Service-Oriented Science: Scaling eScience Impact

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Context: System-Level Science

Problems too large &/or complex to tackle alone ...
Two Perspectives on System-Level Science

- System-level problems *require* integration
  - Of expertise
  - Of data sources (“data deluge”)
  - Of component models
  - Of experimental modalities
  - Of computing systems

- Internet *enables* decomposition
  - “When the network is as fast as the computer's internal links, the machine disintegrates across the net into a set of special purpose appliances” (George Gilder)
Integration & Decomposition: A Two-Dimensional Problem

- **Decompose** across network
  - Clients **integrate** dynamically
    - Select & compose services
    - Select “best of breed” providers
    - Publish result as new services
  - **Decouple** resource & service providers

Fig: S. G. Djorgovski
A Unifying Concept: The Grid

“Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations”

1. Enable integration of distributed resources
2. Using general-purpose protocols & infrastructure
3. To deliver required quality of service

System-Level Problem

Decomposition

Implementation

Facilities
Computers
Storage
Networks
Services
Software
People

Grid technology

U. Colorado
Experimental Model

UIUC
Experimental Model

COORD.
Computational Model

NCSA
Service-Oriented Systems: Applications vs. Infrastructure

- **Service-oriented applications**
  - Wrap applications as services
  - Compose applications into workflows

- **Service-oriented Grid infrastructure**
  - Provision physical resources to support application workloads

“The Many Faces of IT as Service”, ACM Queue, Foster, Tuecke, 2005
Scaling eScience: Forming & Operating Communities

- Define membership & roles; enforce laws & community standards
  - I.e., policy for service-oriented architecture
  - Addressing dynamic membership & policy
- Build, buy, operate, & share infrastructure
  - Decouple consumer & provider
  - For data, programs, services, computing, storage, instruments
  - Address dynamics of community demand
Defining Community: Membership and Laws

- Identify VO participants and roles
  - For people and services
- Specify and control actions of members
  - Empower members → delegation
  - Enforce restrictions → federate policy

Diagram:

- Effective Access
- Policy of site to community
- Access granted by community to user
- Site admission-control policies

Access granted by community to user
Evolution of Grid Security & Policy

1) Grid security infrastructure
   - Public key authentication & delegation
   - Access control lists ("gridmap" files)
     \( \rightarrow \text{Limited set of policies can be expressed} \)

2) Utilities to simplify operational use, e.g.
   - MyProxy: online credential repository
   - VOMS, ACL/gridmap management
     \( \rightarrow \text{Broader set of policies, but still ad-hoc} \)

3) General, standards-based framework for authorization & attribute management
Core Security Mechanisms

- Attribute Assertions
  - C asserts that S has attribute A with value V
- Authentication and digital signature
  - Allows signer to assert attributes
- Delegation
  - C asserts that S can perform O on behalf of C
- Attribute mapping
  - \{A1, A2... An\}vo1 \Rightarrow \{A’1, A’2... A’m\}vo2
- Policy
  - Entity with attributes A asserted by C may perform operation O on resource R
Security Services for VO Policy

- Attribute Authority (ATA)
  - Issue signed attribute assertions (incl. identity, delegation & mapping)
- Authorization Authority (AZA)
  - Decisions based on assertions & policy
Security Services for VO Policy

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Closing the Loop: GT4 Security Toolkit

Authz Callout: SAML, XACML

Services (running on user’s behalf)

SSL/WS-Security with Proxy Certificates

Access

Rights

CAS or VOMS issuing SAML or X.509 ACs

Users

MyProxy

KCA

VO

Rights’

Shib

Rights

Compute Center

Local policy on VO identity or attribute authority

Notes:

- Authz Callout: SAML, XACML
- Services (running on user’s behalf)
- SSL/WS-Security with Proxy Certificates
- Access
- Rights
- CAS or VOMS issuing SAML or X.509 ACs
- Users
- MyProxy
- KCA
- VO
- Rights’
- Shib
- Compute Center
- Local policy on VO identity or attribute authority
Security Needn’t Be Hard: Earth System Grid

- **Purpose**
  - Access to large data

- **Policies**
  - Per-collection control
  - Different user classes

- **Implementation (GT)**
  - Portal-based User Registration Service
  - PKI, SAML assertions

- **Experience**
  - >2000 users
  - >100 TB downloaded

See also:
GAMA (SDSC), Dorian (OSU)

www.earthsystemgrid.org
Scaling eScience: Forming & Operating Communities

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  - I.e., policy for service-oriented architecture
  - Addressing dynamics of membership & policy

- Build, buy, operate, & share infrastructure
  - Decouple consumer & provider
  - For data, programs, services, computing, storage, instruments
  - Address dynamics of community demand
Bootstrapping a VO by Assembling Services

1) Integrate services from other sources
   • Virtualize external services as VO services

2) Coordinate & compose
   • Create new services from existing ones

“Service-Oriented Science”, *Science*, 2005
Providing VO Services:
(1) Integration from Other Sources

- Negotiate service level agreements
- Delegate and deploy capabilities/services
- Provision to deliver defined capability
- Configure environment
- Host layered functions
Virtualizing Existing Services into a VO

- Establish service agreement with service
  - E.g., WS-Agreement
- Delegate use to VO user
Deploying New Services

WSRF (or WS-Transfer/WS-Man, etc.), Globus GRAM, Virtual Workspaces
Available in High-Quality Open Source Software...

