International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 05 | May 2024 www.irjet.net p-ISSN: 2395-0072

Performance and Scalability of Cloud Object Stores: Systematic Literature Review

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Abstract—In recent times, the adoption of cloud object stores has been increasing fast due to their combination of important benefits, including high availability, elasticity, and a pricing model that enables applications to scale according to demand. Currently, the common approach is to either utilize a single set of configuration settings or depend on statically pre-set storage rules for a cloud object store deployment, even when the store is utilized to support various types of applications with changing requirements. The significant disparity between the specific demands and capabilities of the object store's many applications is a pressing matter that needs to be resolved to attain optimal efficiency and performance. This investigation's chief goal is to explore the performance and scalability of cloud object stores through research analysis. The study utilizes a comprehensive literature review methodology. This study examined a total of 30 papers that were published from 2018 to 2024. This research suggests that comparing the specifications and techniques of services offered by different cloud vendors can provide a more impartial assessment of the capacity and promise of cloud computing (CC) and object storage. This comparison helps eliminate bias risk and delivers a more accurate evaluation of the technology. The assessments yield significant information regarding the strengths and limitations of various cloud storage (CS) systems. This aids organizations in making educated decisions when choosing and improving their storage infrastructure to suit changing business requirements.

***Index Terms*—Cloud Computing; Object Storage; Performance; Scalability; Cloud Storage Systems.**

I. INTRODUCTION

The proliferation of the Internet has led to the creation of numerous little files through Web applications. Internet users contribute to this by uploading massive quantities of photographs, movies, and music, while the daily exchange of emails reaches the hundreds of billions [1]. Based on statistics from the Internet Data Centre (IDC), the data will grow by 44 times in the next decade. Out of this, 80% will be unstructured data, with most of it being inactive [2]. The block storage area network (SAN) alongside network attached storage (NAS), which have petabyte-level expansion file storage potential, cannot manage such a massive volume of data. Typically, the size of a logical unit number (LUN) on a block storage area network (SAN) is limited to just a few terabytes (TB). CC effectively addresses concerns related to scalability, resource allocation, and computing costs. It simplifies system operations and eliminates the need to understand intricate details of cloud technologies, thereby reducing the indirect cost of studying [3]. The primary providers of CC services are predominantly firms that specialize in the IT industry and provide solutions and services for CC. This includes infrastructure, data centers, and various tools associated with CC platforms. Cloud vendors like Amazon Web Services (AWS), alongsideMicrosoft Azure, alongside Google Cloud Platform, alongside Red Hat, and VMware each possess distinct traits and product offerings [4].

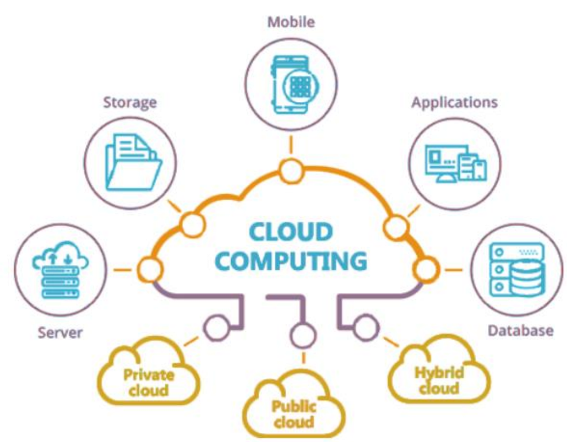


Fig. 1: Cloud Computing [5]

Fig. 2: Cloud Computing Vendors [6]

A. Scope of the study

The study on "Performance and Scalability Analysis of Cloud Object Stores" aims to assess the performance and scalability features of several cloud object storage systems. The study seeks to provide insights and recommendations for optimizing the efficiency and scalability of CS infrastructure through comprehensive performance benchmarks and scalability tests. This investigation's objectives are the following:

1) To explore performance and scalability analysis of cloud object stores and to study about different CS services
2) To study the effects of novel developments in cloud object storage and to identify the emerging trends and future directions in cloud object storage.

B. Research Questions

1) What is the performance and scalability analysis of cloud object stores, and what are the various CS services that are available?
2) What are the implications of the advanced features that are available in cloud object storage, and what are the rising trends and future directions that are associated with cloud object storage?

