ISSN 1726-5479

SENSORS & TRANSDUCERS

11 vol. 16 Special /12

Intelligent Data Acquisition and Information Process Technologies and Their Applications

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 16, Special Issue
November 2012

www.sensorsportal.com

ISSN 1726-5479

Guest Editors: Gongfa Li, Tinggui Chen and Hegen Xiong

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and on CD.

Sensors & Transducers Journal

Contents

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Special Issue
November 2012

www.sensorsportal.com

ISSN 1726-5479

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Sensors & Transducers Journal, Vol. 16, Special Issue, November 2012, pp. 52-60

www.sensorsportal.com

Sensors & Transducers

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LTS: An Improved Self-Adaptive Data Replication Strategy for File Sharing in Grid

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Received: 11 September 2012 /Accepted: 11 October 2012 /Published: 20 November 2012

Abstract: In Grid computing, the overall performance is limited by the data access efficiency. NAS is usually used in local regions of Grid and clusters for its feature of direct access to block. Placing replicas in Grid sites can reduce the network latency of the access, which make NAS can be used in a wide area Grid. In this paper, a Load Topology Self-adaptive (LTS) replication strategy is proposed based on the classic Cascading strategy for NAS file sharing. It searches the best site for the replica and creates replicas iteratively. Meanwhile, the loads of the NAS servers are considered in LTS to avoid the decline of access rate caused by the overloading of the file servers. Then, LTS is simulated with the Data Grid simulator - OptorSim. The result of the simulation shows that LTS has high efficiency of placing the replicas for NAS file sharing in Grid. *Copyright © 2012 IFSA.*

Keywords: Grid computing, Data replication strategy, Block-based file access,

1. Introduction

As the amount of data grows rapidly, data intensive jobs in Grid computing become more and more. File sharing with distributed file system can be used in data exchange of Grid computing to promote the efficiency of data access [1]. It allows machines to access the data on remote machines directly, which makes the computation and data exchange execute in a parallel mode and prevents the computing resources from idle waiting for the data transfer. In data centre, file sharing can also bring down the response time compared with file downloading.

However, the efficiency promotion relies on the high bandwidth and low latency of the network between machines. As Grid shares many features with a global peer-to-peer system, such as

decentralized-controlled and Internet-based, the network bandwidth and latency are usually limited between Grid sites. Site failure happens occasionally, either. These make the file access unreliable and make the access rate fluctuate a lot, especially when the access is based on direct file sharing. Replicating file in different sites can not only improve the availability of the file, but also speed up the access rate to the file. Thus, data replication strategies are widely used in Data Grid.

Data replication strategy is a series of algorithm, rules and methods to act in the process of data replicating. It directs which file should be replicated, where and when to create a replication. If the space of the storage on the grid site is not enough, it decides which file in the site should be replaced. In addition, it introduces how to keep the replications of a file consistent when some of them are modified.

The file sharing is provided by distributed file systems. They are implemented based on different architectures. Basic architectures include Storage Area Network (SAN) [2], Network Attached Storage (NAS) [3] and Object-based Storage(OBS) [4]. These architectures can be combined to hybrid architectures. However, not all the architectures are feasible to provide file sharing in Grid. As Grid is composed of heterogeneous computers, the distributed file system utilized in Grid should be platform independent to support all the computational resources of the Grid, and the security control of the file system is required. Since SAN provides block level access, it is not suitable in a Grid environment despite the high access performance. OBS saves data in objects but not files. Although it has advantages on both performance and security, and can be platform independent, the data saved as objects in the sites. These objects must be managed by the meta-server. Thus, it breaks the rules of autonomy of grid sites and non-centralized control in grid. So it is not an option for Grid file sharing, neither. NAS provides the file sharing on top of local file system of the file server, which is easy to support various OS and control the security of file access. It performs the file sharing flexibly and satisfies all the requirements of Grid.

