Grid Computing

Reference: Grid Computing – on Demand Series,

Joshy Joseph & Craig Fellenstein, Pearson, IBM Press, 2011

Overview

- Introduction to Grid
- Elements of Grid
- Grid Topologies
- Types of Grid
- Components of Grid
- Applications of Grid
- Grid Projects
- Grid Simulators

Grid Computing

- **Grid computing** is a form of distributed computing whereby a "super and virtual computer" is composed of a cluster of networked, loosely coupled computers, acting in concert to perform very large tasks.

- Grid computing (Foster and Kesselman, 1999) is a growing technology that facilitates the executions of large-scale resource intensive applications on geographically distributed computing resources.

- Facilitates flexible, secure, **coordinated large scale resource sharing** among dynamic collections of individuals and institutions.

- Enable communities ("virtual organizations") to share geographically distributed resources as they pursue common goals

Criteria for a Grid

- Coordinates resources that are not subject to centralized control.
- Uses standard, open, general-purpose protocols and interfaces.
- Delivers nontrivial qualities of service.

Benefits

- Exploit Underutilized resources
- Resource load Balancing
- Virtualize resources across an enterprise
  - Data Grids, Compute Grids
- Enable collaboration for virtual organizations
- Performance with scalability.
- Management and Reliability.

Elements of Grid

- Grid computing combines elements such as
  - Distributed computing,
  - High-performance computing and
  - Disposable computing depending on the application of the technology and the scale of operation
- Grids can create a virtual supercomputer out of the existing servers, workstations and personal computers.

Elements of Grid

- **Functional View**
  - Components vary depending on the design of grid.
  - Grid Portal, Security (GSI), Broker, Scheduler, Resources and (Data, Job , Resource) management
- **Physical View**
  - Network, Computation Storage. Scientific equipments, software and licenses.
- **Service View**
  - SOA, SOAP(Simple Object Access Protocol), Web Service standards, WSDL (Web Service Description Language), WSIL (Web Service Inspection Lang), UDDI (Universal Description, Discovery and Integration) and WSRF (Web Service Resource Framework)

How Grid Works

- Application **partitioning** that involves breaking the **problem** into **discrete pieces**
- **Discovery** and **scheduling** of tasks and workflow
- Data **communications** distributing the problem data where and when it is required
- **Provisioning** and **distributing application codes** to specific system nodes
- **Results management** assisting in the decision processes of the environment
- Autonomic features such as **self-configuration, self-optimization, self-recovery, and self-management**

Grid Topologies

- Intragrid
  - Local grid within an organization
  - Trust based on personal contracts
- Extragrid
  - Resources of a consortium of organizations connected through a (Virtual) Private Network
  - Trust based on Business to Business contracts
- Intergrid
  - Global sharing of resources through the internet
  - Trust based on certification

Computational Grid

"A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities."

"The Grid: Blueprint for a New Computing Infrastructure", Kesselman & Foster

Example : Science Grid (US Department of Energy)

Data Grid

- A **data grid** is a grid computing system that deals with data — the **controlled sharing and management of large amounts of distributed data**.

- Data Grid is the storage component of a grid environment. Scientific and engineering applications require access to large amounts of data, and often this data is widely distributed. A data grid provides seamless access to the local or remote data required to complete compute intensive calculations.

Example :

Biomedical informatics Research Network (BIRN),

the Southern California earthquake Center (SCEC).

Other Types of Grid

- **Scavenging grids:** Commonly used to find and harvest machine cycles from idle servers and desktop computers for use in resource-intensive tasks (scavenging is usually implemented in a way that is unobtrusive to the owner/user of the processor)

- **Market-oriented grids** : which deal with price setting and negotiation, grid economy management and utility driven scheduling and resource allocation.

P2P Computing vs Grid Computing

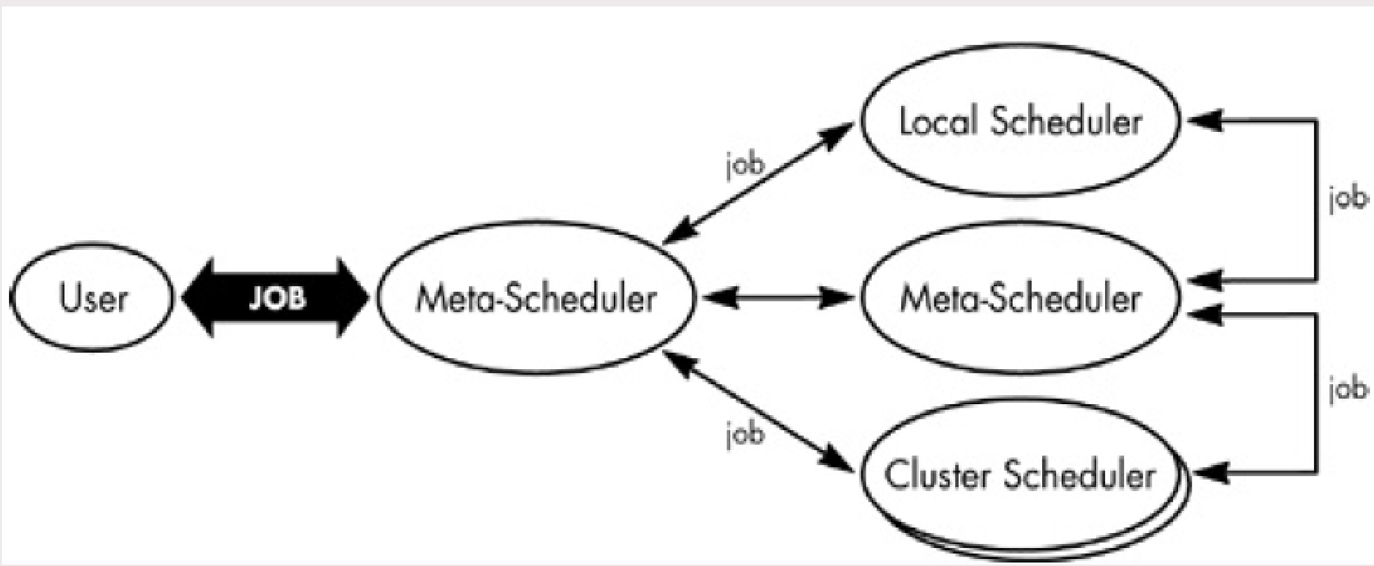
- Differ in Target Communities
- Grid system deals with more **complex**, more **powerful**, more **diverse** and **highly interconnected** set of **resources** than P2P.
- Virtual Organizations - Virtual organization for weather prediction & financial modeling need software applications and tools to perform prediction and financial analytics.
- P2P will have **unreliable computers** and is limited to certain **applications** which does **not require security**.
- Eg: Online games

Key Components of Grid

- **Resource management**: a grid must be aware of what resources are available for different tasks.
- **Security management**: the grid needs to take care that only authorized users can access and use the available resources.
- **Data management:** data must be transported, cleansed, parceled and processed.
- **Services management:** users and applications must be able to query the grid in an effective and efficient manner.

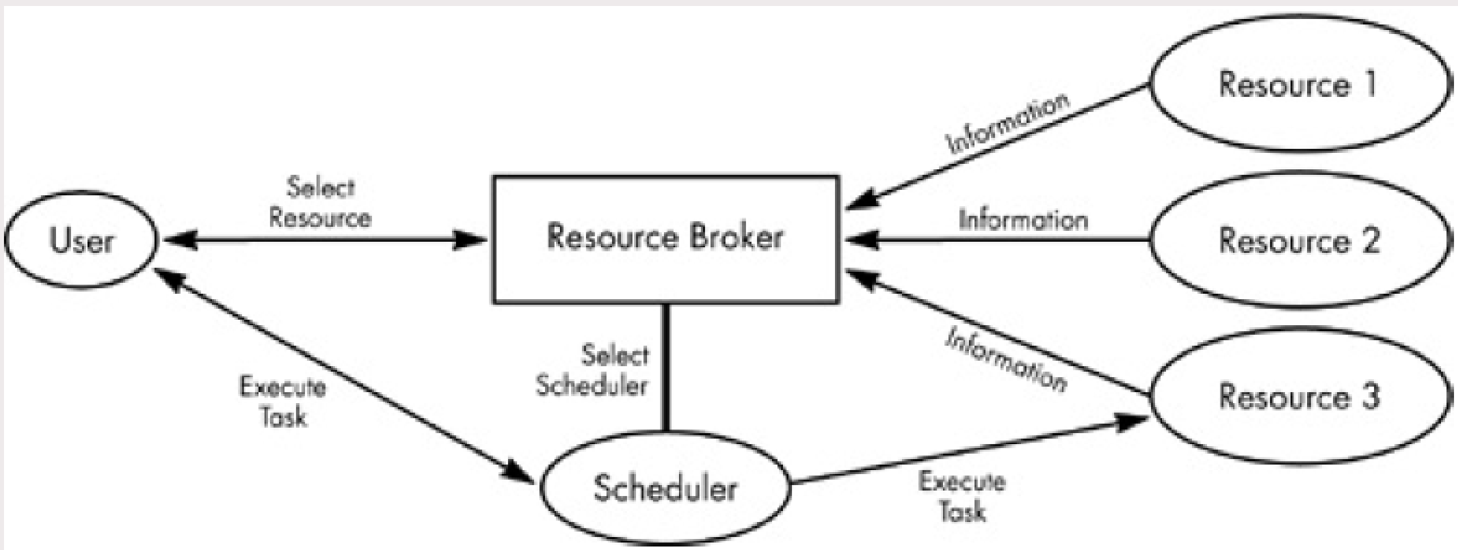
Components of Grid

- **Scheduler**
  - Schedulers are responsible for the management of jobs, such as allocating resources needed for any specific job, partitioning of jobs to schedule parallel execution of tasks, data management, event correlation, and service-level management capabilities