II. RESEARCH BACKGROUND

The increasing popularity and expansion of social media and the Internet of Things (IoT) have led to a significant shift in the demand for the allocation of computer resources. With the advent of the IoT era, there is a significant difficulty in meeting the computing resource demands of consumers globally [7]. Individual clients and businesses necessitate network services that are more secure, efficient, reliable, and user-friendly. The previous technique such as static routing and physical sever allocations of resources is founded on a localized and unchanging model. The processing capability is only determined by the local physical machine, which hinders the scalability of computing resources and fails to meet the time-sensitive demands of certain resource management tasks [8]. Therefore, the previous solutions are inadequate in achieving greater competitiveness and efficiency. CC has emerged as a viable solution for meeting the demands of providing internet services while optimizing cost and performance, as opposed to traditional local computing. Due to the proliferation of computing services and advancements in Information Technology, CC is evolving into a framework that offers services to users, becoming an essential part of everyday life [7]. CC encompasses the delivery of applications or services via the Internet, as well as the physical components, storage systems, and system software involved. CC is a flexible and scalable resource pool that caters to many customers. It provides network access to users who need computational resources in a convenient manner. These resources can include networks, servers, applications, or storage systems [8] [2].

A. Methodology

The study utilizes the Systematic Literature Review technique. This study employs the PRISMA approach to conduct a Performance and Scalability Analysis of Cloud Object Stores. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) offers a methodical structure for discovering pertinent research, extracting crucial data, and combining findings to support decision-making based on evidence.

This was accomplished by creating a search string (SS). The search terms consist of Performance analysis cloud object stores* OR Scalability evaluation cloud object storage* OR Cloud object store benchmarking* OR Performance metrics for cloud object storage* OR Scalability assessment of cloud object stores* OR Cloud object storage throughput analysis* OR Latency measurement cloud object stores* OR Performance comparison cloud object storage solutions* OR Cloud object storage workload analysis* OR Evaluation of cloud object store performance under load. The strings were used to extract the title and abstract sections. Only papers released between 2018 and 2024 were selected for assessment to concentrate on the most recent advancements in the area.

B. Inclusion/Exclusion Criteria

The table II presents the potential criteria for inclusion and exclusion in this systematic literature review on the investigation of performance and scalability in cloud object stores:

The data was collected by producing and evaluating the search phrase in several renowned databases. Once the references were imported using Endnote, they underwent a filtering process to eliminate any occurrences of duplication. As a result, a grand total of 220 papers remained, all of which were fully distinct from one another. Through a thorough examination of titles and abstracts, this study successfully identified papers that included the selected keywords. Subsequently, the created references were exported directly to an Excel spreadsheet with the intention of applying filters and conducting further analysis. Said spreadsheet contained information regarding the authors, alongside the year of publication, alongside the title, alongside the abstract. So, the Excel spreadsheet includes a grand total of 189 research publications. All papers' abstracts were examined in Excel, with a specific focus on the ones directly relevant to the research objectives. Initially, 111 articles were found, but some of them were excluded since they were classified as grey literature, books, or parts of books. In addition, a portion of the articles were not available for download, resulting in their removal from circulation. There was a total of 26 papers in the final shortlist. The method used to choose articles for the SLR during a literature search is depicted in a flow diagram (Figure 3) that bases itself on the PRISMA Flow Diagram.

III. RESULTS AND DISCUSSION

CC data centers are built with a straightforward infrastructure that is designed to handle failures well. They employ cost-effective, specialized, expandable solutions, such as servers, alongside storage systems, alongside networking equipment, while also leveraging conventional delivery patterns and significant economies of scale [9]. CC data centers, on the other hand, do not buy pre-made equipment specifically made for the conventional mass-IT market. The cost of these solutions is excessive, and their features do not align with the specific needs of cloud-based data center infrastructure and application necessities.

