International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.018 ISSN: 2581-4621

Intelligent Multi-Cloud Storage for Online Social Networks

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Abstract: The provision of Storage as a Service (STaaS) in many geo-distributed datacenters by several Cloud Storage Providers (CSPs) has made online cloud storage a great choice for replicating and distributing objects that are accessed worldwide. Online Social Networks (OSN) such as Facebook and Twitter have billions of active users worldwide accessing shared objects. These users expect to access these objects within a tolerable time. To minimize users' access latency time of these objects, OSN service providers must host several replicas of objects in many datacenters. However, this replication process produces a higher monetary cost. This paper addresses crucial issues, including how many replicas are required to fulfil the expected workload of the object and the optimal data centers to host these replicas to reduce latency time for users and monetary costs for OSN service providers. Two online algorithms are proposed to determine the suitable number of replicas for each object and the optimal placement of these replicas. The DTS algorithm establishes the replication and placement of objects using deterministic time slots, while the RTS algorithm is based on randomized time slots. Experimental results show the effectiveness of the proposed algorithms for producing latency time below certain thresholds and reducing the monetary cost.
Keywords: Cloud, Storage, Social Networks, Intelligent, data centre

Introduction

A fundamental innovation of cloud computing is the transformation of the arrangement of computing resources from static, long term and high upfront ownership investment based systems to dynamic provisioning systems. By providing cloud infrastructure and platform as services dynamic resource sharing across organizational and geographical boundaries can be enabled seamlessly to respond to changing demands and requirements. As a result, we witness the growing attentions of hybrid cloud and multi data center cloud deployment from both industry and academic research communities. These cloud technologies offer solutions to deal with high velocity and high volume of big data generated from geographically dispersed sources while providing real-time experience to a broader range of cloud consumers. More companies, such as IBM, Google, and Facebook, are managing multiple cloud-based data centres, which are usually geographically dispersed, to deal with the increasing computational requirements on large-scale data intensive analysis while providing guaranteed low latency to their customers. Furthermore, recent study on efficient energy management for datacenters [1] shows that compared with putting all the infrastructures into a single datacenter, it is more energy efficient to divide a single high-density datacenter into multiple smaller datacenters, and keep low energy costs for each of them.. Cloud computing has recently gained significant popularity as a cost-effective model for delivering large-scale services over the Internet. In a Cloud computing environment, infrastructure providers (namely, cloud providers) build large data centers in geographically distributed locations to achieve reliability while minimizing operational cost [1]. The service providers (SPs), on the other hand, leverage geo-diversity of data centers to serve customers from multiple geographical regions. Today, large companies like Google, Yahoo and Microsoft have already adopted this model in their private clouds, offering a wide range of services to millions of users world-wide. As Cloud computing technologies become mature, an increasing

