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Applications of Intelligent Agent Technology to the Grid

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Information Sciences Institute
University of Southern California
Globus Alliance

In collaboration with
Nick Jennings & **Ian Foster**

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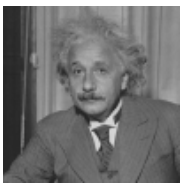
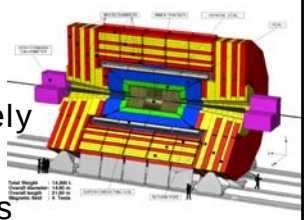
Why the Grid?
Origins: Revolution in Science



- Pre-Internet
  - Theorize &/or experiment, alone or in small teams; publish paper
- Post-Internet
  - Construct and mine large databases of observational or simulation data
  - Develop simulations & analyses
  - Access specialized devices remotely
  - Exchange information within distributed multidisciplinary teams



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Why the Grid?
New Driver: Revolution in Business

- Pre-Internet
  - Central data processing facility
- Post-Internet
  - Enterprise computing is highly distributed, heterogeneous, inter-enterprise (B2B)
  - Business processes increasingly computing- & data-rich
  - Outsourcing becomes feasible → service providers of various sorts
  - Growing complexity & need for more efficient management

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Common Requirements

- Dynamically link resources/services
  - From collaborators, customers, eUtilities, … (members of evolving "virtual organization")
- Into a "virtual computing system"
  - Dynamic, multi-faceted system spanning institutions and industries
  - Configured to meet instantaneous needs, for:
- Multi-faceted QoX for demanding workloads
  - Security, performance, reliability, …

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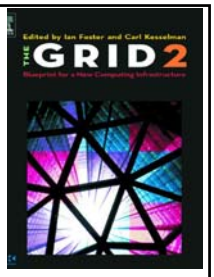
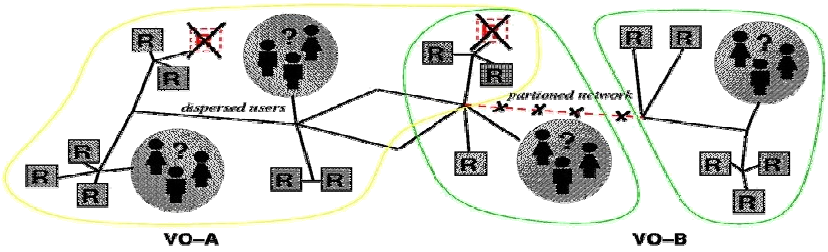
The Grid

"Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations"





1. Enable integration of distributed resources
2. Using general-purpose protocols & infrastructure
3. To achieve better-than-best-effort service

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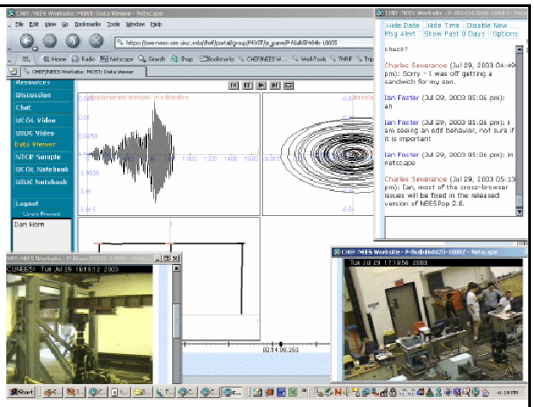
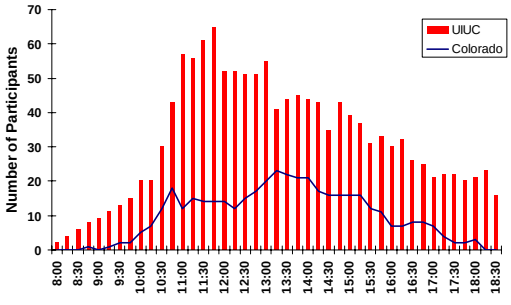
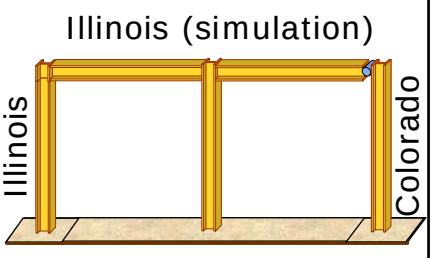
Grid in Practice: Earthquake Engineering Example

