Taxonomy of Optimization Approaches of Resource Brokers in Data Grids

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Abstract

In this paper we look at approaches where grid resources are acquired and their selection strategies are studied. The aim of the study is to determine the common concepts and observe their performance.

Keywords: Data grids; Replica selection Broker ; Selection technique; Resource Broker

1. Introduction

Resource Broker is a decision making tool that determines how and when to acquire grid services and resources for higher level components. Several Brokers with various replica selection strategies are proposed and developed by different commercial companies and academic research groups.

In the last few years there were two directions followed by researchers to reduce the execution time for Data Grid jobs. The first approach focused on reducing the time of selecting the best replica site, however, researchers proposed different selection strategies which have been used by Replica Optimization Service Broker to enhance the selection process [2]. The second approach aims to exploit rate differences among various computing site and replica provider links and also to address dynamic rate fluctuations by dividing files into multiple blocks of equal sizes to improve the performance of data transfer in Data Grids [12]. It is focused on dividing files into multiple parts, then co-allocation architecture is used to enable parallel downloading of data sets from multiple replica provider servers.

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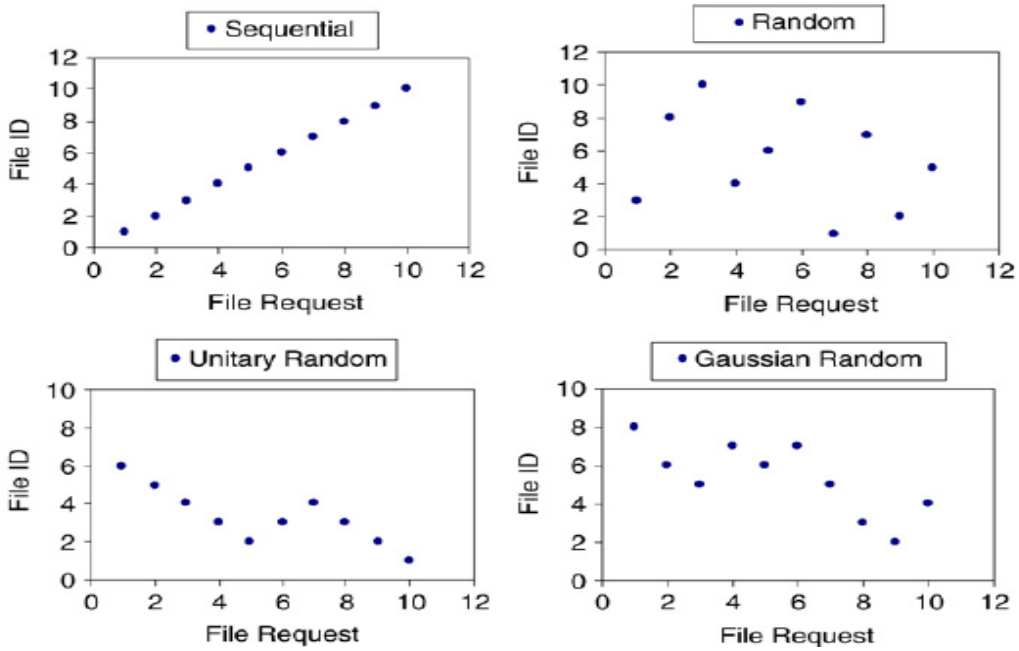

Figure 1: Various file access patterns [3]

2. History of selection strategies

This section is about to present some selection strategies which are proposed in the literature to improve the performance of a Resource Broker.

R. M. Almuttairi et al. [1] a novel replica selection Broker is proposed to reduce the total execution time of Data Grid job by selecting a set of uncongested network links of replica providers and the providers in the selected set have a close match to the user/application requirements.

J. Gwertzman and M. Seltzer [27] and J. Guyton and M. Schwartz [30] proposed replica selection approaches based on binding a client to the nearest replica, with respect to some static metric such as the geographical distance in miles and the topological distance in number of hops [31]. However, as several experimental results [15, 25] show, the static metrics are not good predictors for the expected response time of client requests. The main drawback of both geographical and topological network metrics is that they ignore the network path's dynamic conditions.

From a different focus, R. Kavitha, and I. Foster [28], used traditional replica catalog based model; for each new request Replica Location Service is queried to get the

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addresses of replica's sites and then probe the network link using HopCount method to select the best replica. The drawback of this approach is that it depends on the number of hops that may not recent the actual network condition such as Network Bandwidth and link's latency.

