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DR^2: A Two-Stage Dynamic Replication Strategy for Data Grid

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***Abstract*— One major challenge in data grids is how to provide good and timely access to huge amount of data in distributed locations, given the high latency of interconnection networks. Dynamic replication strategies are regarded as one of the major optimization technique for reducing access latency. In addition to reducing data access time, replication also aims to use network and storage resource efficiently. Some strategies for data replication have previously been proposed, but they assumed unlimited storage for replicas. In this paper, we propose a two-stage dynamic replication strategy to provide an integrated environment for efficient access to data. Simulation results demonstrate that DR^2 maintains a balance between improvement in data access time and storage resource usage.**

***Index Terms*— Data Grid, Replication Strategy, Mean Job Time, Access Pattern**

I. INTRODUCTION

Data Grids systems are evolving as prominent platforms of choice for many scientific disciplines [1][2][4]. The idea behind data grids, that of integrating the different providers together into one virtual system, results in increased capacity as well as lower energy costs. However, such systems have different constraints and requirements to those of traditional high performance computing systems, such as heterogeneous computing resources and considerable communication delays.

Dynamic replication strategies are regarded as one of the major optimization technique for reducing access latency. Replication technique is one of the major factors affecting the performance of data grids. Dynamic replication strategies [6] [7] adapt to changes of data request, bandwidth and storage availability, create replica on new node or delete the replica dynamically. Every dynamic replication strategy would be faced with three fundamental questions that must be answered: When should the replication is created? Which files should be replicated? Where the replicas should be placed? Data replication not only reduces access costs, but also increases data availability in many applications. However, maintaining a large number of data copies in grid systems are expensive, and therefore, the number of replicas should be bounded. Clearly, optimizing access cost of data requests and reducing the cost of replication are two conflicting goals, so finding a good balance between them is a challenging task.

A two-stage dynamic replication algorithm is proposed in this paper. In the first stage, a decision regarding creation of replica is made and accordingly the selection of best network link from local node to the nodes containing other replicas of same file is carried out in second stage.

II. RELATED WORK

An initial work on dynamic data replication in grid was done by [9] proposing six replication strategies: No Replication, Best Client, Cascading, Plain Cascading, Cascading plus Caching and Fast Spread. The analysis reveals that among all these, Fast Spread shows a relatively consistent performance through various access patterns. In [14], a replica scheme based on the economical-model has been proposed. The authors use an auction protocol to make the replica decision for long-term optimization. The authors show the scheme outperforms other replica strategies with sequential file access patterns. Various dynamic replication strategies within a simulated grid environment are discussed in [3] [6] [8] and their combination with scheduling algorithms are studied in [5][9][10]. The performance comparison of a centralized and distributed dynamic replication algorithm in combination with different grid scheduling heuristics, Shortest Turnaround Time (STT), Least Relative load (LRL) and DP (Data Present) is presented in [11]. [12] Developed the Hierarchical Cluster Scheduling (HCS) algorithm and the Hierarchical Replication Strategy (HRS), which maximize the required data in a region in order to fetch replicas faster. [13] Demonstrates a closely related work in terms of utility based replication model, which makes buying or replacement decision based on utility model.

III. DR^2 (TWO-STAGE DYNAMIC REPLICATION) STRATEGY

The data grid model used is similar to OptorSim architecture as presented in Fig.1. A Resource Broker (RB) handles the scheduling of jobs to grid sites, where they run on CE. Each site handles its file content with a Replica Manager (RM), within which a Replica Optimizer (RO) contains replica algorithm and control file replication according to proposed algorithm.

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Dynamic replication algorithm is implemented in two stages.

