The Grid: Past, Present, Future

Fran Berman, Geoffrey Fox, and Tony Hey

Grid Computing – Making the Global Infrastructure a Reality
Fran Berman, Geoffrey Fox, and Tony Hey
2002 John Wiley & Sons, Ltd.
Chapter 1

Contents

- The Grid
- Beginnings to the Grid
- A Community Grid Model
- Building Blocks of the Grid
  - Networks and Computational “nodes” on the Grid
  - Pulling it all Together
  - Common Infrastructure: Standards
- Grid Applications and Application Middleware
- Futures – Grids on the Horizon

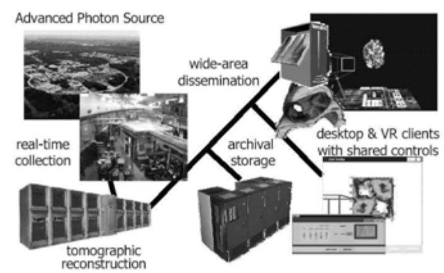
The Grid

- What is the Grid?
  - **The computing and data management infrastructure** that will provide the electronic underpinning for a global society in business, government, research, science and entertainment
  - Integrate networking, communication, computation and information to provide a virtual platform in the same way
  - Fig.2 shows a typical early successful application with information pipelined through distributed systems (next page)

The Grid infrastructure will provide us with the ability to dynamically link together resources as an ensemble to support the execution of large-scale, resource-intensive and distributed applications

The Grid

- What is the Grid? (cont.)



http://epics.aps.anl.gov/welcome.html

Fig. 2: Computational Environment for analyzing real-time data taken at Argonne's Advanced Photon Source was an early example of a data intensive Grid application [6]. The picture shows data source at APS, network, computation, data archiving and visualization

The Grid Problem

- Flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resource

From "The Anatomy of the Grid: Enabling Scalable Virtual Organizations"

- Enable communities ("virtual organizations") to share geographically distributed resources as they pursue common goals -- *assuming the absence* of…
  - central location,
  - central control,
  - omniscience,
  - existing trust relationships.

Elements of the Problem

- Resource sharing
  - Computers, storage, sensors, networks, …
  - Sharing always conditional: issues of trust, policy, negotiation, payment, …
- Coordinated problem solving
  - Beyond client-server: distributed data analysis, computation, collaboration, …
- Dynamic, multi-institutional virtual orgs
  - Community overlays on classic org structures
  - Large or small, static or dynamic

Beginnings to the Grid

- Parallel computing in the 1980's and '90's
  - Focused on providing powerful mechanisms for managing communication between processors, and development and execution environments for parallel machines
    - PVM, MPI, HPF, and OpenMP for scalable applications
- The first modern Grid is the I-WAY (SC95)
  - Aggregate a national distributed testbed with over 17 sites networked together by the vBNS
  - Over 60 applications were developed for the conference
  - A rudimentary Grid software infrastructure to provide access, enforce security, coordinate resources, and other activities
  - Distributed computing : geographical separation
  - Grid research : integration and management of software

Beginnings to the Grid

- Projects after I-WAY
  - The Globus and Legion infrastructure
  - The Condor experimented with high throughput scheduling
  - Mars and Prophet experimented with high performance scheduling
  - NWS (Network Weather Service) focused on resource monitoring and prediction
  - Storage Resource Broker focused on uniform access to heterogeneous data resources
  - NetSolve and Ninf focused on remote computation via a client server model
- The Grid Forum in the late 1990's
  - Open Grid Services Architecture (OGSA) which integrates Globus and Web Services approaches

The Grid

- The UK e-Science Program
  - A major initiative developed to promote scientific and data-oriented Grid application development for both science and industry
  - Includes a wide variety for projects such as health, medicine, genomics, and bioscience, etc.
  - In the next few years, e-Business, e-Government, e-Science, and e-life
  - The link is http://www.escience-grid.org.uk

