Improving Hierarchy Storage for Video Streaming in Cloud

Mahmoud Darwich1, Yasser Ismail2, Talal Darwich3, Magdy Bayoumi4
1Department of Mathematical and Digital Sciences, Bloomsburg University of Pennsylvania, PA 17815
2Electrical Engineering Department, Southern University and A&M College, Baton Rouge LA 70807
3Microchip Technology Inc., San Jose, CA 95134
4Department of Electrical and Computer Engineering, University of Louisiana at Lafayette, LA 70504
Email: mdarwich@bloomu.edu, yasser_ismail@subr.edu, talal.darwich@microchip.com, magdy.bayoumi@louisiana.edu

Abstract—Frequently accessed video streams are pre-transcoded into several formats to satisfy the characteristics of all display devices. Storing several video stream formats imposes a high cost on video stream providers using the old classical way. Alternatively, cloud providers offer a high flexibility of using their services and at a low cost relatively. Therefore, video stream companies adopted cloud technology to store their video streams. Generally, having all video streams stored in one type of cloud storage, the cost rises gradually. More importantly, the variation of the access pattern to frequently accessed video streams impacts negatively the storage cost and increases it significantly. To optimize storage usage and lower its cost, we propose a method that manages the cloud hierarchy storage. Particularly, we develop an algorithm that operates on parts of different video streams that are frequently accessed and stores them in their suitable storage type cloud. Experiments came up with promising results on reducing the cost of using cloud storage by 18.75 %.

Index Terms—cloud, storage, video stream, pre-transcoding, clustering

I. INTRODUCTION

The advances in display devices technology from big screens of TVs, computer monitors, etc., to small screens of mobile devices, allows people around the globe to afford to purchase these devices. In addition to social media applications, it opened the doors to all users to watch a video stream and even stream their videos through their devices. Managing a huge number of videos became challenging for video stream providers. Gratefully, Cloud technology came up to offer a solution that helped video stream companies to process the video streams easily and less costly. However, the exponentially rapid growth of video streams number adds a further challenge in the cloud that needs to be addressed [1].

Cloud services provide two essential operations on a video stream either transcoding or storing. Transcoding is an operation applied on a video stream to create another format, it requires extensive computational resources which are considered high cost, while cloud storing costs less because the computational virtual machines and storing servers are charged in hourly and monthly rates respectively [2].

Several formats for each video stream are created to meet the characteristics of all devices specification [2]. Accordingly, to avoid the high cost of transcoding, many formats of a video are pre-transcoded and stored in the cloud. The criteria for storing video formats is based on the frequent accesses to them, thus, They are called Frequently Accessed Video streams (FAVs).

Amazon Web Services (AWS) is well known as a cloud services provider and is adopted in our research to implement the experiments. However, our approach could be applied to other cloud platforms. Amazon storage offers a variety of storage options. In this research we consider the following:

- S3 Standard: It is typically used to store frequently accessed video streams.
- S3 Standard-Infrequent Access (S3 Standard-IA): is used to store infrequently accessed video streams.
- One Zone-Infrequent Access (S3 One Zone-IA): is used to store less infrequently accessed video streams.
- S3 Glacier: stores frequently access video streams for long term.

The research problem in this work is how to store the part of the video which is frequently accessed in different cloud storages. Therefore, an approach that carries out clustering on the parts of different video streams is proposed to optimize the cloud storage cost.

The contribution of this research is summarized as follows: (1) We propose a method that decides parts of a video stream to be stored in different cloud storage. This is done through clustering of frequently accessed parts. (2) We analyze the efficiency of the proposed method when the number of accessed video streams varies.

Our proposed work differs from our previous work [4] in that we propose a method that clusters the frequently accessed parts of video streams in different storage and thus it reduces the cloud cost.

The paper is organized as follows: Section II discusses the related works. In section III, the clustering method is detailed. Section IV reveals the experiment setup and section V presents the results. Section VI concludes the paper.

II. RELATED WORK

Darwich et al. [9] proposed methods to manage frequently accessed video streams in a repository to reduce the cost of storing video streams.
cloud services. They came up with an algorithm that measures the hotness of the frequently accessed video stream, their method stores the frequently accessed video streams. The results show a cost reduction of using cloud services.

Darwich et al. [3] proposed an approach that decides whether a video stream should be stored in the cloud or re-transcoded upon request. Particularly, the calculated cost ratio of storing cost to transcoding cost. If the ratio is less than 1, the method will store the video stream. Their approach could reduce the cost significantly.

