Data Replication in Conventional Computing Environment

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Abstract
Increasing data or service availability is a major concern of any network / computing environment. A user in a network may encounter the problem of data unavailability due to several reasons such as server crash, network partition, link failure etc. Data is replicated in several systems in order to make it available to the user in presence of any network problems as stated above. A network can be characterized based on the type of systems, communication medium and the mobility of systems. There are several types of network/ computing paradigm that has evolved which are diverse in characteristics and functionality. Though replication has been known as a popular mechanism to increase data availability in traditional networks, a need for contemporary solution arises along with evolution of recent Network/computing paradigms such as Mobile Ad –Hoc, Vehicular, Cloud and IoT. As these environments are characterized diversely, each of them demands a customized replication approach. We perform an in-depth survey on various replication approaches used in different computing environment with varying network entities. We present the possible scope for future research in Replication for various computing paradigm.

Keywords: *Replication, Quality of Service, Selfish Aware Replication, High Availability, Response time, MANET, CLOUD, content delivery networks, Google File System, Hadoop.*

1. Introduction

A computer network comprises of systems such as clients, servers and peers where each performs task according to the role assigned to them. For example a server system that maintains a database or file provides access to the content upon a request from a client. An authenticated client can avail various services offered by a particular type of server such as Data access, Object Access, Method access, file service, name services and web services. Agreed upon a protocol, these services can be offered to any client with valid credentials. The size of the network was small and it had very few numbers of systems at the initial stages of network evolution. The rate of data or service unavailability was insignificant, when the size of the network and the number of participating systems were small. With the advent of various network types that uses different communication mediums such as wired, wireless, cellular and satellite the size of the network has grown very larger.[24] The Internet has the ability to connect any system around the world which may be different in terms of hardware and software aspects, that uses different communication medium. While having the size of network increased exponentially with millions of systems connected within it, the rate of server failure has also increased significantly that lead to frequent data or service unavailability to its client.

Replication is a technique to make multiple copies of data/service available at different systems other than the original one [13]. In case of failure of server, server unavailability due to network link failure or channel congestion, the client can access the data or service from the other system or server without any interruption. The server that holds the replicated data or service can be called as secondary server. Due to the high switching capacity of the network between different systems, the client may not able to find the switching time significantly.

Replicating the data or service over several systems in the network would increase the availability to a large extent. It is necessary that the systems which are part of the network have sufficient resources such as memory space, disk storage and processing power. More memory space is required to accommodate the data replicated by other systems and the processing capacity of the system should be equal to that of original server to satisfy the service requirement for the client. Traditional wired networks such as Local Area Networks (LAN), WAN, MAN and wireless networks consists of systems that has more memory space , disk space and processing power. Replication techniques proposed for traditional systems are concerned with increasing data availability and optimizing the computational time of replication algorithms. But recent network types such as Mobile, Mobile ad hoc, Vehicular Ad hoc and cloud are characterized with different system components and communication medium. Since most of the systems in the mobile network are equipped with battery power, they lag in processing, memory space and disk storage. Replication algorithms proposed for the recent evolutionary networks are not only concerned with increasing data availability and optimizing computational time. They need to consider the characteristics of mobile computing devices which have les features compared to the systems of traditional networks. In addition, devices in mobile network show poor cooperation in storing replica data for other nodes due to less memory space available. It raises a need to consider the non cooperative behaviour of mobile nodes while devising the replication algorithm.

Energy aware algorithms are very important to the mobile environment which minimizes the energy consumption of mobile devices. Many applications such as multimedia, data intensive and scientific oriented involves in processing large volume of data and Quality of service (QoS) [1][3][4][5]is an important requirement for them. Cloud computing is one of the recent computing paradigm which involves heterogeneous types of systems on which data can be stored or an application can be run. It is important to find whether a system meets the QoS requirement as that of original, while replicating data or service in heterogeneous environment.

Even though various replication algorithms have been implemented for various traditional networks, the evolutionary computing environments with its diverse system characteristics raise the need for cutting edge and dynamic replication strategies.

In rest of the paper we present various replication strategies for different computing paradigm available in the literature. We study the characteristics of each computing paradigm and present the replication strategies available for each and summarize various parameters concerned.