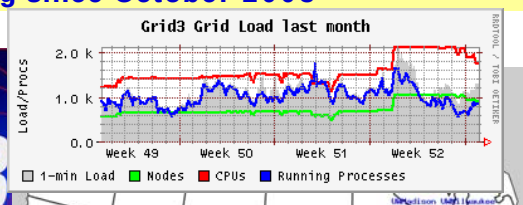






Grid2003: An Operational Grid

- 28 sites (2100-2800 CPUs) & growing
- 400-1300 concurrent jobs
- 7 substantial applications + CS experiments
- Running since October 2003



Korea

http://www.ivdgl.org/grid2003

(Very Small) Example Workflows

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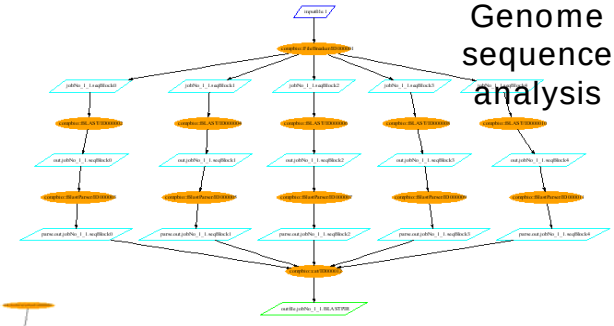
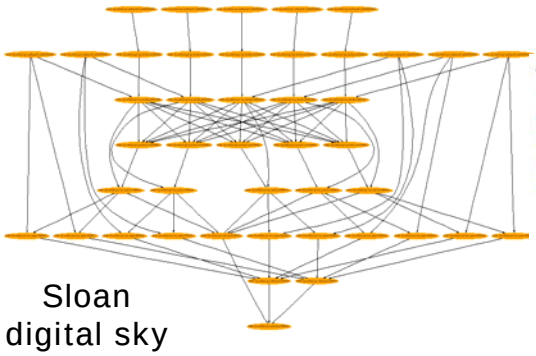
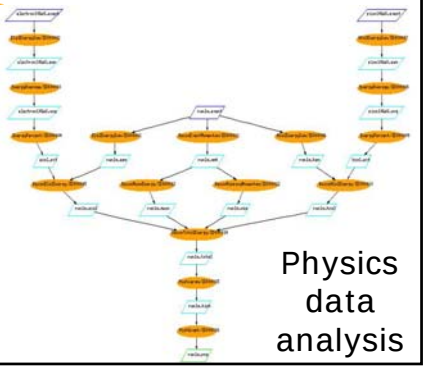