A Community Grid Model

- A layered abstraction of the Grid

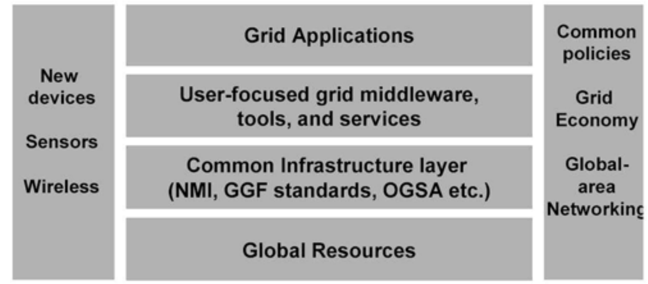


Fig. 3: Layered Architecture of a Community Grid Model

A Community Grid Model

- Global Resources
  - Such resources include computers, networks, data archives, instruments, visualization devices, etc.
  - Be distributed, heterogeneous, very different performance, and highly dynamic
- Common infrastructure
  - The software services which will represent the Grid as a unified virtual platform and provide the target for more focused software and applications
  - Example : NFS's Middleware Initiative (NMI), OGSA
- User-focused grid middleware, tools, and services
  - To enable applications to use Grid resources by masking some of the complexity involved in system activities such as authentication, file transfer, etc.
  - To connect applications and users with the common Grid infrastructure

A Community Grid Model

- Grid applications
  - To ensure that the Grid presents a robust, stable, usable and useful computational and data management platform to the user
- Influence of new devices
  - Sensors, PDAs, wireless as well as global-area networking
    - Need to be integrated with the Grid
    - Require serious consideration of **policies for sharing** and using resources
    - Be important to develop Grid social and economic policies

Building Blocks of the Grid

- Networks
  - The heart of any Grid is its network- networks link together geographically distributed resources and allow them to be used collectively to support execution of a single application
  - National network backbone
    - In 2002, such national networks exhibit 10 Gigabits/sec backbone performance in the U.S
    - Analogous efforts can be seen in the UK SuperJanet
    - CA*net3 from Canarie in Canada and the Asian network APAN
  - The ratio
    - A typical Grid research environment as a 10:1:0.1 Gigabits/sec ratio representing *national:organization:desktop* links
    - By 2006, GTRN aims at a 1000:1000:100:10:1 gigabit performance ratio representing *international backbone:national:organization:optical desktop: Copper desktop*
  - In the future
    - Although network bandwidth will improve, we do not expect latencies to improve significantly
    - A critical area of future work is network quality of service and here progress is less clear
    - wired networks will be further enhanced by continued improvement in wireless connectivity

Abilene Network Backbone

Feb 2004 Upgrade to OC-192c 10Gbps links

Building Blocks of the Grid

- Computational "nodes" on the Grid
  - Expect a peak single machine performance of 1 petaflops/sec by around 2010
  - ASCI White (LLNL) had peak performance of 12 teraflops/sec
  - The NEC Earth Simulator machine has 640 8-processor nodes and offers 10 terabytes of memory and 700 terabytes of disk space (Mar 2002)
  - The Fujitsu HPC2500 with up to 16384 processors and 85 teraflops/sec peak performance
  - Complex software environments will be needed to smoothly integrate resources from PDAs to terascale/petascale resources

Building Blocks of the Grid

- Pulling it all Together
  - NASA's Information Power Grid (IPG)
  - DoE's Science Grid
  - UK e-Science Grid
  - NSF's TeraGrid
    - Will connect the San Diego Supercomputer Center (SDSC), California Institute of Technology, Argonne National Laboratory, and the National Center for Supercomputing Applications (NCSA)
    - Will link the four in a Grid which will comprise in aggregate over .6 Petabyte of on-link disk, over 13 TeraFLOPS compute performance, and be linked together by a 40Gb/s network

Building Blocks of the Grid

- Common Infrastructure: Standards
  - Both the Internet and the IETF, and the Web and W3C consortium have defined key standards such as TCP/IP, HTTP, SOAP, XML and now WSDL – Web Services definition language that underlines OGSA
  - The Global Grid Forum is building key Grid-specific standars such as OGSA
  - NSF's Middleware Initiative and the UK's Grid Core Program are seeking to extend, standardize and make more robust key pieces of software for the Grid arsenal such as Globus, Condor, and the NWS