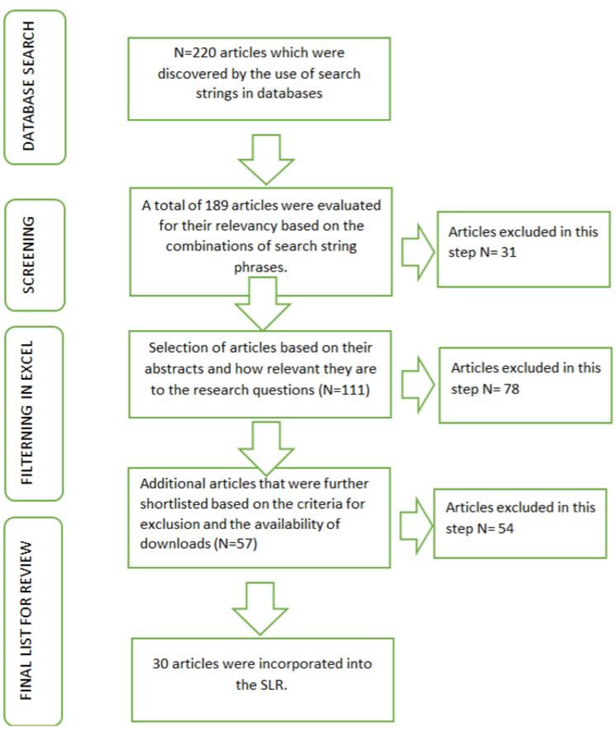


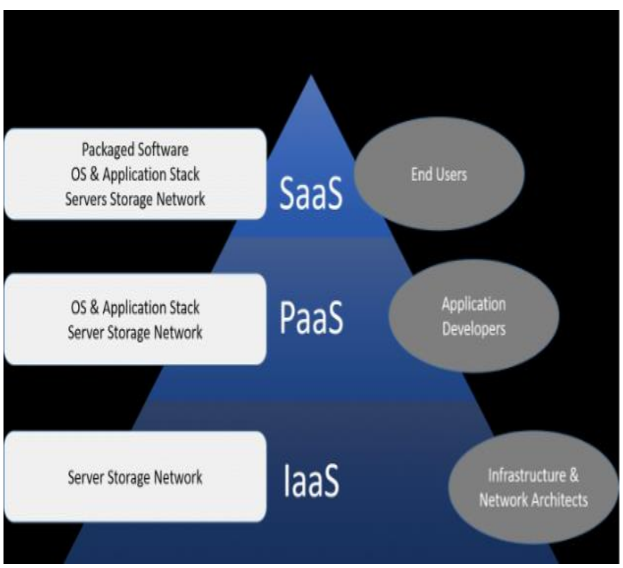
Fig. 3: Literature search for SLR publications.

Digital Library	URL
Scopus	https://www.scopus.com/sources.uri?zone=TopNavBar&origin=searchbasic
Semantic Scholar	https://www.semanticscholar.org/
IEEE Xplore	https://ieeexplore.ieee.org/Xplore/home.jsp
Science Direct	https://www.sciencedirect.com/
Springer	https://link.springer.com/
Web of Science	https://wosjournal.com/
PubMed	https://pubmed.ncbi.nlm.nih.gov/

TABLE I: Relevant publications were identified from internet repositories in this study.

Criteria	Inclusion	Exclusion
Type of Study	Academic Research papers and Review articles	Editorials and opinions
Publication date	Studies published within the last 5 years	Studies published over 5 years ago
Subject Are	Cloud computing, object storage	Irrelevant Subjects
Access Availability	Open access studies	Studies behind paywalls or lacking access
Peer – Review	Peer-reviewed studies	Non-peer-reviewed studies

TABLE II: Inclusion/Exclusion Criteria



The services are categorized into three broad categories which is illustrated in Figure 4.

RQ1: What is the performance and scalability analysis of cloud object stores, and what are the various CS services that are available?

A. Cloud Storage (CS) Architectures

CS architectures focus primarily on providing storage as needed in a greatly scalable and multi-tenant manner. As technology advanced, users experienced a significant increase in their computer needs. This led organizations to integrate additional processing and storage resources [11]. Implementing systems on a big scale necessitates significant efforts Fig. 4: Cloud Services cite [10]

and substantial costs, leading enterprise clients to delegate their computing and storage resources to external providers [12], [13]. Users lack complete autonomy over the computer resources accessible through the Internet cloud [14]. The research interest in CS is increasing due to the growing need for data-intensive applications, which results in a doubling of storage capacity requirements and data usage per year. This spurred several business enterprises to pursue an alternative cloud service known as ”on demand storage.” At present, storage providers are mostly focused on other areas of CS, such as cost concerns, performance challenges, and integrating numerous storage options [15]. The Figure 5 illustrates the configuration of the master and data nodes in a CS system.

