Grid Technology

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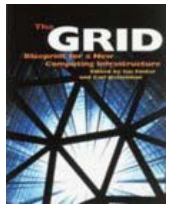
What is the Grid?

" Grid computing [is] distinguished from conventional distributed computing by its focus on large-scale resource sharing, innovative applications, and, in some cases, high-performance orientation...we review the "Grid problem", which we define as flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources - what we refer to as virtual organizations."



From "The Anatomy of the Grid: Enabling Scalable Virtual Organizations" by Foster, Kesselman and Tuecke

Why Grids?

- Large-scale science and engineering are done through the interaction of people, heterogeneous computing resources, information systems, and instruments, all of which are geographically and organizationally dispersed.
- The overall motivation for "Grids" is to facilitate the routine interactions of these resources in order to support large-scale science and engineering.

From Bill Johnston 27 July 01

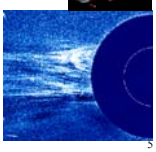
Why Now?

- Moore's law improvements in computing produce highly functional endsystems
- The Internet and burgeoning wired and wireless provide universal connectivity
- Changing modes of working and problem solving emphasize teamwork, computation
- Network exponentials produce dramatic changes in geometry and geography
  - 9-month doubling: double Moore's law!
  - 1986-2001: x340,000; 2001-2010: x4000?

What is e-Science?

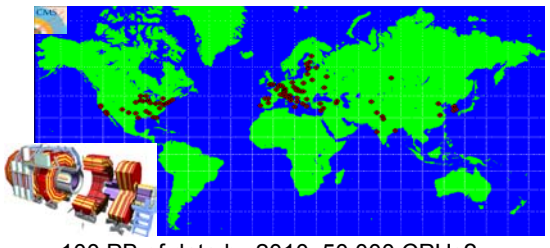
- Applied Scientists are becoming e-scientists
- Dependent on remote electronic services
- Utilising scarce expensive instruments
- Involvement in global collaborations
- Interaction through mobile devices

Urgent need for an integrated environment to support this actvity



CERN's Large Hadron Collider

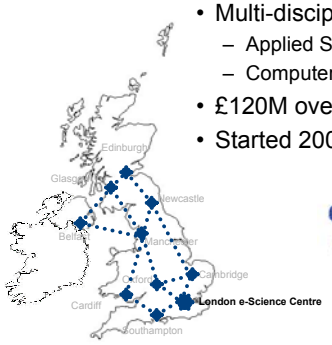
1800 Physicists, 150 Institutes, 32 Countries



100 PB of data by 2010; 50,000 CPUs?

www.griphyn.org www.ppdg.net www.eu-datagrid.org

UK e-Science Programme



- Multi-disciplinary projects
  - Applied Scientists
  - Computer Scientists
- £120M over three years
- Started 2001

London e-Science Centre

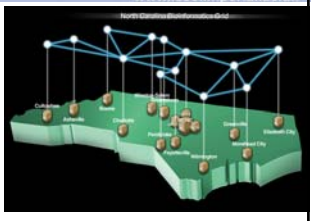
London e-Science Centre

'Enabling the e-Scientist'

- Established applied multi-disciplinary research
- Industrial Collaborations:
  - Sun Centre of Excellence in e-Science
  - Intel Virtual European Centre of Grid Computing
- Cross-campus collaborations:
  - Bioinformatics
  - High Energy Physics
  - Computational Engineering
- Specialisation: Next Generation Grid Middleware
- http://www.lesc.imperial.ac.uk/

Classical Grids

- Classical Grids emphasise the sharing of physical resources.
- Existing Grid middleware (e.g. Globus, Condor, Unicore) allows resource discovery, resource allocation, data movement & certification
- Focus on low-level services not the application

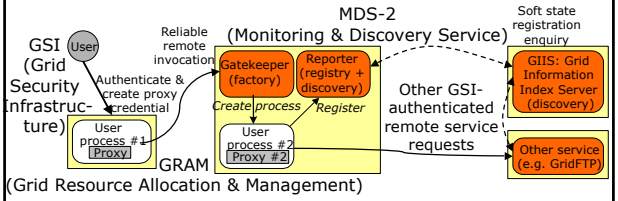


The Globus Toolkit ™

- Widely adopted Grid Middleware
- Result of 5+ years (100+ man years) work
- Provides protocols to support three services:
  - Job Submission and Monitoring (~HTTPS)
  - Monitoring and Discovery Service (~LDAP)
  - Data Transfer (~FTP)
- Infrastructure to federate distributed resources
  - Support for access control
  - Wide area security mechanisms (PKI)

