# The Evolution of the Grid

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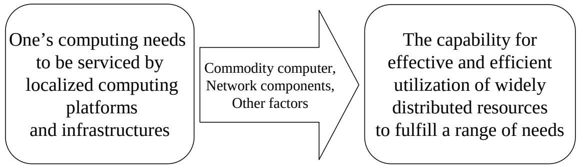
Grid Computing – Making the Global Infrastructure a Reality
Fran Berman, Geoffrey Fox, and Tony Hey
2002 John Wiley & Sons, Ltd.
Chapter 3

Based on slides by Kwangwon, Koh



# Introduction

- The situation has changed




- The issues in designing, building and deploying distributed computer systems have now been explored over many years
  - Metacomputing, Scalable computing, Global computing, Internet computing, and Grid computing



# Introduction (cont.)

- Grid problem (Foster, Kesselman, Tuecke, 2001)
  - Flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources
    - Emphasizes the importance of information aspects to essential for resource discovery and interoperability
    - XML, Resource Description Framework (RDF)



# The Evolution of the Grid: The First Generation

- The early Grid efforts started as projects to link supercomputing sites
- FAFNER and I-WAY had to overcome a number of similar hurdles, including communications, resource management, and the manipulation of remote data, to be able to work efficiently and effectively

## The First Generation: FAFNER 1995

- FAFNER – Factoring via Network-Enabled Recursion
- To factor RSA130 using a new numerical technique called the Number Field Sieve (NFS) factoring method using computational Web servers
- Contributors downloaded a sieving software daemon that used HTTP GET/POST to get values and post results
- CGI scripts supported cluster management minimizing impact on owners by regulating day/night usage
- Three factors combined to make this approach successful:
  - The NFS implementation allowed even workstations with 4Mbytes of memory to perform useful work
  - FAFNER supported anonymous registration
  - A hierarchical network of servers reduced the potential administration bottleneck



## The First Generation: I-WAY

- I-WAY was an experimental high performance network linking many high performance computers (17 sites) and advanced visualization environments
- Not to build a network but to integrate existing high bandwidth networks (ATM)
- To help standardize the I-WAY software interface and management, the key sites installed I-POP servers to act as gateways to I-WAY
  - The I-POP servers were UNIX workstations configured uniformly and possessing a standard software environment called I-Soft
  - The I-POP server mechanisms allowed uniform I-WAY authentication, resource reservation, process creation, and communication functions
- I-WAY developed
  - resource scheduler Computational Resource Broker (CRB)
  - Security using telnet modified to use Kerberos
  - Used Andrew File System (AFS)
- To support user-level tools, a low-level communications library, Nexus, was adapted to execute in the I-WAY environment



## A Summary of Early Experience

- FAFNER and I-Way attempted to produce metacomputing environments by integrating resources from opposite ends of the computing spectrum
- FAFNER was tailored to a particular factoring application that was in itself trivially parallel and was not dependent on a fast interconnect
  - Forerunner of the likes of SETI@home and Distributed.Net
- I-WAY was designed to cope with a range of diverse high performance applications that typically needed a fast interconnect and powerful resources
  - Forerunner of the likes of Globus and Legion
  - Had a few shortcomings
    - I-POP had to be specially set up and was single point of failure



## The Evolution of the Grid: The Second Generation

- Today the grid infrastructure is capable of binding together more than just a few specialized supercomputing centers
- Grid: a viable distributed infrastructure on a global scale that can support diverse applications requiring large-scale computation and data
  - Three main issues
    - Heterogeneity
    - Scalability - latency tolerance, handle authentication over organizational boundaries
    - Adaptability – tolerant of resource failure
- Middleware is used to hide the heterogeneous nature and provide users and applications with a homogeneous and seamless environment by providing a set of standardized interfaces to a variety of services on the Grid

## Requirements for the data and computation infrastructure

- Administrative Hierarchy
- Communication Services – various types needed, QoS
- Information Services – dynamic info on location/type of services
- Naming Services – uniform namespace (X500 or DNS)
- Distributed File Systems and Caching – uniform global namespace
- Security and Authorization
- System Status and Fault Tolerance - monitoring tools required
- Resource Management and Scheduling – efficient global scheduling that interact with local schedulers
- User and Administrative GUI – intuitive/heterogeneous, usually Web-based

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## Second Generation Core Technologies

- Globus
  - A software infrastructure that enables applications to handle distributed heterogeneous computing resources as a single virtual machine
  - The GTK provides a bag of services which developers of specific tools or applications can use to meet their own particular needs
  - The GTK is modular and consists of the following:
    - GRAM: Globus Toolkit Resource Allocation Manager – HTTP based
    - GridFTP – security, parallelism
    - GSI: Grid Security Infrastructure- authentication
    - LDAP: Lightweight Directory Access Protocol – distributed access to structure/state information
    - GASS: Global Access to Secondary Storage
    - GEM: Globus Executable Manager – construction, caching, location of executables
    - GARA: Globus Advanced Reservation and Allocation

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## Second Generation Core Technologies (cont.)

