A cost-effective and reliable cloud storage

Yongmei WEI
School of Engineering, Nanyang Polytechnic
Singapore, Singapore
Sophia_wei@nyp.edu.sg

Yong Wee Foo
School of Engineering, Nanyang Polytechnic
Singapore, Singapore
Foo_yong_wee@nyp.edu.sg

***Abstract*—The project aims to provide a scalable, reliable and cost effective cloud storage solution based on a Low Density Parity Check (LDPC) code-based framework. The novelties of the project lie in the following aspects. Firstly, the proposed framework utilizes a new technique called dynamic parameterization so that the existing resources can be used more efficiently. Secondly, a tailored error correction code with localized property is specifically designed to minimize the cost occurred during encoding and decoding for the distributed storage system. Thirdly, a neuroevolution approach is proposed, combining artificial neural network learning algorithm with evolutionary method, to develop predictive models for dynamic resource allocation and performance optimization.**

Keywords-component; dynamic parameterization; error correction codes; distributed storage; cloud storage; predictive model; neuroevolution

I. INTRODUCTION

Cloud storage outages happened from time to time. e.g. Google Docs October outage in October 2011, and the unavailability incidents for Amazon EC2, April 2011. Kroll Ontrack survey reveals that 65% of business has frequently lost data from a virtual environment, up by 140% from 2010. Therefore, adding redundancy is a must to ensure certain level of reliability. In current practice, the most popular technique to add redundancy is to use replication-based method. Replication-based method relies on making and storing multiple copies. Unfortunately, replication-based method introduced large spatial overhead. Generally, two additional copies have to be created and stored resulting in 200% storage space overhead. As a result, there is a surge of interests in applying more powerful error correction codes to tolerate multiple failures in the cloud storage systems with reduced spatial overhead. Unfortunately, there exists a major concern on their computational overhead occurred causing deteriorated using experience such as longer latency. This project aims to provide a scalable, reliable, high performance and cost effective cloud storage solution in a dynamic and competitive cloud service environment. The framework will vastly increase storage efficiency, dramatically decrease latency and data centre footprint, and radically drive cost down. Furthermore, the framework also has the potential to provide higher reliability with moderate increase of the storage space for any data center operators or cloud storage service providers.

II. APPROACH AND SYSTEM ARCHITECTURE

Figure 1 shows the overall system architecture. The project will deliver a service-based prototype so that it can be easily integrated with the existing cloud storage platform such as Hadoop [1]. Cloud Storage Services Adaptation layer shown in Figure 1 is responsible for generating the corresponding requests/responses to the service provider to realize different functionalities such as reading, modifying and appending. LDPC core shown in Figure 2 is responsible for applying LDPC encoding/decoding during the users' request such as read, write, modification, appending and deletion. Figure 2 shows LDPC Core in more details. The steps such as encoding and decoding will introduce additional overhead compared with traditional replication techniques. Therefore, it is extremely important that the encoding and decoding is efficient enough without compromising the overall performance and the user experience. These are facilitated by introducing dynamic parameterization, tailored LDPC for the cloud storage application and a predictive model to optimize the cloud storage resources. More specifically, the QoS control policy shown in Figure 2 realizes the dynamic parameterization to configure the parameters k and n of LDPC codes adaptively based on inputs from the predictive model that takes into account file attributes, QoS requirements from the user and consumption of the system resources of the cloud storage service provider. This is because our preliminary studies show that these two key parameters influence the system performances in various aspects including latency, spatial efficiency and etc. The output k and n from the QoS control policy will be used to control combiner/slicer to divide the file received into k chunks. The LDPC encoder/decoder shown in Figure 2 will realize the tailored LDPC code to do the encoding and decoding with the selected k and n from the QoS control policy. And finally, guided by the block placement policy, the block contents will be dynamically placed to achieve the required performance and resource optimization.

III. NOVELTIES

A. *Dynamic parameterization*

The basic principle behind this technique is to incorporate the requirements of Quality of Service (QoS) policy from the users as the first criterion for adjusting the parameters related to LDPC code so that the existing resources can be used more efficiently and the time-sensitive requests have the resources they require, while allowing other applications access to the storage.

