Analytical Survey of Dynamic Replication Strategies in Cloud

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ABSTRACT
With the emergence of the storage in cloud, more and more people are moving their data to the cloud. With increased data in cloud, service providers of cloud face a challenge to ensure maximum data availability and reliability. Data replication is highly employed by commercial large scale cloud storage systems to improve data availability and reliability. In this paper, already existing replication techniques are studied and examined for various parameters like, availability, reliability, storage space consumption, storage cost, bandwidth consumptions, number of replicas, response time. A survey of the different replication strategies is accomplished consolidating the above mentioned parameters. The outcome of such survey will enable the users to determine the replication strategy best suited for their needs.

General Terms
Data Replication Strategies, Cloud Storage Systems.

Keywords
Cloud Computing, Data Availability, Dynamic Replication, Reliability

1. INTRODUCTION
The rapid progress of technology and large scale use of internet has resulted in generation of an enormous amount of data. With the emergence of internet as a highly reliable system, the organizations have realized the importance of outsourcing of the activities like, computation, processing, etc as a utility. Large Organizations have begun to outsource services like platforms, network, and storage as it is perceived as a cost effective option rather than investing heavily on these requirements within. A new concept of internet based computing called as cloud computing has evolved, where shared resources and services are provided to users on demand. Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The services themselves have long been referred to as Software as a Service (SaaS). The datacenter hardware and software constitute together to be called as a Cloud. When a Cloud is made available in a pay-as-you-go manner to the general public, it is called as a Public Cloud. The service being sold is called as Utility Computing. Thus, Cloud Computing is the sum of SaaS and Utility Computing [1,2].The Cloud Computing is soon becoming popular amongst large organizations, as it offers to lower the infrastructure costs, increased computing power and unlimited storage capacity. The cloud could now provide features like broad network access, resource pooling and rapid elasticity [3]. However there are certain disadvantages pertaining to the safety, security and privacy of the data stored.

1.1 Emergence of Storage in Cloud
With the rise of social media, high use of data acquisition devices in scientific research, news, and web based applications; there is a huge amount of generation of structured and unstructured data. The availability of cloud storage services is becoming a popular option for consumers to store data that is accessible via a range of devices such as personal computers, tablets and mobile phones [4]. Smaller organizations having large web applications have started to move their data to the cloud storage system like Drop Box, Gigaspaces, and Elephant Drive. Cloud storage system consolidates large numbers of geographically distributed computers into a single storage pool and provides large capacity high performance storage service at low cost [5].Distributed File Systems is a critical component of Cloud Storage Systems. Google File Systems (GFS) [11], Hadoop Distributed File System (HDFS) [12], & Amazon Simple Storage Service (S3) [13] are the working examples of distributed file systems. These file systems are typically used for efficient and reliable storage of large data sets.

As the data storage is accomplished by employing large number of data nodes the probability of failure of these nodes is quite high. This issue is augmented by unreliable connectivity and limited bandwidth of the network. Therefore improving the data availability and reliability has become a prominent challenge in cloud storage

1.2 The Need for Replication
Data replication has been widely used, as a mean to increase data availability and reliability of cloud storage systems. Storage Systems like HDFS, GFS, Amazon S3, employ conventional three replication strategy where three copies of the data including original copy are stored on geographically distributed servers or nodes [5]. Failure of one data node does not affect the system performance as copies of same are available on different locations, thus improving data availability and reliability. But increase in the number of replicas does not always increase the availability instead increases the storage space and cost which is not beneficial for the user.

Data replication algorithm can be divided into two broad categories, Static Replication and Dynamic Replication [6].In static replication strategy, number of replicas and their location is predetermined and fixed; on the other hand dynamic replication automatically creates replicas according to changing access patterns, and location of replicas can be changed dynamically based on capacity of nodes [3].