However, NAS has some disadvantages, either. As the meta-data of the shared files are managed by the file server, the overhead of the server is high. Although each grid site has more or less processing ability to deal with the file sharing, the site might be overloaded when the simultaneous file access happens. Besides, the network latency restrains the performance of the file sharing. The maximum packet of NAS is 65535 bytes(in CIFS). If the access of a file requests more than 65535 bytes of data, the access is divided into several packets. In this case, the access rate is affected seriously by the network latency. Fortunately, these issues can be fixed by replicating the files among Grid sites.

The rest of the paper is organized as follows: 1) the related work on data replication is introduced in section 2; 2) an advanced replication strategy is proposed in the light of the disadvantages of NAS file sharing in Grid in section 3; 3) the advanced replication strategy is simulated and the performance of the strategy is compared with the original strategies in section 4; and 4) the conclusion is made in section 5.

2. Related Work

In Grid Computing, the network access rate of the remote files is promoted by the means of distributing data replicas over the grid. The popularity and the access sites are counted. Based on these types of information, many classic strategies to create data replicas are proposed and implemented, with the performance improvement of the data access in grid [5, 6]. K. Ranganathan and I. Foster proposed 6 basic strategies, including No Replication, Best Client, Cascading, Plain Caching, Caching plus Cascading and Fast Spread, to create data replica in grid, and compared them in different access patterns in hierarchical Grid architecture [5]. The result shows that Cascading provides the best performance in the pattern that the data access has the property of geographic locality. In [6] the data accesses are assigned different weights in the replication strategy, namely Latest Access Largest Weight(LALW), which means the data access happened latest has the highest weight to make the decision of replication creation. The simulation result shows that LALW successfully increases the effective network usage.

Meanwhile, many other factors, such as network bandwidth, latency, topology, are taken into consideration in the data replication strategies [7, 8], in order to earn more promotion of performance. By monitoring and estimating the bandwidth and access pattern of the running applications, algorithm intents to minimize the cost of file replication is proposed in [7]. The simulation suggests that the algorithm can achieve higher performance than simple strategies. To reduce the data access time by avoiding network congestions, Bandwidth Hierarchy Replication (BHR) algorithm is proposed in [8]. It extends the strategy from 'sites level' to 'network level' by considering the bandwidth of different level. BHR intends to maximize the network level locality which means to place the required replica in each region of the Grid. In [9], a modified BHR algorithm is proposed. It tries to replicate files within a region and stores the replica in a site where the file has been accessed frequently based on the assumption that it may require in the future. The Modified BHR brings a further performance promotion as well as the reduction of the network usage. A dynamic replication strategy is proposed and argued in [10]. The strategy switches between No replication and Always replication based on the file size and type of access.

In addition, some strategies borrows the theories from the other disciplines, such as Economies and Statistics, to pursue the optimal replication distribution in Grid environment [11-14]. An economic model is adapted for the replication strategies proposed in [11, 12]. The model focuses on optimizing the replication of data in a Grid environment to reduce job turnaround time. It evaluates the local file value according to the popularity of the files and helps the Grid sites to decide whether to replace the less popular file in the site with the more popular one. The strategy can make the local storage optimized. P-median model is applied in the replication strategy in [13]. It finds the location of P candidate sites to create a replica that optimize the aggregated response time. Since a Grid environment dynamically changes time to time, the candidate sites holding the replicas should changes according to the environment. Thus, the strategy reallocates the candidate sites when the performance of the file access degrades. Ant colony algorithm is used to choose the optimal replica site from a great number of sites in peer-to-peer system [14]. The strategy can help to realize the global optimization. It increases the high availability of popular files by the means of placing the popular replicas in high performance sites. It also takes full consideration of many other factors that affect the replica location, such as path load, delay and so on. The simulation shows that the strategy can effectively reduce the request and response time.

Most of the replication strategies above are proposed based on Data Grid model and the data access using file downloading with GridFTP[15] or the other file transfer protocols. However, data access using NAS file sharing is different in some ways between GridFTP. In next section, a replication strategy for NAS file sharing in grid is proposed based on the classic strategies.