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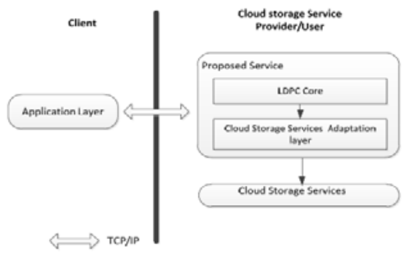

Figure 1: System Architecture

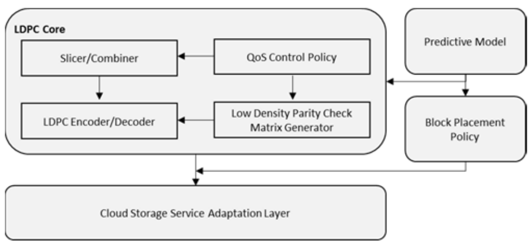

Figure 2: LDPC Core

The selection of most appropriate parameters largely influences the system performance in terms of latency, reliability and internal load. This is because these parameters are interrelated with many factors such as spatial overhead, transmission delay and etc. Therefore, a framework is to be developed to dynamically determine the configurations of LDPC codes in terms of n and k to achieve the best trade-off between efficiency and reliability. This innovative aspect enables achieving the following benefits,

- The requirements of QoS from the users will be included as the first criterion for adjusting the parameters related to LDPC so that the existing resources can be used more efficiently and the time-sensitive and mission-critical applications have the resources they require, while allowing other applications access to the storage.
- Different metrics will be formulated to characterize the consumption of system resources. The parameters of the LDPC can be optimized through balanced consumption of system resources. This is a key to guarantee the desired maximum system capacity as it can avoid the situation that one type of resource is used up while other resources remain un-used for a large portion.

B. Tailored Low Density Parity Check (LDPC) code

The second innovation aspect is about tailored LDPC. One of the major complexities incurred by error correction code based method is the costs incurred during repair. The project intends to develop effective LDPC to minimize the corresponding cost so that the benefits can be achieved including shorter latency to the users and less consumption of bandwidth within the cloud. As LDPC codes have originally been designed for communication models and do not necessarily appropriately account for all the above mentioned costs related to storage systems. Therefore, a new type of systematic LDPC code with a more localized decoding property is going to be developed with the aim to minimize the cost occurred during repair and modification. Traditionally, the decoding requires all the relevant chunks including both data chunks and parity chunks to be gathered to a single location. This will introduce huge traffic within the cloud. With the localized decoding property, the number of chunks to be gathered is decreased. As a result, the decoding operations can be more localized to reduce the bandwidth consumption within the cloud. Secondly, the block size of LDPC code n tolerates variation. This leads to variable block sizes in generator matrix as well. As a result, appending can then been easily realized by increasing the corresponding generator matrix. Thirdly, distributed decoding and encoding will be exploited to shorten the latency especially for files with big size.

C. Predictive Modelling

Cloud storage service offers a common repository to store any kind of file, including documents, images, music, photos and videos. These files have attributes such as creation time, file name, size and access pattern. Statistical evidence has shown significant association between the file attributes and its properties such as read, write and access [3] [4]. The abililty to accurately predict the file properties can lead to substantial improvement in system performance. For instance, if a file will be frequently read, adapting to a conservative compression scheme and placing its block contents in proximity to each other improves read performance. On the other hand, if a file will be rarely read, a more aggressive compression scheme can be adapted to increase spatial efficiency. Here, we proposed neuroevolution modeling, using evolution to optimize Artificial Neural Networks (NN) learning algorithm, to predict the file properties at creation time. The neuroevolution predictive model is used to guide the QoS control policy and Block Placement policy to achieve more granular control over LDPC parameterization, and to optimize performance through improving reference locality and resource utilization.

IV. TESTING AND BENCHMARKING

The testing and benchmarking with the traditional RAID-6 and its variance [2] is to be done in three stages. The prototype will be tested firstly within our in-house infrastructure - a small Hadoop cluster with 30-50 virtual machines. Secondly, virtual cluster containing up to 1000 virtual machines will be tested. Lastly the prototype will be integrated with commercial cluster to further test the effect on the latency and computational overhead.

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