A Taxonomy and Survey of Grid Resource Planning and Reservation Systems for Grid Enabled Analysis Environment

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Abstract

The concept of coupling geographically distributed resources for solving large scale problems is becoming increasingly popular forming what is popularly called grid computing. Management of resources in the Grid environment becomes complex as the resources are geographically distributed, heterogeneous in nature and owned by different individuals and organizations each having their own resource management policies and different access and cost models. There have been many projects that have designed and implemented the resource management systems with a variety of architectures and services. In this paper we have presented the general requirements that a Resource Management system should satisfy. The taxonomy has also been defined based on which survey of resource management systems in different existing Grid projects has been conducted to identify the key areas where these systems lack the desired functionality.

1.0 Introduction

Today, Grid users have to transform their high-level requirement into a workflow of jobs that can be submitted for execution on the Grid. Each job must specify which files contain the code to be run, selected by mapping the high level requirements to available application components and selecting a physical file from the many available replicas of the code in various locations. The job also specifies the location (or host) where it should be run, based on the code requirements (e.g., code is compiled for MPI, parallelized to run on tightly-coupled architecture, preferably with more than 5 nodes) and on user access policies to computing and storage resources. An executable workflow also includes jobs to move input data and application component files to the execution location.

Current Grid management systems allow the discovery of the available resources and data location but the users have to carry out all these steps manually. A resource planning and reservation system is thus required which can automate the whole process of workflow generation.
2.0 Planning and Reservation

Planning and reservation is an important task to be performed by the Grid Resource Management System. Planning and Reservation is the process of analyzing the job and determining the resources required for successful execution of the job. Based on these results resources are reserved seamlessly to the user.

2.1 Requirements for planning and reservation

Resource management is a complex task involving security and fault tolerance along with scheduling. It is the manner in which resources are allocated, assigned, authenticated, authorized, assured, accounted, and audited. Resources include traditional resources like compute cycles, network bandwidth, space or a storage system and also services like data transfer, simulation etc.

Following are the requirements that a Grid RMS (Resource Management System) must satisfy in order to perform resource planning and reservation:

- A Grid RMS needs to schedule and control the resources on any element in the network computing system environment.
- Grid RMS should predict the impact that an application’s request will have on the overall resource pool and quality of service guarantees already given to other applications.
- Grid RMS should preserve site autonomy. Traditional resource management systems work under the assumption that they have complete control on the resource and thus can implement the mechanisms and policies needed for effective use of that resource. But the Grid resources are distributed across separate administrative domains. This results in resource heterogeneity, differences in usage, scheduling policies and security mechanisms.
- Grid RMS must ensure Co-allocation of the resources. Co-allocation is the problem of allocating resources in different sites to an application simultaneously.
- Different administrative domains employ different local resource managements systems like NQE, LSF etc. A grid RMS should be able to interface and interoperate with these local resource management systems.
- In a Grid system resources are added and removed dynamically. Different types of applications with different resource requirements are executed on the Grid. Resource owners set their own resource usage policies and costs. This necessitates a need for negotiation between resource users and resource providers so a grid RMS should enable such negotiation.
- The resource management framework should allow new policies to be incorporated into it
without requiring substantial changes to the existing code.

- The Grid RMS is also responsible for ensuring the integrity of the underlying resource and thus enforces the security of resources. The resource management system must operate in conjunction with a security manager.

3.0 Taxonomy

The taxonomy followed by us is based on the architecture of the planning and reservation system. Based on this taxonomy we have surveyed and classified various grid projects.

Different attributes in the taxonomy aim to differentiate RMS implementations according to the impact on overall Grid system scalability and reliability thus classification of RMS is based on grid type, resource namespace, resource information (discovery, dissemination), scheduling model and scheduling policy.

3.1 Grid Type

Grid systems are classified as Compute, Data and Service grids as shown in figure 2. The computational Grid category denotes the systems that have a higher aggregate computational capacity available for single applications than the capacity of any constituent machine in the system. The major resource managed by GRMS in compute grids is “Compute Cycles”.

In Data Grids the resource management system manages data distributed over geographical locations. Data Grid is for systems that provide an infrastructure for synthesizing new information from data repositories such as digital libraries or Data Warehouses that are distributed in a wide area network. The Service Grid category is for the systems that provide services that are not provided by any single machine. This category is further subdivided in On Demand, Collaborative, and Multimedia Grid Systems.

3.2 Resource Namespace

Resources in a grid are managed and named by the Grid Resource Management System; the naming of resources effects others functions of GRMS like resource discovery, resource dissemination and also affects the structure of the database storing resource information. Different approaches to naming are Relational, Hierarchical and graph based.