Darwich et al. [4] proposed a method that stores frequently accessed videos in different types of cloud storage. They clustered frequently accessed video streams in the cloud storage which have low prices and thus their method could reduce the incurred cost.

Jokhio et al. [6] developed a method that reduces the cost of cloud services. Their method is based on calculating the popularity of video stream, they used a weighted graph to trade-off between transcoding storing operation, their proposed approach decides which video that should be stored or transcoded upon request.

Gao et al. [10] developed a scheme to manage the contents of video streams in media clouds. Particularly, they could split video streams into segments and then analyze them based on the view pattern. Their method decides which segments should be stored in the cloud and deletes the rest. The authors aim to minimize the operational cost of the cloud. Accordingly, They proposed an algorithm that could reduce the total cost by up to 30%.

Zhao et al. [7] presented an approach to build a relationship between video views and its version. The authors came up with a strategy that uses a graph to form a relationship among video versions. Based on the graph, they could calculate the transcoding cost of each video in each version. Moreover, they compute the storage costs of videos. They analyze the transcoding and storage costs with views, their approach resulted in a reduction significantly in the cost of cloud services.

III. PROPOSED GOPS CLUSTERING METHOD

A. Entity of Video Stream

A video stream is built by many sequences as shown in Fig.1. Each sequence is composed of Group Of Pictures (GOPs). Further, a GOP is made by different types of frames (i.e., B (bi-directional) frames, P (predicted), and I (intra). Each frame is divided into small slices called macroblocks (MB) as shown in Fig.1. Video processing is achieved at the GOPs level because they are processed independently [11]. Thus in this research, we consider storing a video stream through storing its GOPs.

B. Proposed Storing Scheme

We present a scheme to manage media storage in the cloud in Fig.2. First, the scheme receives the GOPs that are decided to be stored (i.e., pre-transcoded), then these GOPs go through the clustering process. At this point, the proposed scheme analyzes each pre-transcoded GOP and distributes it to its suitable storage. The diagram provides four types of cloud storage; S3 Standard, S3 Standard-IA, S3 One Zone-IA, S3 Glacier are dedicated for cluster 1, cluster 2, cluster 3, and cluster 4 respectively.

C. Proposed algorithm

The proposed algorithm is an enhanced version of the previous one [4]. Its goal is to reduce the cost of storing frequently accessed video streams in the cloud. The algorithm mechanism applies clustering on the frequently accessed GOPs of video streams and then distribute them to their suitable storage in the cloud. The algorithm is executed on frequently accessed GOPs periodically and its pseudo-code is presented in algorithm [1]. The algorithm receives the size of each frequently GOP, its number of views, and the cloud storage price as input. The algorithm output clusters the frequently accessed GOPs into four clusters and then calculates their storage costs.
Fig. 3: Clustering of frequently accessed GOPs in the long-tail distribution

According to Miranda et al. [8], the access pattern to GOPs in a video stream follows the long-tail distribution. That means the beginning of video GOPs are watched frequently more than the remaining other GOPs. However, many videos could have random access patterns. In this case, many GOPs are frequently accessed by viewers. Those frequently accessed GOPs are distributed across the video starting at the beginning through the whole video as illustrated in Fig.3.

In this case, the proposed algorithm clusters the frequently accessed GOPs into four clusters. The clustering process is based on a similar number of views of GOPs. Cluster 1, cluster 2, cluster 3, and cluster 4 contain GOPs that have a similar number of views (Step 1). Then, the storage cost is computed for each cluster (Step 2 - Step 5). In Step 6, the total storage cost of all clusters is calculated.

Algorithm 1: GOPs storing cost

Input : Frequently accessed GOPs: GOP_i
Size of each frequently accessed GOP_i
Cloud Storages price: P_S1, P_S2, P_S3, P_S4
Number of views of each frequently accessed GOP_i

Output: Storage Cost of all frequently accessed GOPs

1 Apply K-Means clustering on all frequently accessed GOPs with K = 4
2 Storage Cost of GOPs Cluster 1:
   \[ C_{S1} = \sum \frac{S_{GOP_i} \cdot P_{S1}}{210} \]
3 Storage Cost of GOPs Cluster 2:
   \[ C_{S2} = \sum \frac{S_{GOP_j} \cdot P_{S2}}{210} \]
4 Storage Cost of GOPs Cluster 3:
   \[ C_{S3} = \sum \frac{S_{GOP_k} \cdot P_{S3}}{210} \]
5 Storage Cost of GOPs Cluster 4:
   \[ C_{S4} = \sum \frac{S_{GOP_l} \cdot P_{S4}}{210} \]
6 Total storage cost of frequently accessed GOPs:
   \[ C_{SGOPs} = C_{S1} + C_{S2} + C_{S3} + C_{S4} \]

