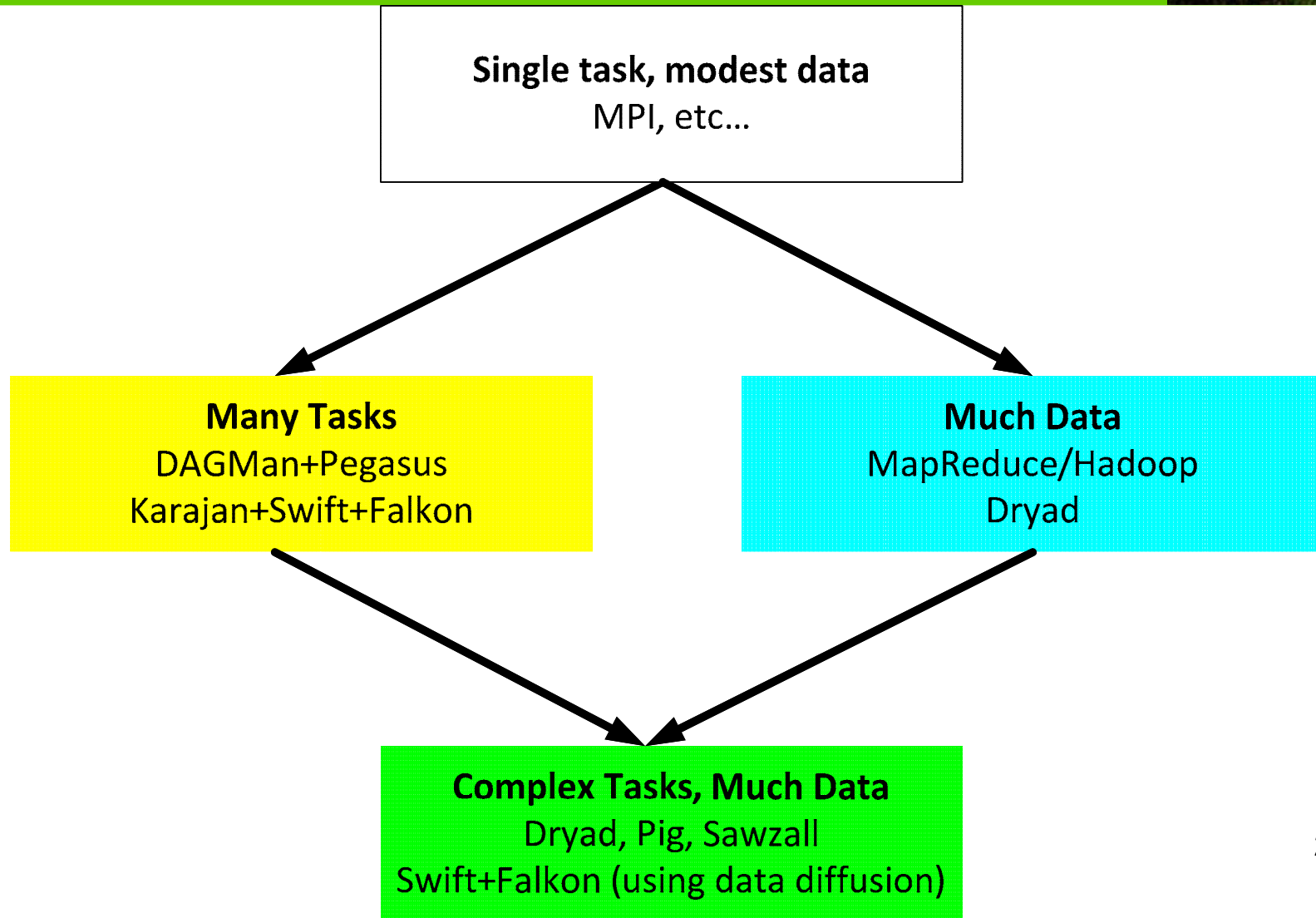


- Grids:
 - Tightly coupled
 - High Performance Computing (MPI-based)
 - Loosely Coupled
 - High Throughput Computing
 - Workflows
 - Data Intensive
 - Map/Reduce
- Clouds:
 - Loosely Coupled, transactional oriented