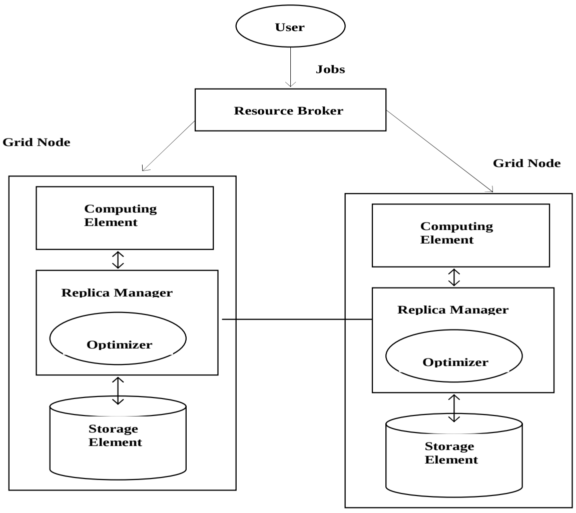

Figure 1. The Conceptual View of Data Grid Model

In the first stage, a decision regarding creation of replica is made and accordingly the selection of best network link from local node to the nodes containing other replicas of same file is carried out in second stage. The 2-stagee replica algorithm can be summarized as follows:

Stage-1:

Step1. The decentralized RM maintains a summarized access record for every file F in data grid for a certain period of time τ .

Let $\eta_{\tau}(F)$: Number of times file F is accessed during τ .

$N_{\tau}(F)$: Number of Replicas of $F(R_F)$ during τ .

Step2. Determine the average amount of data accessed in τ .

$$D_{avg}(\tau) = \frac{\sum_{i=1}^{T_f} \left(\eta_{\tau}(F) \times |F|\right)}{T_f}$$, where T_f is total number of unique file in data grid during τ . The average amount of data accessed is used as a metric rather than average access frequency of a file, since the resources such as network bandwidth and memory largely depends on file's size. So a large file with more access time is a suitable candidate for replication as compared to a small file that is accessed several times.

Step3. Calculate the amount of data accessed for file F in time period τ as:

$$D_F(\tau) = \eta_{\tau}(F) \times |F|$$

Step4. If $\frac{D_{avg}(\tau)}{D_F(\tau)} \rangle N_{\tau}(F)$, create another R_F and enters Phase-2. Otherwise exit.

Stage-2:

Step1. Let Ξ_F is the set of nodes containing R_F . Find $\forall_{i \in \Xi_F} H_i$, where H_i refers to the minimum hop from local node to other node i having replica of this data file.

Step2. Determine $\forall_{i \in \Xi_F} B_i$, where B_i refers to the maximum available bandwidth from local node to other node i having replica of this data file.

Step3. Node k satisfying condition $\min_{i=1}^{|\Xi_F|} \left(\frac{H_i}{B_i}\right)$ is selected for transfer of R_F to local node. Once a replica is created and source node for transfer of replica is selected then LRU is used as a replacement strategy.

IV. SIMULATION RESULTS

In order to evaluate the performance of proposed DR^2, OptorSim tool is used for data grid topology shown in Fig.2. Table 1 show the parameters used in simulation experiment. The parameters to be varied are number of jobs. We ran a simulation at five levels of workloads-100 jobs, 200 jobs, 300 jobs, 400 jobs and 500 jobs.

Table 1: Grid and Job Configuration

Parameter	Value
Nodes with Computing Element (CE)	9
Storage at Nodes with CE	20 GB
Storage at Nodes without CE	30 GB-80GB
Size of Single File	1 GB
Number of Files	70
Number of File Access per Job	12-25
Access Pattern	Zipf Based
Zipf Distribution Shape	0.85
Number of Job Type	4
Number of Jobs	100,200,300,400,500