A relational namespace divides the resources into relations and uses the concepts from relational databases to indicate relationships between tuples in different relations.

A hierarchical namespace divides the resources in the grid into hierarchies organized around the physical or logical network structure of the grid i.e. it follows a system of systems approach, a name is constructed by traversing down a hierarchy.
In Graph Based Naming resources are linked together and a resource name is constructed by following the links from one object to another.

### 3.3 Resource Information

#### 3.3.1 Resource Dissemination

Resource dissemination is the process of advertising information about resources. The protocols used for dissemination are “periodic” and “on demand”. In periodic resource dissemination the information database is updated periodically so update is not driven by resource status change indeed all changes are batched and updated in information database after specific interval. On Demand protocol updates the resource information database as the change occurs in the status of any of the resource.

#### 3.3.2 Resource Discovery

Resource management system performs resource discovery to obtain information about available resources. There are two approaches to resource discovery namely “agent based” and “query based”. In Agent based approach agents traverse the grid system to gather information about resource availability. In Query Based approach resource information store is queried for resource availability.

### 3.4 Scheduling model

Scheduling model describes how machines involved in resource management make scheduling decisions. Scheduling models normally used are centralized and decentralized; in a centralized model all jobs are submitted to a single machine which is responsible for scheduling them on available resources. The problems with this approach are that the single scheduler will be single point of failure. It will also affect scalability of the grid. In decentralized model there is no central scheduler, scheduling is done by the resource requestors and owners independently. This approach is scalable and suits grid systems. But individual schedulers should cooperate with each other in making scheduling decisions.

### 3.5 Scheduling Policy

Scheduling policy governs how resources are scheduled on the matched resources. In a Grid environment there can be no single global scheduling policy, Different administrative domains may set different resource usage policies, so the RMS should allow for the policies to be added or changed with minimal overhead.

### 4.0 Survey

Resource management in Condor, Globus, Legion, European Data Grid, and Nimrod G has been surveyed, keeping in view the above discussed taxonomy.

#### 4.1 Planning and reservation system in Condor

The main function of Condor [4] is to allow utilization of machines that otherwise would be idle thus solving the wait-while-idle problem. Condor uses Classified Ads (which is a resource specification language) to specify resource requests. Through its unique remote system call capabilities, Condor preserves the job’s originating machine environment on the execution machine,
even if the originating and execution
machines do not share a common file
system and/or user ID scheme. Condor
jobs with a single process are
automatically checkpointed and
migrated between workstations as
needed to ensure eventual completion.

Condor has a centralized scheduling
model. A machine (Central Manager) in
the Condor system is dedicated to
scheduling. Each Condor work station
submits the jobs in its local queue to the
central scheduler which is responsible
for finding suitable resources for the job
execution. The information about
suitable available resources to run the
job (execution machine information) is
returned to the job submission machine.
A shadow process is forked on the
submission machine for each job, which
is responsible for contacting and staging
the job on the execution machine and
monitoring its progress. Condor supports
pre-emption of running jobs, if the
execution machine decides to withdraw
the resources Condor can preempt the
job and schedule it on another machine
thus providing for resource owner
autonomy.

4.2 Planning and reservation system
in Globus

Globus provides software infrastructure
that enables applications to view
distributed heterogeneous computing
resources as a single virtual machine.
The toolkit consists of a set of
components that implement basic
services, such as security, resource
location, resource management, data
management, resource reservation, and
communications.

Planning and reservation system of
Globus consists of resource brokers,
resource co-allocators and resource
manager or GRAM. The resource
requests are specified in extensible
resource specification language (RSL).

Globus offers Grid information services
via an LDAP-based network directory
called Metacomputing Directory
Services (MDS). The Resource Brokers
discover resources by querying the
information service (MDS) for resource
availability. MDS consists of two
components Grid Index Information
service (GIIS) and Grid resource
information service (GRIS). GRIS
provides resource discovery services.
GIIS provides a global view of the
resources by pulling information from
the GIIS’s. Resource information on the
GIIS’s is updated by push dissemination.
Hierarchical name space organization is
followed in Globus for naming resources
and the scheduling model is
decentralized i.e. scheduling is done by
application level schedulers and resource
brokers. Co-allocator takes care of multi-
requests, a multi request is a request
involving resources at multiple sites
which need to be used simultaneously,
and passes each component of the
request to appropriate resource manager
and then provides a means for
manipulating each resultant set of
managers as a whole. The Co-allocation
of resources is done by the DUROC
component of Globus.