On the other hand, Sudharshan et al. [22, 5, 20] contributed in many research results. In their work they used the history of previous file transfer information to predict the best site holding a copy of the requested file. When a file transfer has been made between two sites, the file size, the available network bandwidth, and transfer time are saved. Thus it can be used later for training and testing the regression model to predict the actual transfer time. In their work they showed that data from various sources can help in better predictions than data from one source. They achieved a better accuracy in file transfer throughput prediction by using data from all of these three sources: network data streams, file size, and past grid transfer information.

Several heuristic data replication schemes have been proposed in the literature [33, 17, 18, 34, 35, 36]. A dynamic replication scheme was proposed based on a variety Vickery auction for an economy based replication solution which is discussed in [17].

F. Corina and M. Mesaac [23] and Ceryen and M. Kevin [17] used different algorithms such as greedy, random, partitioned and weight algorithms in the selection engine.

Rashedur et al. [6] exploited a replica selection technique with the K-Nearest Neighbor (KNN) rule used to select the best replica from the information gathered locally. The KNN rule selects the best replica for a file by considering previous file transfer logs indicating the history of the file and those similar. The technique has a drawback as they mentioned in their paper: the misclassification will increase in case of the large file transfer and will cost more than a couple of small file transfer misclassifications. Especially in the Gaussian random access pattern the accuracy is the lowest. Another drawback in KNN is that one needs to save all previous instances (file requests) to use them to select the best replica site, which means it will take some time to search in the large history of Database and the result might or might not be correct.

H. Lin, et al [2] have explored the effectiveness of economy-based resource management in Data Grids and proposed a policy for a data replication Broker that improved replication. An economic data resource management system was shown to perform with marked improvements when using a variable pricing scheme that is based on the expected actions of a rational agent compared to a fixed pricing scheme. The policy displayed an effective means of improving the performance of the grid network traffic and was indicated by the improvement of speed and cost of transfers by Brokers.

Rashedur et al. [6] proposed a Neural Network (NN) predictive technique to estimate the transfer time between sites. The predicted transfer time can be used as an estimate to select the best replica site among different sites. Simulation results demonstrate that Neural Network predictive technique works more accurately than the multi-regression model, which was used before NN [22, 20, 5]. Nevertheless, NN technique does not always give the right decision because the copy of the file may no longer be available

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in the predicted site (this is a common occurrence in grid), so in this case the Traditional Model has to be used.

A. Jaradat et al. [9] proposed a new approach that utilizes availability, security and time as selection criteria between different replicas, by adopting K-means clustering algorithm concepts to create a balanced (best) solution. The best site does not mean the site with shortest time of file transfer, but the site which has three accepted values: security level, availability and time of file transfer. The problem of using K-means is: the selection is being trapped in local clustering centroids. The problem of finding an optimal replica allocation at a given state of the grid, i.e. an allocation that has minimum transfer cost for a given read-write pattern, has been shown to be NP-complete by Ouri Wolfson and Amir Milo [29].

Vazkhudai et al. [21, 5] show that disk I/O effects on the transfer time in Grid environment so, all these criterion can be used during the selection process. All previous strategies were looking for finding the best single replica site using different approaches. By not assessing the quality of service one receives from a provider, the consumer cannot be considered completely economically rational. From an economic perspective this blind side to quality of service allows for lower quality services to be offered at lower costs { slowly forcing a global reduction in grid service quality over a time as higher quality services become ignored and unprofitable.

3. Drawbacks of the selection Methods

Here a brief drawbacks of previous selection strategies are listed:

1. History file is used in K-Nearest Neighbor rule (KNN) method, it does not react the recent information; it is outdated information
2. Bandwidth alone and Hop counts alone are used in Traditional Method (TM), Neural Network (NN) and KNN methods, each might not describe the real network condition
3. In the classification method, the misclassification will increase in case of transferring large files and using a Gaussian Random file access pattern as it is shown in Figure 1. None of the previous methods reflect the real information of network links and, all previous strategies were looking for finding the best *single* replica site but with different approaches. To overcome these drawbacks, some of alternative Replica Selection Strategies and Brokers are proposed by researchers.

4. Taxonomy of Replica Selection Strategies

Figure. 2. explains the taxonomy of replica selection techniques which are used in the management system of replica selection process in Data Grids.