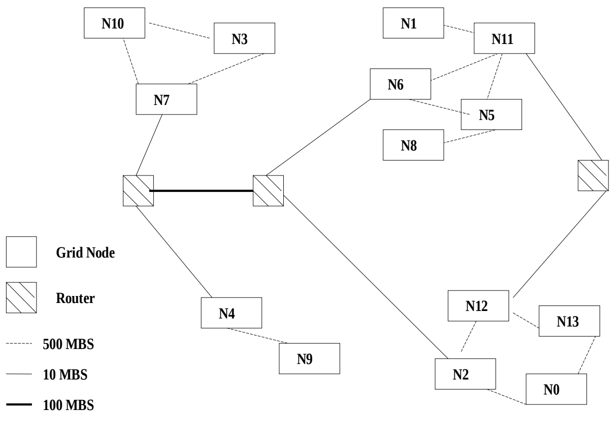

Figure 2. Data Grid Topology

We ran a simulation at five levels of workloads-100 jobs, 200 jobs, 300 jobs, 400 jobs and 500 jobs. The DR^2 strategy is tested to measure its performance against LRU replica placement strategy. The replication strategies are compared on the basis of mean response time, number of replicas generated and percentage of storage usage. The scheduling strategy set up for this test is combination of file access cost and job queue access cost strategy.

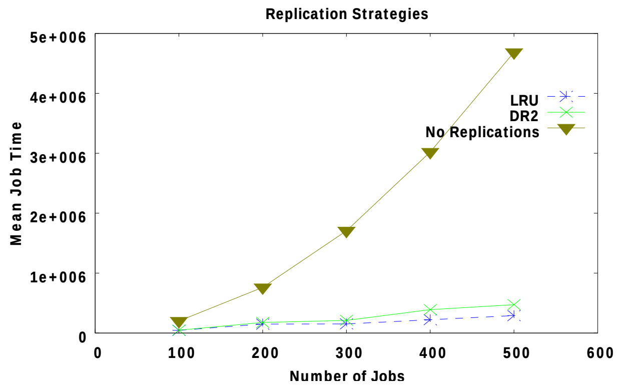

Figure 3. Mean Job Time with Zipf based Access Pattern

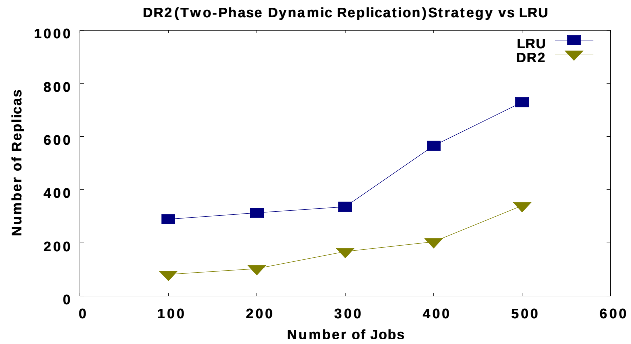

Figure 4. Replication Frequency

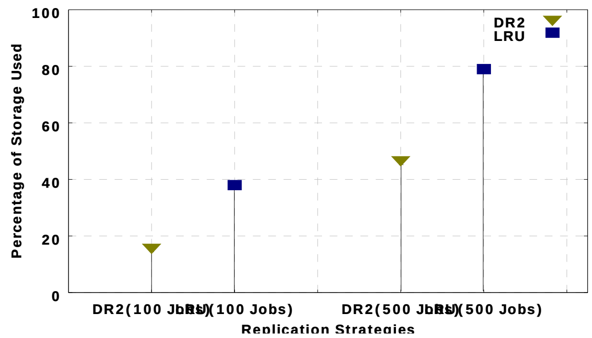

Figure 5. Storage Usage

From Fig.3, we can infer that performance of LRU is better than our proposed replication strategy, but the increase in mean job time is marginal even in heavily loaded data grids. Fig.4 shows that DR^2 strategy results in less replica creation, it is due to fact that the proposed strategy creates replicas on the basis of access load. The storage usage in case of DR2 is smaller than LRU as shown in Fig.5. So DR2 achieves the performance almost near as LRU in terms of mean job time and also makes a more economic usage of data grid storage.

V. CONCLUSION

In this paper we propose a two-stage dynamic replication strategy for data grid environment. The creation of replicas is made on the access load. For all tested data , DR^2 (Two-Stage Dynamic Replication Strategy) maintains a balance between improvement in data access time and storage resource usage due to less number of replicas creation. With DR^2 we can get favorable mean response time even when the storage capacity available in data grid is small. As a part of our future work, we plan to evaluate our strategy with more replication algorithms.

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