Genome sequence analysis



Sloan digital sky survey



Physics data analysis

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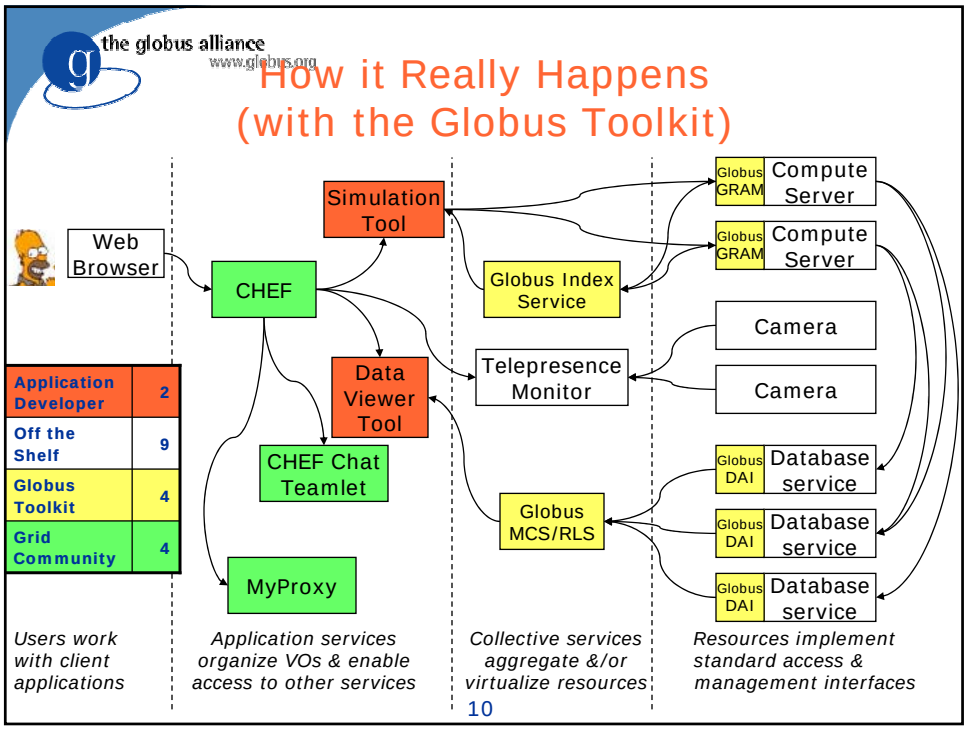
TERAGRID
grid.it project
Grid-Ireland
iVDgL
PPDG
Open Science Grid
INFN GRID
EUROGRID
K*GRID
National Grid NG SINGAPORE
Data GRID
Grid3 2003
ACCESS GRID
NEESgrid
Building the National Virtual Collaboratory for Earthquake Engineering.
grangenet
GRID UK Particle Physics
DataTAG
GriPhyN
Data Intensive Science
CERN
openlab for DataGrid applications
LCG
WestGrid
GridCat
NORDUGRID
Grid Solution for Wide Area Computing and Data Handling
eGee
Enabling Grids for E-science in Europe
APEC APGrid
Asia-Pacific Grid Implementation Project
NAREGI
超高速コンピュータ網形成プロジェクト
National Research Grid Initiative
Grid Applications
Grid Middleware
Networking
国立情報学研究所グリッド研究開発推進拠点 NII -The National Institute of Informatics
GridLab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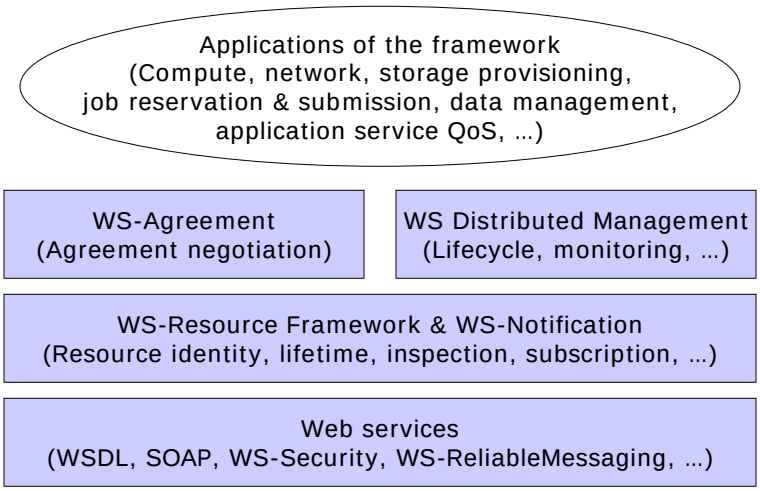
How it Really Happens
(with the Globus Toolkit)
Web Browser
CHEF
Simulation Tool
Globus Index Service
Data Viewer Tool
Telepresence Monitor
CHEF Chat Teamlet
Globus MCS/RLS
MyProxy
Globus GRAM
Compute Server
Globus GRAM
Compute Server
Camera
Camera
Globus DAI
Database service
Globus DAI
Database service
Globus DAI
Database service
Application Developer 2
Off the Shelf 9
Globus Toolkit 4
Grid Community 4
Users work with client applications
Application services organize VOs & enable access to other services
Collective services aggregate &/or virtualize resources
Resources implement standard access & management interfaces
10

WS Core Enables Frameworks: E.g., Resource Management



The Need for Automation: Critical if Grid is to Scale

- Who contributes & gets to consume what?
  - Policy negotiation, enforcement, auditing
- How do I schedule jobs & data movement?
  - Adaptive scheduling
- Who can be trusted to do what?
  - Community membership, reputation, trust negotiation, intrusion detection
- Why do things fail?
  - Failure detection, problem determination, fault isolation, system adaptation

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Virtual Organizations

- VOs play a central role in Grids
  - Widely adopted approach in scientific applns.
- Manually established (acceptable use policy, resource allocation, membership, services available)
- Some infrastructure support (e.g. VO based discovery, membership services)
- More automation needed
  - Need autonomous VO formation