Replica *Optimization Service* ROS is an internal service component of the Replica Management Services used as a selection service [2]. It is classified into three types which are:

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- **Scheduling Optimization:** Using long-term scheduling strategy, ROS is used to allocate the job site by considering suitability of the location of replicas and the computational capabilities of the sites.
- **Short-term Optimization:** When a job requests a file, the ROS is used to find the best replica on the Grid in terms of the cost of transferring the file to the local site where the job is running. It improves the decision of choosing the location from which replicas are fetched by considering available network bandwidth between sites.
- **Long-term Optimization:** Using long-term data access patterns, the ROS can create and delete replicas anywhere on the Grid according to its predictions of file usage across the Grid. Here, ROS decides which file should be retained as a replica [26].

As we mentioned, selection problem has been investigated by many researchers. The research work is divided into two aspects: first was related to enhancement of the replica selection strategy. Second aspect is related to enhancing the file transfer strategy [2].

The objective of the first aspect is to enhance selecting process by new methods which select set of replica servers instead of one [1]. However, The objective of the second aspect is to exploit rate differences among various client-server links and to address dynamic rate fluctuations by dividing files into multiple blocks of equal sizes to improve the performance of data transfer in Data Grids [12].

To optimize job in such a way that satisfy the requirement of the Data Grid's user/application, replicas selection strategies provide the best single replica site or the best set of replicas (*M:* number of replica sites). However, Replica Selection services are classified according to how many providers could be selected simultaneously while applying replica selection strategy. There are two types which are:

- **A Single replica provider:** To determine the best replica provider site among all available replica sites. This is just a single site with no other fall back options or ranking of other sites
- **Multiple replica providers:** To determine multiple replica sites among all available replica provider sites. The **Link Analyzes** by **Association Rules** is used to find the hidden relationships of network links of replica providers [16].

In both of above methods, the total execution time and the total cost (price) of obtaining a replica (file) are the most important factors required by a user/application. However, the requirements of any data grid user/application can be described through:

- **Minimizing (reducing) Cost:** The selection strategy selects the cheapest replica to be the best replica site using the answer from auction protocol [1]
- **Minimizing (reducing) Time:** The selection strategy attempts to reduce the total job execution time in different ways such as reducing look up time, reducing searching time or reducing transmission time.
- **Minimizing both:** The selection strategy reduces cost and time such that the answer from selection strategy is used in the economy-based data replication Broker [2

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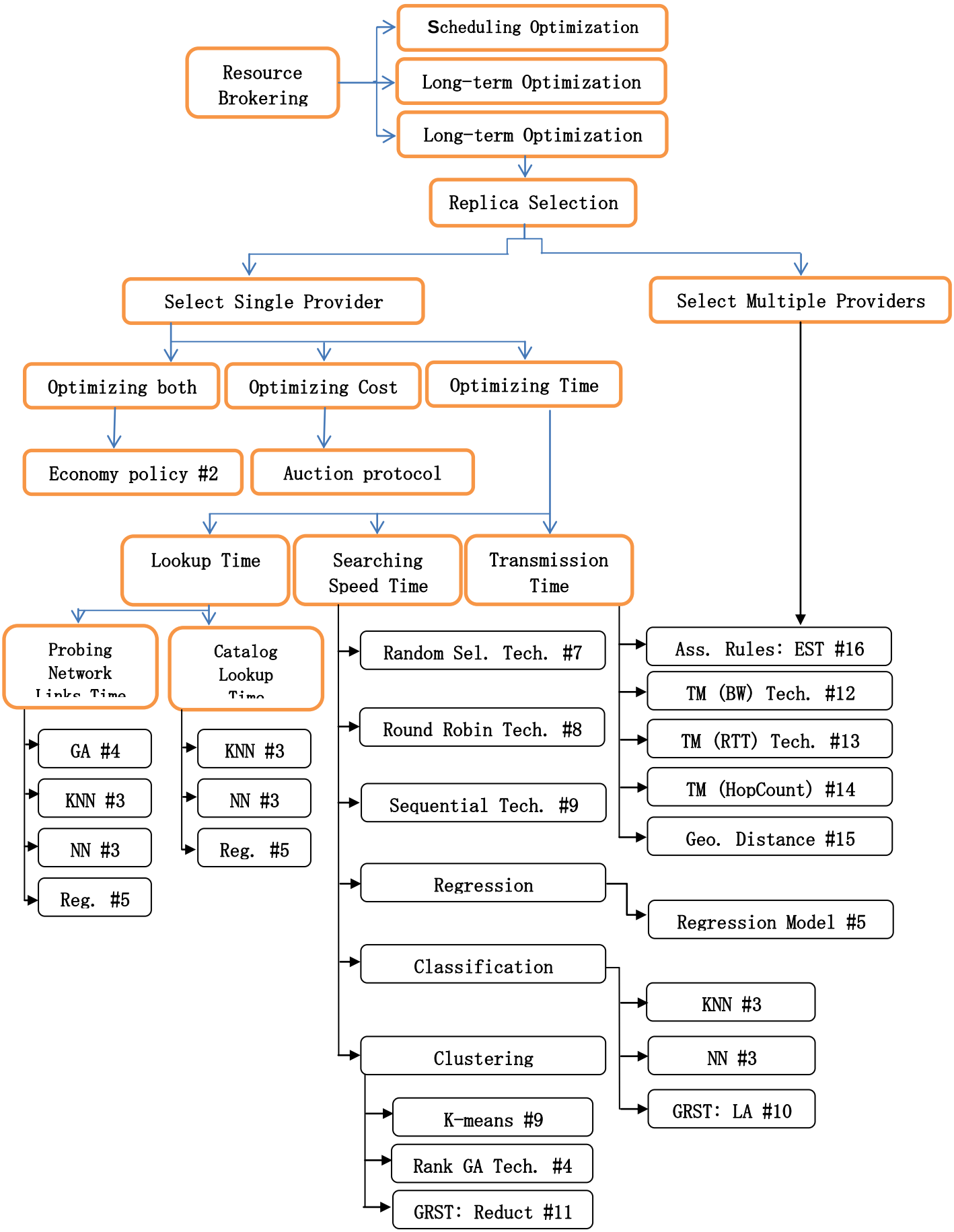