2. Increasing data availability using Replication Algorithms for various Computing Environments

2.1 Replication in Transparent and Hierarchical Web Proxies [12]

The work in [12] proposed replication mechanism amidst of transparent and hierarchical web proxies. Web servers maintain data objects that can be accessed by clients upon request. The client can send request to access an object maintained by a server. The server responds back to the client by transferring the requested data to it. The response time which is defined as the elapsed time between sending the request and arrival of response from the server, depends upon the locale of the server. The distance between client and server is measured in terms of Hops. The response time will be more if the data to be accessed is placed in a server which is far from client as shown in figure 1. In order to reduce the response time the data object accessed from the origin server can be replicated to a server which is nearer to the client in terms of hop count.

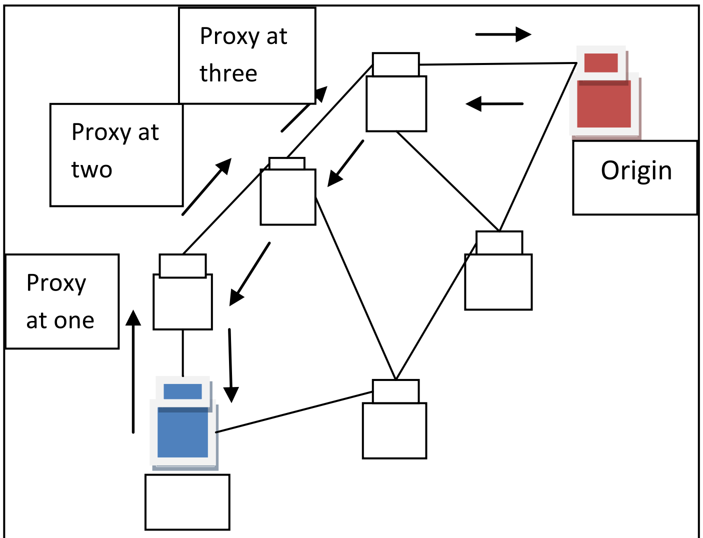

Figure 1 Replication in hierarchical and transparent web proxies

The server that contains the replicated data on behalf of an origin server is called as proxy server. It is selected based on various factors such as hop distance from client, reliability of the communication link and history of server crash or failure. The proxy server is selected for a client based on the above criteria. Replicating data object at different level of hierarchy increases availability and response time. At the other side more overhead are associated in maintaining consistency with the origin server. The overhead increases proportionately to the number of proxy servers.

The work [12] aims at finding an optimal set of hierarchical proxy servers for replication. The degree of availability increases along with the number of proxy servers. At the same time replicating data on too many proxy servers would increase the web traffic. An efficient design is required to balance the trade off between the replication benefits and web traffic.

The work [12] considered two types of proxy servers based on their storage capacity named proxy servers with unlimited storage capacity and limited storage capacity. An optimal solution has been provided for the proxies with unlimited storage capacities.

The work [12] can be extended to the mobile ad hoc networks. Since mobile nodes have limited storage capacity, it requires an efficient replication algorithm that would consider the limited characteristics of mobile devices. The stability of the route between client and server in mobile networks is less compared to the static environment. This is an important characteristic to be considered. It would be effective to deploy less number of proxy servers in the mobile environment since mobile nodes may leave the network frequently.

Applications with quality of service requirements may be another concern that can be incorporated in the replication mechanism. Applications such as scientific analysis, pattern finding from large data sets and multimedia oriented need certain QoS guarantees on channel reliability, latency, jitter and bandwidth. These features can be considered while devising replication algorithm that involves set of proxy servers.