Dynamic replication strategies have three important issues that must be addressed. They are as below,

1. Selection of the data file to be replicated and the decision regarding when to replicate so as to meet users requirement such as waiting time reduction and data access speeding up. Proper selection of data files if not done then, it will lead unnecessary consumption of storage space, thereby increasing the storage cost. Similarly too early replication of a data file will lead to same issues.
2. Finding the optimal number of new replicas, to be created in the system for meeting the system availability, reliability requirement and the cost of replica maintenance, because after a certain point of time increasing the number of replicas does not increase the availability but might bring unnecessary spending like extra storage space consumption and associated storage cost [5].
3. Placement of replicas in a balanced way to meet system task successful execution rate and bandwidth consumption requirement. Idea is to place the replicas closer to the user, in order to minimize the response time, and thus job execution time. This will increase the throughput of the system [10]

This paper gives a survey of dynamic replication strategies considering the above mentioned issues and comparison of the replication strategies based on different parameters like availability, bandwidth consumption, reliability, access time and number of replicas.

2. LITERATURE REVIEW

Da-Wei Sun. et al. [3] proposed a dynamic data replication strategy D2RS (Dynamic Data Replication Strategy). The strategy focuses on parameters, System Availability, Number of Replicas & Bandwidth Consumption. The decision for the selection of the data file for replication is based on the theory of temporal locality. The probability that most recently accessed data file will be accessed again in the future, this is called as a theory of temporal locality. The analysis of the data pertaining to access information of the users is carried out. Based on this analysis, the popularity degree and replica factor are calculated. The popularity degree is number of times the block or a file is accessed, within a given time period and is calculated by a time based forgetting function. The replica factor is calculated as ratio of popularity degree and the total number of bytes of data file f_i requested. These two parameters are very crucial in determining the popular data file and also for the decision regarding the replication. When the popularity of a data file passes a dynamic threshold, the replication operation will be triggered. A mathematical relationship is formulated between, system availability requirement and the number of replicas. This relationship reveals the optimal number of new replicas to be created in the system. The number of new replicas to be created at the directly connected data center is calculated based on the total number of new replicas and the replica factor. Replicas will be placed based on access information of directly connected data centers so as meet the system execution rate and bandwidth consumption requirement. The D2RS (Dynamic Data Replication Strategy) strategy is evaluated in Cloudsim environment.

Experimental results demonstrate that D2RS(Dynamic Data Replication Strategy) scheme improves data availability, cloud system task successful execution rate, response time, minimizes cloud system bandwidth consumption, and achieves load balance by placing popular data files according to access history . As the probability of block availability increases, higher system byte availability ratio is achieved with minimum number of replicas, however if the block availability is lowered, then to maintain a higher system byte availability ratio, more number of replicas are required. Also it is seen that lower the block availability, lower the successful execution rate [3].

Qingsong Wei et.al [5] proposed a dynamic replication scheme called CDRM (Cost Effective Dynamic Replication Management) which improves availability and performance of the system by balancing workload in a cost effective way. It is implemented with the help of Hadoop Distributed File System. (HDFS). The key investigating parameters are Replica Number and Data Availability and its relationship with Replica Number. A mathematical model is proposed to calculate minimum replica number that satisfies the given availability requirement, of a file. If a data node fails and current replica number is less than minimum replica number (r_{min}), a new replica will be created on data node to guarantee the availability requirement. Initially the number of replicas is set to 1 and the current availability of the input file is calculated. If the single replica does not meet this availability then one more replica is added. The availability requirement is checked again with two numbers of replicas and if it is not met, then the process is repeated again till the user specified availability is met. This scheme also addresses the issue of how to place the replicas effectively to maximize the load balancing. Replica placement is based on capacity (CPU power, memory, bandwidth etc) and blocking probability of the nodes in heterogeneous environment. Blocking probability of the node is calculated by using the request arrival rate of the system and the time required to serve the request. The name node maintains the information pertaining to the blocking probability of the entire node by using the data structure B+ tree. Each node calculates the information about its blocking probability and updates it to the name node. Based on the updated information, the name node decides the on which data nodes to place the replicas. The replicas are placed on the data node with the lowest blocking probability.