The Globus Toolkit in One Slide

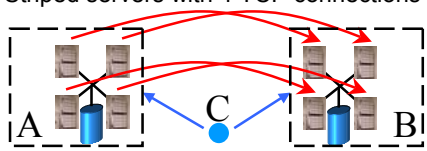
Grid protocols (GSI, GRAM, …) enable resource sharing within virtual orgs; toolkit provides reference implementation (= Globus Toolkit services)



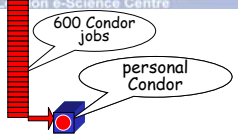
Protocols (and APIs) enable other tools and services for membership, discovery, data mgmt, workflow, …

GridFTP

- GSI authentication on data & control channels
- Parallel streams (client to 'clustered' server)
- TCP buffer tuning for maximum performance
- Third party file transfer
- SC2001: 231GB/hour (1.55 GB/s)
  - 8 Striped servers with 4 TCP connections

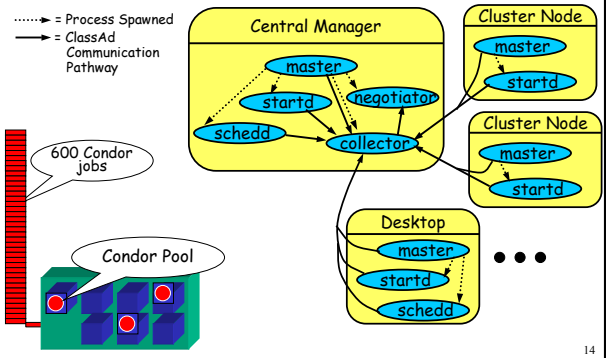


Personal Condor



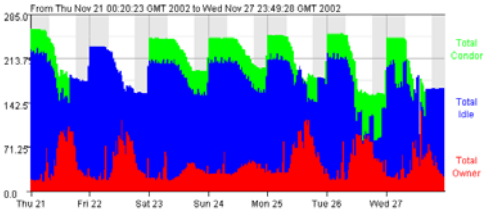
- One user & one machine (no root access)
- Provides a persistent execution environment that will run jobs when your policy allows them to run
- Need jobs to run without any user interaction

Layout of the Condor Pool

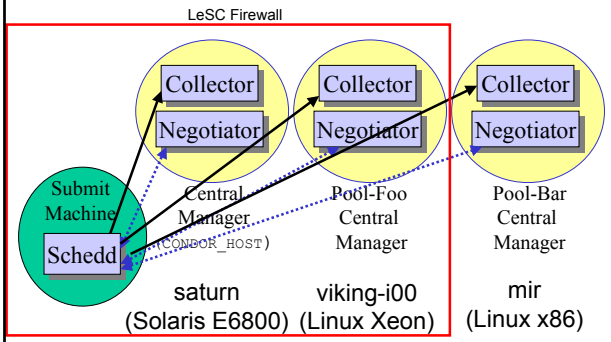


Condor pool within DoC

Imperial College - Department of Computing Condor Pool Machine Statistics for Week

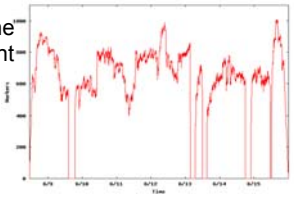


Resource Sharing through Condor



Mathematicians Solve NUG30

- Looking for the solution to the NUG30 quadratic assignment problem
- An informal collaboration of mathematicians and computer scientists
- Condor-G delivered 3.46E8 CPU seconds in 7 days (peak 1009 processors) in U.S. and Italy (8 sites)



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

MetaNEOS: Argonne, Iowa, Northwestern, Wisconsin

Global Grid Forum - www.gridforum.org

Convergence between e-Science and e-Business

- A biochemist exploits 10,000 computers to screen 100,000 compounds in an hour;
- A biologist combines a range of diverse and distributed resources (databases, tools, instruments) to answer complex questions;
- 1,000 physicists worldwide pool resources for petaop analyses of petabytes of data
- Civil engineers collaborate to design, execute, & analyze shake table experiments

From Steve Tuecke 12 Oct. 01

Convergence between e-Science and e-Business (contd.)

