The Grid

Where we’ve been, Where We Are and Where We’re Going

Carl Kesselman
carl@isi.edu
Information Sciences Institute
University of Southern California

Joint work with Ian Foster, ANL and U Chicago
Disclaimers

● Describing work of many other people
  - ANL, ISI, NCSA, CIT, SDSC, NASA, etc.

● Important work by others is left out
  - I’ve picked a representative sample
The Grid

- Emerging computational and networking infrastructure
  - pervasive, uniform, and reliable access to remote data, computational, sensor, and human resources
- Enable entirely new approaches to applications and problem solving
  - remote resources the rule, not the exception
Why Now?

- The Internet as infrastructure
  - Increasing bandwidth, advanced services
- Advances in storage capacity
  - Terabyte store is ~$150,000
- Increased availability of compute resources
  - clusters, supercomputers, etc.
- Advanced applications
  - simulation based design, advanced scientific instruments, ...
Talk in a nutshell….

- Where we’ve been:
  - Special purpose networks, stunts

- Where we are:
  - Development of core middleware services
  - Limited, but growing application set
  - Persistent testbeds

- Where we’re going:
  - Production grids
  - Common application use
  - High level services and development tools
Where We’ve Been...
The CASA Gigabit Testbed

- One of four testbeds constructed in early nineties in the US
- Dedicated network
  - HIPPI over SONET, required custom built hardware
  - Connected CIT, SDSC, and LANL
- Focus on distributed, supercomputer applications
  - Large distributed memory and vector supercomputers
CASA Software Environment

- Express message passing library modified to support TCP/IP
- No scheduling support, security, remote file access, etc.
- Application included coupled atmospheric/ocean model, quantum chemistry
- Machine/application heterogeneity to achieve application speedup
The I-Way

- Focus on application demonstration
  - SC95
- OC-3 backbone
- Large-scale use of immersive displays
  - CAVE and I-Desk
- I-Soft programming environment
I-Soft (Foster et. al)

- Kerberos based authentication
  - I-POP initiated rsh to local resources
- AFS for distribution of software and state
- Central scheduler
  - Dedicated I-WAY nodes on resource
  - Interface to local scheduler
- Nexus based communication libraries
  - MPI, CaveComm, CC++
I-POP Design (Foster et.al)
Cloud Detection

- Cloud detection from multimodal satellite data
- Uses remote supercomputer to enhance instruments with
  - Real-time response
  - Enhanced function, accuracy
- Issues
  - Scheduling, network QoS

Lee et al., Aerospace Corporation/Caltech
Combustion System Modeling

- A shared collaborative space
  - Link people at multiple locations
  - Share and steer scientific simulations on supercomputer

- Issues
  - Scheduling, multiple datatypes
  - Multiple access modalities

Freitag et al., Argonne National Laboratory/NALCO
Where We Are...
# Grid Services Architecture

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## Applications
- **High-energy physics data analysis**
- **Collaborative engineering**
- **On-line instrumentation**

## Grid Services
- **Information**
- **Resource mgmt**
- **Fault detection**

## Grid Fabric
- **Transport**
- **Multicast**
- **QoS mechanisms**

## Application Toolkit Layer
- **Distributed computing**
- **Data-intensive**
- **Remote viz**

## Grid Services Layer
- **Security**
- **Data access**

## Grid Fabric Layer
- **Instrumentation**
- **Control interfaces**

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**The Globus Project**

[www.globus.org](http://www.globus.org)
Grid Fabric

- Networking Infrastructure
  - OC-3 to OC-12
  - Coming: faster and more services

- Resources:
  - clusters, supercomputers, displays, archives, …
  - Coming: network caches, policy based allocation, advanced reservation
Grid Services ("Middleware")

- **Standard services that**
  - Provide uniform, high-level access to a wide range of resources (including networks)
  - Address interdomain issues of security, policy, etc.
  - Permit application-level management and monitoring of end-to-end performance

- **Middleware-level and higher-level APIs and tools targeted at application programmers**
  - Map between application and Grid
Globus Grid Services