Problem Types



An Incomplete and Simplistic View of Programming Models and Tools



MTC: Many Task Computing



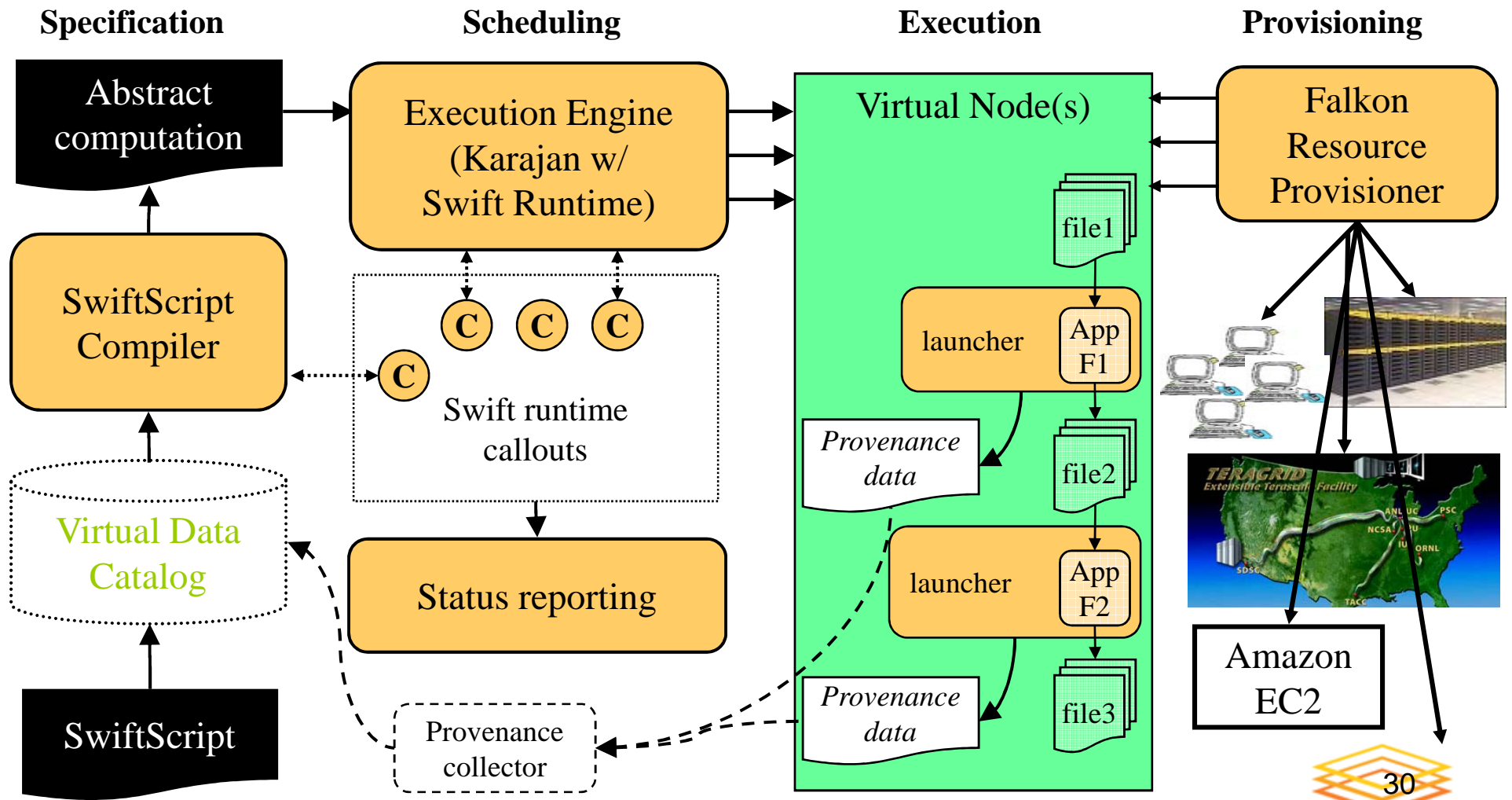
- Loosely coupled applications
 - High-performance computations comprising of multiple distinct activities, coupled via file system operations or message passing
 - Emphasis on using many resources over short time periods
 - Tasks can be:
 - small or large, independent and dependent, uniprocessor or multiprocessor, compute-intensive or data-intensive, static or dynamic, homogeneous or heterogeneous, loosely or tightly coupled, large number of tasks, large quantity of computing, and large volumes of data...

Programming Model Issues



- **Multicore** processors
- Massive **task parallelism**
- Massive **data parallelism**
- Integrating **black box applications**
- Complex **task dependencies** (task graphs)
- **Failure**, and other execution management issues
- **Dynamic task graphs**
- Documenting **provenance** of data products
- **Data management**: input, intermediate, output
- **Dynamic data access** involving large amounts of data

