Grid Computing Research

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Overview

- Grid computing & its importance to DOE
- Grid R&D at Argonne
- Defining and instantiating a Grid Services architecture
- Data Grids
- Future directions
The Grid: The Web on Steroids

**Web:** Uniform access to HTML documents

**Grid:** Flexible, high-perf access to all significant resources

*On-demand creation of powerful virtual computing systems*

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Grid Computing: Take 2

- Enable communities ("virtual organizations") to share geographically distributed resources as they pursue common goals—in the absence of central control, omniscience, trust relationships

- Via investigations of
  - New applications that become possible when resources can be shared in a coordinated way
  - Protocols, algorithms, persistent infrastructure to facilitate sharing
Grids and DOE

- Distinctive characteristics of much DOE science encourages Grid concepts
  - Unique and expensive facilities: accelerators, microscopes, supercomputers, ...
  - Large-scale, multidisciplinary science: climate, materials, high energy physics, ...
  - Large-scale simulation, data-intensive science

- The question is not whether to Grid-enable DOE Science—but how
Grid Communities & Applications: Data Grids for High Energy Physics

There is a "bunch crossing" every 25 nsecs. There are 100 "triggers" per second. Each triggered event is ~1 MByte in size.

Physicists work on analysis "channels". Each institute will have ~10 physicists working on one or more channels; data for these channels should be cached by the institute server.

Image courtesy Harvey Newman, Caltech
Grid Communities & Applications: Online Instrumentation

Advanced Photon Source

real-time collection

tomographic reconstruction

wide-area dissemination

archival storage

desktop & VR clients with shared controls

DOE X-ray grand challenge: ANL, USC/ISI, NIST, U.Chicago
Grid Communities and Applications: Mathematicians Solve NUG30

- Community = an informal collaboration of mathematicians and computer scientists
- Condor-G delivers $3.46 \times 10^8$ CPU seconds in 7 days (peak 1009 processors) in U.S. and Italy (8 sites)
- Solves NUG30 quadratic assignment problem

MetaNEOS: Argonne, Iowa, Northwestern, Wisconsin

14, 5, 28, 24, 1, 3, 16, 15, 10, 9, 21, 2, 4, 29, 25, 22, 13, 26, 17, 30, 6, 20, 19, 8, 18, 7, 27, 12, 11, 23
Grid R&D at Argonne

- Started in 1995 (I-WAY experiment, s/w)
- Globus R&D (much joint with USC/ISI)
  - Innovative security, resource management, data access, information, communication, fault detection, etc., etc. technologies
  - Large user base among tool developers
  - Widespread adoption in “production” grids: e.g., NASA IPG, NSF NTG, DOE DISCOM
  - Exciting application demonstrations
- Access Grid collaboration technologies
Access Grid Collaboration Technology

- Designed spaces for group interactions
- Hands free audio
- Multiple video and audio streams
- Wide field of view

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Addressing Cross-Cutting Technical Issues

- Development of **Grid protocols & services**
  - Protocol-mediated access to remote resources
  - New services: e.g., resource brokering
  - “On the Grid” = speak Intergrid protocols
  - Mostly (extensions to) existing protocols

- Development of **Grid APIs & SDKs**
  - Facilitate application development by supplying higher-level abstractions

- The (hugely successful) model is the Internet

- The Grid is **not** a distributed OS!
Layered Grid Architecture (By Analogy to Internet Architecture)

“Specialized services”: user- or appln-specific distributed services

“Managing multiple resources”: ubiquitous infrastructure services

“Sharing single resources”: negotiating access, controlling use

“Talking to things”: communication (Internet protocols) & security

“Controlling things locally”: Access to, & control of, resources
Instantiating the Grid Architecture: Connectivity Layer Protocols & Services

- **Communication**
  - Internet protocols: IP, DNS, routing, etc.

- **Security: Grid Security Infrastructure (GSI)**
  - Uniform authentication & authorization mechanisms in multi-institutional setting
  - Single sign-on, delegation, identity mapping
  - Public key technology, SSL, X.509, GSS-API
  - Supporting infrastructure: Certificate Authorities, key management, etc.

GSI: www.globus.org
Instantiating the Grid Architecture: Resource Layer Protocols & Services

- **Grid Resource Allocation Mgmt (GRAM)**
  - Remote allocation, reservation, monitoring, control of compute resources
- **GridFTP protocol (FTP extensions)**
  - High-performance data access & transport
- **Grid Resource Information Service (GRIS)**
  - Access to structure & state information
- **Network reservation, monitoring, control**
- **All integrated with GSI: authentication, authorization, policy, delegation**

GRAM, GridFTP, GRIS: www.globus.org
Instantiating the Grid Architecture: Collective Layer Protocols & Services

- Index servers aka metadirectory services
  - Custom views on dynamic resource collections assembled by a community
- Resource brokers (e.g., Condor Matchmaker)
  - Resource discovery and allocation
- Replica catalogs
- Co-reservation and co-allocation services
- Etc., etc.