B. Performance and Scalability

Investing in performance incurs financial expenses. Performance and cost are effectively balanced in a well-architected application. To achieve this, it is crucial to align an enterprise’s business performance needs with the appropriate technology. This, in turn, necessitates the firm to convert its requirements from business language to IT measurements [10]. Due to the complexity of this translation, organizations frequently find themselves with inflexible IT architectures that are unable to satisfy the evolving performance needs of the company. Latency remains rather high due to two primary factors: the

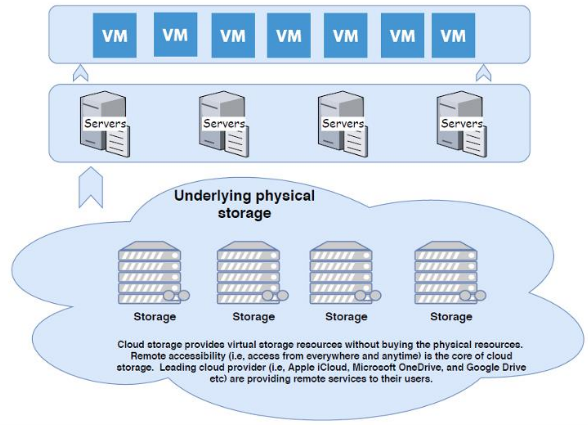


Fig. 5: Structure of cloud storage [16]

access mechanism utilized and the kind and configuration of the storage media being implemented [17]. The access method is a hierarchical arrangement of protocols that operate on top of the OSI Model’s physical layer. Data access that utilizes a shared physical layer, such as Ethernet, and multiple layers of protocols, typically results in higher latency compared to a dedicated physical layer, such as Fiber Channel, alongside running FCP. Many mass market cloud services also utilize the Internet for data access, resulting in increased latency in accessing data [18]. Figure 6 shows the capacity required vs storage performance required.

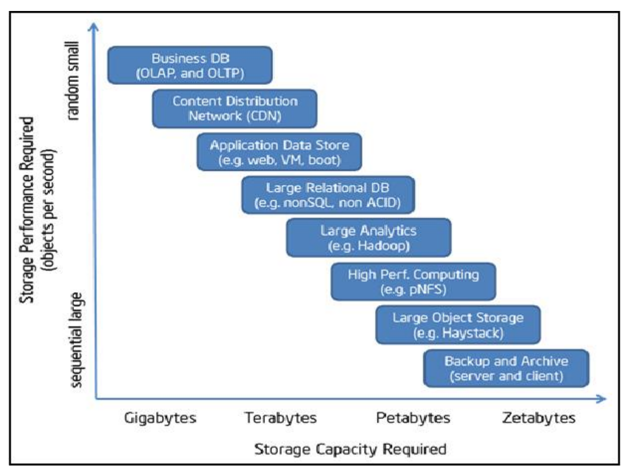


Fig. 6: Cloud Object Store System VS Performance [19]

Scalability should be ensured for both the storage capacity (functionality scaling) and the data transfer rate to the storage (load scaling). One important aspect of CS is the capacity to distribute data geographically (geographic scalability), which means that the data can be located closest to the users across many CS data centers (via migration) [20]. Replication and dissemination of read-only data can be

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 05 | May 2024 www.irjet.net p-ISSN: 2395-0072

achieved, as is commonly done through the utilization of content delivery networks [21]. Figure 7 shows the scalability benefits of cloud storage.

This study specifically addresses the challenges pertaining to these two categories and provides a comprehensive analysis of potential resolutions for these issues. The Figure 8 illustrates the common issues in CS.