Swift Architecture



Cloud Computing and Grid Computing 360-Degree Compared

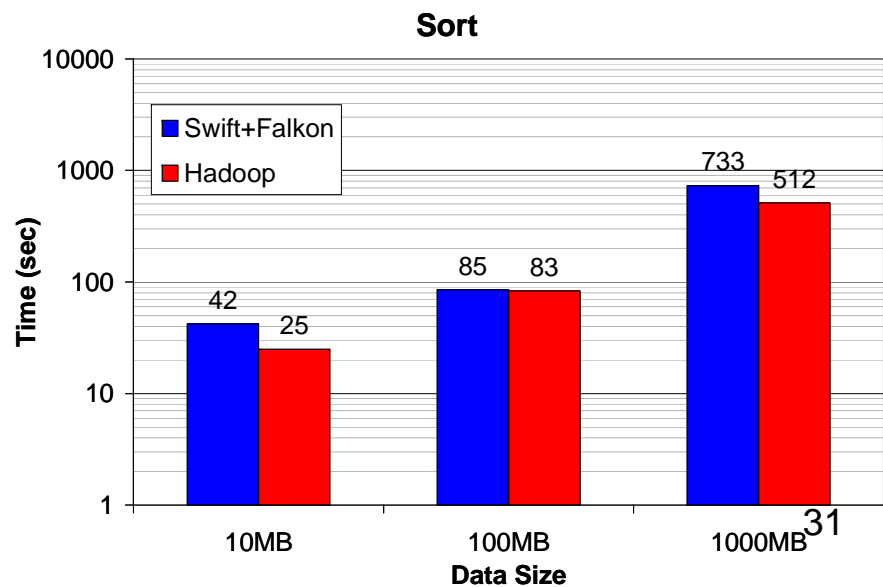
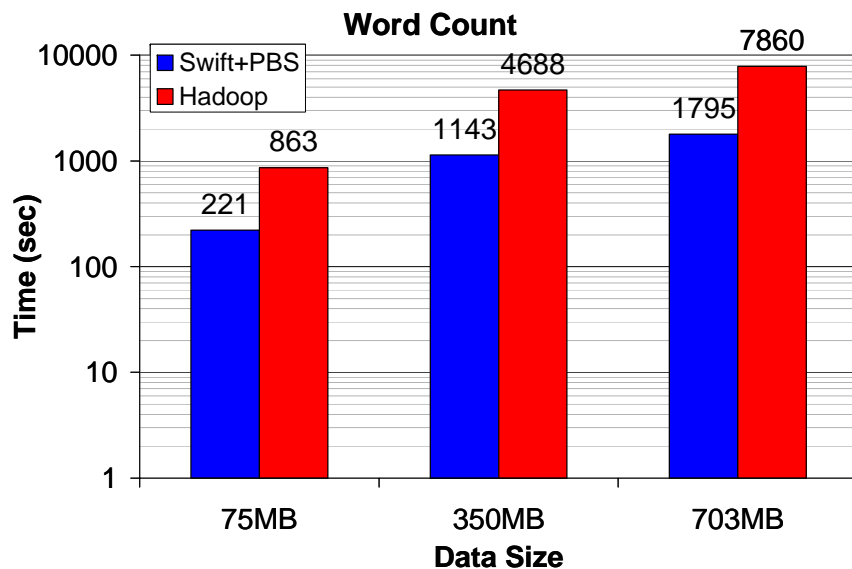


Open Science Grid

Comparing Hadoop and Swift



- Classic benchmarks for MapReduce
 - Word Count
 - Sort
- Swift performs similar or better than Hadoop (on 32 processors)



Gateways



- Aimed to simplify usage of complex resources
- Grids
 - Front-ends to many different applications
 - Emerging technologies for Grids
- Clouds
 - Standard interface to Clouds

Gateway to Grids



AstroPortal: Stacking Service

User ID:
Password:

[Stacking Description](#)

194.940047132658	2.98364884441	r
194.993034538067	2.95438381572631	r
194.993436485523	2.89844869849326	r
194.941075099309	2.93405258125417	r
194.986003214584	2.91017907077681	r
194.997068893042	2.97217602975886	r

[Upload Description File](#)

For more information about the AstroPortal, please see the [About Page](#).

AstroPortal: Stacking Service Results

User ID: *iraicu*
Password: *password*
Stacking Description: [stacking_description.txt](#)
Stacking Size: 20
AstroPortal Web Service Location: <http://tg-viz-login.uc.teragrid.org:50001/wsr/services/AstroPortal/core/WS/APFactoryService>

RESULT:



Size: 43 KB
Dimensions: 100x100 pixels
Download result: [stacked_result.fits](#)

Time to complete Stacking: 5.164 seconds
Number of physical resources utilized: 16
Number of Stackings completed successful: 18
Number of Star Objects not found in the SDSS dataset: 1
List of Star Objects [ra, dec, band] not found:

- [194.969060213455, -13.90189344168167, r]

Number of Data Objects not found in the data cache: 1
List of Data Objects [ra, dec, band] filename [x_coord x y_coord] not found:

- [[194.969705877549, 2.93855950426612, r]
/data/secchi/gppfr1/iraicu/sds/gr/class_sds.org/DR4/data/imaging/752/40/corr/6fpc-000752-r6-0245.fits.gz [0 x 0]]

For a new stacking, go back to the main [Stacking Service](#).