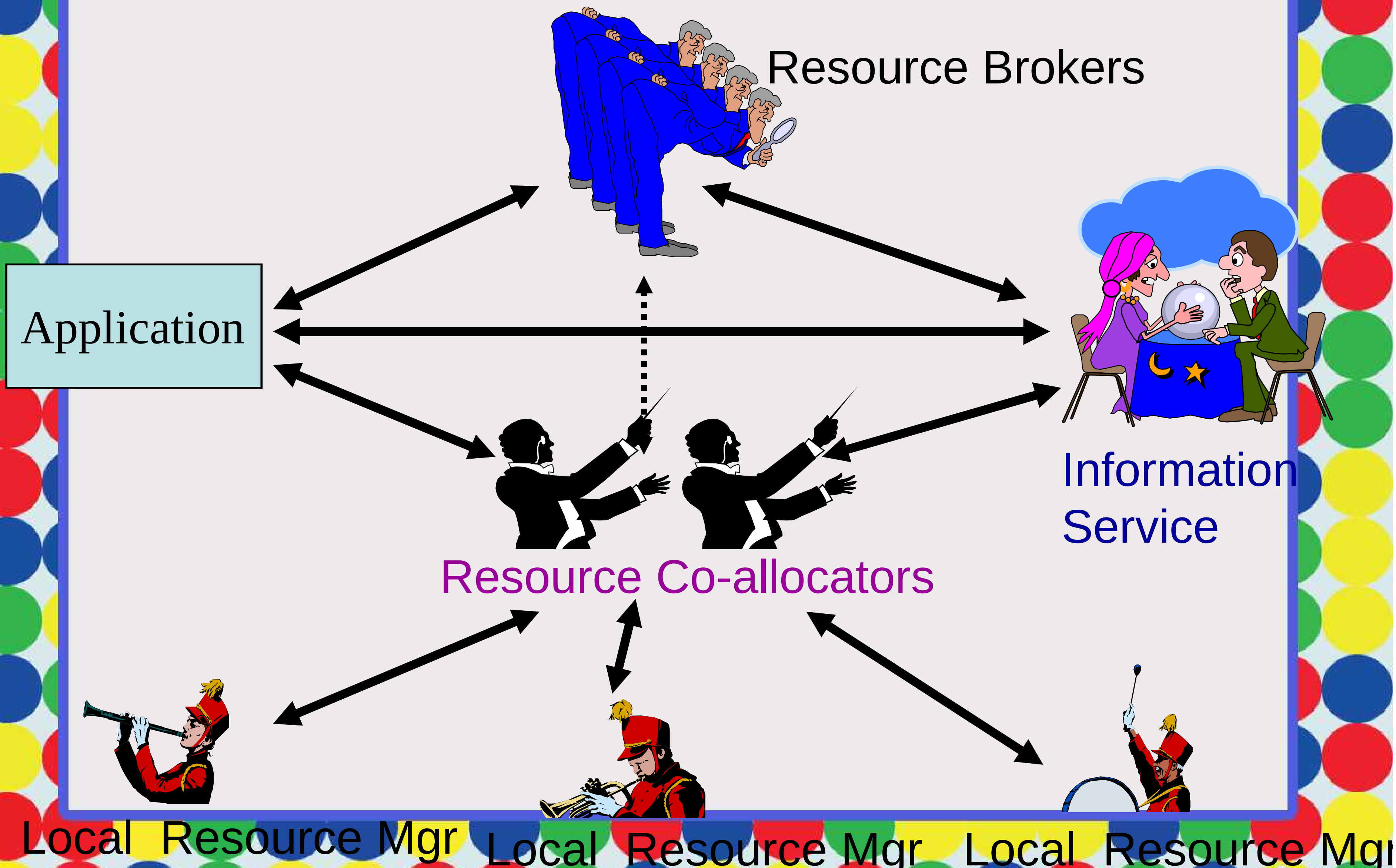


Components of Grid

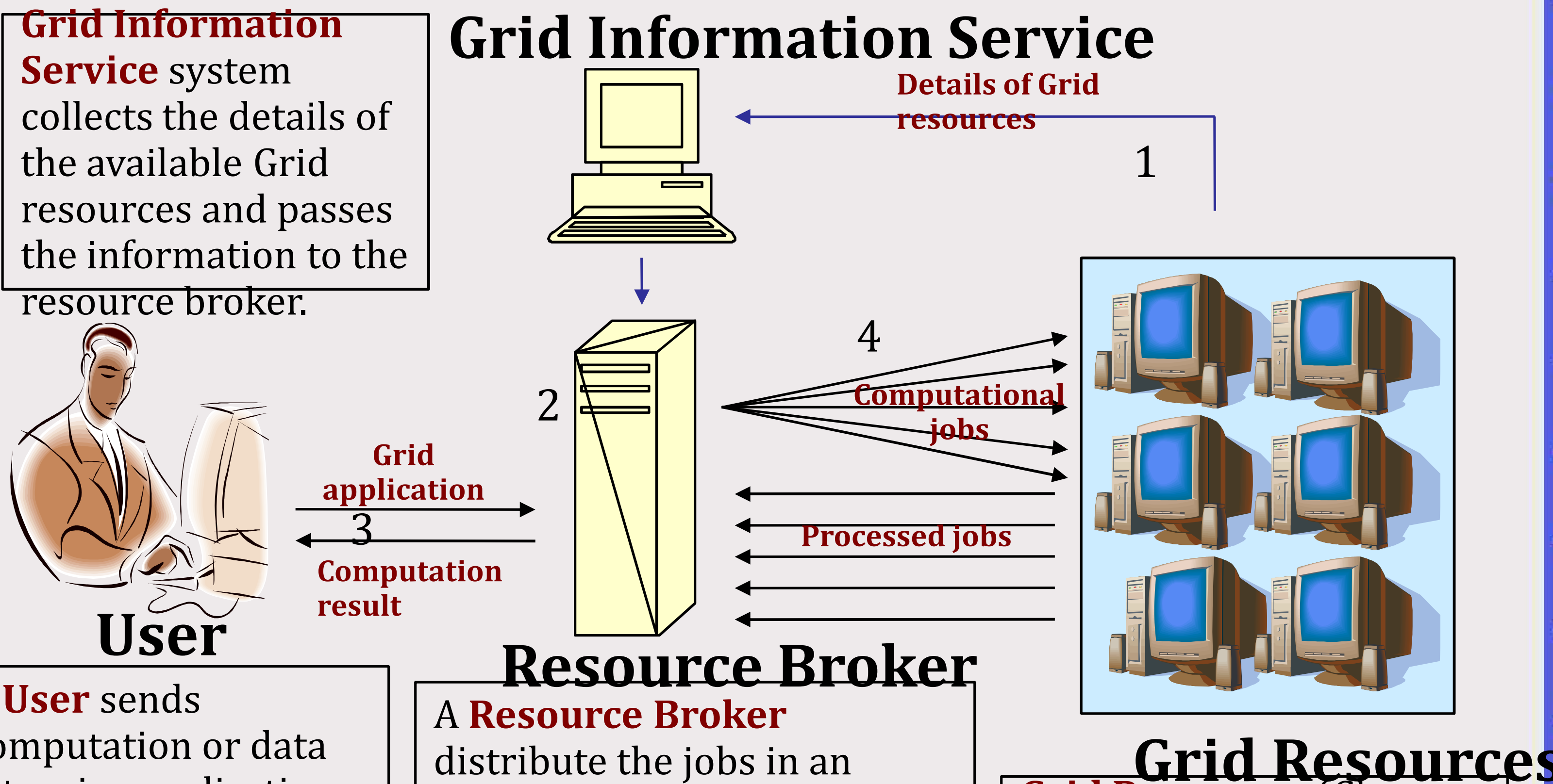
- **Resource Broker**
  - The resource broker provides pairing services between the service requester and the service provider. This pairing enables the selection of best available resources from the service provider for the execution of a specific task.



Resource Management Architecture



A typical view of Grid environment



Grid Information Service system collects the details of the available Grid resources and passes the information to the resource broker.

A **User** sends computation or data intensive application to Global Grids in order to speed up the execution of the application.

A **Resource Broker** distribute the jobs in an application to the Grid resources based on user's QoS requirements and details of available Grid resources for further executions.

Grid Resources (Cluster, PC, Supercomputer, database, instruments, etc.) in the Global Grid execute the user jobs.