- Legion - UVa
  - An object-based 'metasystem'
  - A system to enable heterogeneous, geographically distributed, high performance machines to interact seamlessly
  - Provide users with a single integrated infrastructure regardless of scale, physical location, language and underlying operating system
  - Difference from Globus
    - Encapsulate all of its components as objects
  - Core object types : classes/metaclasses, host objects, vault objects, implementation objects/caches, binding agents, context objects/spaces

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## Distributed Object Systems

- Common Object Resource Broker Architecture (CORBA)
  - Open distributed object-computing infrastructure
  - Automates network programming tasks such as object registration, location activation; request de-multiplexing; framing/error handling; parameter marshalling; operation dispatching
  - Negatives: may be difficulty in crossing organizational boundaries; real-time/multimedia not in original design
- Java/JVM
  - Single implementation framework; mask heterogeneity
  - Can have Java wrappers around non-Java code
  - Negatives: computational speed; concurrency

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## Distributed Object Systems

- Jini and RMI
  - To provide a software infrastructure that can form a distributed computing environment that offers network plug and play
  - In Jini, applications will normally be written in Java and communicate using the Java Remote Method Invocation (RMI) mechanism
  - Concepts
    - Lookup: search for a service and download the code needed to access it;
    - Discovery: spontaneously find a community and join;
    - Leasing: time-bounded access to a service;
    - Remote Events: service A notifies service B of A's state change.
    - Transactions: used to ensure that a system's distributed state stays consistent
  - Does not provide file system, scheduling or logins



## Grid Resource Brokers and Schedulers

- Batch and Scheduling Systems
  - Condor
    - A software package for executing batch jobs on a variety of UNIX platforms, in particular those that would otherwise be idle
    - Features: resource location, job allocation, check pointing, migration
  - PBS (Portable Batch System)
    - A batch queuing and workload management system
    - Allows sites to determine own scheduling policies
  - SGE (Sun Grid Engine)
    - Jobs (with requirements profile) wait in a holding area and queues located on servers provide the services for jobs
  - LSF (Load Sharing Facility)
    - A commercial system from Platform Computing Corp.
    - LSF comprises distributed load sharing/ batch queuing and monitoring of resources/workloads on a network of heterogeneous computers



## Grid Resource Brokers and Schedulers (cont.)

- Storage Resource Broker (SRB)
  - To provide "uniform access to distributed storage" across a range of storage devices
  - Key feature
    - SRB supports metadata associated with a distributed file system, such as location, size and creation date information
  - SRB is attractive for Grid applications in that it deals with large volumes of data



## Grid Resource Brokers and Schedulers (cont.)

- Nimrod/G Resource Broker and GRACE
  - Nimrod-G : a Grid broker that performs resource management and scheduling of parameter sweep and task-farming applications
  - Components
    - A task farming engine: allows user defined schedulers, customized applications or problem solving environments
    - A scheduler: support resource discovery, selection, scheduling, and the execution of user jobs on remote resources
    - A dispatcher: uses Globus for deploying Nimrod G agents on remote resources in order to manage the execution of assigned jobs
    - Resource agents
  - Supports user-defined deadline and budget constraints for scheduling optimization and manages the supply and demand of resources in the Grid using a set of resource trading services called GRACE (GRid Architecture for Computational Economy)
    - Scheduling algorithms: Cost, time, cost-time optimization, conservative

## Grid Portals

- A Grid portal provides access to grid resources specific to a particular domain of interest
- The NPACI HotPage hotpage.npaci.edu
  - A user portal that has been designed to be a single point-of-access to computer-based resources, to simplify access to resources that are distributed across member organizations and allows them to be viewed either as an integrated Grid system or as individual systems
  - Provides information, resource access/management
- The SDSC Grid Port Toolkit gridport.npaci.edu
  - A reusable portal toolkit that uses HotPage infrastructure
  - Web portal to allow the execution of secure portal services and an application API to enable development of customized science portals

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## Integrated Systems

- Cactus
  - An open source problem-solving environment
  - Modular structure
  - Provide a front-end to many core backend services
    - Globus, HDF5 file library, PETSc, visualization
- EU DataGrid eu-datagrid.Web.cern.ch
  - A computational and data-intensive Grid of resources for the analysis of data coming from scientific exploration
    - LHC (Large Hadron Collider) , which will operate at CERN from about 2005 to 2015
    - Main challenge of the LHC is providing the means to share many petabytes of distributed data over the current network infrastructure

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## Integrated Systems (cont.)

