Rule-Based Distributed Data Management

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Introductory tutorial
Duration half-day
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Abstract:
Data grids are used to assemble shared collections that may be distributed across multiple administrative domains. As the size of the shared collections grows, we observe that the administrative management becomes onerous. A rule-based data system automates the application of management policies. We will present an open-source data grid, iRODS – integrated Rule-Oriented Data System, and describe the concepts on which the rule-oriented system is based. The tutorial will include installation of the software on Mac/Linux PCs, the creation of a shared collection, the dynamic creation of rules for controlling the environment, and the automated application of the rules to assert policies for authenticity and integrity across the shared collection.

Within iRODS, rules control the execution of remote operations, encapsulated as micro-services. Persistent state information is managed to track the outcome of the application of each micro-service. Rules can be created that query the persistent state information, and compare the result against desired management policies. Rules can be executed periodically, automating management tasks such as integrity and authenticity checks. New rules, new micro-services, and new state information can be added in parallel with existing capabilities. This means that the system can evolve over time. One can create rules that control the migration of a shared collection from an old set of rules and micro-services to a new set of rules. Thus it is becoming possible to create a system that controls its own evolution.

In collaboration with digital library, preservation, and cyberinfrastructure communities, a set of standard micro-services has been identified. Rules are now being developed that control the execution of these micro-services. The iRODS environment supports the dynamic creation of new rules that control the composition of the standard micro-services into the desired capabilities. IRODS is intended to support all distributed data management applications.
Detailed Tutorial Description

Data grid concepts

The academic community is implementing data sharing environments that are used to promote collaborative research. The data sharing environments are built on data grid technology, software middleware installed at each site participating in the collaboration. The shared collections are assembled by collaborators residing at multiple institutions. The data grid manages all interactions with the shared data, including access controls, persistent state information, and transport over wide-area-networks. Data grids provide the control mechanisms needed to ensure that the shared data can be identified, accessed and manipulated by only the collaborators and persons they designate. Thus data grids provide both management and control needed to promote research collaborations.

The Storage Resource Broker (SRB) data grid is used to build shared collections out of digital entities that are located at multiple sites across multiple administrative domains. The digital entities may be files, directories, database tables, SQL commands, or URLs. The shared collection organizes the digital entities into collection (or directory) hierarchies. Each digital entity may independently be assigned descriptive metadata attributes. The metadata can be queried to discover relevant data. The data can then be retrieved from the remote site and manipulated within a preferred client interface or web browser.

The SRB provides persistent global name spaces for the names of the digital entities, the curators of the shared collection, the storage resources, and even the metadata attributes associated with each file. The result is an environment in which the files may be moved from site to site without having to worry about the file name changing. Access controls that are set on the files and user-defined metadata remain unchanged as well.

The data grid makes it possible to discover a digital entity without having to know its name or its storage location. The user can retrieve the digital entity through a preferred access mechanism instead of the protocol that the remote storage system understands. It is possible to construct an environment in which all the properties of the shared collection are managed independently of the choice of storage system or database. This capability is called infrastructure independence, and is the essential design feature needed to manage technology evolution. Data grids use infrastructure independence to ensure that data can be uniformly managed with strong access controls, even when the files are distributed across multiple types of storage systems.

Data grids also implement trust virtualization. The data that are written into a remote storage system are owned by the data grid. When a user accesses a data grid, the identity of the user is authenticated. Access controls are checked to verify whether the user is allowed to execute the requested operation. The data grid then performs the desired operation on behalf of the user and returns the result.

As the size of the shared collection increases, the management of integrity and authenticity assertions becomes onerous. Even though administrative commands are provided to verify checksums and synchronize replicas, the execution and monitoring of these tasks can require a full time effort. The iRODS (integrated Rule-Oriented Data System) environment automates the execution of management policies. This requires the ability to express rules that control the execution of remote operations that are encapsulated as micro-services. The state information that is created by each operation is
persistently saved. Rules can be written that examine the persistent state information to validate the successful implementation of management policies. Figure 1 shows how rule-based systems validate assertions about the shared collection.

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Figure 1. Mapping from conserved properties to control mechanisms on remote operations.

A typical data management application (digital library, persistent archive, data grid, or real-time sensor data system) imposes conservation properties on the shared data. Examples include authenticity and integrity for persistent archives, arrangement and indexing for digital libraries, federation for sensor streams, and access controls for data grids. Each property represents an assertion that may change over time as technology and the shared collection evolve. A property that may be true today may no longer be true tomorrow if a remote resource becomes corrupted. Thus the desired properties must be continually verified, with corrective measures taken whenever a problem is identified.