Gateway to Clouds



Gateway to Clouds



Gateway to Clouds



Gateway to Clouds



Cloud Computing and Grid Computing

Gateway to Clouds



Gateway to Clouds



Security Model



- Grids
 - Grid Security Infrastructure (GSI)
 - Stronger, but steeper learning curve and wait time
 - Personal verification: phone, manager, etc
- Clouds
 - Weaker, can use credit card to gain access, can reset password over plain text email, etc

Conclusion



- Move towards a mix of micro-production and large utilities, with load being distributed among them dynamically
 - Increasing numbers of small-scale producers (local clusters and embedded processors—in shoes and walls)
 - Large-scale regional producers
- Need to define protocols
 - Allow users and service providers to discover, monitor and manage their reservations and payments
 - Interoperability
- Need to combine the centralized scale of today's Cloud utilities, and the distribution and interoperability of today's Grid facilities
- Need support for on-demand provisioning
- Need tools for managing both the underlying resources and the resulting distributed computations
- Security and trust will be a major obstacle for commercial Clouds by large companies that have in-house IT resources to host their own data centers

More Information



- Ioan Raicu
 - <http://people.cs.uchicago.edu/~iraicu/>
 - iraicu@cs.uchicago.edu
- Original Blog from Ian Foster
 - There's Grid in them thar Clouds*
 - <http://ianfoster.typepad.com/blog/2008/01/theres-grid-in.html>
- Paper published in IEEE Grid Computing Environments 2008
 - http://people.cs.uchicago.edu/~iraicu/publications/2008_GCE08_Clouds_Grids.pdf
- Cloud Computing and Its Applications Workshop
 - <http://www.cca08.org/>

MTAG508: Workshop on Many-Task Computing on Grids and Supercomputers - Mozilla Firefox

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http://dsl.cs.uchicago.edu/MTAG508/

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MTAGS

Workshop on Many-Task Computing on Grids and Supercomputers

co-located with [ACM/IEEE SC08 \(International Conference for High Performance, Networking, Storage and Analysis\)](#)
 Austin, Texas -- November 17th, 2008

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Important Dates

Papers Due: August 15th, 2008
Notification of Acceptance: October 1st, 2008
Camera Ready Papers Due: October 15th, 2008
Workshop Date: November 17th, 2008

Committee Members

Workshop Chairs

Yong Zhao, Microsoft
 Ian Foster, University of Chicago & Argonne National Laboratory
 Ioan Raicu, University of Chicago

Technical Committee

Ian Foster, University of Chicago & Argonne National Laboratory
 Dan Ardelean, Google
 Bob Grossman, University of Illinois at Chicago
 Indranil Gupta, University of Illinois at Urbana Champaign
 Tefik Kosar, Louisiana State University



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Main Page

Megajobs: How to Run One Million Jobs [edit]

- **What:** Birds-of-a-Feather Session at Supercomputing 2008, Austin Texas
- **Date:** Tuesday, November 18th, 2008
- **Time:** 05:30PM - 07:00PM
- **Location:** Room 13A/13B
- **Primary Session Leader:**
 - Marlon Pierce (Indiana University)
- **Secondary Session Leader:**
 - Ioan Raicu (University of Chicago)
 - Ruth Pordes (Fermi National Laboratory)
 - John McGee (Renaissance Computing Institute)
 - Dick Repasky (Indiana University)

As large systems surpass 200K CPU cores and as applications increase in complexity, more scientists need to run thousands to millions of closely related jobs that are associated with individual projects. Scientists seek convenient means to specify and manage many jobs, arranging inputs, aggregating outputs, identifying successful and failed jobs and repairing failures. System administrators seek methods to process extraordinary numbers of jobs for multiple users without overwhelming queuing systems or disrupting fair-share usage policies. Under development are a new generation of queuing and scheduling systems and multi-level schedulers for use with existing queuing and scheduling systems, schedulers designed to handle millions of jobs. This Birds-of-feather session provides a venue for the exchange of information about processing large numbers of jobs. Short presentations of an invited sample of projects will be followed by discussion.

We are currently soliciting participation in the "Megajobs" BOF. We are looking for short, piquant presentations (5-10 minutes) from people who have worked on this problem or have a problem like this that needs to be worked on. If you are interested, please send a brief title and abstract (250 words) to [Marlon Pierce](#) by October 27th, 2008. Please feel free to contact us if you have questions.

For the latest information hosted by SC08, see <http://scyourway.nacse.org/conference/view/bof118>. The Megajobs BOF handout can also be found [here](#).

Related activities at SC08, that might be of interest to BOF attendees are:

- [Grid Computing Environments \(GCE\)](#)
- [Workshop on Many-Task Computing on Grids and Supercomputers \(MTAGS\)](#)

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