Components of Grid

- **Load Balancing**
  - Load balancing feature must always be integrated into any system in order to avoid processing delays and over commitment of resources.
  - To support for failure detection and management. These load distributors can redistribute the jobs to other resources if needed.
- **Grid Portals**
  - Grid Portals are similar to Web Portals.
  - Grid portals provide capabilities for Grid Computing resource authentication, remote resource access, scheduling capabilities, and monitoring status information

Methods of Grid Computing

- Distributed Supercomputing
- High-Throughput Computing
- On-Demand Computing
- Data-Intensive Computing
- Collaborative Computing
- Logistical Networking

Grid Applications

- **Distributed HPC (Supercomputing):**
  - Computational science.
- **High-throughput computing:**
  - Large scale simulation/chip design & parameter studies.
- **Content Sharing**
  - Sharing digital contents among peers (e.g., Napster)
- **Remote software access/renting services:**
  - Application service provides (ASPs).
- **Data-intensive computing:**
  - Data mining, particle physics (CERN), Drug Design.
- **On-demand computing:**
  - Medical instrumentation & network-enabled solvers.
- **Collaborative:**
  - Collaborative design, data exploration, education.

Distributed Supercomputing

- Combining multiple high-capacity resources on a computational grid into a single, virtual distributed supercomputer.

- Tackle problems that cannot be solved on a single system.

High-Throughput Computing

- Uses the grid to schedule large numbers of loosely coupled or independent tasks, with the goal of putting unused processor cycles to work.

On-Demand Computing

- Uses grid capabilities to meet short-term requirements for resources that are not locally accessible.
- Models real-time computing demands.

Collaborative Computing

- Concerned primarily with enabling and enhancing human-to-human interactions.
- Applications are often structured in terms of a virtual shared space.

Data-Intensive Computing

- The focus is on synthesizing new information from data that is maintained in geographically distributed repositories, digital libraries, and databases.
- Particularly useful for distributed data mining.

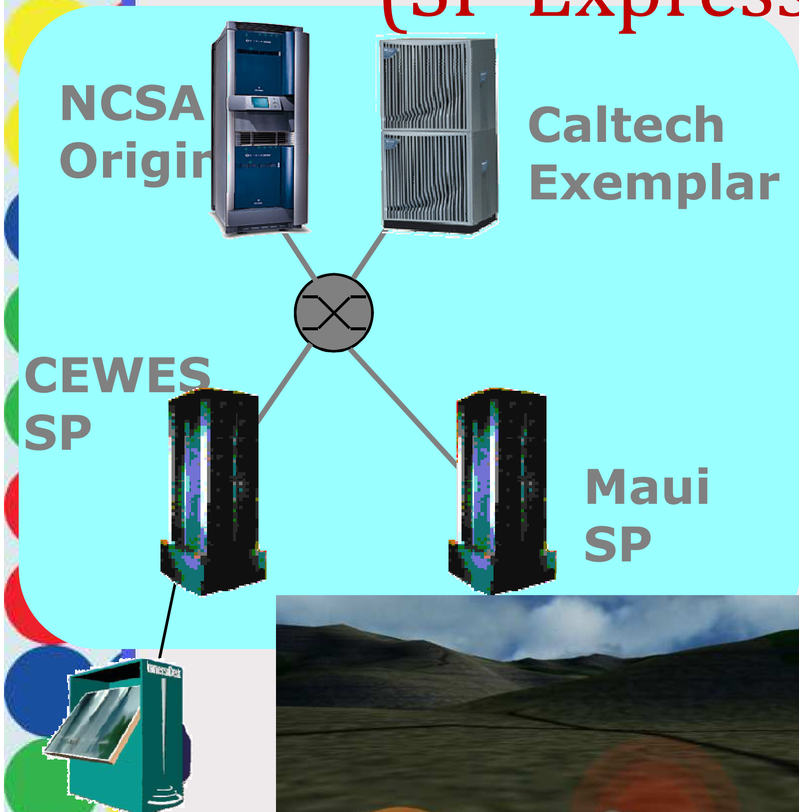
Logistical Networking

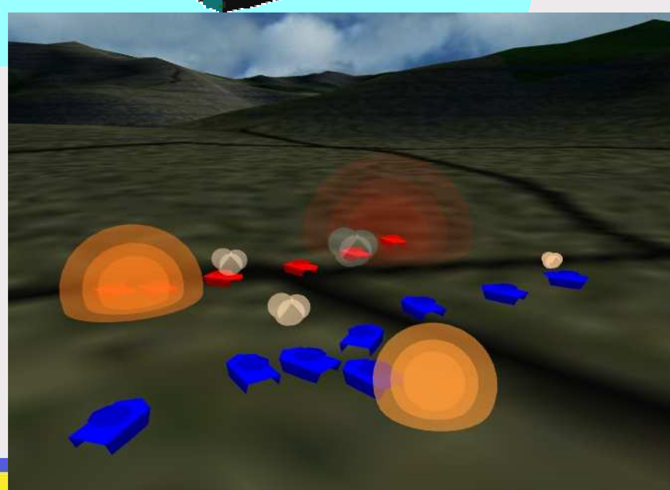
- Logistical networks focus on exposing storage resources inside networks by optimizing the global scheduling of data transport and data storage.
- Contrasts with traditional networking, which does not explicitly model storage resources in the network.

Grid Applications

- Life Sciences
- Financial Analysis and Services
- Research Collaboration
- Engineering and Design
- Collaborative Games
- Government

Distributed Supercomputing (SF-Express/MPICH-G, Caltech)



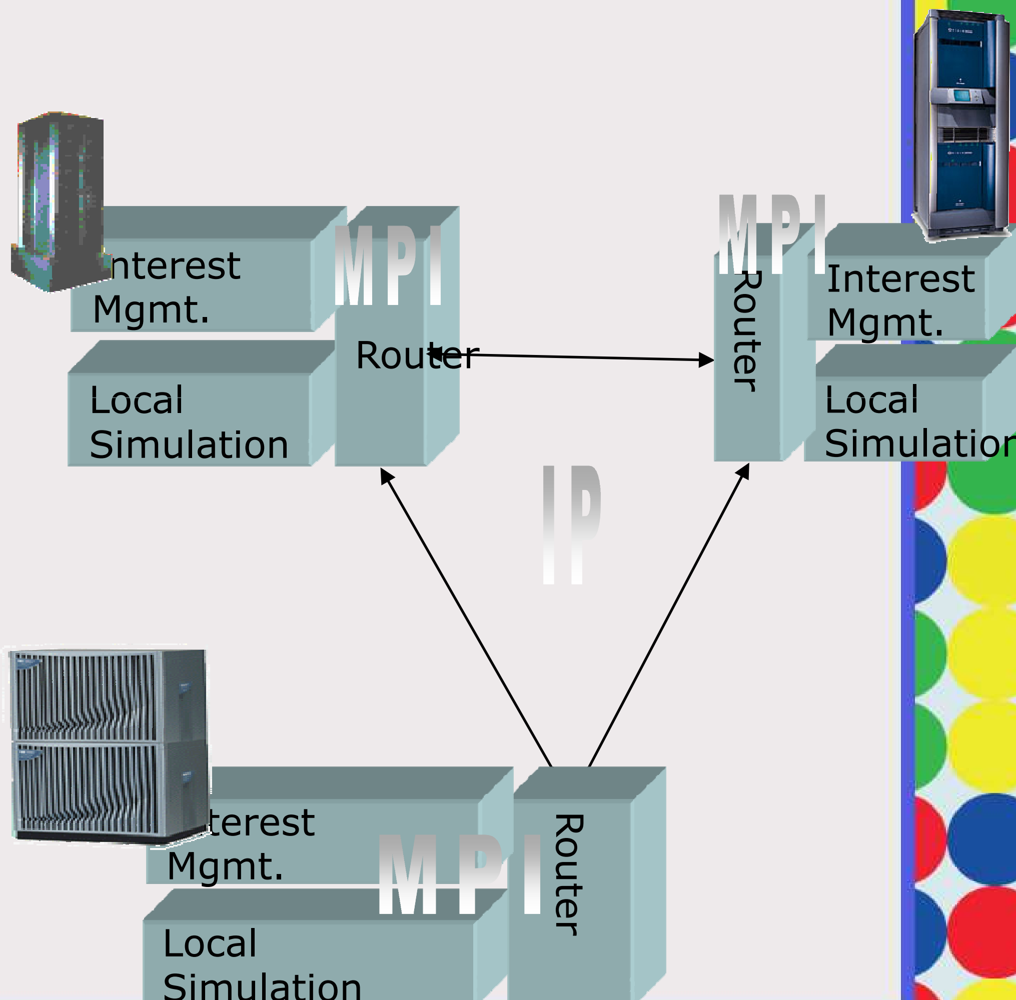


- SF-Express distributed interactive simulation.
- 100K vehicles (2002 goal) using 13 computers, 1386 nodes, 9 sites.
- Globus mechanisms for
  - Resource allocation;
  - Distributed startup;
  - I/O and configuration;
  - Security.