Globus Toolkit v4
www.globus.org

Globus Toolkit Version 4: Software for Service-Oriented Systems, LNCS 3779, 2-13, 2005
Welcome

This is the new home Globus software development; it is still under construction. The current status of our efforts to build this environment can be found on this page. Comments regarding this site can be sent to info@globus.org. Thank you for your interest in Globus development!

Globus was first established as an open source software project in 1996. Since that time, the Globus development team has expanded from a few individuals to a distributed, international community. In response to this growth, the Globus community (the "Globus Alliance") established in October 2005 a new source code development infrastructure and meritocratic governance model, which together make the process by which a developer joins the Globus community both easier and more transparent.

The Globus governance model and infrastructure are based on those of Apache Jakarta®. In brief, the governance model places control over each individual software component (project) in the hands of its most active and respected contributors (committers), with a Globus Management Committee (GMC) providing overall guidance and conflict resolution. The infrastructure comprises repositories, email lists, Wikis, and bug trackers configured to support per-project community access and management.

For more information, see:

- The Globus Alliance Guidelines, which address various aspects of the Globus governance model and the Globus community.
- A description of the Globus Alliance Infrastructure.
- A list of current Globus projects.
- Information about Globus community events.
- The conventions and guidelines that apply to contributions.
Virtual Workspaces (Kate Keahey et al.)

- GT4 service for the creation, monitoring, & management of virtual workspaces
- High-level workspace description
- Web Services interfaces for monitoring & managing
- Multiple implementations
  - Dynamic accounts
  - Xen virtual machines
  - (VMware virtual machines)
- Virtual clusters as a higher-level construct
How do Grids and VMs Play Together?

- **Client**
  - Request
  - VM EPR
  - Inspect & manage
  - Deploy, suspend
  - Start program

- **VM Factory**
  - Create new VM image

- **VM Repository**
  - Use existing VM image

- **VM Manager**

- **Resource**
  - VM
Virtual OSG Clusters

"Virtual Clusters for Grid Communities,” Zhang et al., CCGrid 2006
Dynamic Service Deployment
(Argonne + China Grid)

- **Interface**
  - Upload-push
  - Upload-pull
  - Deploy
  - Undeploy
  - Reload

“HAND: Highly Available Dynamic Deployment Infrastructure for GT4,” Li Qi et al., 2006
Providing VO Services: (2) Coordination & Composition

- Take a set of provisioned services ...
  ... & compose to synthesize new behaviors

- This is traditional service composition
  - But must also be concerned with emergent behaviors, autonomous interactions
  - See the work of the agent & PlanetLab communities

The Globus-Based LIGO Data Grid

LIGO Gravitational Wave Observatory

Replicating >1 Terabyte/day to 8 sites
>40 million replicas so far
MTBF = 1 month

www.globus.org/solutions
Data Replication Service

- Pull “missing” files to a storage system

Data Movement

“Design and Implementation of a Data Replication Service Based on the Lightweight Data Replicator System,” Chervenak et al., 2005
Pull “missing” files to a storage system

Data Movement

Reliable File Transfer Service

GridFTP

Local Replica Catalog

Replica Location Index

Data Location

“Design and Implementation of a Data Replication Service Based on the Lightweight Data Replicator System,” Chervenak et al., 2005
Data Replication Service

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Data Movement

- Reliable File Transfer Service
- GridFTP

Data Replication

- Data Replication Service

List of required Files

Data Location

- GridFTP
- Local Replica Catalog
- Replica Location Index

“Design and Implementation of a Data Replication Service Based on the Lightweight Data Replicator System,” Chervenak et al., 2005
Composing Resources ...
Composing Services

State exposed & access uniformly at all levels
Provisioning, management, and monitoring at all levels
Composing Resources ...
Composing Services

State exposed & access uniformly at all levels
Provisioning, management, and monitoring at all levels
Decomposition Enables Separation of Concerns & Roles

“Provide access to data $D$ at $S_1$, $S_2$, $S_3$ with performance $P$”

“Provide storage with performance $P_1$, network with $P_2$, ...”
Another Example: Astro Portal Stacking Service

- **Purpose**
  - On-demand “stacks” of random locations within ~10TB dataset

- **Challenge**
  - Rapid access to 10-10K “random” files
  - Time-varying load

- **Solution**
  - Dynamic acquisition of compute, storage
Astro Portal
Stacking Performance (LAN GPFS)
Summary

- **Community based science** will be the norm
  - Requires collaborations across sciences—including computer science

- **Many different types of communities**
  - Differ in coupling, membership, lifetime, size

- **Must think beyond science stovepipes**
  - Community infrastructure will increasingly become the scientific observatory

- **Scaling requires a separation of concerns**
  - Providers of resources, services, content

- **Small set of fundamental mechanisms** required to build communities
For More Information

- Globus Alliance
  - www.globus.org
- Dev.Globus
  - dev.globus.org
- Open Science Grid
  - www.opensciencegrid.org
- TeraGrid
  - www.teragrid.org
- Background
  - www.mcs.anl.gov/~foster

2nd Edition
www.mkp.com/grid2