3. Replication Strategy for NAS file Sharing

NAS delivers the file sharing that makes the remote file access same as the access on local. It can directly respond the data in block that the user request rather than the whole file. Thus, it is not necessary to download the needed files to local sites (which is called File Stage-In in Grid job) where the program runs. Therefore, the optimal situation of the replication access is different. Using GridFTP, the optimal situation is that the file is located in local site from which the access is requested. However, if the remote access rate of NAS file sharing matches (is higher than) the process rate of the Grid site, the access reaches the optimal performance. A simple example is file compression[1]: when the files on a NAS server are compressed by a remote Grid site, the data compression rate is lower than the remote file access rate. In this case, downloading the file to local site would lead to no performance promotion but wasting network resources. Therefore, the replication for NAS file sharing can be terminated when the access rate matches the process rate of the program.

The overhead of NAS server is high, especially when the simultaneous access happens. The rising of the overhead might lead to the decline of the access rate. If the site of NAS server overloads, the accesses to it might fail. Unfortunately, the failure often affects more than one process, because the overload failure is almost caused by multiple accessing processes. Thus, the cost of NAS server must be considered in the replication strategy.

Placing replicas in Grid sites can reduce the network latency of the access, improve the availability of the files, as well as balance the load of the system. K. Ranganathan and I. Foster's work [5] suggests that Cascading has the best performance in the Grid with hierarchical architecture and the feature of geographic locality access. Thus, Cascading is used as a basic replication strategy in this paper. It involves the notion of Best client. Best client of a file is the site that has access to the file most frequently during a fixed time interval. Cascading replicates the file to the site directly linked to the current site on the path to its Best client. Since the access has the feature of geographic locality, Cascading makes the path from the replica to the all the clients shorter. Fig. 1 shows the topology of a hierarchical Grid. Suppose that the original file is stored in A, and the clients that access the file are G, H and I, and the Best client is H. In two time intervals, Cascading has replicated the file to B and D. In this case, all the clients can access the replica in D which is closer than A and B. Therefore, Cascading can optimize not only the access performance of the Best client, but also the performance of the clients around it. In Fig. 1, if all the access from G, H and I are invoked by the same job, the overall execution time of the job is reduced.

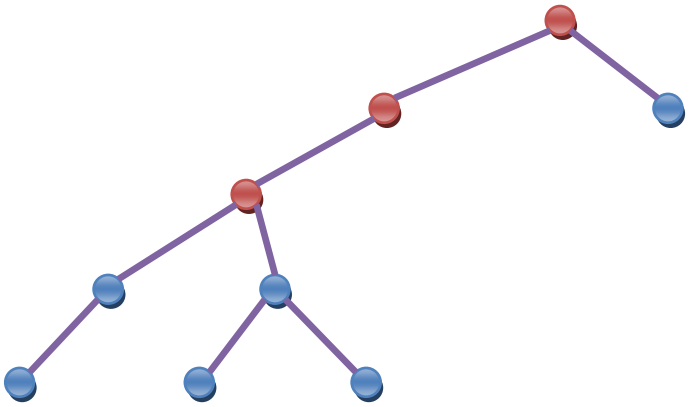

Fig. 1. The topology of a hierarchical grid.

Cascading is modified to meet the requirement of NAS file sharing in this paper. Based on the analysis above, the following points are considered in the modified strategy.

The length of the path from file server to accessing site: The access rate of NAS declines fast as the latency of network. If the length of the path from file server to access site is too long, the access rate will be low. Thus, it should be ensured that the available replica of the file exists in the surrounding sites of the accessing site.

Load of the file server: As the number of the concurrent clients increases, the load of the NAS server grows violently. It will lead to the descending of the access rate of each client. As the file access and data process are parallel in Grid, it will finally leads to the decline of the execution performance of grid job. Thus, the distribution of file replicas and the load balance should be considered according to the load of the file server.

The consumption of the network bandwidth: NAS file sharing delivers concurrent data access in Grid. As the replicas are distributed in the Grid, the accessing sites and file servers are mixed together. So the creation of replica in Grid might occupy the bandwidth for the file access. Thus, the unnecessary creation of the replica should be constrained in order to decline the consumption of the network bandwidth.

Based on the analysis above, Load and Topology Self-adaptive (LTS) strategy is proposed. It searches the best site for the file and creates replicas iteratively. With the iteration method, the algorithm is self-adapted according to the status of the network and the sites. The strategy is illustrated as follows.