P. Messina et al., Caltech
http://www.globus.org/applications/

SF-Express Architecture

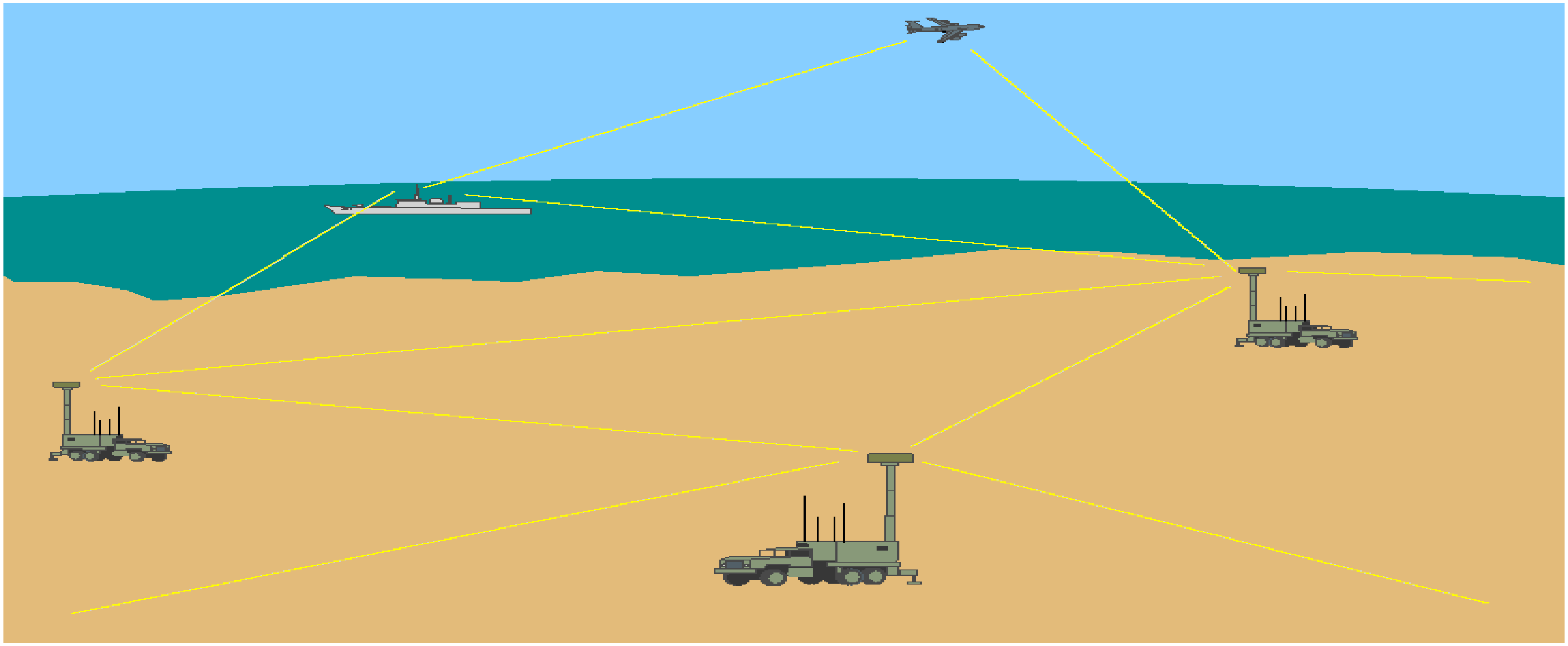
- Create synthetic, representations of interactive environments.
- Scalability via interest management.
- Starting point:
  - MPI and socket communication;
  - Hand startup.



High Throughput Computing (parameter sweep applications)

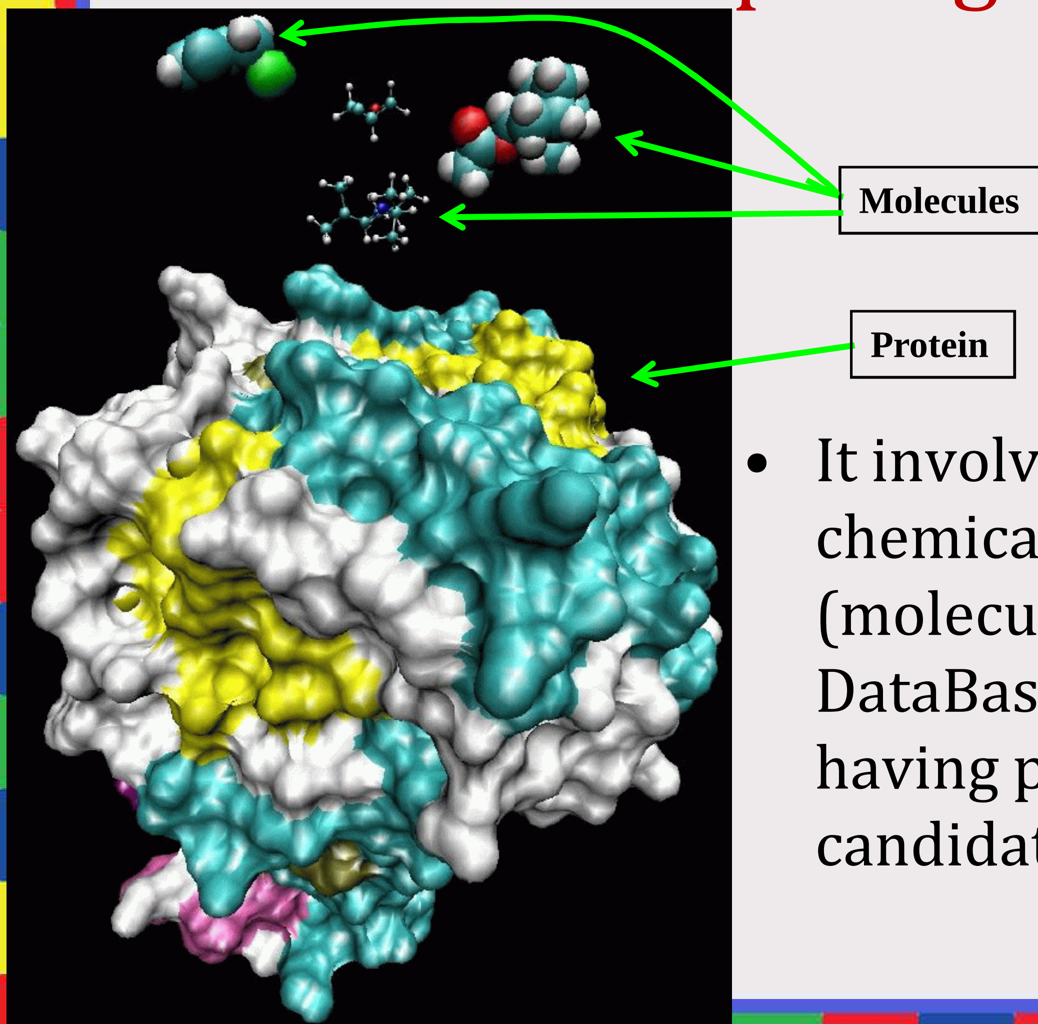
- A study involving exploration of possible scenarios - i.e., execution of the same program for various design alternatives (data).
- It consists of large number of tasks (1000s).
- Generally, no inter-task communication (task farming).
- Large size data (MBytes+) files and I/O constraints
- A large class of application areas:
  - Parameter explorations and simulations (Monte Carlo);
  - A large number of science, engineering, and commercial applications: Astrophysics, Drug Design, NeroScience, Network simulation, structural engineering, automobiles crash simulation, aerospace modeling, financial risk analysis
- Condor, Nimrod/G, DesignDrug@Home, SETI@Home, FOLD@Home, Distributed.net.

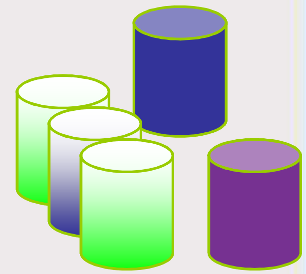
Ad Hoc Mobile Network Simulation



Ad Hoc Mobile Network Simulation: Network performance under different microware frequencies and different weather conditions – uses Nimrod.