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number of companies are expected to adopt this model by moving into clouds. A key technique of each SP in cloud service management is to distribute servers in multiple data centers in order to meet the performance requirements specified in Service Level Agreements (SLA), while reducing operational costs by optimizing the placement of servers in multiple data centers. This typically involves solving two problems jointly: (1) deciding on the number of servers placed in each data center, and (2) routing each request to appropriate servers to minimize response time. As infrastructure providers typically offer on-demand and elastic resource access, it is possible to adjust the number of servers to match service demand in a dynamic way. Furthermore, the cost of reconfiguration (i.e. the cost of adding and removing servers) must be taken into account. The consideration for reconfiguration cost is important for ensuring the system stability and minimum management overhead and costs. For instance, these operations have costs for setup (e.g., VM image distribution) and tear-down (e.g., data / state transfer). Thus, it is in the interest of SPs to reduce such reconfiguration cost. On the other hand, the price of resources offered by infrastructure providers are also subject to change. In particular, energy consumption is a major contributor to the operation cost of a data center. In many regions of the U.S., the electricity grid of each region is managed independently by a Regional Transmission Organization (RTO) which operates wholesales electricity markets in order to match supply and demand for electricity, as illustrated [4]. As a result, electricity prices in each region can vary independently over time. Based on this fact, recently there have been several studies on dynamic server placement [2], [3] and request dispatching [4] in private clouds, taking into account fluctuating energy costs. The same benefit can be achieved\ in public clouds by introducing some degree of dynamic pricing, such as the one being used by Amazon EC2 [5]. Fig .1 Scaling Networks Beyond mere server scalability, some other elements need to be taken into account that affect the overall application scaling potential. For instance, load balancers (LBs) need to support the aggregation of new servers (typically, but not necessarily, in the form of new VMs) in order to distribute load among several servers [6, 5, 4]. Amazon already provides strategies for load balancing your replicated VMs via its Elastic Load Balancing capabilities [9]. LBs and the algorithms that distribute load to different servers are, thus, essential elements in achieving application scalability in the cloud. Having several servers and the mechanisms to distribute load among them is a definitive step towards scaling a geo distributed cloud application. However, there is another element of the datacenter infrastructure to be considered towards complete application scalability. Network scalability is an often neglected element that should also be considered [7]. In a consolidated datacenter scenario, several VMs share the same network, potentially producing a huge increase in the required bandwidth (potentially collapsing the network). It is, thus, necessary to extend infrastructure clouds to other kinds of underlying resources beyond servers, LBs and storage. Cloud applications should be able to request not only virtual servers at multiple points in the network, but also bandwidth-provisioned network pipes and other network resources to interconnect them (Network as a Service, NaaS) [7]. Our work proposes such an online algorithm for dynamic, optimal scaling of a Online social Network (OSN) application in a geo-distributed cloud Our contributions are as follows: By exploiting social influences among users, this paper proposes efficient proactive algorithms for dynamic, optimal scaling of a online social network application in a geo-distributed cloud. Our key contribution is an online content migration and request distribution algorithm with the following features: (1) future demand prediction by novelly characterizing social influences among the users in a simple but effective epidemic model; (2) one shot optimal content migration and request distribution based on efficient optimization algorithms to address the predicted demand, and (3) a Δ( )t -step look-ahead mechanism to adjust the one-shot optimization results towards the offline optimum.

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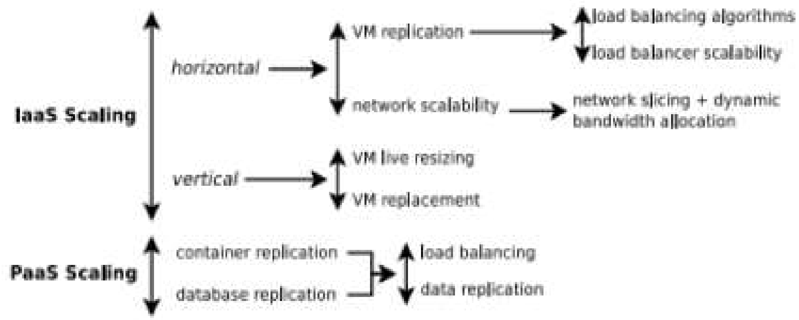