For each site in Grid, a replicator is deployed as a daemon. The replicator creates replicas according to the following rules.

Given k is an integer, T is long integer, p is a real number and p>0, h1 and h2 are real number and h1>0, h2>0, then, if a file in the site is accessed by its best client more than k times in time interval T and the promotion of access rate of the file is more than p in percentage to that of the last replica (no replica mean the promotion is 100 %), a file replication request is sent to the next site on the path to the best client.

When a file replication request is received, if the load of the site does not exceed the threshold value h1 and the site has more than 2 neighbor sites, or if the site is the best client, the replica is created on the site. Else, the request is repeated to the next site in the path to the best client.

If the load in the site exceeds the threshold value h2, the replication request of the file that is most usually accessed in the current accessing files is sent to the next site on the path to the best client.

In order to make LTS adaptive to the topology of network, the tier of the node in the tree topology is considered. As the replica moves down, the lower tier nodes decrease. It means that the access possibility declines. Thus, a factor that controls the threshold k should be added to (1) in LTS. In this paper, the factor f is decided by the length of the path to the best client. The length of path from the original file node to the best client is Lo, and length from current replica to the best client is Lc. The factor is calculated as follow:

$$f = L_c / L_o, \tag{1}$$

and k in LTS is replaced by k':

$$k' = f \times k, \tag{2}$$

4. Simulations

4.1. Simulator

In this section, the performance of LTS is evaluated using the Grid simulator OptorSim [16]. OptorSim was developed by European Data Grid (EDG) [17] project which is written in Java. It can be used to simulate a Grid environment in which dynamic replication strategies can be tested.

OptorSim simulates a Grid environment with distributed sites and the connections between them. A site comprises Computing Element (CE) and Storage Element (SE). The sites in OptorSim are divided into three types including Computing Site, Storage Site and Switcher, which is decided by the amount of CEs

and SEs. A Computing Site is a site with one or more CEs; A Storage Site is a site with one or more SEs; A Switcher is a site with neither CE nor SE.

The file access simulation in OptorSim is based on file downloading. The configuration defines the mapping of the job and the involved files. To simulate access based on file sharing, the involved files are divided into several pieces (files) of the same size. The size of the piece indicates the size of the packet of NAS. In the simulation, the size is set to 10 MB rather than 64KB, in order to simplify the configuration. Fig. 2 shows the principle of the file sharing simulation in OptorSim.

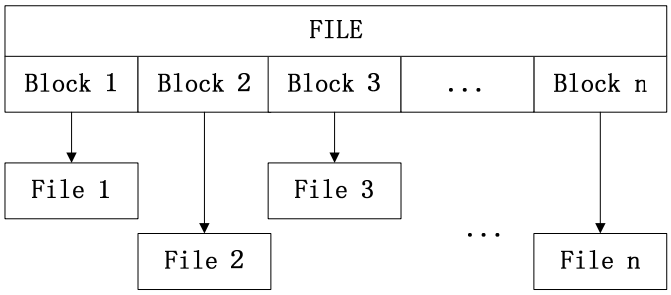

Fig. 2. File sharing Simulation in OptorSim.

4.2. Configuration

In the simulation, the topology of the Grid environment is defined as Fig. 3. It is a hierarchical architecture. Every site of the Grid comprises a Computing Element and a Storage Element. The capacity of the SE is 1TB, which is enough to store the replicas.