Metadirectory: www.globus.org; Condor: www.cs.wisc.edu/condor
Example: User Portal

**AppIn**
Web Portal

**User**
Source code discovery, application configuration

**Collective**
Brokering, co-allocation, certificate authorities

**Resource**
Access to data, access to computers, access to network performance data, ...

**Connect**
Communication, service discovery (DNS), authentication, authorization, delegation

**Fabric**
Storage systems, clusters, networks, ...

API
SDK
Lookup Protocol
Source Code Repository

API
SDK
Access Protocol
Compute Resource
Example: High-Throughput Computing System

**AppIn**
- High Throughput Computing System

**User**
- Dynamic checkpoint, job management, failover, staging

**Collective**
- Brokering, certificate authorities

**Resource**
- Access to data, access to computers, access to network performance data

**Connect**
- Communication, service discovery (DNS), authentication, authorization, delegation

**Fabric**
- Storage systems, schedulers

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Data Grid R&D

- “Enable a geographically distributed community to pool their resources to perform sophisticated, computationally intensive analyses on Petabytes of data”
- Specific issues addressed
  - Network QoS for bulk data transfer
  - Replica management technologies
  - High-speed data transfer protocols & tools
  - Community-based access control
- Applications in climate and physics
Network Quality of Service Research: Overall Picture

- Secure, policy-driven bandwidth allocation for high-end applications
- Immediate and advance reservations
- Co-reservation and co-allocation of multiple resources for end-to-end flows
- All supported in a modular architecture widely used for Grid apps (Globus Toolkit)
- Experience with differentiated services
- Future opportunities in all-optical context
- Collaborative effort with LBNL
When a reservation begins, the bulk-transfer backs off.

When a reservation ends, the bulk-transfer speeds up.

The competitive UDP traffic never interferes.
Bulk Transfer (WAN)
## Data Grid Architecture

<table>
<thead>
<tr>
<th>Category</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appln</strong></td>
<td>Discipline-Specific Data Grid Application</td>
</tr>
<tr>
<td><strong>User</strong></td>
<td>Coherency control, replica selection, task management, virtual data catalog, virtual data code catalog, ...</td>
</tr>
<tr>
<td><strong>Collective</strong></td>
<td>Replica catalog, replica management, co-allocation, certificate authorities, metadata catalogs, ...</td>
</tr>
<tr>
<td><strong>Resource</strong></td>
<td>Access to data, access to computers, access to network performance data, ...</td>
</tr>
<tr>
<td><strong>Connect</strong></td>
<td>Communication, service discovery (DNS), authentication, authorization, delegation</td>
</tr>
<tr>
<td><strong>Fabric</strong></td>
<td>Storage systems, clusters, networks, network caches, ...</td>
</tr>
</tbody>
</table>
Globus Data-Intensive Services Architecture

Custom Servers
- globus-url-copy
- globus_replica_manager

Custom Clients
- globus_gass
- globus_gass_copy
- globus_gass_transfer
- globus_ftp_client
- globus_ftp_control

Legend
- Program
- Library
- Already exist

Replica Programs
- globus_io
- globus_common
- OpenLDAP client
- GSI (security)
High-Level View of Earth System Grid: A Model Architecture for Data Grids

Metadata Catalog

Application

Replica Catalog

Replica Location 1

Replica Location 2

Replica Location 3

Disk Array

Tape Library

Disk Cache

Attribute Specification

Logical Collection and Logical File Name

Selected Replica

GridFTP commands

Performance Information & Predictions

MDS

NWS

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Future Directions

- "Grid computing" represents a significant success story for DOE research and opportunity for turbocharging DOE science
- Timely to take things to the next level, by
  - Aggressive programs focused on Grid-enabling key DOE applications (climate, physics, combustion, etc.)
  - New efforts focused on security, next-gen optical technologies, Grid tools, etc.
  - Infrastructure: faster networks, protocols, services (ESnet -> ESgrid?)
Abbreviated Acknowledgments

- Globus project Co-PI: Carl Kesselman
- Other Globus principals include: Steve Tuecke, Ann Chervenak, Bill Allcock, Gregor von Laszewski, Lee Liming, Steve Fitzgerald
- Access Grid: Rick Stevens & many others
- DOE Grid collaborators: Arie Shoshani, Reagan Moore, Miron Livny, Bill Johnston, Brian Tierney, others
- ESG collaborators: Dean Williams & others
- PPDG PIs: Richard Mount, Harvey Newman
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For More Information

- Book (Morgan Kaufman)
  - www.mkp.com/grids
- Globus
  - www.globus.org
- Grid Forum
  - www.gridforum.org
- PPDG
  - www.ppdg.net