Fig .1 Scaling Networks

Literature Survey

Federation of geo-distributed cloud services is a recent development of cloud computing technologies. The open data center alliance [2], for instance, aims to provide solutions to unify cloud resources from different providers to produce a global scale cloud platform. The current literature focus on designing inter-connecting standards and APIs [1] [3] [4], while our study here explores utilization of a geo-distributed cloud platform for efficient application support. Social application deployment based on cloud computing. Cloud computing is a new computing paradigm in which both hardware and software are provided to users over the Internet as services, in the form of virtualized resources [8]. Different cloud providers provide different types of services [9], including IaaS, PaaS, SaaS (Software as a Service), etc., based on different pricing schemes [6], e.g., by actual CPU cycles in Google AppEngine [2] or by the number of VM instances in Amazon EC2. Due to its elasticity, cloud computing has also been widely used by startup companies whose demands of resources grow over time [5]. Traditional systems, such as the Web [2] and video streaming [3], have been being successfully deployed in the cloud. Among multiple cloud providers, Li et al. [21] have proposed a service comparison methodology to compare the performance withdifferent cloud providers. Rehman et al. [8] have proposed a multi-criteria cloud service selection strategy, to determine the service that best matches the users' requirements from amongst numerous available services. Chohan et al. [10] have studied the extension of PaaS to facilitate the distributed execution of applications over virtualized cluster resources. In the context of social applications, cloud computing has been explored for the social media distribution. Pujol et al. [12] have investigated the difficulties of scaling online social network, and designed a social partitioning and replication middleware in which users' friends can be co-located in the same server. Tran et al. [13] have studied the partition of contents in the online social network by taking social relationships into consideration. Cheng et al. [14] have studied the partitioning schemes for social contents to achieve a balanced load at the servers and preserve the social relationships. Wu et al. [15] have studied the problem of cost effective video distribution in a social network by migrating videos in geo-distributed clouds. In geo-distributed clouds for ehealth monitoring systems, resource allocation acts as a critical component to provide timely and reliable services [16]. Previous works on resource allocation for geo-distributed clouds have two objectives: one is to reduce the service delay for users and the other is to reduce the cost for the service provider. From a user's perspective, Alicherry and Lakshman [15] proposed a centralized resource allocation scheme for geo-distributed clouds to minimize the service delay among selected servers, and a heuristic algorithm to partition a requested resource among the chosen servers. By exploiting the characteristics of social influences, Wu et al. [17] proposed an online resource allocation scheme to efficiently migrate contents, and redirect user requests to appropriate servers for timely responses. To reduce the operating cost for service providers, a scheme that distributes requests among geo-distributed clouds to utilize the spatial differences in electricity price is proposed in [8]. For service providers, load balance is also an important requirement for its crucial role played to maintain the

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stability of all servers. As pointed out by paper [12], without proper resource allocation, requests may be redirected to a single server, leading to congestions. Manfredi et al. [18] designed a distributed scheme for geodistributedclouds, which stabilizes all the servers. Liu et al. [60] focused on the inter-data-center communication of the OSN service. Maintaining a replica of a remote user's data at a local data center reduced the inter-data-center read operations as local users could access such data without going to remote data centers; however, this replica at the local data center needed to be updated for consistency with remote replicas and thus incurred the inter-data-center update operations. The authors proposed to replicate across data centers only the data of the users selected by jointly considering the read and the update rates in order to ensure that a replica could always reduce the total inter-data-center communication. Wittie et al. [19] claimed that Facebook had slow response to users outside US and Internet bandwidth was wasted when users worldwide requested the same content. The authors found that the slow response was caused by the multiple round trips of Facebook communication protocols as well as the high network latency between users and Facebook US data centers; they also observed that most communications were among users within the same geographic region. The authors proposed to use local servers as TCP proxies and caching servers to improve service responsiveness and efficiency, focusing on the interplay between user behavior, OSN mechanisms, and network characteristics. They advocated using geo-distributed clouds for scaling the social media streaming service. However, the challenges remained for storing and migrating media data dynamically in the clouds for timely response and moderate expense. To address such challenges, the authors proposed a set of algorithms that were able to do online data migration and request distribution over consecutive time periods based on Lyapunov optimization techniques. They predicted the user demands by exploiting the social influence among users; leveraging the predicted information, their algorithms could also adjust the online optimization result towards the offline optimum. Wang et al. [20] targeted social applications which often had a workflow of "collection" → "processing" → "distribution". The authors proposed local processing, which collected and processed user-generated content at local clouds, and global distribution, which delivered processed content to users via geodistributed clouds, as a new principle to deploy social applications across clouds, and designed protocols to connect these two components. They modeled and solved optimization problems to determine computation allocation and content replication across clouds, and built prototypes in real-world clouds to verify the advantages of their design. Online social applications. In a social media system, contents spread among users by users sharing them. A number of research efforts have been devoted to studying content propagation in social media applications. Kwak et al. [20] investigated the impact of users' retweets on information diffusion in Twitter. Social applications have greatly changed our assumptions in traditional content service deployment, e.g., content distribution is shifted from a central-edge manner to an edge-edge manner, resulting in the massive volume of user-generated contents and a dynamically skewed popularity distribution [17]. In this paper, we not only focus on the distribution of contents already in an online social network, but also the collection and processing and contents generated by users in a social application. In particular, we explore the deployment of social applications based on cloud computing. The work in this category focuses on the performance of OSN services [16] and social applications [17], and the monetary expense of provisioning and scaling social media in the clouds [12].