Figure 2: A Replica Selection Taxonomy

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According to reduce the total execution time, the selection strategies of previous works are classified into three types according to the time period they wanted to minimize. The previous strategies had aimed to:

1. **Reducing the lookup time:** Usually most of selection approaches, minimize total execution time by minimizing time of replicas selection process. This can be done by reducing catalog lookup time and probing network links time. It is done either by using a classification technique such as K-Nearest Neighbor rules [6] or predictive technique like Neural Network techniques [3] or Genetic algorithm technique [4]. All these methods attempt to avoid lookup time during predicting the total transferring time. All tried to enhance the traditional models which used the catalog look up time
2. **Reducing data transmission time:** This is to reduce the total time of file transfer, various selection methods were used such as, selection of the highest bandwidth among replicas or the shortest round trip time link, or the least number of hops (routers), or the shortest geographical distance. Recently association rules mining is also proposed by us [19]
3. **Reducing the searching time:** In this process to get list of providers, the catalog must be looked up. That means, the catalog lookup time cannot be ignored. The searching time is the time that is consumed to find the replica provider who has the closest match to the user/application requirements. This cost of *time* can be minimized by various selection strategies as researchers worked on, which are:

    a) **Random selection:** The best replica is chosen randomly [7]
    b) **Round Robin:** Round robin method is used for the selection process [8]
    c) **Sequential searching method:** Sequential Method is used for the selection process [9]. These methods can be used in case of equality of the replica's attributes where Euclidean distance equation can be sequentially used to find the shortest distance between the user requirement and the list of replicas.
    d) **Classification Modeling:** Used to classify the replicas using the history information to select the best one such as K-Nearest Neighbor rules [6].
    e) **Predictive Modeling:** Used to predict the best replica depending on the history sa78i8ewsaz information such as regression [5] or Neural Network techniques [6].
    f) **Database Segmentation/ Clustering:** In this method the replicas are grouped into different clusters, the replicas within a cluster have similar characteristics so the distance between two replicas in a cluster is smaller than between two replicas belonging to different clusters. These approaches used different clustering methods which are:

        1. **K-means algorithm** [9]
        2. **Genetic algorithm** [4]
        3. **Grey-based Rough Set Theory (GRST)** [10]

In the selection techniques of GRST the following concepts is used:

1. **Lower and Upper approximations** [10]
2. **Reduct** [11]

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5. Summary

This work has presented the following. First we give an introduction to Brokers in Data Grids. Then an introduction to submitting a job to the Broker is presented. A comparison of four different file access patterns is presented followed by previous selection strategies. Some of them are used by well known Grid infrastructures such as Globus [24] and GridBus [2] and others are proposed in the literature. Taxonomy of replica selection strategies is given and we related it to the meaning and the importance of the optimizer (we proposed) is discussed in the next chapter.

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