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VO Formation

- Need to:
  - Determine policy (negotiation, trust management)
  - Determining membership and role (coalition formation)
  - Creating VO wide services (global behaviors)
  - Managing work (collaborative problem solving, workflow management)
  - Evolution
- Related to coalition formation (Lesser's talk yesterday)
  - May be driven strictly by policy
    - "Coalition of the willing…."
  - May be driven by contribution or utility to goals
    - e.g. N lowest bidders for a service (Normana, Preecea, et. a.l., 2004),
  - May be dynamic and nested
    - Mapping of workflow to defined agent set
    - Creation of global services

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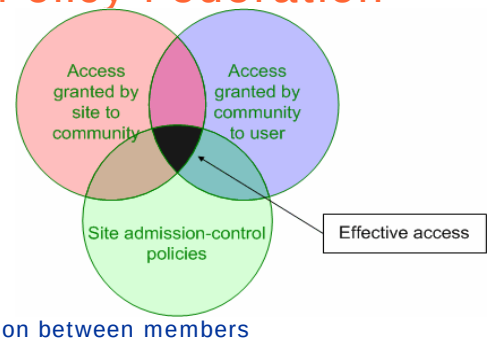
Policy Federation



- Policy negotiation between members
  - Creation of coalition policy (e.g. Ao & Minsky 2003)
- Reasoning about trust
  - Rule based, or logic based decision making (e.g. KAoS ontologies, policy services)
- Application of policy
  - Assignment of role (Sims, Corkill, and Lesser 2004)
  - Learning and adaptation of trust & reputation (Ramchurn, Huynh, Jennings, 2004)

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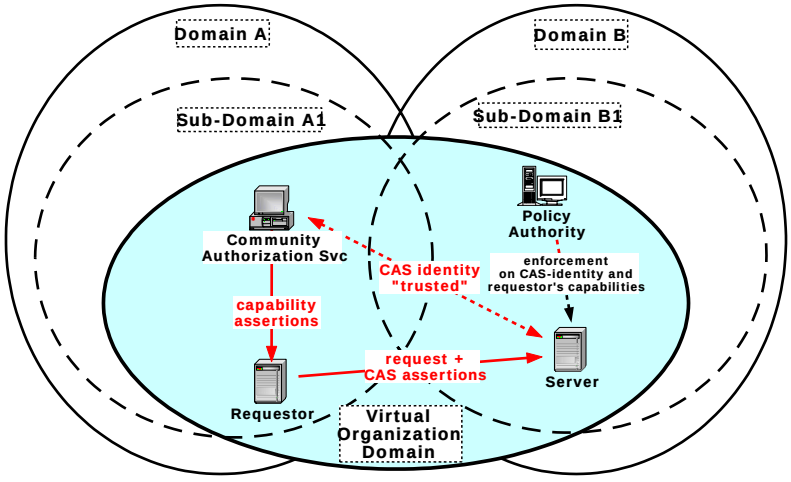
Community Authorization Service



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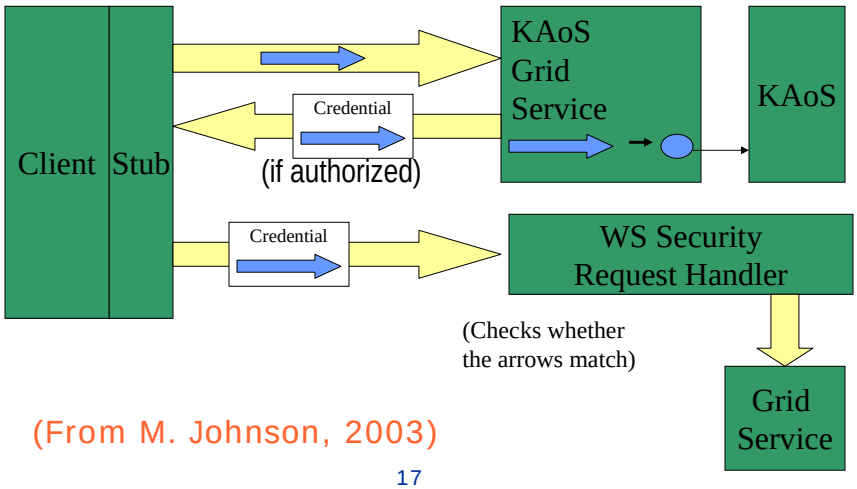
Using KAoS Policy Services