Drug Design: Data Intensive Computing on Grid

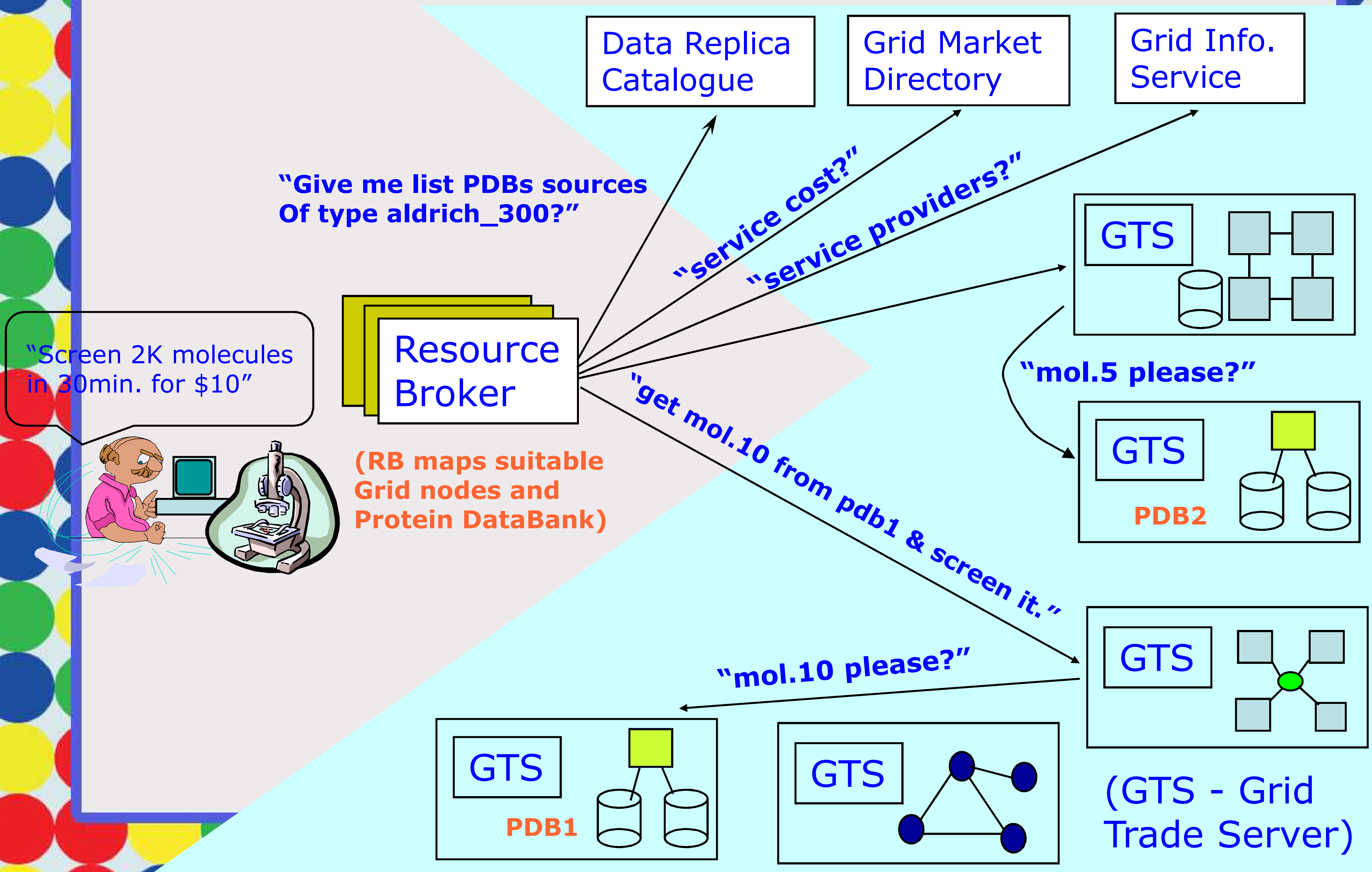




Chemical Databases
(legacy, in .MOL2 format)

- It involves screening millions of chemical compounds (molecules) in the Chemical DataBase (CDB) to identify those having potential to serve as drug candidates.

DesignDrug@Home Architecture
A Virtual Lab for "Molecular Modeling for Drug Design" on P2P Grid



MEG(MagnetoEncephaloGraphy) Data Analysis on the Grid: Brain Activity Analysis

64 sensors MEG

Analysis All pairs (64x64) of MEG data by shifting the temporal region of MEG data over time: 0 to 29750: 64x64x29750 jobs

2

Data Generation

3

Data Analysis

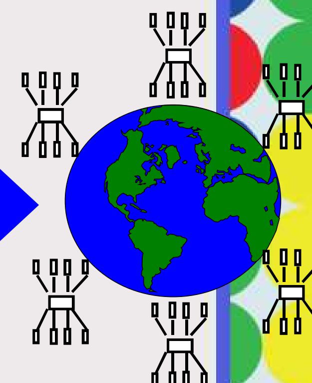
Nimrod-G

1

5

Results

4



World-Wide Grid

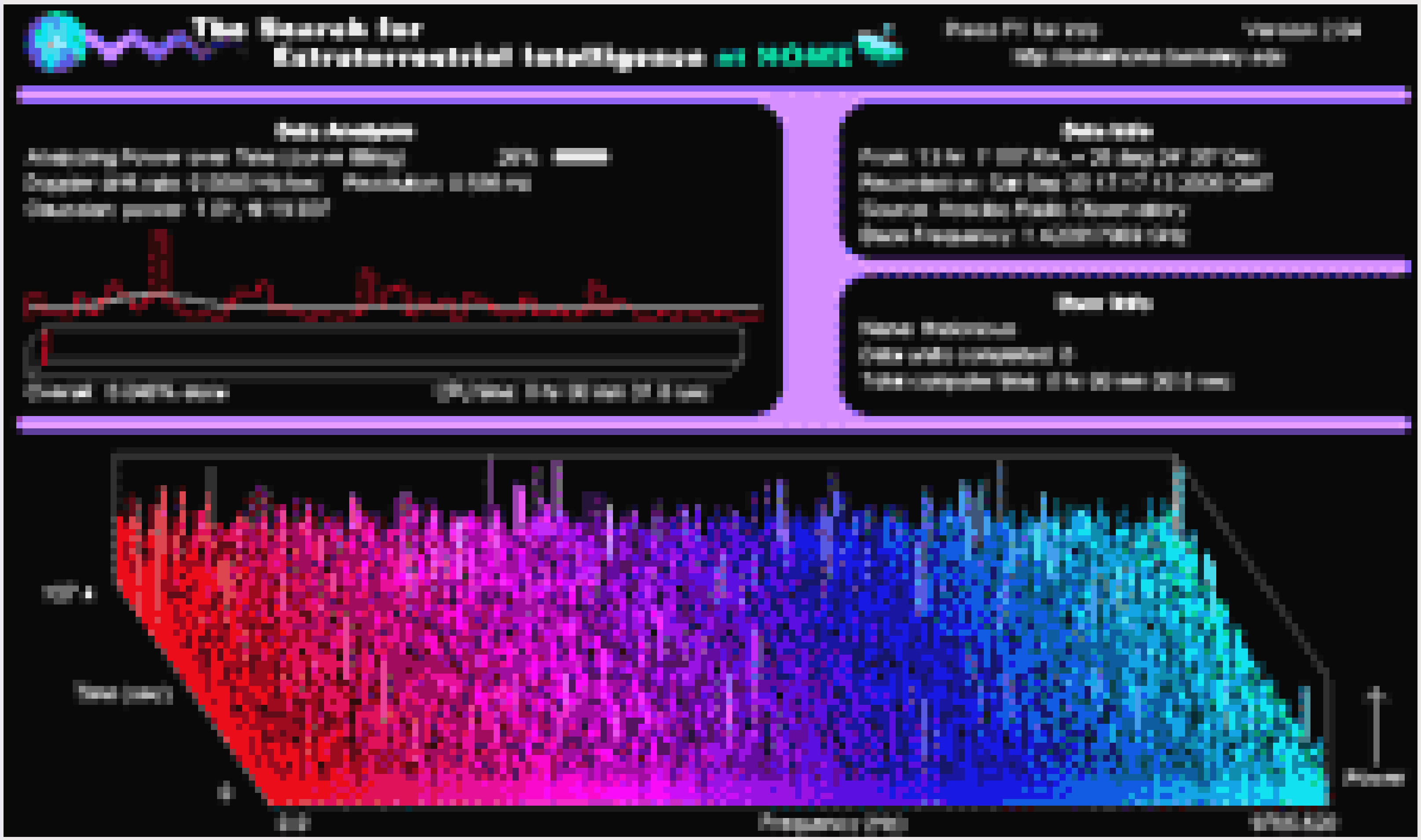
Life-electronics laboratory, AIST

•[deadline, budget, optimization preference]