Results

The exponential growth of Online Social Networks (OSNs) has created an urgent need for scalable, secure, and cost-efficient storage solutions. To address these challenges, the Intelligent Multi-Cloud Storage Framework leverages cutting-edge technologies such as Artificial Intelligence (AI), Blockchain, and Edge Computing. This framework aims to enhance data management, security, and performance while optimizing costs. Below, we explore the key components and features of this future-oriented framework.

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1. Multi-Cloud Architecture

The framework adopts a multi-cloud strategy to distribute data across multiple cloud providers, ensuring redundancy, cost efficiency, and enhanced privacy.

Hybrid Cloud Model
- Combines public cloud resources (for scalability and cost-effectiveness) with private cloud infrastructure (for sensitive data and enhanced privacy).
- Enables organizations to balance cost and security based on data sensitivity and usage patterns.

Decentralized Cloud Storage
- Utilizes blockchain technology and peer-to-peer (P2P) networks to distribute data storage across multiple cloud providers.
- Reduces reliance on a single cloud provider, mitigating risks such as vendor lock-in and service outages.

Adaptive Load Balancing
- Employs AI-driven algorithms to dynamically allocate storage resources based on usage patterns and network conditions.
- Ensures optimal performance and resource utilization across the multi-cloud environment.

2. AI-Driven Storage Optimization

AI plays a pivotal role in optimizing storage efficiency, performance, and cost.

Predictive Caching and Data Migration
- Machine Learning (ML) models analyze user behavior to predict data access patterns.
- Frequently accessed data is migrated to high-performance cloud tiers, while less frequently accessed data is moved to cost-effective storage tiers.

Automated Data Classification
- AI classifies data into hot (frequently accessed), warm (moderately accessed), and cold (rarely accessed) tiers.
- Ensures cost-efficient storage while maintaining quick retrieval times for critical data.

AI-Based Threat Detection
- Real-time anomaly detection powered by AI identifies and mitigates potential cyber threats.
- Protects data from unauthorized access and cyberattacks, ensuring robust security.

3. Enhanced Security and Privacy

The framework incorporates advanced security measures to safeguard sensitive data.

Blockchain-Based Access Control
- Smart contracts enable fine-grained access control, ensuring that only authorized users can access sensitive data.
- Enhances transparency and accountability in data access management.

End-to-End Encryption

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- Utilizes homomorphic encryption to perform computations on encrypted data without decryption.
- Ensures data privacy and security throughout its lifecycle.

Zero Trust Architecture
- Implements continuous authentication and monitoring to minimize the risk of internal and external security breaches.
- Assumes no user or device is inherently trustworthy, requiring verification at every access attempt.

4. Edge Computing and CDN Integration

To improve performance and reduce latency, the framework integrates Edge Computing and Content Delivery Networks (CDNs).

Edge Nodes
- Deploys storage resources closer to end-users, reducing latency and improving real-time content delivery.
- Enhances user experience for latency-sensitive applications, such as video streaming and real-time analytics.

Dynamic Content Distribution
- CDNs dynamically distribute content to edge nodes based on user demand and network conditions.
- Reduces bandwidth costs and improves content delivery efficiency.

5. Cost Optimization and SLA Management

The framework employs intelligent cost management strategies to optimize expenses while meeting performance requirements.

AI-Powered Cost Prediction
- Uses real-time pricing models and AI algorithms to select the most cost-effective storage provider.
- Balances cost and performance to meet organizational budgets.

Dynamic SLA Optimization
- Ensures that Service Level Agreements (SLAs) are met while minimizing costs.
- Dynamically adjusts resource allocation and storage tiers based on user expectations and performance requirements.

The Intelligent Multi-Cloud Storage Framework represents a transformative approach to addressing the storage challenges posed by the rapid growth of OSNs. By integrating AI, Blockchain, and Edge Computing, the framework enhances data management, security, and performance while optimizing costs. Key features such as multi-cloud architecture, AI-driven storage optimization, enhanced security measures, and edge computing integration ensure that the framework is scalable, secure, and cost-efficient. This future-oriented solution not only meets the current demands of OSNs but also provides a robust foundation for emerging technologies and applications. As the digital landscape continues to evolve, the Intelligent Multi-Cloud Storage Framework will play a critical role in enabling organizations to manage their data effectively, securely, and economically.