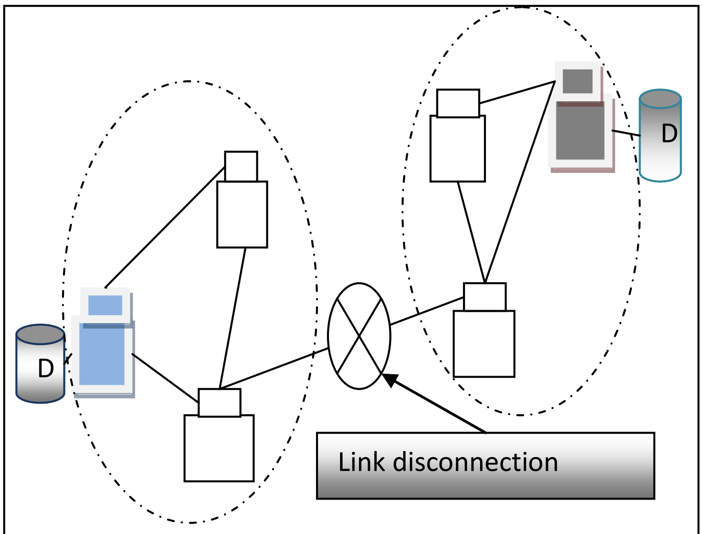

Figure 2 Network partitioning in mobile ad hoc network

2.2 A study on Relationship between Mobility and Data Availability [11]

The work in [11] discusses about the relationship between data availability and mobility in mobile ad hoc networks. Mobile nodes form a network on ad hoc basis i.e. without a base point or infrastructure. Communication takes place between two mobile nodes by transmitting data across several other nodes which acts as a router in between the source and destination. Mobility of nodes causes network partitioning making a node not to communicate with other node. This reduces data accessibility to a large extent as shown in figure 2. After network partitioning D1 can be accessible by the nodes only within the new group.

Several replication algorithms have been proposed in the literature to improve data accessibility in presence of network partitioning. Though several algorithms are proposed to improve data accessibility by means of replication or data dissemination, they have not studied the influence of node mobility over data accessibility. The work in [11] proposes various metrics to determine the influence of node mobility over accessibility.

2.3 Replicating Data to satisfy Applications with QoS constraints in Cloud [1]

Cloud computing supports large volume of data storage in heterogeneous storage devices connected as part of cloud.[2][3][4] These storage devices vary in the performance specification such as processing capacity, disk access latency and bandwidth support across different nodes.[8][9][10] Many applications running in the cloud environment may require strict QoS constraints. Applications running on a system accesses data stored in different storage nodes. The performance specifications such as disk access latency may not be same for two different data nodes as shown in figure 3. The data belongs to an application should be stored in nodes that will satisfy required QoS constraints. The work in [1] proposes an algorithm that will replicate the data of High QoS applications first. The work considers Hadoop Distributed File system [5][6][7]to implement the replication technique. It consists of a set of data nodes and name nodes .The data nodes belongs to a rack are connected by an Intra Rack switch and those belongs to different nodes are connected by an Inter Rack switches. Each storage node specifies its disk access latency. Given a set of requests from applications, the algorithm finds a set of nodes that satisfies the request and stores data replica based on a value called replication factor. In addition to reducing the QoS violated data replicas, the work [1] has also attempted to minimize the computational time of the algorithm. The work in [1] also proposed an algorithm based on Minimum cost and maximum flow to reduce the computational time called MCMFC. It uses node combination techniques to achieve the reduction in computational time.

The work in [1] proposed a replication algorithm that handles the QoS requirements of applications. In addition to that energy aware concepts can be added to minimize the overall energy consumed in terms of reduction in message flow.

2.4 Increasing Data Availability in Mobile Ad Hoc Networks in presence of Non Cooperative Nodes [13]

A mobile ad hoc network has gained more popularity due to its easy deployment in places like disaster sites, communication in battlefield and video conferencing. The participating nodes in MANET are characterized by limited storage capacity, bandwidth and battery power.[13] Frequent network partition is caused due to the mobility of the nodes. The data maintained by a particular node cannot be accessed by other nodes due to network partition. Replication helps to improve data availability to a large extent in presence of network partition. In order to perform efficient replication of data, each node should contribute a portion of its memory space to accommodate the replica allocated by other nodes.