- Climate scientists visualize, annotate, & analyze terabyte simulation datasets
- An emergency response team couples real time data, weather model, population data
- A multidisciplinary analysis in aerospace couples code and data in four companies
- A home user invokes architectural design functions at an application service provider

From Steve Tuecke 12 Oct. 01

Today's Grid

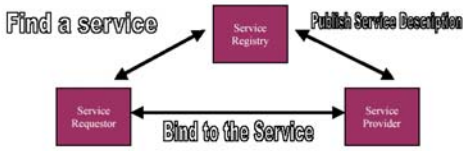
- A Single System Imterface
- Transparent wide-area access to large data banks
- Transparent wide-area access to applications on heterogeneous platforms
- Transparent wide-area access to processing resources
- Security, certification, single sign-on authentication
  - Grid Security Infrastructure,
- Data access,Transfer & Replication
  - GridFTP, Giggle
- Computational resource discovery, allocation and process creation
  - GRAM, Unicore, Condor-G

Grid Evolution

- 1st Generation Grid
  - Computationally intensive, file access/transfer
  - Bag of various heterogeneous protocols & toolkits
  - Recognises internet, Ignores Web
  - Academic teams
- 2nd Generation Grid
  - Data intensive -> knowledge intensive
  - Services-based architecture
  - Recognises Web and Web services
  - Global Grid Forum
  - Industry participation

We are here!

Convergence on Service Oriented Architectures



- Globus: Grid Index Information Service (LDAP)
- Jini: Look-up Server
- CORBA
- Web Services
  - Open Grid Services Architecture in the Grid community

The Future… Web Services

- Increasingly popular standards-based framework for accessing network applications
  - W3C standardization; Microsoft, IBM, Sun, others
- WSDL: Web Services Description Language
  - Interface Definition Language for Web services
- SOAP: Simple Object Access Protocol
  - XML-based RPC protocol; common WSDL target
- WS-Inspection
  - Conventions for locating service descriptions
- UDDI: Universal Description, Discovery, & Integration
  - Directory for Web services

Supporting 'Grid Services'

- Dynamic Services
  - Created & destroyed on user demand
- Stateful Services
  - Expose internal service state
- Flexible Service Discovery Infrastructures
  - Federate local service registries
  - Build Virtual Organisations

Open Grid Services Architecture (OGSA)

- Utilise standard Web services infrastructures
- Building on current Globus Toolkit:
  - Grid service: semantics for service interactions
  - Management of transient instances (& state)
  - Factory, Registry, Discovery, other services
  - Reliable and secure transport
- Multiple hosting targets: J2EE, .NET, "C", …
- Service orientated architecture enables resource virtualisation
- Delivery via open source Globus Toolkit 3.0
  - ⇒ Leverage GT experience, code, mindshare

Open Grid Services Infrastructure (OGSI)

- Global Grid Forum
  - Grid Standards Organisation
  - Modelled on the IETF
  - Mixture of Research & Working Groups
  - Further details www.gridforum.org
- Grid Services Specification (v1.0),
  - Produced by the OGSI Working Group
  - Entered 60 day comment period March 2003

Grid Service Specification

- Define minimal set of ports & behaviours:
  - GridService
  - HandlerResolver
  - Notification Source, Sink & Subscription ports
  - Factory
  - Registration
- Other issues to be defined elsewhere
  - Exposing an EJB as a Grid Service
  - Security…