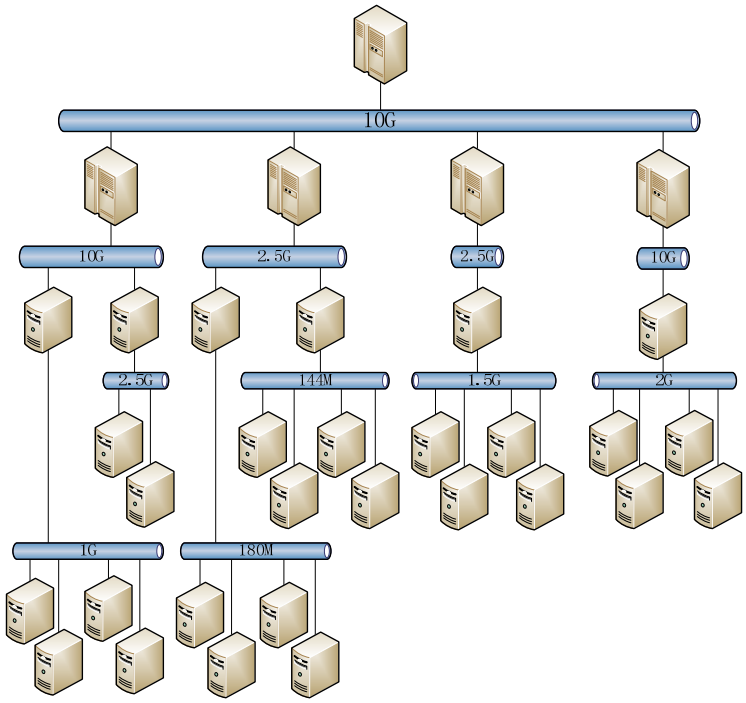

Fig. 3. The topology of the grid environment.

4.3. Comparison

In the simulation, a series of equivalent jobs are submitted in file sharing mode. The job schedule has the property of geographic locality. The simulation is repeated using Cascading, Fast spread and LTS, and the result of the simulation is shown in Table 1.

Table 1. Results in File Sharing Mode.

	Cascading	**Fast spread**	**LTS**
Mean Job Time	29215	30059	28923
Total Number of Replicas	28	37	20
Total Number of Local Accesses	151	146	96
Total Number of Remote Accesses	15939	15944	15994
Effective Network Usage	97.03 %	97.96 %	95.13 %

Table 1 shows that LTS has the highest performance in the three strategies. Although the number of remote accesses in LTS is larger than that in the other two strategies, the network usage is the lowest. This is because that the number of replicas is less as well as the remote accesses happen in a local region of the Grid, which saves the overall network usage. Therefore, it can be concluded that LTS has a high efficiency of placing the replicas for NAS file sharing, while the overhead is low. Fig. 4 shows the comparison of the different strategies in file sharing mode.