Experimental results demonstrate that CDRM is cost effective and outperforms the default replication scheme of HDFS in terms of performance and load balancing. When popularity is small, the performance of CDRM is much better, than default replication strategy of HDFS [5].

Wenhao Li et al. [7] proposed a strategy PRCR (Proactive Replica Checking for Reliability) for enhancing reliability of large cloud storage data with minimum replication & storage space consumption. Their key investigating parameters are Data Reliability, Number of Replicas, Disc Failure Rates, storage space, storage cost. The study focuses on minimizing the number of replicas. The experiments pertaining to this strategy were performed for the Parkes Radio Telescope which is used for generating large amount data related to astronomical observations. The data is stored on disks & each replica of the data is proactively & periodically checked. The loss of replicas is discovered and recovered within each period. By conducting proactive replica checking at a certain frequency, a certain level of data reliability assurance can be provided. The data gathered from above application is classified based on the reliability requirement. For the data having short reliability requirement only one replica is maintained, while for the data having high reliability, multiple replicas are generated. If the reliability assurance of the data falls below the requirement, then a replica of the data is created. In this strategy, the storage duration prediction algorithm, determines the minimum replica number for meeting the data reliability requirement & calculating the longest duration of the data. The metadata distribution algorithm maximizes the utilization of PRCR. The PRCR is implemented in Amazon web services AWS.

The experimental results indicate that PRCR compared with conventional three replication strategy can reduce from one-third to two-thirds of the Cloud storage space consumption, hence significantly lowering the storage cost in cloud [7].

Wenhao Li et al. [8] proposed a cost effective incremental replication strategy (CIR). The CIR is used to manage the data having uncertain reliability requirement. The incremental replication method reduces storage cost simultaneously meeting the data reliability requirement.CIR incrementally creates replicas when current replicas cannot assure the reliability specified by the user. Initially one replica of the data is created and maximum limit of the number of replica to be created is set to three. Whenever any new data is uploaded by the user or replica creation time point is reached the new replica is created in the system. The replica creation time point indicates that the current number of replica cannot meet the reliability requirement specified by the user. However this study does not find the optimal number of replicas nor does it address the placement of the new replicas. Replicas are placed on randomly selected data nodes. As placement of new replicas is not considered, the response time reduction and bandwidth consumption are not addressed.

Experimental results indicate that CIR could save up to two thirds of storage cost as compared to conventional tri-replication strategy. Also CIR occupies less storage space when the storage duration is shorter. [8].

Mohammed K et al. [9] proposed a light weight data replication strategy (LWDRS) exhibiting high flexibility in selection of data files for improving the overall system reliability & availability. The key investigating parameters are data availability & reliability, place. The study however does not address the response time, bandwidth consumption, storage space consumption. The selection of data file to be replicated is based on light weight time series technique, named Holt's Linear Exponential Smoothening (HLES), which predicts future access frequency of the data. Such a prediction is based on analysis of past data access requests. If the predicted future request for the data exceeds the dynamic threshold then the replication operation is triggered. The number of replicas is decided by an adjustable parameter α in HLES technique. Greater the number of block request and the value of adjustable parameter α, the more the number of replicas are required to improve the file availability. Heuristic search is used to find the suitable data nodes for the placement of new replicas. The above strategy is evaluated using a CloudSim Environment.

Experimental results indicate that reliability of the data is increased but the response time also increases with the increasing number of tasks [9].

Table-1 presents an overview of how the different replication strategies considered, are addressing the issues like which data to replicate, when to replicate, how many number of replicas to be created, where to place these replicas created.

