Taking stock of Grid technologies - accomplishments and challenges

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The Grid: Blueprint for a New Computing Infrastructure
Edited by Ian Foster and Carl Kesselman

The grid promises to fundamentally change the way we think about and use computing. This infrastructure will connect multiple regional and national computational grids, creating a universal source of pervasive and dependable computing power that supports dramatically new classes of applications. The Grid provides a clear vision of what computational grids are, why we need them, who will use them, and how they will be programmed.
Claims for “benefits” provided by Distributed Processing Systems

- High Availability and Reliability
- High System Performance
- Ease of Modular and Incremental Growth
- Automatic Load and Resource Sharing
- Good Response to Temporary Overloads
- Easy Expansion in Capacity and/or Function

“What is a Distributed Data Processing System?” , P.H. Enslow, Computer, January 1978
“The term “the Grid” was coined in the mid 1990s to denote a proposed distributed computing infrastructure for advanced science and engineering [27].

... 

Is there really a distinct “Grid problem” and hence a need for new “Grid technologies”? If so, what is the nature of these technologies and what is their domain of applicability?”

Benefits to Science

- **Democratization of Computing** - “you do not have to be a SUPER person to do SUPER computing.” (accessibility)
- **Speculative Science** - “Since the resources are there, lets run it and see what we get.” (unbounded computing power)
- **Function shipping** - “Find the image that has a red car in this 3 TB collection.” (computational mobility)
The Ethernet Protocol

IEEE 802.3 CSMA/CD - A truly distributed (and very effective) access control protocol to a shared service.

♥ Client responsible for access control
♥ Client responsible for error detection
♥ Client responsible for fairness
GridFTP

A high-performance, secure, reliable data transfer protocol optimized for high-bandwidth wide area networks.

- Based on FTP, the highly-popular Internet file transfer protocol.
- Uses GSI.
- Supports third party transfers.
The NUG30 Quadratic Assignment Problem (QAP)

$$\min_{p_1, \ldots, p_n} \sum_{i=1}^{n-1} \sum_{j=1}^{n} a_{ij} b_{p(i)p(j)}$$
NUG30 Personal Grid ...

Managed by one Linux box at Wisconsin

**Flocking:**
-- the main Condor pool at Wisconsin (500 processors)
-- the Condor pool at Georgia Tech (284 Linux boxes)
-- the Condor pool at UNM (40 processors)
-- the Condor pool at Columbia (16 processors)
-- the Condor pool at Northwestern (12 processors)
-- the Condor pool at NCSA (65 processors)
-- the Condor pool at INFN Italy (54 processors)

**Glide-in:**
-- Origin 2000 (through LSF) at NCSA. (512 processors)
-- Origin 2000 (through LSF) at Argonne (96 processors)

**Hobble-in:**
-- Chiba City Linux cluster (through PBS) at Argonne
  (414 processors).

www.cs.wisc.edu/~miron
### Solution Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientists</td>
<td>4</td>
</tr>
<tr>
<td>Wall Clock Time</td>
<td>6:22:04:31</td>
</tr>
<tr>
<td>Avg. # CPUs</td>
<td>653</td>
</tr>
<tr>
<td>Max. # CPUs</td>
<td>1007</td>
</tr>
<tr>
<td>Total CPU Time</td>
<td>Approx. 11 years</td>
</tr>
<tr>
<td>Nodes</td>
<td>11,892,208,412</td>
</tr>
<tr>
<td>LAPs</td>
<td>574,254,156,532</td>
</tr>
<tr>
<td>Parallel Efficiency</td>
<td>92%</td>
</tr>
</tbody>
</table>
Accomplish an official production request of the CMS collaboration of 1,200,000 Monte Carlo simulation data with Grid resources.
Time to process 1 event:
500 sec @ 750 MHz
How Effective is our Grid Technology?
“We encountered many problems during the run, and fixed many of them, including integration issues arising from the integration of legacy CMS software tools with Grid tools, bottlenecks arising from operating system limitations, and bugs in both the grid middleware and application software.

Every component of the software contributed to the overall "problem count" in some way. However, we found that with the current level of functionality, we were able to operate the US-CMS Grid with 1.0 FTE effort during quiescent times over and above normal system administration and up to 2.5 FTE during crises.”

You are here

Intra Grids

... or here

Goal

One of a kind

Benefits

Effort
It takes two (or more) to tango!!!
Application Responsibilities

- Use algorithms that can generate very large numbers of independent tasks - “use pleasantly parallel algorithms”
- Implement self-contained portable workers - “this code can run anywhere!”
- Detect failures and react gracefully - “use exponential back off, please!”
- Be well informed and opportunistic - “get your work done and out of the way!”
A “good” Grid application is an application that has always work “ready to go” for any possible Grid resource
Being a Master

Customer “deposits” task(s) with the master that is responsible for:

- Obtaining resources and/or workers
- Deploying and managing workers on obtained resources
- Assigning and delivering work units to obtained/deployed workers
- Receiving and processing results
- Notify customer.
Customer requests:

Place $y = F(x)$ at $L$!

Master delivers.
A simple plan for $y = F(x) \rightarrow L$

1. Allocate $(\text{size}(x) + \text{size}(y) + \text{size}(F))$ at SE(i)
2. Move $x$ from SE(j) to SE(i)
3. Install $F$ on CE(k)
4. Compute $F(x)$ at CE(k)
5. Move $y$ to L
6. Release allocated space

Storage Element (SE); Compute Element (CE)
Technical Challenges
(the what)
Data Placement (DaP)

Management of storage space and movement of data should be treated as “first class” jobs.