(The arrows represent SOAP messages)



(From M. Johnson, 2003)

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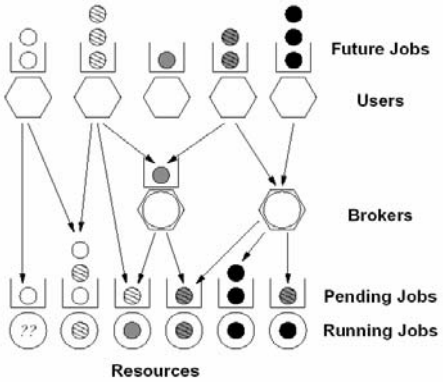
Grid Resource Management



Large number of users utilizing resources either through direct job-submission or through intermediaries (brokers)

Issues of how to:

- identify potential providers
- choose between alternatives

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Resource selection: Matchmaking

- Classified Advertisement (ClassAds) describe:
  - Attributes of consumers & providers
  - Constraints on compatible entities
  - Preference (rank)
- Matchmaker matches compatible ClassAds
  - Symmetric match on attributes & constraints
  - Selection based on ranking function

(Raman, Livny and Solomon 1998)

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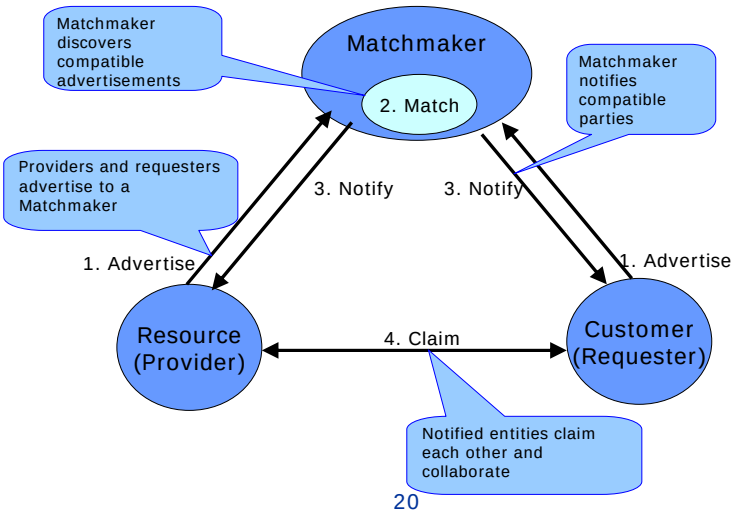
Matchmaking: The Protocol



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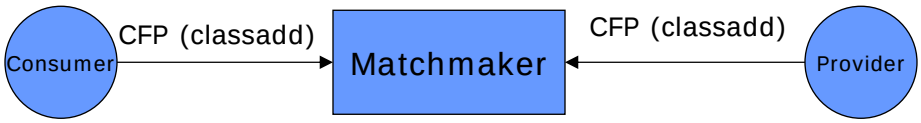
Matchmaking as a Contract Net



- Matchmaker acts as communication hub
- Can apply more sophisticated evaluation criteria
  - Auction, market based, …
- Still need to address claiming protocol
  - Match is only advisory

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How to choose between providers?

- Application driven selection
- Computational economies (e.g. Wolski, Brevik, Plank and Bryan, 2003)
  - Commodities markets
  - Auction markets

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Resource selection through Q-learning

- Agent updates a Q-value after each completed job at that resource
  - $Q_i \leftarrow^{r} Q_i + \alpha(r - Q_i)$ α is the learning rate
  - r is the reward signal:
    $r = 1$ *if* $T_w \leq \langle T_w \rangle$
    $r = -1$ *if* $T_w > \langle T_w \rangle$
- $\langle T_w \rangle$ wait time averaged over all the jobs submitted by the agent
- Resource choosing according to ε-greedy rule

(Galstyan, Czajkowski and Lerman, 2004)

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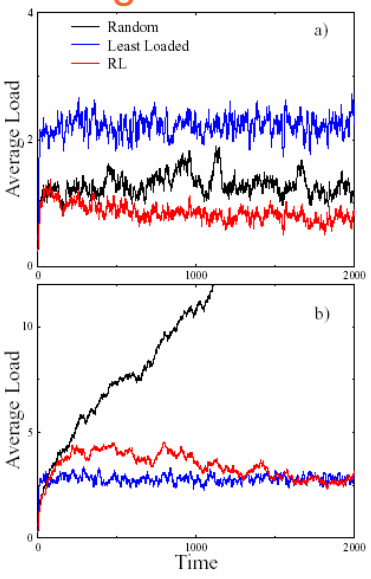
Average Load