TABLE-1 Issues addressed by the replication strategies

Strategies	Issues pertaining to replication			
	Which Data to Replicate	**When to Replicate**	**How many number of Replicas**	**Where to Place Replicas**
CDRM	Not Addressed	Access frequency is more than Threshold	Mathematical Model to capture relationship between number of replicas and availability requirement	Replica Placed on data node with lowest blocking probability
D2RS	Only popular data	Whose popularity of the data exceeds threshold	Mathematical Model to capture relationship between number of replicas and availability requirement	Replica will be placed based on access information of data centers
CIR	Not Addressed	Replica creation time point is reached	No method is addressed for how many replica	Placement is not addressed
PRCR	Data having relatively higher reliability & longer storage duration.	Original copy does not meet the user specified reliability requirement.	An algorithm is proposed for relationship between, storage duration, number of replica and user specified reliability requirement.	Not Addressed
LWDRS	Only popular data selected by light-weight time series prediction technique.	Replication factor is less than the specified threshold.	The numbers of replicas are calculated by a parameter α called as Smoothening factor, in HLES Technique.	Placement achieved by placing replicas based on Heuristic search Algorithm

3. COMPARISION

We find that strategies like D2RS, CDRM, PRCR, and LWDRS have determined the optimal number of replicas therefore; the availability is increased .For strategies, PRCR, CIR and LWDRS the reliability is increased. In PRCR and CIR the failure rates of storage units are considered. So, lower the probability of failure, higher will be the reliability. CIR and PRCR initially store only one replica (original copy of the data). Then as per the reliability requirement, it will create additional number of replicas. Therefore the storage cost and storage space associated with these two strategies will automatically be less than the other strategies, because all the other strategies from the beginning maintain a fixed number of replicas, which can be two, three or even more. In strategies D2RS and CDRM, the bandwidth consumption and response time is reduced as these two strategies are placing the replicas in a balanced way. Since CIR and PRCR are not considering the placement of replicas, bandwidth consumption and response time reduction is not reduced. Almost all strategies calculate the number of replicas using a mathematical model.

These all strategies are compared against each other for the parameters like availability, reliability, storage space, storage cost, bandwidth consumption, optimal number of replicas, response time reduction, load balancing and fault tolerance in a tabular format below.

TABLE-2 Comparison between Different Replication Strategies in Cloud Environment

Parameters	Replication Strategies				
	D2RS	CDRM	PRCR	CIR	LWDRS
Availability	Increased	Increased	Increased	Not addressed	Increased
Reliability	Not addressed	Not addressed	Increased	Increased	Increased
Storage Space	Not addressed	Not addressed	Reduced	Reduced	Not addressed
Storage Cost	Not addressed	Not addressed	Reduced	Reduced	Not addressed
Bandwidth Consumption	Reduced due to balanced placement of replicas	Reduced due to balanced placement of replicas	No Reduction	Not addressed	Not addressed
Optimal Number of Replicas	Yes	Yes	Yes	Not addressed	Yes
Response Time	Reduced due to placement of replicas	Reduced due to placement of replicas	No Reduction	No Reduction	Not addressed
Load Balancing	Achieved by placing the Replicas based on access history of Data Nodes	Achieved by placing replicas based on Blocking Probability and Capacity of Data Nodes	Not addressed	No Load Balancing is done	Achieved by placing replicas based on Heuristic search Algorithm
Fault Tolerance	No	Yes	Yes	Yes	No

4. CONCLUSION & FUTURE WORK

In this paper, the different dynamic replication techniques are surveyed and compared for like increased availability, reliability, storage space reduction, etc. From the above comparison, the strategies, PRCR and CIR reduce the storage space and hence the storage cost of the data, whereas D2RS, CDRM and LWDRS minimize the bandwidth consumption of the data. The response time is reduced by D2RS and CDRM only as they address the placement of replicas. The Fault tolerance is achieved by PRCR, CIR and CDRM as they have considered the failure rates of storage unit.