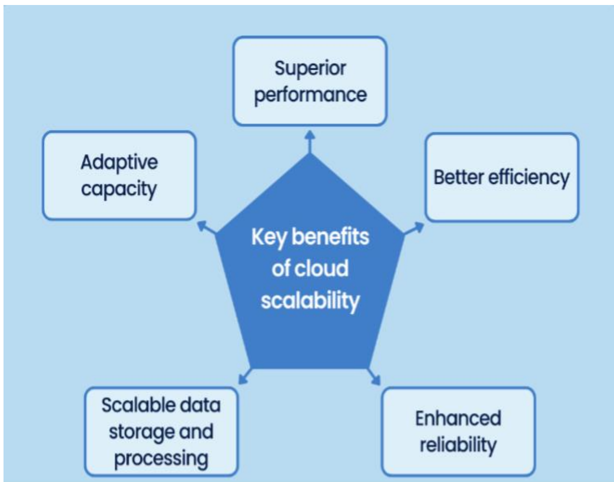


Fig. 7: Scalability benefits of Cloud Storage [22]

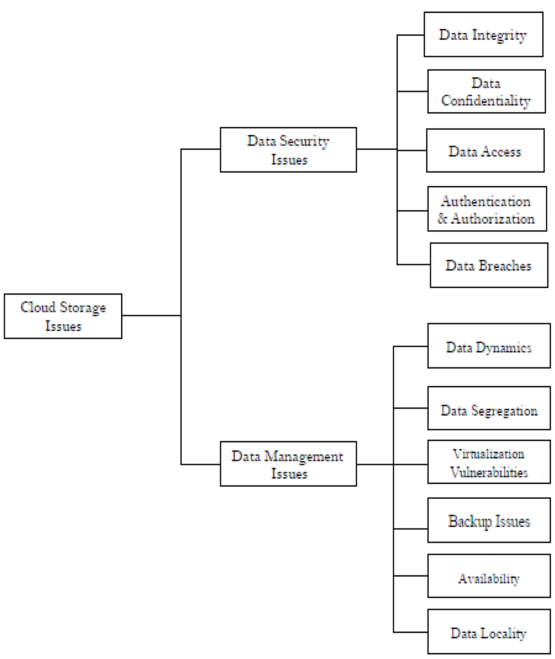


Fig. 8: Cloud Storage Issues cite [16]

C. Three major cloud storage services

CS services are increasingly appealing to individuals as they offer the ability to synchronize information with cloud servers and across many devices. It enables automatic file sharing and synchronization across several users. This section provides an overview of three prominent cloud object storage services:

1) Amazon S3

Amazon S3 provides a range of storage classes designed to meet varied storage needs. These options consist of the Standard storage for commonly accessible data, referred to as general-purpose storage, the Standard Infrequent access storage for infrequently accessed and long-lived data, and Amazon Glacier for archiving purposes. Policies are established to effectively govern data over its entire lifespan. Once a policy is established, data migration straight to the most suitable storage class will occur automatically, without requiring any modifications to the application [22]. Amazon S3 Standard - Infrequent Access (Standard - IA) is a storage option designed for less frequently accessed data, but still requires quick access when required. The Standard - IA option offers excellent performance in terms of high throughput, durability, and low latency. Additionally, it provides cost-effective pricing with a low rate per GB for both storage and retrieval. Standard - IA is an ideal choice for disaster recovery, alongside long-term storage, alongside backups because to its excellent performance and affordable price [23]. Amazon Glacier is a highly affordable, long-lasting, and secure storage solution designed for data archiving. It offers a dependable storage option for any quantity of data at a lower or comparable cost compared to on-premises alternatives [24].

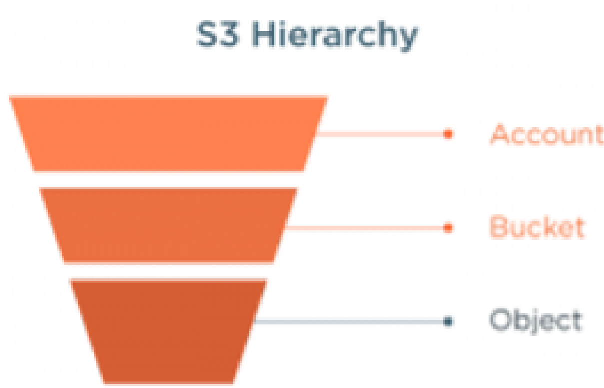


Fig. 9: S3 hierarchy cite 23 []