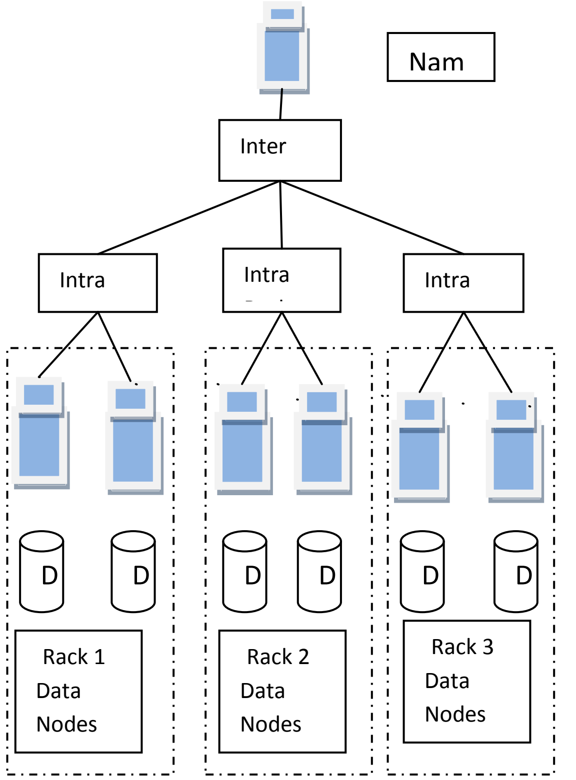

Figure 3 Replication scenario in Cloud computing –Hadoop Distributed file

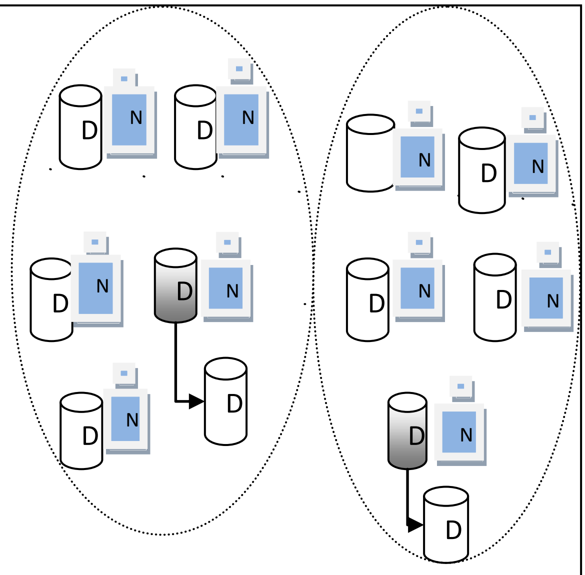

Figure 4 A scenario in Selfish aware Replication in MANET

Cooperation among mobile nodes is expected in order to achieve high data availability. But recent studies show that a node in mobile environment behaves selfishly. i.e. a node is always willing to store the data for its own benefit and shows least cooperation to store data for the benefit of other node. A selfish nature of Node N4 and N8 is illustrated in figure 4. Node N4 stores data D3 instead of D4 which is a replica allocated thereby making the data D4 unavailable to the members in the network. Similarly node N8 retains D6 instead of allocated replica D8 due to its selfishness.

The work in [13] studies the selfish behaviour of the mobile nodes in the MANET environment and proposed a novel replication algorithm based on the measured selfishness of nodes.

2.5 Reducing Access Time and Overall Network Traffic using a Distributed Replication algorithm in Distributed Replication Group. [14]

The work [14] proposed a replication strategy to reduce the access time of data objects maintained by different servers within a network. If the data is accessed from a nearby server it reduces the access time as well as the amount of network traffic. The work [14] aims at minimizing the access time and the network traffic for a given set of object requests and a set of servers with a specified storage capacity. It considers a set of servers used to contain the replicated objects called replication servers. Such a group is called distributed replication group [14].

2.6 An analysis on Server Selection in Content Replication Networks [15]

Web servers in Internet maintains resources such as text files, data base records, data objects, audio and video files that can be accessed by its client. Response time is an important criterion for a high performance server that provides the requested content to its client. The frequently accessed contents are maintained by servers which are near to clients. The proposed work in [15] offers a convenient mechanism to choose servers that provide the contents in a shorter response time. Few nodes are designated as super nodes that receives request from clients and assigns a server which has shorter response time. The work proposes two schemes for server selection namely Equal Delay [21][22] and Equal Load. Equal delay sets the access probabilities to the servers so that the average delay at all the servers are equal or at the same order. Equal load [20][21][22] sets the access probabilities to the server so that all the servers have same utilization. Though analysis has been done through parameterized simulations [15], the performance of these server selection algorithms have not been studied on the real network models due to its inherent complexity in modeling such a one.