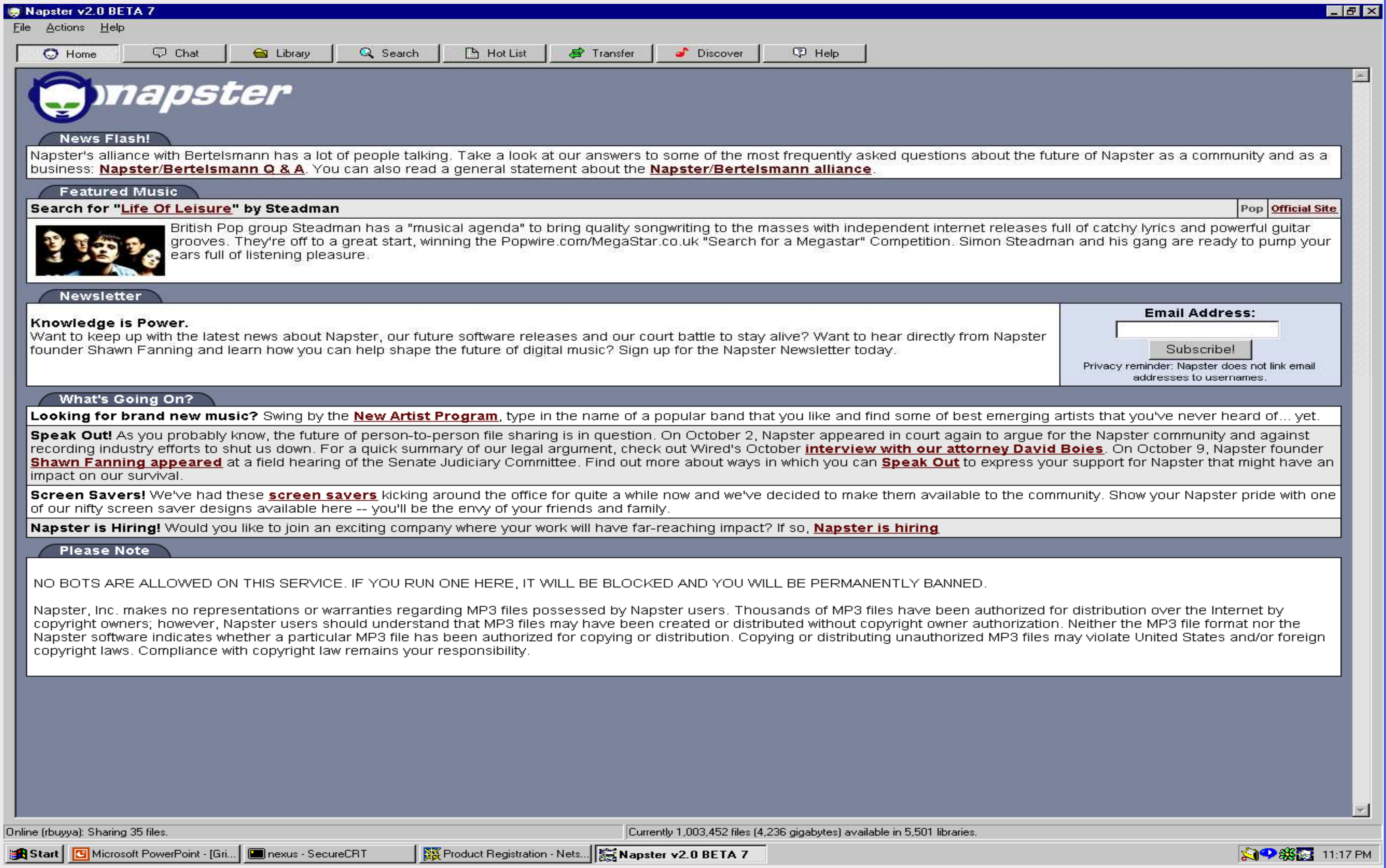
- Provision of expertise in the analysis of brain function
- Provision of MEG analysis

[Collaboration with Osaka University, Japan]

SETI@home: Search for Extraterrestrial Intelligence at Home

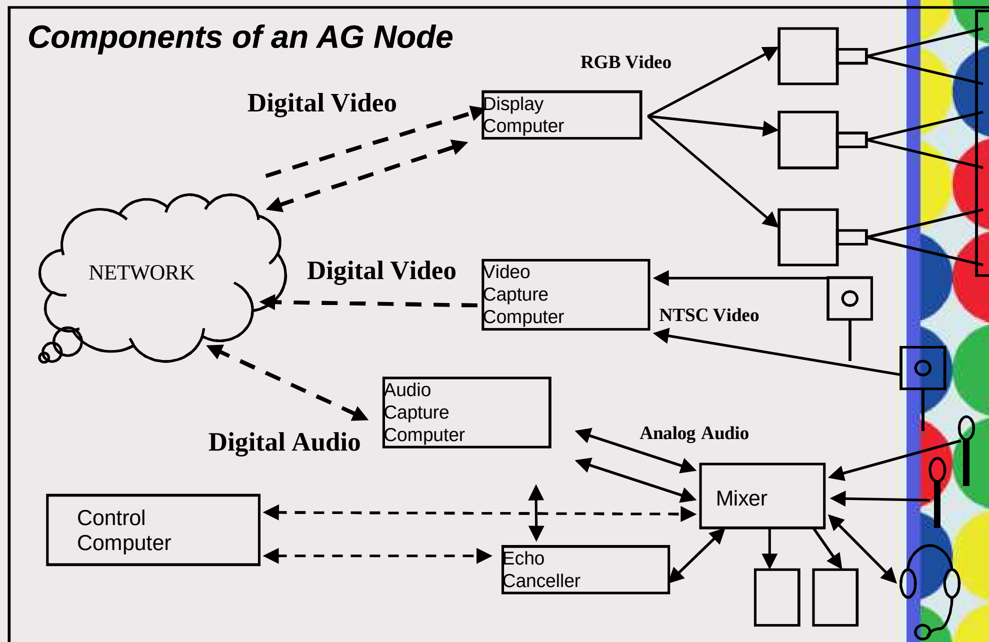


Content Sharing – P2P



Collaborative Engineering

ACCESS GRID : http://www-fp.mcs.anl.gov/fl/accessgrid/



- •Group to group interactions.
- •Human collaboration across distributed locations
- •Remote visualizations, virtual meeting, seminars,etc.
- •Uses grid technologies for secure communication etc.
- •May have interaction with scientific apps.