Authors and Years	Feature	Description	Impacts
Kougkas et al., (2020) [25]	Auto-Tiering	Automatically moves data between storage tiers	The process involves placing often accessed data in high-performance tiers, which results in reduced latency. Additionally, it optimizes costs by transferring less frequently accessed data straight to lower-cost tiers.
Patgiri (2018) [26]	Deduplication	Identifies and eliminates duplicate data	Enhances storage efficiency and accelerates data processes by eliminating duplicate data, hence dropping store space necessities.
Liu et al., (2022) [27]	Edge Catching	Caches frequently accessed data at the network edges	Minimizes delay by delivering content from nearby cache servers and enhances the ability to handle increased demand by diverting traffic away from the main storage systems.

TABLE III: Impact of additional features on performance optimization

2) Google Cloud storage (GCS)

GCS is a well-known CS service provided by Google. It is specifically designed to give flexible and long-lasting storage for various purposes, catering to both small-scale initiatives and major corporate applications. Below are few prominent characteristics and facets of GCS [25]:

a) GCS has extensive scalability, enabling you to store and retrieve vast quantities of data as required. It has the capacity to handle datasets that vary in size from a few gigabytes to petabytes or even larger. GCS stores data as objects, not files or blocks. Unstructured data like photographs, videos, and backups can be stored in objects with data, metadata, and a unique identifier.

b) GCS offers exceptional longevity for stored data. It duplicates data among various locations and storage systems within a specific area to guarantee the accessibility and resilience of data, even in the case of hardware failures or other interruptions.

c) This service provides comprehensive security safeguards to safeguard your data.

d) GCS seamlessly connects with other Google Cloud Platform (GCP) services, counting Compute Engine, Big Query, and AI Platform.

e) GCS utilizes a flexible pricing structure that enables you to just pay for storage and data transfer you consume.

f) GCS boasts a worldwide footprint, featuring numerous storage facilities located across the globe.

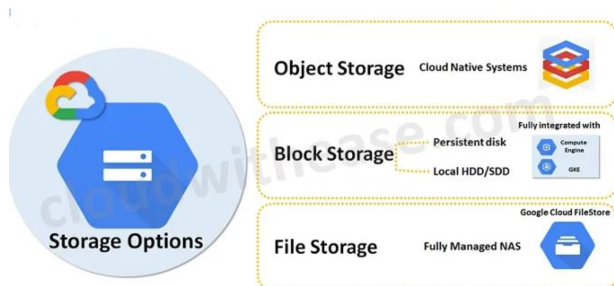


Fig. 10: Google Cloud storage options [26]

3) Microsoft Azure Blog Storage

Blob Storage, or Object Storage, is a storage system specifically designed for storing unstructured object data. A blob can refer to either binary data or even any sort of text. The file can be a document, application installer or even media file. Azure Storage offers two storage levels for Blob object storage, allowing data to be stored in the most cost-effective manner based on its utilization [24].

a) The Azure hot storage tier is designed for the storage of data that is accessed frequently. Data need exceptional durability, availability, and expedient accessibility.

b) The Azure cool storage tier is designed for the storage of data that has a long lifespan and is accessed infrequently. Data necessitates a high level of durability and comparable time-to-access alongside throughput as hot data. However, it can withstand slightly lower availability.

To guarantee optimal accessibility and long-lasting preservation, the data within the storage account is consistently copied. Depending on the chosen replication option, data is either duplicated to a secondary data center or within the same data center. Through the process of replication, the preservation of data availability is ensured, and data is safeguarded against any potential hardware failures. Replicating data to a secondary data center has the benefit of preserving and safeguarding data in case a catastrophic failure at the first location. Microsoft Azure storage account offers various replication options:

a) Locally redundant storage (LRS) maintains three data copies in a single data center and region. It safeguards data from traditional hardware failures, but not from a single data center failure. Discounts are available for LRS.

b) Zone-redundant storage (ZRS) keeps three copies of data across two to three sites, regions, or inside a region. It has better durability than LRS. It verifies data durability within a particular region. After selecting ZRS, it cannot be changed to another replication type.

c) Geo-redundant storage (GRS), Data is stored in six copies. Having three copies in the primary and secondary regions ensures maximum endurance. Azure Storage switches to the backup region in case of primary region failure. It ensures data durability in two regions.

d) Read-access geo-redundant storage (RA-GRS) replicates data to a secondary place and allows read access. If the first site fails, the secondary location can access data. Replication defaults to RA-GRS.