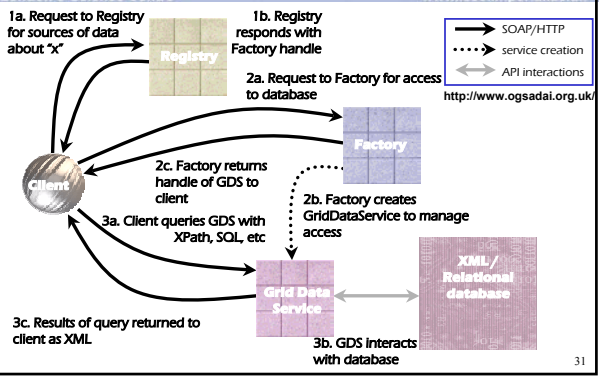
Service Data Elements (SDE)

- Describes the public internal service state
- All SDE's have attributes to define:
  - goodFrom
  - goodUntil
  - availableUntil
  - User definable extensibility elements
- Examples
  - Current CPU load, available memory, etc

Factory Interface within the GSS

- Creates a new Grid service instance
  - Reliable creation (once-and-only-once)
- Service-specific creation parameters:
  - Request 16 processors for 4 hours
  - Temporary disk space of 500Mb
- Returns a **Grid Service Handle** (**GSH**)
  - A globally unique URL
  - Uniquely identifies the instance for all time

OGSA Enabled Database Access



Future Grid Challenges

- Need 'power stations' on the Grid
  - Buy (obtain) resources as required
- Need to understand how applications behave
  - Balance out data transfer vs. compute shipping
- Need to scalable wide-area service discovery
  - Peer to Peer or centralised servers
  - Meta-data to describe Grid Services
- Need to exploit distributed services
  - Grid Service Orchestration
  - Optimise service selection and recover from failure

Classifying Services

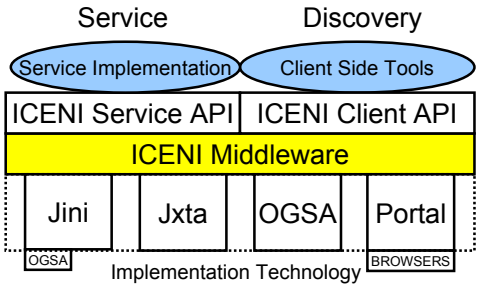
- Web Service model:
  - Service meta-data in UDDI
  - DAML-S
- Grid Services (Current)
  - 'Well known' naming of services & ports
- Grid Services (Future)
  - Domain Specific Service Ontologies
    - MONET, MyGrid, …
  - Generic Service Ontologies

ICENI – Imperial College e-Science Networked Infrastructure

The Iceni, under Queen Boudicca, united the tribes of South-East England in a revolt against the occupying Roman forces in AD60.

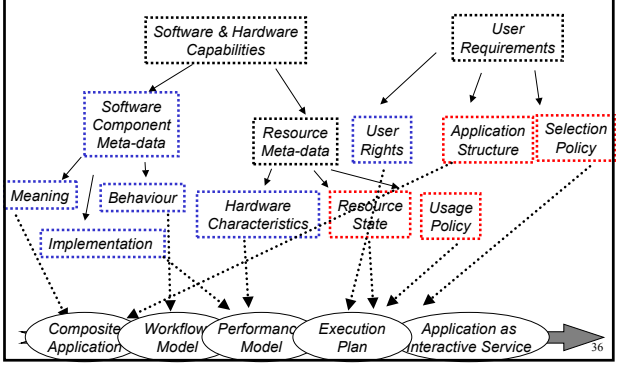
- Developed by LeSC Grid Middleware Group
- Collect and provide relevant Grid meta-data
- Use to define and develop higher-level services
- Interaction with other frameworks,
  - e.g. Web Services, Jxta etc.

ICENI Middleware Architecture

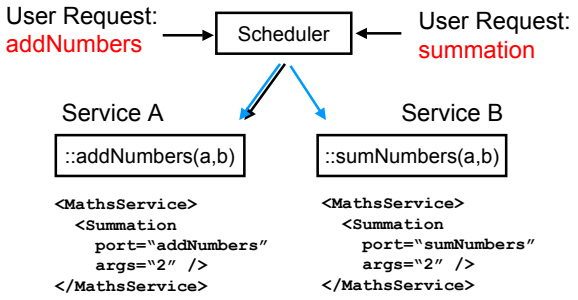


Exploit common meta-data and service implementation across multiple platforms

Information Capture & Utilisation



Service Selection through Ontologies




```
<MathsService>
  <Summation
    port="addNumbers"
    args="2" />
</MathsService>
```

```
<MathsService>
  <Summation
    port="sumNumbers"
    args="2" />
</MathsService>
```