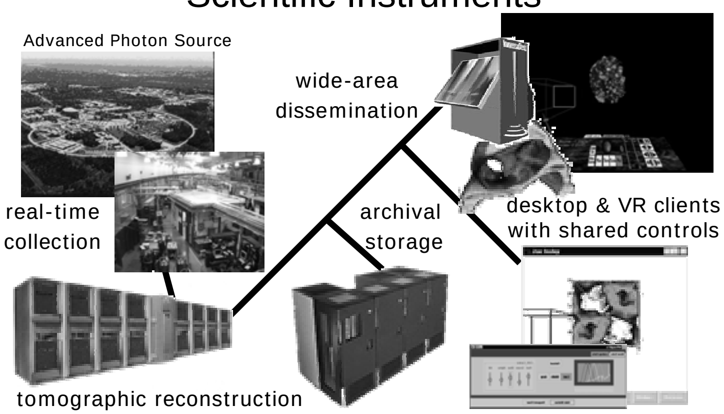
Grid Applications and Application Middleware

- Commercial Applications
  - Used in an innovative way in a wide variety of areas including inventory control, enterprise computing, games, etc.
  - The Butterfly Grid and the Everquest muliplayer gaming environment are current examples of gaming systems using Grid-like environments
  - The Entropia system of peer-peer or Megacomputing
  - SETI@HOME
  - Climateprediction.com is being developed by the UK e-Science program

Grid Applications and Application Middleware

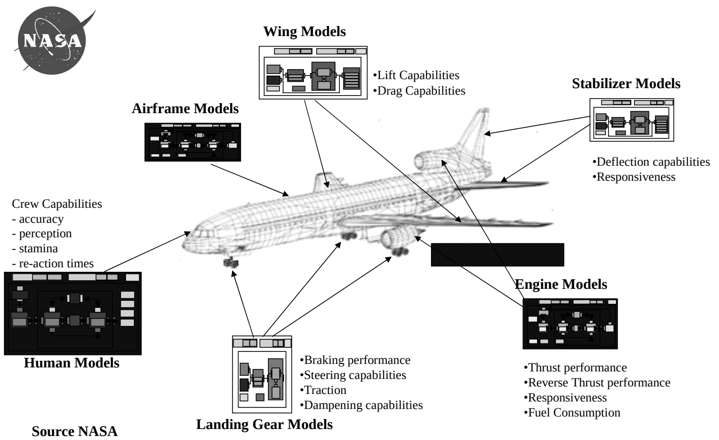
- Commercial Applications (cont.)
  - End to End Automation
  - End to end Security
  - Virtual Server Hosting
  - Disaster Recovery
  - Heterogenerous Workload Management
  - End to End Systems Management
  - Scalable Clustering
  - Accessing the Infrastructure
  - "Utility" Computing
  - Access new capability more quickly
  - Better performance
  - Reducing up front investment
  - Gaining expertise not available internally
  - Web based access (portal) for control (programming) of Enterprise fuction

Online Access to Scientific Instruments



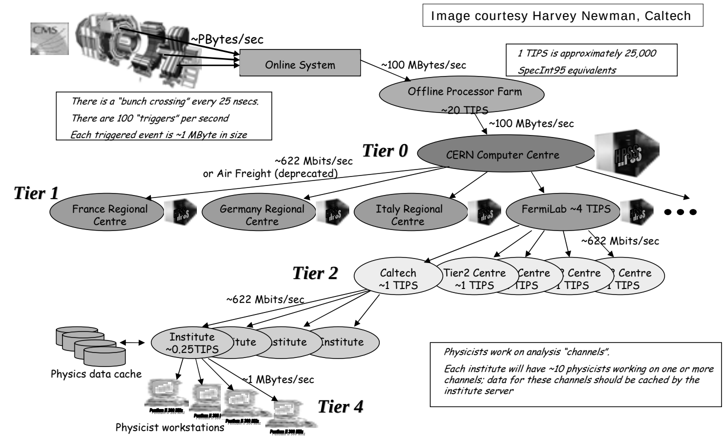
[redacted]