RQ2: What are the implications of the advanced features that are available in cloud object storage, and what are the rising trends and future directions that are associated with cloud object storage?

a) Impacts of advanced features: Advanced functionalities such as auto-tiering, deduplication [27], and edge caching can greatly enhance performance optimization in cloud object storage systems. The Table III illustrates the individual contributions of each feature towards enhancing performance: Cloud object storage systems must effectively tackle scalability concerns to efficiently manage large amounts of data and accommodate high levels of concurrency. Below is an examination of how various systems effectively handle these challenges:

a) Horizontal Scalability: Cloud object storage solutions are specifically built to achieve horizontal scalability, which means they can effortlessly expand by incorporating additional storage nodes or clusters as the data volume increases. This method of horizontal scaling guarantees that the storage capacity can be expanded without causing substantial interruptions to current processes [28].

b) Distributed Architecture: Cloud object storage systems commonly utilize a distributed architecture, in which data is spread across numerous storage nodes or data centers. The distributed structure of this system enables data redundancy, fault tolerance, and load balancing, which guarantees high availability and reliability, even in case of hardware failures or network disruptions [29] [30].

c) Catching and Content Delivery Networks: To enhance efficiency and manage large numbers of simultaneous users, cloud object storage systems can utilize caching methods and content delivery networks to store frequently accessed data in closer proximity to end-users or application servers [29].

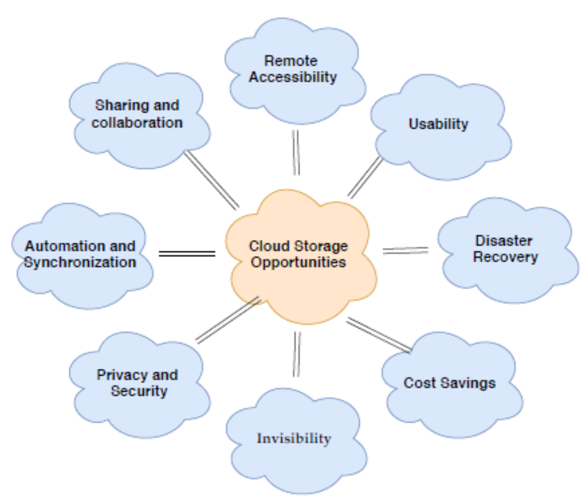


Fig. 11: Opportunities of Cloud Object store systems [16]

4) Emerging trends and future directions in cloud object storage: The future of CC is nothing short of a visionary

concept. The integration of artificial intelligence in items such as self-driving vehicles, the interconnected network of IoT devices, and the implementation of 5G connection are revolutionizing the way people live. The IT industry is undergoing rapid and transformative changes. The straightforward and user-friendly interface, absence of cost and capacity limitations, and numerous other characteristics are appealing to both individual users and the market. Due to the swift advancement in smart technology, there is an increasing focus on CS. In addition to AI, block chain technology is enhancing the safety alongside security of CS. The maturity of this storage technology will enhance client confidence in cloud services. The diagram below depicts the prospective paths of CS [31]. Figure 11 shows the opportunities of cloud object store systems.

IV. CONCLUSION

CC, alongside its interconnected technologies, is a rapidly evolving technology that is significantly transforming traditional computing. Additionally, it is shown that despite the convenience and cost advantages, CS technology still faces various challenges. The CS architecture is primarily obscured by security concerns, such as confidentiality, access, integrity, authentication, data breaches, and authorization. Additionally, there are data management difficulties related to dynamics, alongside data segregation, virtualization, and backup. Nevertheless, significant research endeavors are required to entice clients, particularly commercial and enterprise customers, to utilize CS for storing their critical data.

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