Arrival rate P=.15

Arrival rate P=.2



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Creating Agreements

- Require standard framework for driving symmetric, bilateral agreement
- Can be used to render many RM problems
  - Task/job submission, reservations, storage, compute, network provisioning
  - WS-Agreement provides frame
- WS-Agreement provides this
  - Global Grid Forum standard activity (www.ggf.org)

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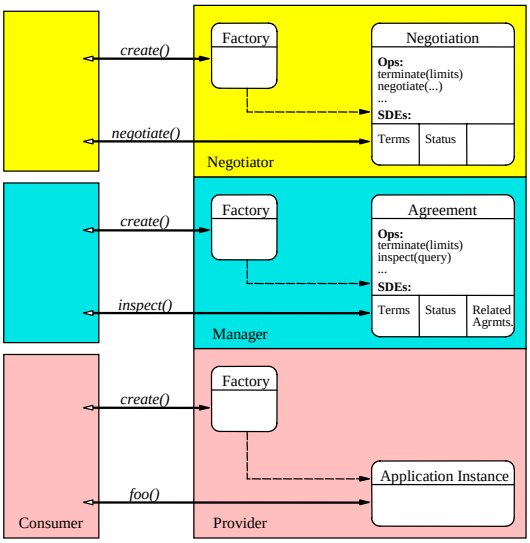
WS-Agreement Conceptual Model



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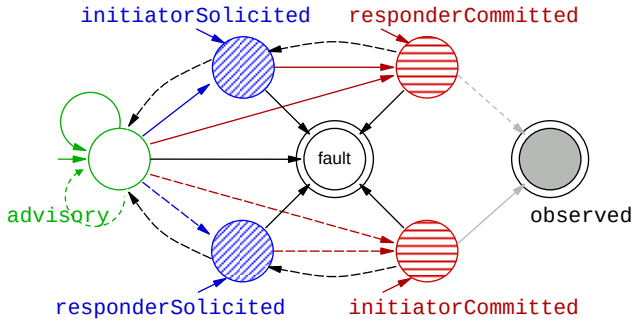
Offer Types and Negotiation State



Complexity due to distributed and faulty nature of system

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WS-Agreement and Negotiation

- Defines an extensible “protocol framework”
  - Standard port types and basic semantics
- Missing pieces:
  - Protocol details: e.g. bi-lateral negotiation, auction, client initiated, server initiated, …
  - Agreement structure, domain specific terms
  - Logic to drive negotiation/agreement
    - Eg, agent based negotiation techniques (Jennings, Faratin, Lomuscio, Parsons, Sierra and Wooldridge 2001)

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Creating VO wide services

- Virtualization creates new service types
- Services by subsetting capabilities,
  - Provisioning
  - hosting
- Services by combining capabilities
  - New functionality
  - Scalable
  - Robust
- Services whose function is distributed especially interesting

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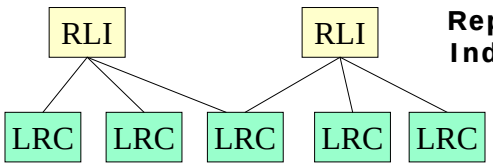
Replica Location Service



Replica Location Indexes (RLI)

Local Replica Catalogs (LRC)

- Distributed registry service for discovery of data replicas
  - Maintains mapping between global and local names
- LRC maintains definitive mapping catalog
- RLI aggregates information from LRCs
  - relaxed consistency of index
- Soft state update with from LRC to RLIs
  - Optional compression of updates reduces overheads
- Membership service identifies LRCs and RLIs

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RLS Design Questions

- How to maintain membership
  - Self organization with adaptation
- How to structure indexes
  - Service structure (where to place indexes, relationship between indexes and catalogs)
- How to distribute logical namespace across indexes
- How to distribute queries across index
- How to structure system for desired scalability, fault-tolerance, performance