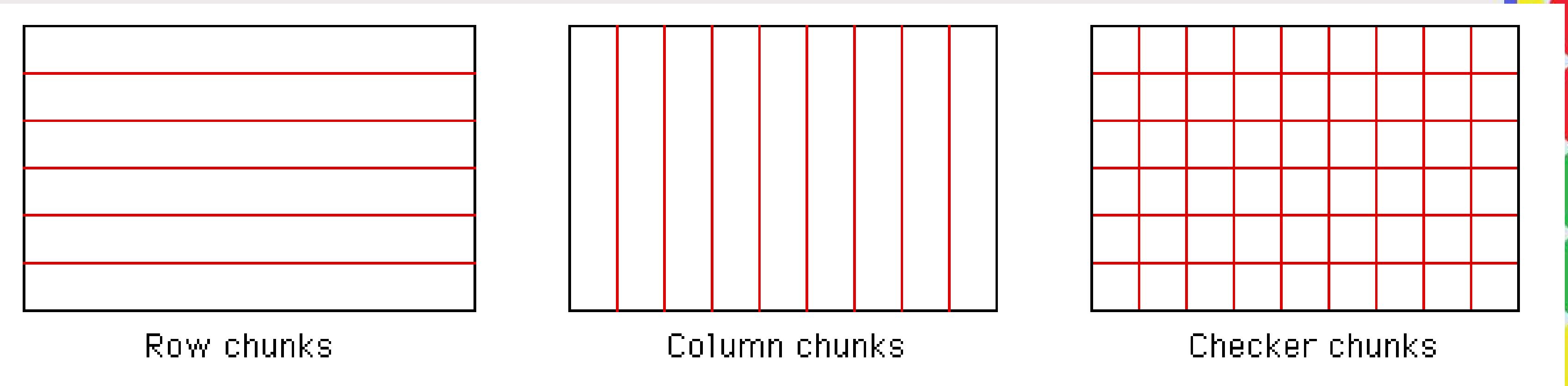
Rick Stevens & Team, ANL

Image-Rendering

http://www.swin.edu.au/astronomy/pbourke/povray/parallel

Parallelization of Image Rendering

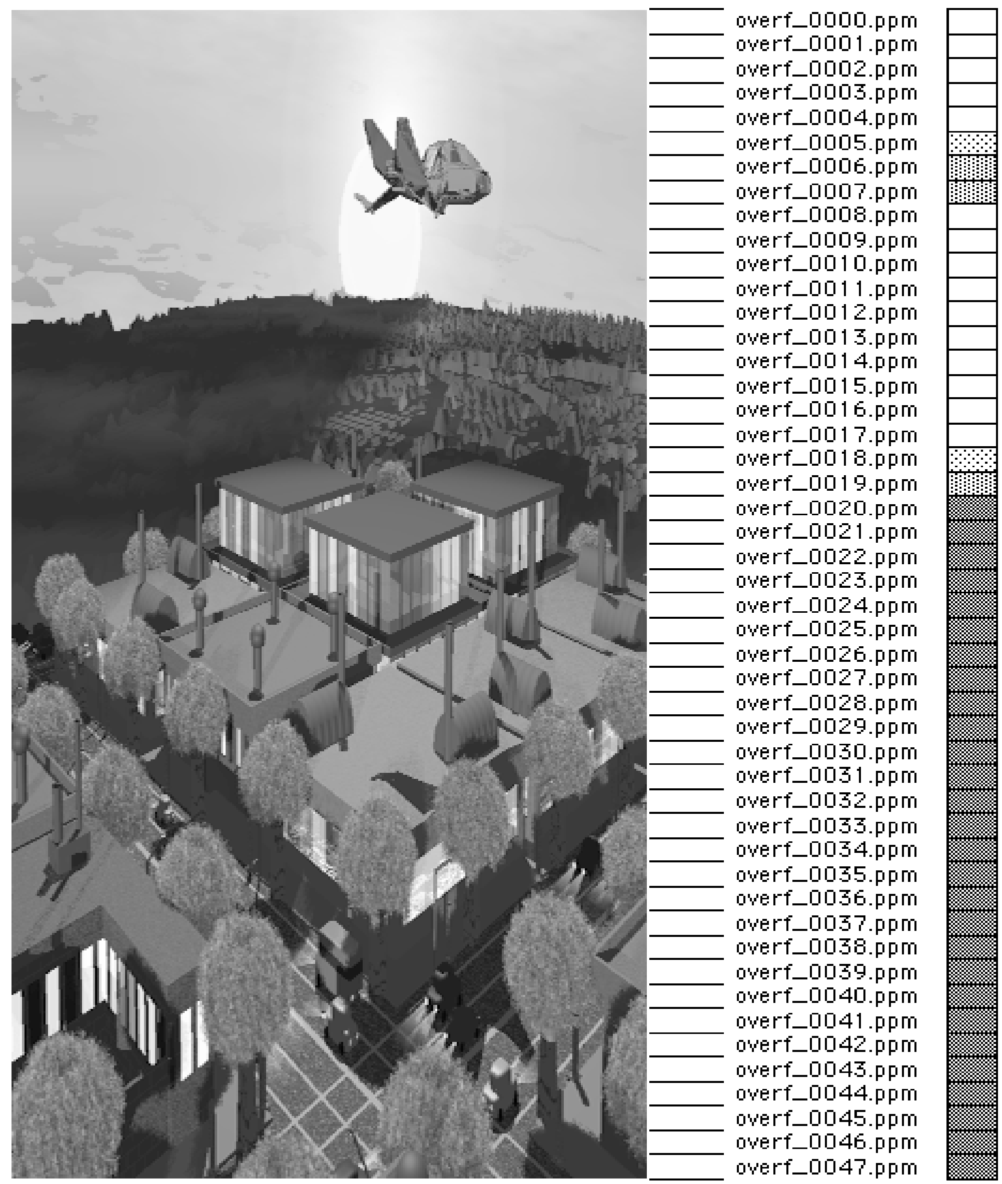
- Image splitting (by rows, columns, and checker)



- Each segment can be concurrently processed on different nodes and render image as segments are processed.

Scheduling (need load balancing)

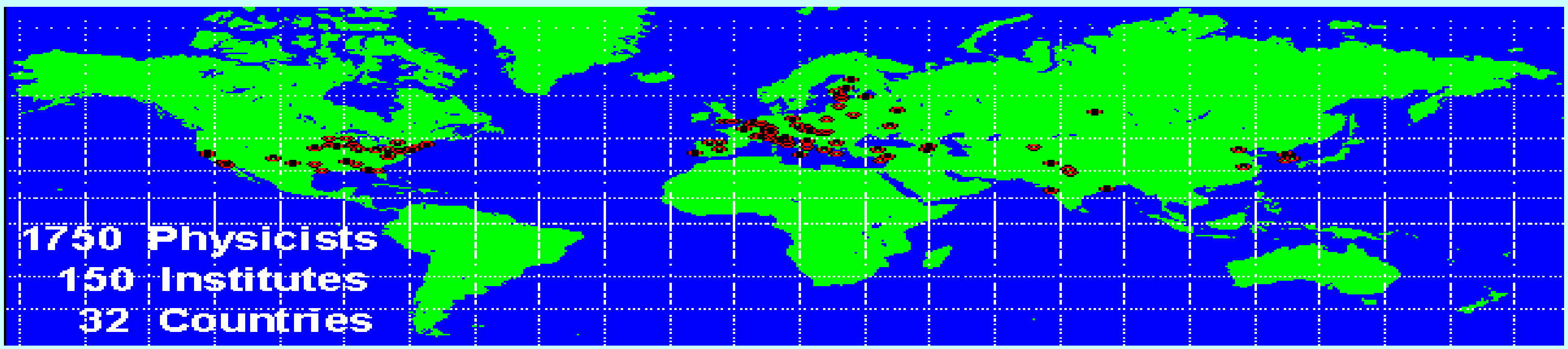
- Each row rendering takes different times depending on image nature – e.g, rendering rows across the sky take less time compared to those that intersect the interesting parts of the image.
- Rending apps can be implemented using MPI, PVM, or p-study tools like Nimrod and schedule.



Data Intensive Computing
e.g., CERN Data Grid initiative

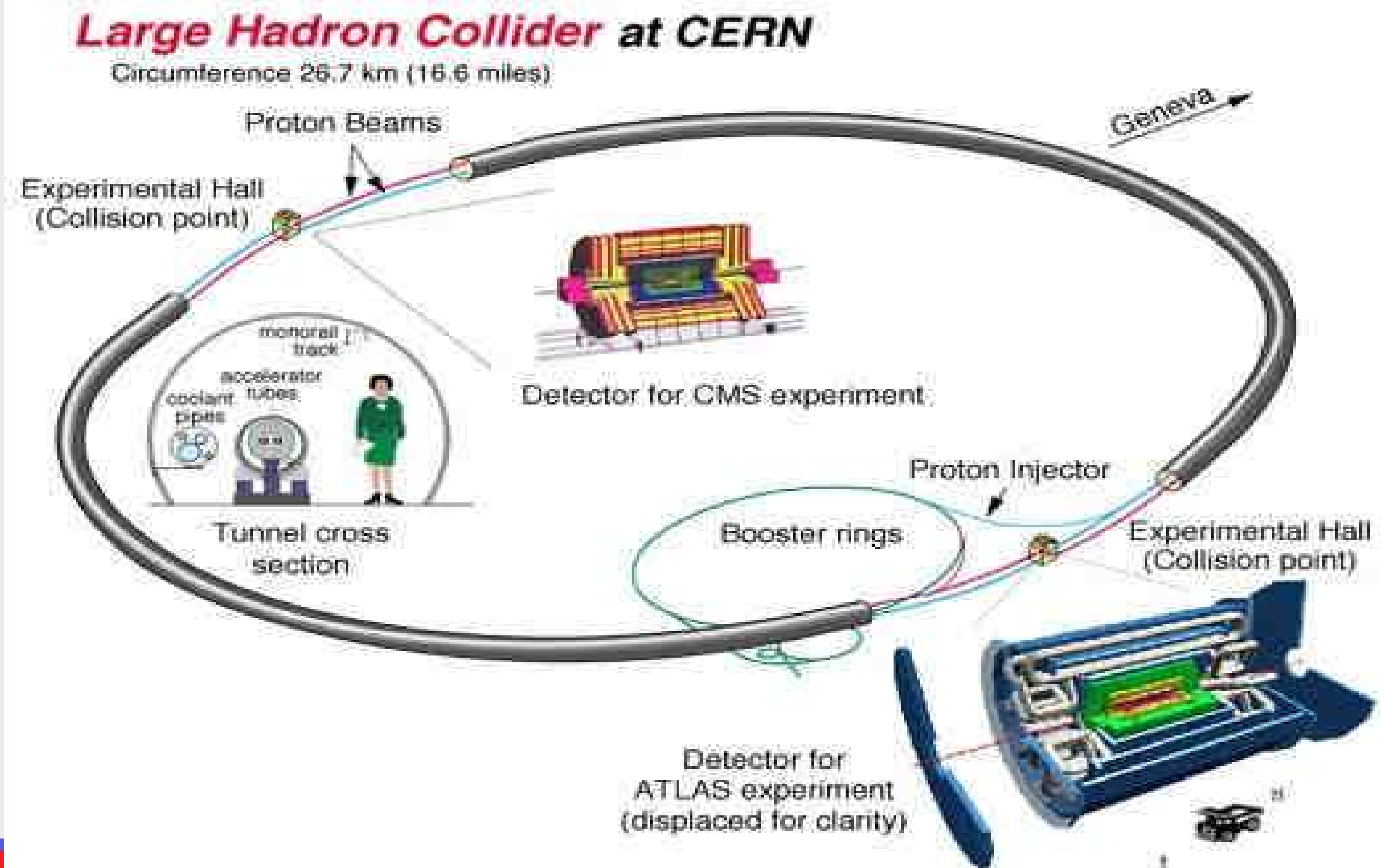
LHC Computing Challenges

- **Geographical dispersion:** of people and resources
- **Complexity:** the detector and the LHC environment
- **Scale:** Petabytes per year of data



Major challenges associated with:
Communication and collaboration at a distance
Distributed computing resources
Remote software development and physics analysis
R&D: New Forms of Distributed Systems

CERN Large Hadron Collider - circular particle accelerator to be placed in 27 km long tunnel in 2005.



"The Computational Grid" is analogous to Electricity (Power) Grid and the vision is to offer a (almost) dependable, consistent, pervasive, and inexpensive access to high-end resources irrespective their location of physical existence and the location of access.