- The Globus toolkit provides a range of basic Grid services
  - Security, information, fault detection, communication, resource management, ...
- These services are simple and orthogonal
  - Can be used independently, mix and match
  - Programming model independent
- For each there are well-defined APIs
- Standards are used extensively
  - E.g., LDAP, GSS-API, X.509, ...
Grid Information Services

- Grid Information Service
  - Currently an LDAP-based directory service
  - Publish structure and state info, dynamic performance info, software info, etc., etc.
  - Resource discovery: “find me an X with property Y available at time T”
  - Auto-configuration: “tell me what I need to know to use A efficiently/securely/...”
  - Gateways to other data sources required
  - Example of integrating “middleware” service
Communication and I/O Services

● Access to remote data (GASS)
  - Uniform access to diverse storage management systems
  - Cache management
  - Integration with SRB, DPSS, HPSS

● Communication (Nexus)
  - Application-level interfaces to comm services
  - Multiple methods: reliable/unreliable, IP/other, unicast/multicast
  - QoS interfaces
Resource Management

- Globus Resource Allocation Manager (GRAM)
  - Uniform interface to resource management
- Globus Arch. for Reservation and Allocation
  - Co-allocation of compute resources
  - Immediate and advance reservation of network and computers in prototype form
- Fault detection service
- Network measurement tools
- Code management and distribution infrastructure
Grid Enabled Tools

- Message Passing Interface
  - Multi-method communication, specialized
- CAVERNSoft
  - Shared state for collaborative environments
- Condor, Nimrod-G
  - High-throughput computing
- Parallel Application Workspace (PAWS)
  - High-speed parallel transfers for coupled apps
GUSTO Computational Grid
Application Examples

- Online instrumentation
- Distributed supercomputing
- Collaborative engineering
- High-throughput computing
- Remote job submission, meta-queueing
Online Instrumentation

Advanced Photon Source

real-time collection

tomographic reconstruction

wide-area dissemination

archival storage

desktop & VR clients with shared controls

DOE X-ray grand challenge: ANL, USC/ISI, NIST, U.Chicago
Distributed Supercomputing

- Starting point: SF-Express parallel simulation code
- Globus mechanisms for
  - Resource allocation
  - Distributed startup
  - I/O and configuration
  - Fault detection
- 100K vehicles (2002 goal) using 13 computers, 1386 nodes, 9 sites

SF-Express Distributed Interactive Simulation: Caltech, USC/ISI
Cactus: Solving Einstein’s Equations

- Modular framework for parallel finite-difference simulation codes.
- Solve Einstein’s equations of gravity
- MPI Code
- Winner of Heinz-Billing Prize
Problem solving environment for comp. chemistry

Globus services used for authentication, remote job submission, monitoring, and control

Future: distributed data archive, resource discovery, charging

ECCE’: Pacific Northwest National Laboratory
Where We’re Going…
Emmerging Production Grids

NASA Information Power Grid

PACI Grid
IPG Target: Aeronautic Design
Today’s Information Infrastructure

- **Network-centric**: simple, fixed end systems; few embedded capabilities; few services; no user-level quality of service

O(10^6) nodes
Tomorrow’s Information Infrastructure: Not Just “Faster and More Reliable”

- **Application-centric**: heterogeneous, mobile end-systems; many embedded capabilities; rich services; user-level quality of service

O(10^9) nodes
New Services

Scalable global services
- Do for the grid what routers do for the network

● Wide variety
  - Resource trading, policy enforcement, agent based scheduling, data management services, etc.

● Exploit emerging network services such as QoS.
New Tools

- Rethink the entire program development cycle
- Introduce runtime adaptation as a basic concept
- Smart libraries
New Application (Examples)

- NSF National Earthquake Engineering Center
  - Integrated instrumentation, collaboration, simulation environment
- High-energy Physics Grid (GriPhy)
Grid Forum

- IETF like body to codify standard practice
- Two meetings held so far, next in April
- European Grid forum established to address Europe specific issues
Summary

- Grids will change the way we do science and engineering
- Transition of services and application to production use
- Future will see increases sophistication and scope of services, tools, and applications
Additional Information

- Book published by Morgan Kaufman
  - http://www.mkp.com
- Globus website:
  - http://www.globus.org
- Grid forum website:
  - http://www.gridforum.org