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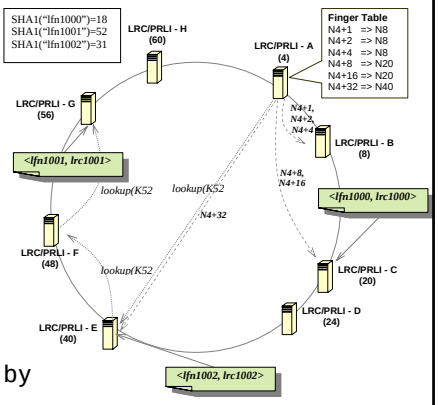
Peer-to-Peer Replica Location Service (P-RLS) Design

- Uses overlay network of the Chord peer-to-peer system to self-organize P-RLS servers
  - Chord is a structured P2P system based on Distributed Hash Tables (DHT)
- A P-RLS server consists of:
  - an unchanged Local Replica Catalog (LRC)
  - a peer-to-peer Replica Location Index node (a P-RLI)
- P-RLI nodes self-organize into a ring topology based on the Chord overlay construction algorithm
  - When P-RLI nodes join or leave, the network topology is repaired by the Chord stabilization algorithm



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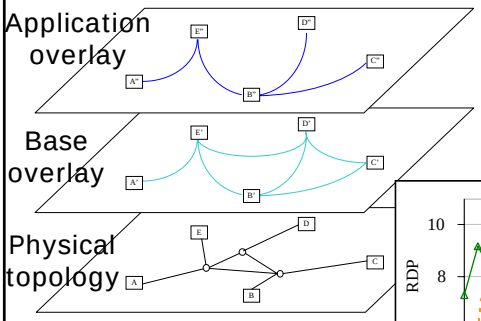
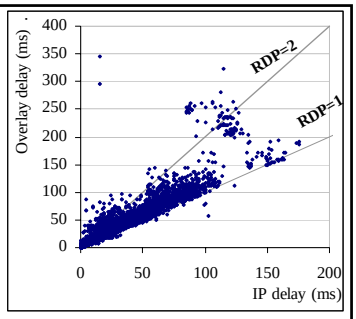
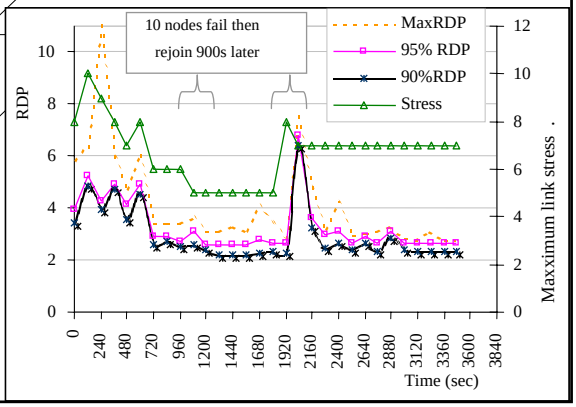
Adaptive Unstructured Multicast







"UMM: A dynamically adaptive, unstructured multicast overlay"
M. Ripeanu et al.

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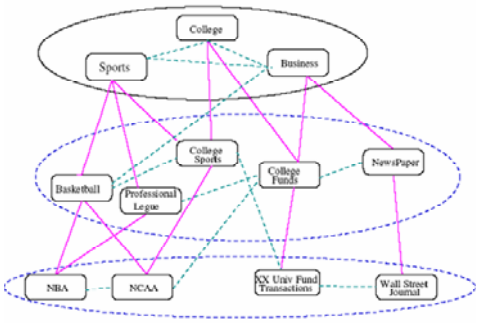
Application of Agents

- Similarity to Agent-based Information Retrieval
- Coalition of indexes
- Distribution of index and catalog function
- Domain optimized, distributed search
  - Dynamic deployment, tasking and configuration



(Zhang & Lesser)

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Summary

- Agents & Grid share a common interest in robust, scalable open distributed systems
- Large-scale scientific and commercial Grid infrastructure being build with expanding applications space
- Many places where agent technology can "drop in"
- Problem perspective and details sometimes different
  - May need to build understanding across communities

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For More Information

- Brain meets brawn: Why Grid and agents need each other, *Proc. 3rd Int. Conf. on Automated Agents and Multi-Agent Systems*
- Globus Alliance
  - www.globus.org
- Global Grid Forum
  - www.ggf.org
- Background information
  - www.isi.edu/~carl
- **GlobusWORLD 2005**
  - **Feb 7-11, Boston**