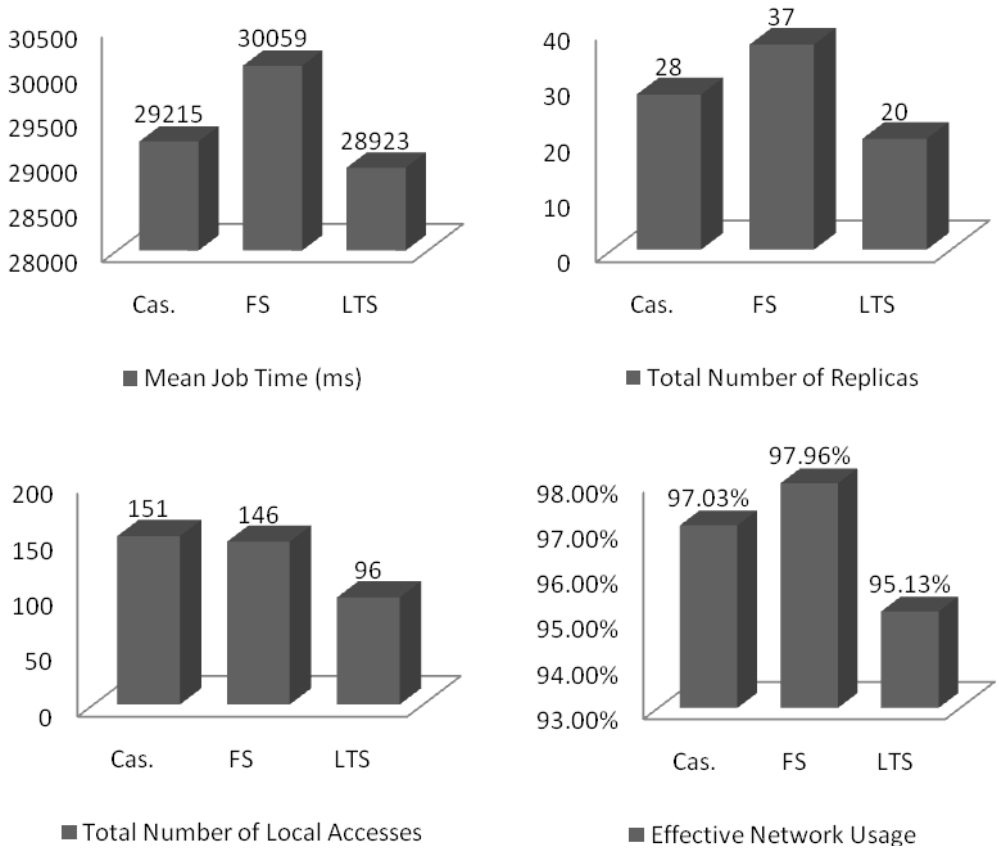

Fig. 4. The comparison of the different strategies.

5. Conclusion

As the amount of data grows violently, data access efficiency affects the overall performance of distributed systems such as Grid. NAS file sharing has the potentiality of promoting the data access efficiency in Grid. However, since the Grid is based on Internet and the network latency between the sites might be high, the performance of NAS file sharing is restrained. By placing replicas in different sites of Grid, the latency might be reduced, as well as the load of file servers can be balanced. Based on the Cascading strategy, LTS strategy is proposed in order to promote the performance of NAS file sharing in Grid. It searches the best sites for replication and creates replicas on them iteratively. Meanwhile, the loads of the NAS servers are considered in LTS to avoid the performance decline caused by the overloading of the servers. Cascading, Fast spread and LTS are simulated with Data Grid simulator Optersim, and the results are compared. The comparison shows that LTS has a higher performance and lower cost in NAS file sharing. Thus, it is suitable for NAS file sharing in Grid.

Acknowledgement

The work in this paper is supported by the National Natural Science Foundation of China (No.61073009), the National High Technology Research and Development Program of China (863 Program) (No. 2011AA010101), the IoT Development Foundation of MIIT of China – The Development and Industrialization of the Middleware Suite Supporting Application in IoT (215050510), and the central grant funded Cloud Computing demonstration project of China, Cloud for SMEs, hosted by Kingdee Software (China) Company Ltd., under the direct of National Development and Reform Committee of China.

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- Virtual instruments;
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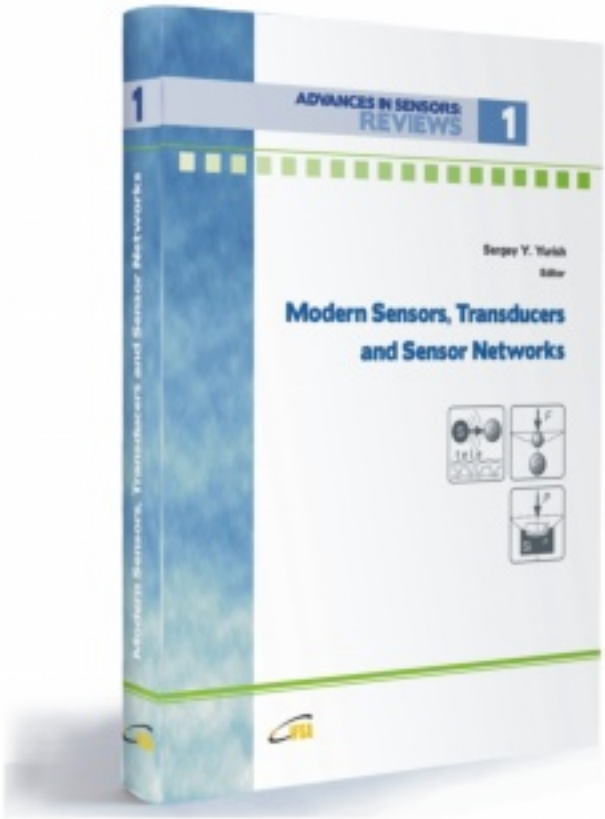

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