- Framework for storage management that supports leasing, sharing and “best effort” services.
- Smooth transition of CPU-I/O interleaving across software layers.
- Coordination and scheduling of data movement.
- Balk data transfers.
Trouble Shooting

How can I figure out what went wrong and whether I can do anything to fix it?

• Error propagation and exception handling.
• Dealing with “rejections” by authentication/authorization agents.
• Reliable and informative logging.
• Software packaging, installation and configuration.
• Support for debugging and performance monitoring tools for distributed applications.
Virtual Data

Enable the user to view the output of a computation as an answer to a query.

- User defines the “what” rather than the “how”.
- Planners map query to an execution plan (eager, lazy and “just in time”).
- Workflow manager executes plan.
- Schedulers manage tasks.
Methodology
Challenges
(the how)
The CS attitude

› “This is soft science! Where are the performance numbers?”
› “We solved all these distributed computing problems 20 years ago!”
› “This is not research, it is engineering!”
› “I prefer to see really new ideas and approaches, not just old ideas and approaches well applied to a new problem!”
US Particle Physics Data Grid Project today

- LBL – STAR, LBL - STACS
- SLAC - BaBar
- Caltech - CMS
- UCSD- CMS
- SDSC - SRB

- U of Wisconsin Condor
- Fermilab - CMS, D0
- ANL – Globus
- ANL - ATLAS
- BNL – STAR, ATLAS
- TJNF

10 sites
A meeting point of two sciences

Physics

Particle Physics

Data Grid

Computer Science
My CS Perspective

• Application needs are instrumental in the formulation of new frameworks and technologies
  – Scientific applications are an excellent indicator to future IT trends
  – The physics community is at the leading edge of IT
• Experimentation is fundamental to the scientific process
  – Requires robust software materialization of new technology
  – Requires an engaged community of consumers
• Multi disciplinary teams hold the key to advances in IT
  – Collaboration across CS disciplines and projects (intra-CS)
  – Collaboration with domain scientists
The Scientific Method

• Deployment of end-to-end capabilities
  – Advance the computational and or data management capabilities of a community
  – Based on coordinated design and implementation

• Teams of domain and computer scientists
  – May span multiple CS project
  – Mission focused
  – From design to deployment
The Condor Project (Established '85)

Distributed Computing research performed by a team of ~33 faculty, full time staff and students who

• face software/middleware engineering challenges in a UNIX/Linux/Windows/MACOS environment,

• involved in national and international collaborations,

• interact with users in academia and industry,

• maintain and support a distributed production environment (more than 2000 CPUs at UW),

• and educate and train students.

Funding - DoD, DoE, NASA, NIH, NSF, INTEL, EU
Micron, Microsoft and the UW Graduate School

www.cs.wisc.edu/condor
“... Since the early days of mankind the primary motivation for the establishment of communities has been the idea that by being part of an organized group the capabilities of an individual are improved. The great progress in the area of inter-computer communication led to the development of means by which stand-alone processing sub-systems can be integrated into multi-computer ‘communities’. ...”

Every community needs a Matchmaker*

* or a Classified section in the newspaper or an eBay.
We use Matchmakers to build Computing Communities out of Commodity Components
High Throughput Computing

For many experimental scientists, scientific progress and quality of research are strongly linked to computing throughput. In other words, they are less concerned about instantaneous computing power. Instead, what matters to them is the amount of computing they can harness over a month or a year --- they measure computing power in units of scenarios per day, wind patterns per week, instructions sets per month, or crystal configurations per year.
High Throughput Computing is a 24-7-365 activity

FLOPY ≠ (60*60*24*7*52)*FLOPS
The NUG30 Workforce

- Condor crash
- System Upgrade
- Application Upgrade

Graph showing workers over time with significant events on 6/10, 6/11, 6/12, 6/13, 6/14, and 6/15.
our answer to
High Throughput MW Computing
on commodity resources
The Layers of Condor

Submit (client)

Application
Application Agent
Customer Agent
Matchmaker
Owner Agent
Remote Execution Agent
Local Resource Manager
Resource

Execute (service)
The World of Condors

› Available for most Unix and Windows platforms at [www.cs.wisc.edu/Condor](http://www.cs.wisc.edu/Condor)
› More than 500 Condor pools at commercial and academia sites world wide
› More than 20,000 CPUs world wide
› “Best effort” and “for fee” support available

www.cs.wisc.edu/condor
Condor Support

![Chart showing the number of emails received each month from March 1999 to March 2003. The chart includes two categories: New Tickets and All RUST Emails. The number of emails ranges from 0 to 450.](image)
Activities and Technologies

1. Bypass
2. Checkpointing
3. Chirp
4. ClassAds and the ClassAd Catalog
5. Condor-G
6. DAGMan
7. Fault Tolerant Shell (FTSH)
8. FTP-Lite
9. GAHP
10. Grid Console
11. Hawkeye System Monitoring Tool
12. Kangaroo
13. Master-Worker (MW)
14. NeST
15. PKI Lab
16. Pluggable File System (PFS)
17. Stork (Data Placement Scheduler)

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How can we accommodate an unbounded need for computing with an unbounded amount of resources?