The conserved properties are evaluated as assessment criteria on the shared collection. Each assessment criterion may require multiple management policies to ensure the system behaves correctly. Each management policy may require the execution of multiple capabilities (data replication, data distribution, standard descriptive metadata, synchronization). The management functions define how the system should be managed. Data grid middleware implements the management functions. A desired capability can be expressed as a set of standard micro-services. A management policy can be decomposed into a set of rules controlling the execution of the micro-services. The assessment criteria may be represented by a set of persistent state information. The data management infrastructure provides the mechanisms needed to express, apply, and monitor the management functions.

The iRODS system integrates rule-based control of micro-services with distributed data management. The architecture is shown in Figure 2. A set of rules is selected for managing a particular {collection} for a particular {user} on a particular {storage resource}. A rule engine applies the rule either each time an operation is invoked, or periodically, or at the request of a data grid administrator. Rules can be queued for later execution. Rules can be created to control a set of micro-services and even other rules. Administrative utilities are used to validate consistency of changes to the rule sets.

The iRODS environment is open-source software that can be installed on Mac, Linux, and Solaris systems. The installation takes about 20 minutes. One can then create vaults in which files are stored, create new rules controlling the operation of the shared collection, and distribute files across multiple storage systems.
During the tutorial, each participant will install the software on their Linux or Mac PC, try out the multiple commands for manipulating distributed data, and create and apply new rules. For participants that do not have a Linux PC or Mac, access will be provided to a remote system on which the operations can be performed.

The schedule for the tutorial is:
- 8:30 – 9:15 Data grid concepts
- 9:15 – 9:45 Rule-based data management
- 9:45 – 10:00 IRODS installation
- 10:00 – 10:30 Break
- 10:30 - 11:00 Creation of a shared collection
- 11:00 – 11:30 Dynamic rule creation and execution
- 11:30 – 12:00 Accessing remote storage vaults

The iRODS technology may be downloaded and installed before the tutorial for persons interested in trying out the technology, from the URL http://irods.sdsc.edu. The iRODS software is distributed under a BSD open source license.
Vita:
Reagan Moore is Director of Data Intensive Computing Environments at the San Diego Supercomputer Center. He coordinates research efforts in development of data grids, digital libraries, and persistent archives. Moore is the principal investigator for the development of the Storage Resource Broker data grid technology, which is used to support internationally shared collections, and the iRODS rule-oriented data system. Collaborations using the technology include the NARA research prototype persistent archive, the NHPRC Persistent Archive Testbed, the NSF National Science Digital Library persistent archive, and the California Digital Library – Digital Preservation Repository. Data grids using the technology include the BaBar high energy physics data grid, the Australian Partnership for Advanced Computing, the UK e-Science Data Grid, the National Optical Astronomy Observatory, and the WorldWide Universities Network.

Moore has been at SDSC since its inception in 1986, initially being responsible for operating system development. Prior to that he worked as a computational plasma physicist at General Atomics on equilibrium and stability of toroidal fusion devices. He has a Ph.D. in plasma physics from the University of California, San Diego, (1978) and a B.S. in physics from the California Institute of Technology (1967).

Arcot Rajasekar is the manager of the SRB/iRODS group at the San Diego Supercomputer Center and one of the principal developers of the SRB/iRODS technology. Raja has led the SRB development work for eight years, and has designed and implemented the rule engine used in iRODS. Raja has a PhD from University of Maryland.

Resource Requirements:
We will need a projector for Powerpoint slides, a wireless network that will be capable of connecting to a remote wiki over the Internet, and sufficient table space for each participant to set up a PC. We will need power outlets for each person attending the session.

Relevance to Grid2007
Rule-oriented data systems comprise the technology needed to manage the size of distributed data collections that are now appearing. For example, the Large-scale Synoptic Survey Telescope will acquire and manage 150 Petabytes of images. The images will be moved from Chile to the US using data grid technology, and stored in both archives and an interactive disk cache. The iRODS technology is being developed to manage the data distribution, replication, integrity checks, and authenticity validation at the petabyte scale. Thus rule-oriented data systems are expected to become the dominant data management infrastructure that supports future collaborative research. The proposed tutorial will demonstrate state-of-the-art data management technology, install the technology on each participants PC, and show the extensibility of this approach for automating execution of management policies.