Grid Middleware

- Grids are typically managed by grid ware - a special type of middleware that enable sharing and manage grid components based on user requirements and resource attributes (e.g., capacity, performance)
- Software that connects other software components or applications to provide the following functions:
  - Run applications on suitable available resources
    - Brokering, Scheduling
  - Provide uniform, high-level access to resources
    - Semantic interfaces
    - Web Services, Service Oriented Architectures
  - Address inter-domain issues of security, policy, etc.
    - Federated Identities
  - Provide application-level status
  - monitoring and control

Middleware

- Globus –chicago Univ
- Condor – Wisconsin Univ – High throughput computing
- Legion – Virginia Univ – virtual workspaces-collaborative computing
- IBP – Internet back pane – Tennesse Univ – logistical networking
- NetSolve – solving scientific problems in heterogeneous env – high throughput & data intensive

Two Key Grid Computing Groups

The Globus Alliance (www.globus.org)

- Composed of people from:

  Argonne National Labs, University of Chicago, University of Southern California Information Sciences Institute, University of Edinburgh and others.
- OGSA/I standards initially proposed by the Globus Group

The Global Grid Forum (www.ggf.org)

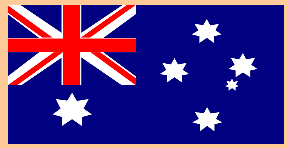
- Heavy involvement of Academic Groups and Industry
  - (e.g. IBM Grid Computing, HP, United Devices, Oracle, UK e-Science Programme, US DOE, US NSF, Indiana University, and many others)
- Process
  - Meets three times annually
  - Solicits involvement from industry, research groups, and academics

Some of the Major Grid Projects

Name	URL/Sponsor	Focus
EuroGrid, Grid Interoperability (GRIP)	eurogrid.org European Union	Create tech for remote access to super comp resources & simulation codes; in GRIP, integrate with Globus Toolkit™
Fusion Collaboratory	fusiongrid.org DOE Off. Science	Create a national computational collaboratory for fusion research
Globus Project™	globus.org DARPA, DOE, NSF, NASA, Msoft	Research on Grid technologies; development and support of Globus Toolkit™; application and deployment
GridLab	gridlab.org European Union	Grid technologies and applications
GridPP	gridpp.ac.uk U.K. eScience	Create & apply an operational grid within the U.K. for particle physics research
Grid Research Integration Dev. & Support Center	grids-center.org NSF	Integration, deployment, support of the NSF Middleware Infrastructure for research & education

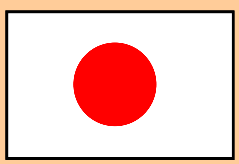
Many Grid Projects & Initiatives

- Australia
  - Nimrod-G
  - GridSim
  - Virtual Lab
  - Gridbus
  - DISCWorld
  - ..new coming up



- Europe
  - UNICORE
  - MOL
  - UK eScience
  - Poland MC Broker
  - EU Data Grid
  - EuroGrid
  - MetaMPI
  - Dutch DAS
  - XW, JaWS

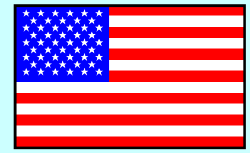
Japan
  - Ninf
  - DataFarm



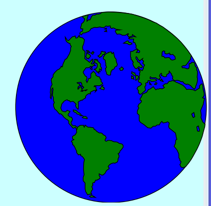
- Korea...

N*Grid

- USA
  - Globus
  - Legion
  - OGSA
  - Javelin
  - AppLeS
  - NASA IPG
  - Condor-G
  - Jxta
  - NetSolve
  - AccessGrid
  - and many more...



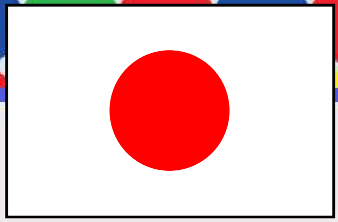
- Cycle Stealing & .com Initiatives
  - Distributed.net
  - SETI@Home, ….
  - Entropia, UD, Parabon,….
- Public Forums
  - Global Grid Forum
  - P2P Working Group
  - IEEE TFCC
  - Grid & CCGrid conferences



http://www.gridcomputing.com

Initiative	Focus and Technologies Developed
UNICORE	The UNiform Interface to Computer Resources aims to deliver software that allows users to submit jobs to remote high performance computing resources – www.fz-juelich.de/unicore
MOL	Metacomputer OnLine is a toolbox for the coordinated use of WAN/LAN connected systems. MOL aims at utilizing multiple WAN-connected high performance systems for solving large-scale problems that are intractable on a single supercomputer – www.uni-paderborn.de/pc2/projects/mol
METODIS	Metacomputing Tools for Distributed Systems – www.hlrs.de/structure/organisation/par/projects/metodis/
Globe	Globe is a research project aiming to study and implement a powerful unifying paradigm for the construction of large-scale wide area distributed systems: distributed shared objects – www.cs.vu.nl/~steen/globe
Pozan	Poznan Centre works on development of tools and methods for metacomputing - www.man.poznan.pl/metacomputing/
Date Grid	This project aims to develop middleware and tools necessary for the data-intensive applications of high-energy physics – grid.web.cern.ch/grid
MetaMPI	MetaMPI supports the coupling of heterogeneous MPI systems, thus allowing parallel applications developed using MPI to be run on Grids without alteration – www.lfbs.rwth-aachen.de/~martin/MetaMPICH/
DAS	This is a wide-area distributed cluster, used for research on parallel and distributed computing by five Dutch universities – www.cs.vu.nl/das
JaWs	JaWS is an economy-based computing model where both resource owners and programs using these resources place bids to a central marketplace that generates leases of use – roadrunner.ics.forth.gr

Initiative	Focus and Technologies Developed
Globus	This project is developing basic software infrastructure for computations that integrate geographically distributed computational and information resources – www.globus.org
Legion	Legion is an object-based metasystem. Legion supports transparent scheduling, data management, fault tolerance, site autonomy, and a wide range of security options – www.legion.virginia.edu
Javelin	Javelin: Internet-based parallel computing using Java – www.cs.ucsb.edu/research/javelin/
AppLes	This is an application-specific approach to scheduling individual parallel applications on production heterogeneous systems – www.infospheres.caltech.edu/
NASA IPG	The Information Power Grid is a testbed that provides access to a Grid – a widely distributed network of high performance computers, stored data, instruments, and collaboration environments – www.ipg.nasa.gov
Condor	This project aims is to develop, deploy, and evaluate mechanisms and policies that support high throughput computing (HTC) on large collections of distributed computing resources – www.cs.wisc.edu/condor/
Harness	Harness builds on the concept of the virtual machine and explores dynamic capabilities beyond what PVM can supply. It focused on developing three key capabilities: Parallel plug-ins, Peer-to-peer distributed control, and multiple virtual machines – www.epm.ornl.org/harness
NetSolve	NetSolve is a project that aims to bring together disparate computational resources connected by computer networks. It is a RPC based client/agent/server system that allows one to remotely access both hardware and software components – www.cs.utk.edu/netsolve/
Grid Port	SDSCs Grid Port Toolkit generalises the HotPage infrastructure to develop a reusable portal toolkit – gridport.npaci.edu/
HotPage	NPACI's HotPage is a user portal that is designed to be a single point-of-access to computer resources – hotpage.npaci.edu/
Gateway	Gateway offers a programming paradigm implemented over a virtual Web of accessible resources - www.npac.syr.edu/users/haupt/WebFlow/demo.html



Initiative	Focus and Technologies Developed
Ninf	Ninf allows users to access computational resources including hardware, software and scientific data distributed across a wide area network with an easy-to-use interface – ninf.etl.go.jp
Bricks	Bricks is a performance evaluation system that allows analysis and comparison of various scheduling schemes on a typical high-performance global computing setting – matsu-www.is.titech.ac.jp/~takefusa/bricks

Simulation tools

- GridSim – job scheduling
- SimGrid – single client multiserver scheduling
- Bricks – scheduling
- GangSim- Ganglia VO
- OptoSim – Data Grid Simulations
- G3S – Grid Security services Simulator – security services

Simulation tool

- GridSim is a Java-based toolkit for modeling, and simulation of distributed resource management and scheduling for conventional Grid environment.
- GridSim is based on SimJava, a general purpose discrete-event simulation package implemented in Java.
- All components in GridSim communicate with each other through message passing operations defined by SimJava.

Salient features of the GridSim

- It allows modeling of **heterogeneous** types of resources.
- Resources can be modeled operating under **space- or time-shared mode.**
- Resource capability can be defined (in the form of **MIPS** (Million Instructions Per Second) benchmark.
- Resources can be located in **any time zone**.
- **Weekends and holidays** can be mapped depending on resource's local time to model non-Grid (local) workload.
- Resources can be **booked** for advance reservation.
- Applications with different **parallel application** models can be simulated.

Salient features of the GridSim

- Application tasks can be heterogeneous and they can be CPU or I/O intensive.
- There is no limit on the number of application jobs that can be submitted to a resource.
- Multiple user entities can submit tasks for execution simultaneously in the same resource, which may be time-shared or space-shared. This feature helps in building schedulers that can use different market-driven economic models for selecting services competitively.
- Network speed between resources can be specified.
- It supports simulation of both static and dynamic schedulers.
- Statistics of all or selected operations can be recorded and they can be analyzed using GridSim statistics analysis methods.

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