The resource manager interacts with
local resource management systems to
actually schedule and execute the jobs.
The implementation of the resource
manager in Globus is called GRAM.
GRAM authenticates the resource
requests and schedules them on the local
resource manager. Each user is associated with a UHE (user hosting environment) on the execution machine. All the jobs from a user are directed to the user’s UHE, which starts up a new Managed Job Factory service (MJFS) instance for every job.

The MJFS communicated with the clients by starting up two instances of File Stream Factory Service (FSFS) for standard input and output. MJFS and FSFS are persistent services.

4.3 Planning and reservation system in Legion

Legion [6] [9] is an operating system for the Grid that offers the infrastructure for Grid computing. Scheduler in Legion has a hierarchical structure. Users or active objects in the system invoke scheduling to run jobs, the higher level scheduler schedules the job on cluster or resource group while the local resource manager for that domain schedules the job on local resources. Scheduling in Legion is done by placing objects on the processors. The resource namespace is graph based.

Information about resources in the grid is stored in database object called a collection. For scalability there could be more than one collection object and collections can send and receive data from each other. Information is obtained from resources either by pull or push mechanism. Users or Schedulers query the collection to obtain resource information.

Legion supports resource reservation and object persistence. When the scheduler object contacts a host object (processor or local resource management system), the host returns a reservation token to the scheduler if the job can be executed on its resources.

Every object is associated with vault object. Vault object holds associated object’s Object Persistent Representation (OPR). This ensures that even if the object fails, it can later be re-constructed from the OPR.

Communication between any two objects goes through the Legion Protocol stack which involves constructing program graphs, making method invocations, checking authorization, assembling or disassembling messages, encrypting, re-transmitting messages etc. This frameworks allows for implicit security and fault-tolerance.

4.5. Planning and reservation system in European Data Grid

EU Data grid was designed to provide distributed scientific communities access to large sets of distributed computational and data resources. The main architecture of the datagrid is layered. The datagrid project develops datagrid services and depends on the Globus toolkit for core middleware services like security. The datagrid services layer consists of workload management services which contain components for distributed scheduling and resource management, Data Management services contains middleware infrastructure for coherently managing information stores and monitoring services provided end-user and administrator access to status information on the grid. The workload management package consists of a user interface, resource broker, job submission service, book keeping and
logging service. A job request from user is expressed in a Job Description Language based on the Classified Ads of Condor. The resource broker (RB) when given a job description tries to find the best match between the job requirements and available resources on the grid, considering also the current distribution of load on the grid. RB interacts with data replication and meta-data information services to obtain information about data location. The information service is LDAP based network directory. Resource discovery is done by queries and employ periodic push for dissemination. Global namespace hierarchical and scheduling is decentralized but instead of having a resource broker for each end-user, each virtual organization is provided resource broker. It does not support advanced reservation or co-allocation of resources. It does not address failures originated by jobs which it simply reports to end user. But the state of the resource broker queues and job submission service queues is persistent and can be recovered fully after a crash.

4.6. Planning and reservation system in Nimrod-G and GRACE

Nimrod-G [7] is a Grid grid-enabled resource management and scheduling system based on the concept of computational economy. It uses the middleware services provided by Globus Toolkit but can also be extended to other middleware services.

Nimrod-G uses the MDS services for resource discovery and GRAM APIs to dispatch jobs over grid resources. The users can specify the deadline by which the results of there experiments are needed. Nimrod-G broker tries to find the cheapest resources available that can do the job and meet the deadline. Nimrod uses both static cost model (stored in a file in the information database) and dynamic cost model (negotiates cost with the resource owner) for resource access cost trade-off with the deadline. GRACE provides middleware services needed by the resource brokers in dynamically trading resources access costs with the resource owners. It co-exists with other middleware systems like Globus. The main components of the GRACE infrastructure are Trade Manager (TM), trading protocols and Trade Server (TS). TM is the GRACE client in the Nimrod-G resource broker that uses the trading protocols to interact with trade servers and negotiate for access to resources at low cost. Trade Server is the resource owner agent that negotiates with resource users and sells access to resources. TS uses pricing algorithms as defined by the resource owner that may be driven by the demand and supply. It also interacts with the accounting system for recording resource usage.

It has an extensible application-oriented scheduling policy and scheduler uses theoretical and history based predictive techniques for state estimation. Scheduler organization is decentralized and the namespace is hierarchical.

5.0. Conclusion

In this paper various issues in resource planning and reservation have been discussed. A taxonomy based on architecture of grid resource management system has been described. Based on this taxonomy a survey of existing planning and reservation
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