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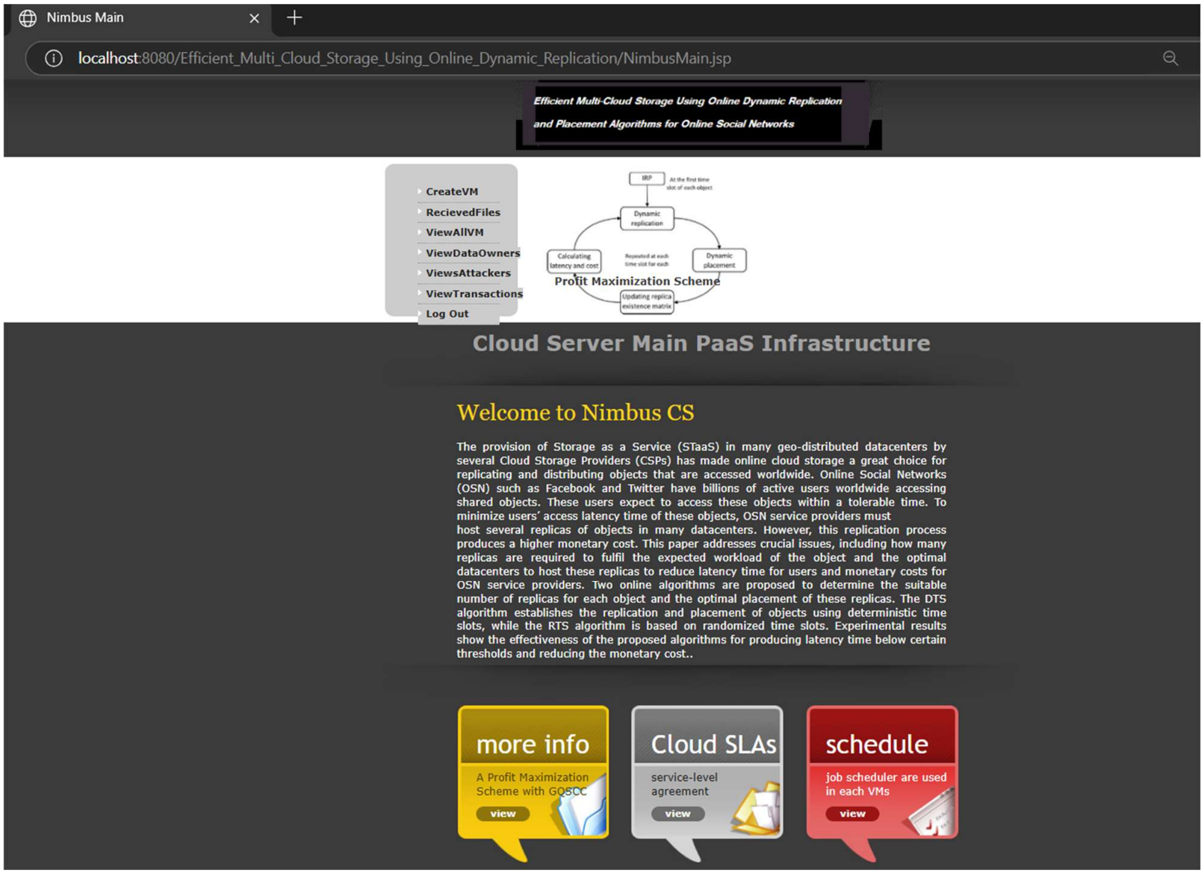

Conclusion

A paradigm change in data management, storage, and security has occurred with the introduction of Intelligent Multi-Cloud Storage for Online Social Networks (OSNs). There is a growing demand for a safe, efficient, and scalable storage infrastructure as OSNs keep producing large amounts of user-generated material. This method makes sure that OSNs can provide strong data protection, low latency, and high-performance data access by combining AI-driven automation with blockchain-based security and edge computing solutions.

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