2.7 A dynamic approach for Replica placement in cloud for Higher availability [24]

The work in [24] proposed a Distributed Dynamic Replication Strategy (D2RS) [24] to improve the availability of data and service in cloud environment. It also improves the scalability and task execution successful byte effective rate of the system. It differs from the previous works for replication in the way the data is replicated. The popularity of the data is calculated dynamically with access requests from the clients. The replica operation is initiated when popularity exceeds a certain threshold. In addition to calculating the popularity of the data dynamically, the algorithm places the replicas in nodes in such a way that it reduces the waiting time of the users and network bandwidth to a large extent. The work maintains a balance between the number of replicas to be generated for a data and maintenance overhead of the system. The proposed work is simulated for an Ultra –Large scale distributed cloud environment using Cloud-Sim toolkit. A multi-tier architecture of data nodes is taken to analyze the proposed mathematical model.

2.8 Division and Replication of data in cloud for optimal performance and security (DROPS) [25]

This early article in press discusses about the replication of data file combined with security in cloud environment. Unlike the traditional approaches, it aims to replicate a data file by dividing it into fragments and storing the fragments in different data nodes in the cloud. The fragments are stored in data nodes which are near to the user so that the user can experience a minimum access time. The details of fragment location for a particular file are hidden using a technique called T-coloring which makes an adversary not to collect any information about the fragments. The proposed approach uses a less computational expensive security measure unlike the conventional cryptographic techniques. The simulation results of this work have shown an improved access time and security with an additional performance overhead.

3. Comparative study

S. No	Area or type of network/computing paradigm	Replication methodology	Objectives	Scope for extension
1	The Internet or Large scale distributed systems spanning in Organizations, Regional and International	Replicating data in hierarchical and transparent web proxies	To minimize the access time for clients. To increase availability by replicating data on several proxy servers	1.Achieving a balance between the number of proxy servers and the incurred traffic overhead to achieve optimal solution
2.	Mobile ad hoc networks	Analyzing and quantifying metrics that will influence Data availability by node mobility	Analyzing the proposed metrics under various mobility model such 1. Random Way point 2. Group mobility 3. Manhattan Mobility	2.Utilizing the proposed metrics in the replication algorithm to achieve efficient solution
3.	Hadoop distributed file system architecture used for data management in cloud computing	1.Random Replication 2. HQFR 3.MCMF 4.CMCMF	To satisfy applications with QoS requirements by storing data on nodes that satisfy the QoS requirement of applications	1.Energy efficient replications 2. Analyzing the performance of the proposed algorithm for real time network models
4.	Mobile ad hoc network in presence of selfish nodes	1. Selfishness measuring algorithm 2.Self Centred Friendship tree construction algorithm 3. SCF Tree based replica allocation algorithm	1. To measure the cooperation of nodes to hold the data replica for others. 2.Constructing SCF tree 3.Allocating replica to nodes based on the constructed tree	1. An equivalent structure similar to SCF tree to reduce the computational time and message overheads in replication. 2. To study the performance of the algorithm for variable sized data.
5.	The internet or large scale distributed system that follows client server architecture in presence of object replication group	Minimization function that takes access time of clients as its attribute.	Minimize access time Maximize throughput	Deriving the model for recent computing paradigms such as MANET and cloud
6.	The Internet/Content delivery networks	Equal delay and Equal Load policies	Minimizing the access time by deploying Super nodes in Content delivery networks	More efficient and server selection policies

7	Cloud using multi-tier data node architecture	Distributed dynamic replication strategy [D2RS]	Reducing waiting time of users, network bandwidth and reducing the system maintenance overhead	Further reducing the access time, availability and implementing the proposed model in the real time cloud environment.
8	Cloud using Three tier, FAT tree and DCELL	DROPS – Division of Data and replication in cloud for optimal performance and security.	It reduces the access time of replica with more security. It divides the data file into fragments and stores it in different data nodes. Uses T-colouring technique to hide the location of fragments of file	Since the proposed work faces performance overhead while offering reduced access time and security, it needs improvement to maintain the balance between the security, replication and performance overhead.

4. Conclusion

The need for contemporary replication algorithms arises along with the emerging network models/computing paradigm. The heterogeneous characteristic of networks such as the participating nodes and communication medium raises a need for high data availability. Replication has been a popular technique used to increase data availability. We have studied in depth the various replication algorithms proposed for different network models/computing paradigm such as distributed (Client-server and peer to peer), MANET, Content Delivery Networks and cloud. We also identified places for improvement and possible extensions in order to improve the efficiency of replication mechanism.

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