Most of the data used in real time is updatable therefore, the consistency of the replica stored in an important parameter which is not addressed by any of the above strategies. This parameter could be an important research area in future. It is also observed that very few strategies are considering the failure rate of the storage units in cloud. Detailed experimentation is needed to evaluate the effect of the disk failure on the availability and reliability of the data stored in cloud. Most of the replication strategies are compared with the default three replica strategy. In future, the performance of these strategies can be evaluated on real cloud computing platforms, and can be compared against each other. It is expected that such a comparison may give an insight into the gains and drawbacks of these strategies. The observed drawbacks can be investigated and an improvement can be proposed in the performance.

5. REFERENCES

[1] M Armburst, A. Fox, R. Griffith, and A. Joseph, "Above the clouds: A Berkeley View of Cloud Computing", Technical Report No. UCB/EECS-2009-28 by the Department of Electrical Engineering and Computer Science University of California, February 10 2009.

[2] M Armburst, Armando Fox, Rean Griffith, Anthony D. Joseph, Randy Katz, Andy Konwinski, Gunho Lee, David Patterson, Ariel Rabkin, Ion Stoica, Matei Zaharia, " A view of Cloud Computing, Communications of the ACM", 53(4), 2010, pp.50-58.

[3] Da-wei Sun, Gui-Ran Chang, Shang-Gao, Li-Zong Jin Xing-ei Wang, " Modeling a Dynamic Data Replication, Strategy to increase system availability in cloud computing Environments", Journal of Computer Science and Technology-Springer, 27(2), 2012, pp.256-272.

[4] Aye Chan Ko, Wint Thida Zaw, " Fault Tolerant Erasure Coded Replication for HDFS based Cloud Storage" , Proc. Fourth IEEE International Conference on Big Data and Cloud Computing, Sydney, Australia, 2014, pp.104-109.

[5] Qingsong-Wei, Bharadwaj Veravalli, Bozhao Gong, Lingfang Zeng, Dan Feng," CDRM: A cost effective dynamic replication management scheme for cloud storage cluster", Proc. IEEE International Conference on Cluster Computing, Herakilon, Crete, Greece, September 2010, pp.188-196.

[6] MyunghoonJeon, Kwang Ho Lim, Hyun Ahn, Byong Dai Lee, " Dynamic Data Replication Scheme In Cloud Computing Environment", Second IEEE Symposium on Network Cloud Computing and Applications, London, UK, November 2012,pp. 40-47.

[7] Wenhao-Li, Yun Yang, Dong-Yuan, "Ensuring Cloud Data Reliability, with minimum replication by proactive replica checking", 2015 IEEE transactions on computers and Manuscript ID.

[8] Wenhao-Li, Yun Yan, Dong Yuan, "A Novel Cost Effective Dynamic Data Replication Strategy for Reliability in Cloud Data Centers", Ninth IEEE International Conference on Dependable, Autonomic and Secure Computing, Sydney, Australia, December 2011,pp.496-501.

[9] Mohammed K. Hussein, Mohammed K. Mousa, "A lightweight Data Replication for Cloud Data Centers Environment" , International Journal of Innovative Research in Computer and Communications Engineering, 2(1), 2014, pp.2392-2400.

[10] Tehmina Amjad, Muhammad Sher, Ali Daud, "A survey of Dynamic Replication strategies for improving data availability in data grids", Future Generation Computer Systems, 28, 2012, pp.337-349.

[11] S. Ghemawat, H. Gobioff, and S. Leung, "The Google file system," in ACM Symposium on Operating Systems Principles, pp. 29-43, 2003.

[12] K. Shvachko, H. Kuang, S. Radia, R. Chansler, " The Hadoop Distributed File System", 26th International Symposium on Mass Storage Systems and Technologies Lake Tahoe, Nevada, USA, May 2010.

[13] Amazon. (2011). Amazon simple storage service (Amazon S3). Available: http://aws.amazon.com/s3/