IV. EXPERIMENT SETUP

A. Videos Synthesis

The experiments are implemented using synthesized video streams. We created repositories of video streams by applying

B. Amazon Storage Rates

Amazon Website Service (AWS) offers to users several types of storage for different purposes of data storing. Table II shows the rates in USD.

| Storage          | Price          |
|------------------|----------------|
| S3 Standard      | $0.023 GB/month |
| S3 Standard-IA   | $0.0125 GB/month |
| S3 One Zone-IA   | $0.01 GB/month  |
| S3 Glacier       | $0.001 GB/month |

C. Methods for Comparison

We assess the proposed method by comparing it to previous works. The description of previous works are summarized as follow:

- **Fully pre-transcoding** method: it stores the whole video streams
- **Fully re-transcoding** method, it deletes the video stream and transcodes it upon request
- **Partial pre-transcoding** method in [3], it stores a part of video stream which receives frequent accesses in the cloud standard storage S3 Standard.
- **Clustering video streams** method in [4]. It clusters the frequently accessed video stream and stores them in different storages in the cloud

V. SIMULATION RESULTS

Table II displays the results of the methods. The fully re-transcoding has the highest cost because each time the video stream is accessed, the video streams provider pays for using the virtual machines to transcode all video streams.

The fully pre-transcoding method has the second-highest cost because the video stream provider pays for using the
TABLE II: Cost comparison in USD when the percentage of frequently accessed video changes

| PAVs % | Fully Re-Transcoding | Full Pre-Transcoding | Partial Pre-Transcoding | Videos Clustering | Proposed GOPs Clustering |
|--------|----------------------|----------------------|-------------------------|------------------|--------------------------|
| 5%     | 1596                 | 839                  | 664                     | 650              | 600                      |
| 10%    | 1596                 | 842                  | 662                     | 620              | 590                      |
| 15%    | 1596                 | 863                  | 643                     | 600              | 560                      |
| 20%    | 1596                 | 947                  | 613                     | 560              | 520                      |
| 25%    | 1596                 | 1424                 | 566                     | 530              | 470                      |
| 30%    | 1596                 | 3137                 | 533                     | 480              | 390                      |

storing servers to store all videos. It is worth mention that the cost of renting the virtual machines to transcode videos is higher than the cost of storing servers in the cloud.

The partial pre-transcoding has a better performance compared to the two previously discussed methods. As the percentage of the frequently accessed video streams increases, this method works better because more parts of video streams are stored and reduce the cost further.

The videos clustering method outperforms the previous method because it stores the frequently accessed video streams in different storages in the cloud, which makes the cost to be less than the cost of storing all video streams in one standard storage S3. As the percentage of frequently accessed video streams increase the cost is reduced further.

The proposed method overcomes the performance of all previously discussed methods. Frequently accessed GOPs are clustered and stored in different cloud storages as shown in Fig. 5. Cluster 1 contains the frequently accessed GOPs that have the highest views. Those GOPs are more demanded by viewers and thus stored in S3 Standard-IA, which has the fastest access and highest cost among the others. Cluster 2 contains all GOPs that have similar views. Its GOPs are less accessed than cluster 1, they are stored in S3 One Zone-IA, which costs less than S3 Standard-IA. The GOPs, which are less demanded, are included in Cluster 3 and cluster 4 which have lower costs. When the percentage of frequently accessed GOPs increases the proposed method reduces the incurred cost by 18.75% compared to the videos clustering method and 27% compared to the partial pre-transcoding method.

For the sake of clarity, Fig. 4 presents the comparison of partially pre-transcoding, video clustering, and proposed GOPs clustering methods, we eliminate the first two methods because of their high numbers which deteriorate the curves visibility.

VI. CONCLUSION

In this paper, our proposed method reduced the cost of the cloud services to store video streams. Particularly, our method clusters the frequently accessed GOPs and store them in four different storages, cluster 1 contains GOPs that has the highest views, which provides fast access to it, while clusters 2, 3, and 4 are for the GOPs with fewer views. The experiment results show that the proposed method reduces the cost by 18.75% compared to the video clustering method and 27% compared to the partial pre-transcoding method.

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