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Combination of data replication and scheduling algorithm for improving data availability in Data Grids

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ABSTRACT

Data Grid is a geographically distributed environment that deals with large-scale data-intensive applications. Effective scheduling in Grid can reduce the amount of data transferred among nodes by submitting a job to a node, where most of the requested data files are available. Data replication is another key optimization technique for reducing access latency and managing large data by storing data in a wisely manner. In this paper two algorithms are proposed, first a novel job scheduling algorithm called Combined Scheduling Strategy (CSS) that uses hierarchical scheduling to reduce the search time for an appropriate computing node. It considers the number of jobs waiting in queue, the location of required data for the job and the computing capacity of sites. Second a dynamic data replication strategy, called the Modified Dynamic Hierarchical Replication Algorithm (MDHRA) that improves file access time. This strategy is an enhanced version of Dynamic Hierarchical Replication (DHR) strategy. Data replication should be used wisely because the storage capacity of each Grid site is limited. Thus, it is important to design an effective strategy for the replication replacement. MDHRA replaces replicas based on the last time the replica was requested, number of access, and size of replica. It selects the best replica location from among the many replicas based on response time that can be determined by considering the data transfer time, the storage access latency, the replica requests that waiting in the storage queue and the distance between nodes. The simulation results demonstrate the proposed replication and scheduling strategies give better performance compared to the other algorithms.

1. Introduction

Nowadays, huge amount of data are generated around the world in many fields such as scientific and engineering applications that are shared among researchers globally for further studying. Hence, management of such large distributed data resources becomes more necessary and is a great challenge for researchers. Grid is a solution for this problem. Grid can be divided as two parts, Computational Grid and Data Grid. Computational Grids are used for computationally intensive applications that require small amounts of data. But, Data Grids deals with the applications that require studying and analyzing massive data sets (Balasangameshwara and Raju, 2012; Chervenak et al., 2000; Li and Li, 2009; Folling et al., 2010; Sonmez et al., 2010; Li, 2010). Data Grids aggregate a collection of distributed resources placed in different parts of the world to enable users to share data and resources.

Data replication is an important optimization step to manage large data by replicating data in various sites. Although memory and storage size of computers are increasing every year, they are still not keeping up with the request of storing large number of data. The major challenge is a decision problem i.e. how many replicas should be created and where replicas should be stored. Hence new methods are needed to create replicas that increase availability without using unnecessary storage and bandwidth. In other words, since maintaining a large number of replicas in Grid system are expensive, therefore the number of data copies should be bounded. Obviously, optimizing access cost of data requests and reducing the cost of replication are two conflicting goals, so finding a good balance between them is an important task. Each grid site has its own capabilities and characteristics; so, choosing appropriate site from many sites that have the required data is an important decision.

In Data Grid reducing job's turnaround time (waiting time in queue, execution time and data transfer time) depends on where

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to assign job for execution and where to get the required data files. Therefore, from scheduling point of view, assigning jobs to proper site (i.e. proper site is a site that has minimum cost of running a job) and getting replicas from proper sites (i.e. proper site which has the minimum response time) are some of the important factors to consider. Since each job before execution requires many data files, data locality has an important role in any scheduling decision. If a job is dispatched to a site where required data are available, there would be no data transfer time. Other factors such as CPU workload, features of computational capability, network load, resource utilization and response time also play an important role in job scheduling, hence schedulers have a difficult task.

In this paper two algorithms are proposed, first a novel job scheduling algorithm called Combined Scheduling Strategy (CSS). Searching the best site from a large number of distributed sites would lead to long latency. CSS uses a hierarchical grid structure and minimize the overhead of searching for the suitable site. It is a two-step decision process. The first step selects a best region i.e. best region that has most of the requested files of job (from size point of view). Second, Combined Cost for each site within best region is computed and the job will be assigned to the site with minimum Combined Cost. The Combined Cost is calculated by considering three parameters: the requested files of job (from size point of view), the number of jobs waiting in queue and computing capacity of sites. This will significantly reduce total transfer time, and reduce the job execution time.