Multi-disciplinary Simulations: Aviation Safety



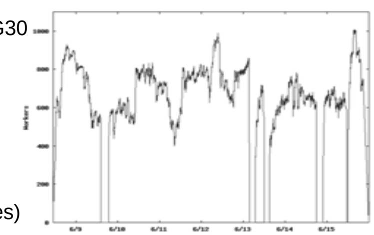
Whole system simulations are produced by coupling all of the sub-system simulations

Data Grids for High Energy Physics



Mathematicians Solve NUG30

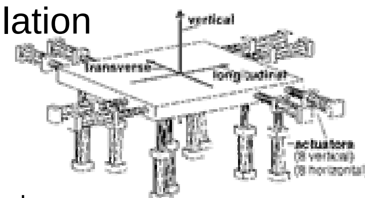
- Looking for the solution to the NUG30 quadratic assignment problem
- An informal collaboration of mathematicians and computer scientists
- Condor-G delivered 3.46E8 CPU seconds in 7 days (peak 1009 processors) in U.S. and Italy (8 sites)



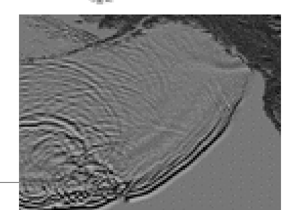
14,5,28,24,1,3,16,15,
10,9,21,2,4,29,25,22,
13,26,17,30,6,20,19,
8,18,7,27,12,11,23

MetaNEOS: Argonne, Iowa, Northwestern, Wisconsin

Network for Earthquake Engineering Simulation

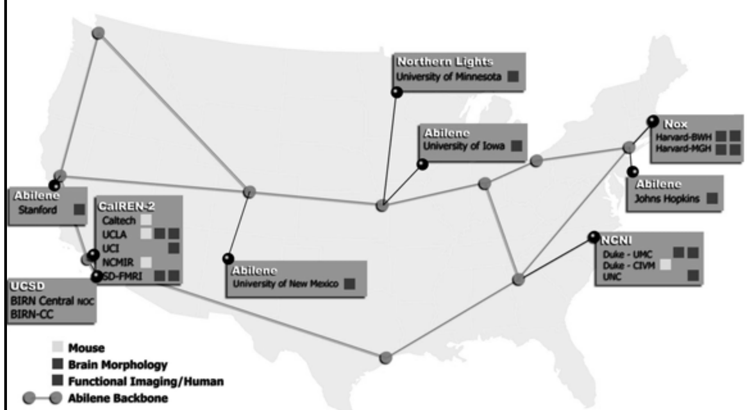


- NEESgrid: US national infrastructure to couple earthquake engineers with experimental facilities, databases, computers, & each other
- On-demand access to experiments, data streams, computing, archives, collaboration



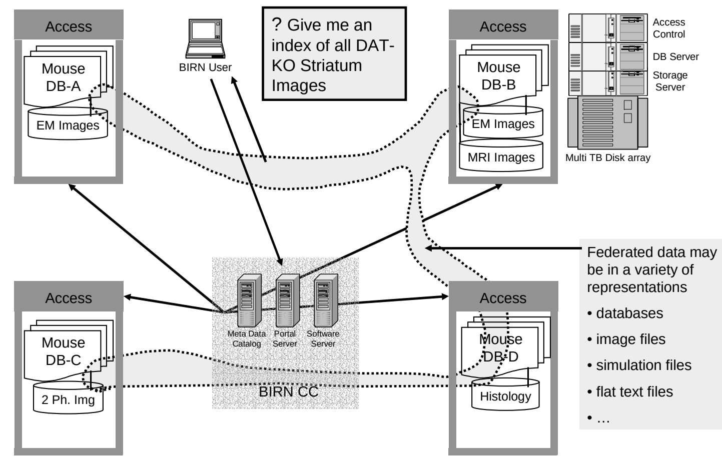
NEESgrid: Argonne, Michigan, NCSA, UIUC, USC