- UNICORE - German Ministry of Education& Research
  - Design goal
    - A uniform and easy to use GUI
    - An open architecture based on the concept of an abstract job
    - A consistent security architecture
    - Minimal interference with local administrative procedures
    - Exploitation of existing and emerging technologies through standard Java and Web technologies
  - Protocol
    - Between the components is defined in terms of Java objects
    - Low level layer called UPL(UNICORE Protocol Layer) handles authentication, SSL communication and transfer of data as in lined byte streams
    - High level layer contains the classes to define UNICORE jobs, tasks and resource requests

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## Integrated Systems (cont.)

- WebFlow
  - A computational extension of the Web model that can act as a framework for wide-area distributed computing
  - Design goal
    - Build a seamless framework for publishing and reusing computational modules on the Web
    - End users can compose distributed applications using WebFlow modules via Web browser
  - The front-end uses applets for authoring, visualization, and control of the environment
  - The backend of WebFlow was implemented using the Globus Toolkit

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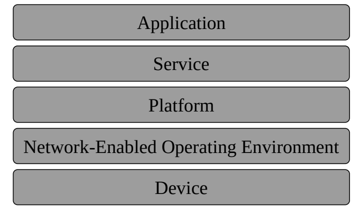
## Peer-to-Peer Computing

- Decentralisation
- To overcome a performance bottleneck and a single point of failure of client-server model
- P2P Computing
  – Napster, Gnutella, Freenet, JXTA
- Internet Computing
  – SETI@home, Parabon, Entropia
- Machines share data and resources via Internet or private networks
- Obstacles
  – Require more computing power to handle communication & security
  – Security
  – Heterogeneous
  – Find resources and services



## Peer-to-Peer Computing (cont.)

- JXTA
  – An open source development community for P2P infrastructure and applications




  – A specification rather than software

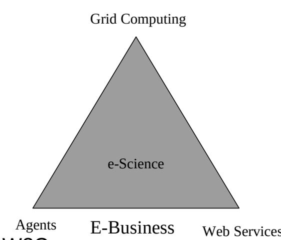


## The Evolution of the Grid: The Third Generation

- Emphasize ‘autonomic’
  – Needs detailed knowledge of its components and status
  – Must configure and reconfigure itself dynamically
  – Seeks to optimize its behaviour to achieve its goal
  – Is able to recover from malfunction
  – Protect itself against attack
  – Be aware of its environment
  – Implement open standards
  – Make optimized use of resources



## Service-oriented architectures




- Web Services - W3C
  – SOAP - Simple Object Access Protocol
    - Envelope for XML data, RPC
  – Web Services Description Language (WSDL)
    - describes services in XML
  – Universal Description Discovery and Integration (UDDI)
    - Distributed registeries

## Service-oriented architectures (cont.)

- The Open Grid Services Architecture (OGSA) Framework (Globus/IBM)
  - Supports the creation, maintenance, and application of ensembles of services maintained by VOs (virtual organization)
  - The standard interfaces
    - Discovery
    - Dynamic service creation
    - Lifetime management
    - Notification
    - Manageability
    - Simple hosting environment
  - Globus
    - GRAM - resource allocation & management
    - MDS 2- metadirectory services
    - GSI - Grid security infrastructure (single sign on)

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## Service-oriented architectures (cont.)

- Agents
  - Characteristics
    - Autonomy
    - Social ability – interact with other agents
    - Reactivity – perceive/respond to environment
    - Pro-activeness - goal directed behavior
  - FIPA (Foundation for Intelligent Physical Agents)
    - Agents communicate by exchanging messages which represent speech acts, and which are encoded in an agent-communication-language
    - Services provide support agents
    - Services may be implemented either as agents or as software

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## Information aspects: relationship with the WWW

- The Web as a Grid Information Infrastructure
  - Does information distribution architecture meet grid requirements?
    - Version control - none in www
    - QoS – link fragility
    - Provenance - no certified publication date
    - Digital Rights Management - no copy protection
    - Curation – www delivery oriented, no content management

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## Information aspects: relationship with the WWW (cont.)

- Expressing Content and Meta-content
  - XML
    - Information exchange is facilitated by the XML
    - Designed to mark up documents
    - The tags are defined for each application using a DTD (Document Type Definition) or an XML Schema
  - RDF
    - A standard way of expressing metadata
    - RDF Schema permit definition of a vocabulary
  - XML and RDF enable the standard expression of content and metacontent

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## Live Information Systems

- Access Grid
  - A collection of resources that support human collaboration across the Grid, including large-scale distributed meetings and training
  - Current Access grid infrastructure is based on IP multicast
- The combination of Semantic Web technologies with live information flows is highly relevant to grid computing



## Summary and Discussion

- First generation systems involved proprietary solutions for sharing high performance computing resources
- Second generation systems introduced middleware to cope with scale and heterogeneity, with a focus on large scale computational power and large volumes of data
- Third generation systems are adopting a service-oriented approach, adopt a more holistic view of the e-Science infrastructure, are metadata-enabled and may exhibit autonomic features



## The Semantic Grid