Second a dynamic data replication strategy, called Modified Dynamic Hierarchical Replication Algorithm (MDHRA) that improves file access time. This strategy is an enhanced version of Dynamic Hierarchical Replication strategy (Mansouri and Dastghaibyfard, 2012). According to the previous works, although DHR makes some improvements in some metrics of performance like mean job time, it shows two deficiencies

(1) In replica replacement step using LRU strategy and bandwidth parameter may delete some valuable files that may not be available in local region and may be needed in future. Therefore, such deletions will result in a high cost of transfer.
MDHRA strategy keeps only the valuable replicas while the other less important replicas are replaced with more important replicas. So, a large number of replica requests can be served locally. MDHRA deletes files in two steps when free space is not enough for the new replica: First, it deletes those files with minimum time for transferring (i.e. only files that are exist in local LAN and local region). Second, if space is still insufficient then it uses three important factors into replacement decision: the last time the replica was requested, number of access, and file size of replica. The number of access in addition to the last time the replica was requested give an indication of the probability of requesting the replica again. Since the storage space is an important issue in the Data Grid, the size of replica is also a valuable parameter in deciding if the replica should be stored.
(2) In replica selection step the transfer time and number of requests are considered to predict the response time, these factors are not sufficient.
Replica selection is the process to choose best replica location from among the many replicas based on response time. The response time is a key parameter that influences the replica selection and thus the job turnaround time. MDHRA strategy selects the best replica location for the users' running jobs by considering new parameters besides the data transfer time, namely, the storage access latency, waiting time in the storage queue and distance between nodes.
Typically, the operating system dispatches the I/O requests in order to improve system performance. Scheduling can be implemented by keeping a queue of requests for the storage device. Thus, the storage media speed and the number of requests in queue has an influence on the average response time experienced by applications. So, the storage access latency is the delayed time for the storage media to perform the requests and this delayed time depends on the file size and storage type.
The proposed algorithm is implemented by using a Data Grid simulator, OptorSim developed by European Data Grid project. The simulation results show that our proposed algorithm has better performance in comparison with other algorithms in terms of job execution time, effective network usage and storage resource usage.
The rest of the paper is organized as follows: Section 2 presents some examples motivating Data Grid use. In Section 3 the classification of data replication strategies is briefly explained. Section 4 explains some advantages of data replication strategies. The scheduling problem is explained in Section 5. Section 6 gives an overview of pervious work on data replication and job scheduling in Data Grid. Section 7 presents the novel data replication and job scheduling strategies. We show and analyze the simulation results in Section 8. Finally, Section 9 concludes the paper and suggests some directions for future work.

2. Motivation

Nowadays large volume data are generated in many fields like scientific experiments and engineering applications. The distributed analysis of these amounts of data and their dissemination among researchers located over a wide geographical area needs important techniques such as Data Grid. For example, the high-energy physics experiment requires a lot of analyses on huge amounts of data sets. CERN is the world's largest particle physics center (CERN). The LHC (Large Hadron Collider) at CERN started to work in 2007. The volume of data sets produced by the LHC is about 10 PB a year. CERN has used the Grid technique to solve this challenging huge data storage and computing problem.

Climate models are important to find climate changes and they are improved after today's models are completely analyzed (Thuy et al., 2007). Climate models require large computing capability and there are only a few sites world-wide that are appropriate for executing these models. Climate scientists are distributed all over the world and they test the model data. Now, model analysis is done by transferring the data of interest from the computer modeling site to the climate scientist's organization for different post-simulation analysis tasks. The effective data distribution method is necessary to the climate science when the data volume is large.

The Biomedical application field (Montagnat and Duque, 2002) wants to use the Grid to help the archiving of biological objects and medical images in distributed databases, communications between hospitals and medical organization and to present distributed access to the data. Hence, data movement is essential.

The Earth observation application area investigates the nature of the planet's surface and atmosphere. One application of Grid technique is for the analyzing and validation of ozone profiles. The processed data sets is scattered to other places worldwide. Use cases for Earth observation science applications are explained in more detail in (Work Package, 2002).

The Human Genome Project (Human Genome Project) produces detailed genetic and physical maps of the human genome. The project requires advanced means of making novel scientific information widely available to researchers so that the results may be used for the public good. A Data Grid consists of a group of geographically distributed computational and storage resources