Benefits

- Decouple service naming and operation
- Standard tools to classify services
- Ability to reason about services
- Providing a persistent service infrastructure

Autonomic Computing

Market for Computational Services

- UK Core e-Science Programme project
- Interfaces & protocols to trade Grid Services
- Funded by Department of Trade & Industry
- Collaborators
  - London e-Science Centre
  - e-Science North West
  - Southampton e-Science Centre
  - UK Grid Support Centre
- Commercial
  - SME's: Software & service provision
  - Multi-national's: Hardware & Software vendors

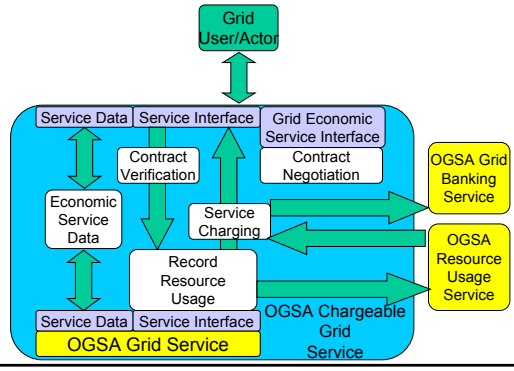
New Economic SDEs

- Trust, Reputation & Reliability (0+)
  - Can I rely on this service? Will it deliver?
  - Has this service been audited for performance & integrity?
  - Allow SDE to updated by signed statements?
- Compensation & Liability (0+)
  - Who can I complain to and can I prosecute?
  - How could the contract be broken?
- Grid Banking Services (1+)
  - Declare which GBS are acceptable
- Resource Usage Service (1)
  - Declare which RUS is used by the service

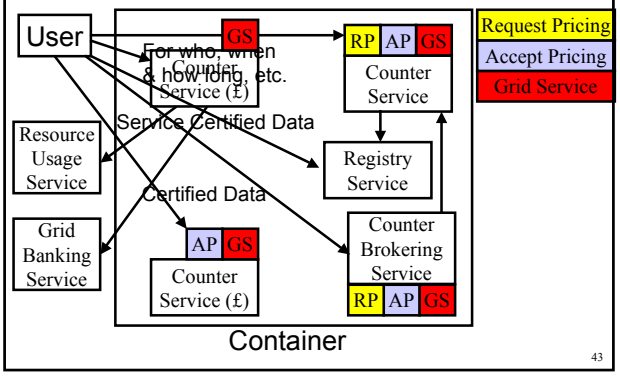
Grid Economic Service Architecture

- GESA enabled client 'obtains' a GSH
  - Grid Service Handle (GSH) provides unique service ID
  - Represents a service & cost for use
  - Changes in price & status through new service & GSH
- GSH passed to an existing client
  - Retains existing client interface for economic services
- Key Issues:
  - Information needed to make the selection (SDE)
  - Two (Multi?) stage commit to support pricing
  - Enable wide ranging exploration of grid economic models

Grid Economic Services Architecture



Buying a simple Counter Service



Project Status

- Kick off meeting in February 2003
- Global Grid Forum activity:
  - GESA-WG & RUS-WG at GGF 6 & 7
  - Well attended & progress on architecture documents & use cases
- Use cases being collected from UK partners
- Implementation starting in next few months

Summary

- Grid is global distributed computing by controlled sharing of resources within & between organisations.
- Strong application drivers & industrial support.
- The supporting technology is emerging
- Open Grid Services Architecture
  - Build on industrial standards
  - Provide the infrastructure for utility & autonomic computing
- ICENI: Open and extensible framework to explore Grid infrastructures

Moving towards Utility Computing

Ultimate vision of the Grid is that computing power is a utility available on demand such as electricity.

- Virtualise & expose resource as services
- Define interaction through contracts / SLA's
- Secure wide area authentication scheme
- Buy and sell services – computational markets
- Describe services and capabilities – ontologies
- Enables Autonomic Computing & Semantic Grid

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