BIRN Network

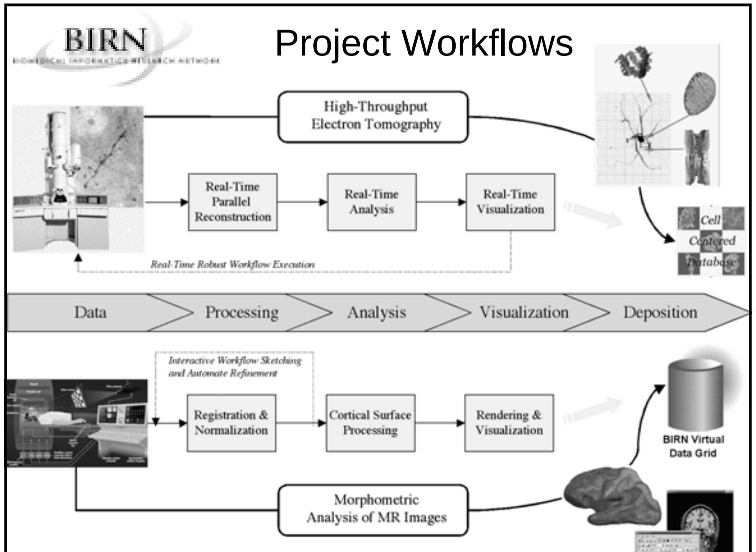


IT Infrastructure to hasten the derivation of new understanding and treatment of disease through use of distributed knowledge

A View of BIRN Federated Data



Project Workflows



Home Computers Evaluate AIDS Drugs

- Community =
  - 1000s of home computer users
  - Philanthropic computing vendor (Entropia)
  - Research group (Scripps)
- Common goal= advance AIDS research

DiSCoV KENT STATE September 2004 Paul A. Farrell Grid Computing 28

Grid Applications and Application Middleware

- Application Summary
  - *Minimal Communication applications :* these include so called "embarrassingly parallel" applications where one divides a problem up into very many essentially
  - *Staged/linked applications (do part A then do part B) :* there include remote instrument applications where one gets input from instrument at site A, compute/analyze data at size B and visualizes at Site C
  - *Access to resources (get stuff from/do something at site A)* : this includes portals, access mechanisms and environments.
- Next generation Grid applications
  - Adaptive applications, Real-time applications, Coordinated applications, Poly-applications (choice of resources for different components)

Futures – Grids on the Horizon

- In the future
  - More resources will be linked by more and better networks
  - Sensors, PDAs, health monitors, and other devices will be linked to the Grid
  - Grid software will become sophisticated, supporting an unprecedented diversity, scale, globalization and adaptation
  - ➢ Require an immense research, development and deployment effort from the community
  - ➢ Grids are high-capacity, high-capability, persistent, evolutionary, scalable, and able to support/promote new applications

Futures – Grids on the Horizon

- Adaptative and Autonomic Computing
  - The infrastructure is largely hidden from the user in the same way as individuals generally do not know which power company, transformer, generator, etc. is being used when they plug their electric appliance into a socket
  - "Adaptative Computing"
    - Allow programs to adapt to the dynamic performance deliberable by Grid resources
  - "Autonomic Computing"
    - IBM is exploring the concepts of software that is self-optimizing, self-configuring, self-healing, and self-protecting to ensure that software systems are flexible and can adapt to change.

Futures – Grids on the Horizon

- Grid Programming Environments
  - Robust, useful and usable programming environments will require coordinated research in many areas
  - ➢ The GrADS project provides a first example of an integrated approach to the design, development and prototyping of a Grid programming environment
- "Programming the Grid"
  - Preparation fo the individual application nuggets associated with a single resource
  - Intergrating the nuggets to form a complete Grid program
  - ➢ The SQL interface to a database, a parallel image processing algorithm, a finite element solver

Futures – Grids on the Horizon

- New Technologies
  - The ubiquitous cell phones and PDAs of today are just the beginning of a deeper paradigm shift
  - It will become important to application developers to intergrate new devices and new information sources with the Grid
  - Sensors and sensor-nets embedded in bridges, roads, clothing, etc. will provide a immense source of data
- Grid Policy and Grid Economies
  - Resource usage and administration must bridge technological, political and social boundaries, and Grid policies will need to incentivize the individual to contribute to the success of the group

DiSCoV KENT STATE September 2004 Paul A. Farrell Grid Computing 33