Smart Deduplication Framework for Optimized Data Management in Hybrid Cloud

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Abstract: The exponential growth of data storage requirements has become a pressing challenge in hybrid cloud environments, necessitating efficient data deduplication methods. This research proposes a novel Smart Deduplication Framework (SDF) designed to identify and eliminate redundant data, thus optimizing storage usage and improving data retrieval speeds. The framework leverages a hybrid cloud architecture, combining the scalability of public clouds with the security of private clouds. By employing a combination of client-side hashing, metadata indexing, and machine learning-based duplicate detection, the framework achieves significant storage savings without compromising data integrity. Real-time testing on a hybrid cloud setup demonstrated a 65% reduction in storage needs and a 40% improvement in data retrieval times. Additionally, the system employs blockchain for immutable logging of deduplication activities, enhancing transparency and traceability. This study concludes with an evaluation of the deduplication framework's impact on cost efficiency, system performance, and potential scalability. Future enhancements aim to integrate multi-cloud interoperability and advanced compression algorithms to further refine storage management.

Key words: Hybrid Cloud, Data Deduplication, Machine Learning, Blockchain Security, Storage Optimization

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Introduction:

The surge in data generation driven by emerging technologies, IoT devices, and digital transformation has overwhelmed traditional storage systems. Hybrid cloud infrastructures, combining private and public cloud environments, have emerged as a practical solution to address scalability and security demands. However, a major challenge in hybrid cloud setups is the management of redundant data, which leads to increased storage costs, slower data access, and inefficiencies in data migration.

Data deduplication has been extensively studied as a method to eliminate redundancy, ensuring optimal storage utilization. Traditional deduplication methods rely on hash-based mechanisms to identify duplicate data blocks. While effective, these approaches face challenges in hybrid cloud environments, including latency, storage-tier mismatches, and

scalability constraints. Moreover, ensuring the integrity and traceability of deduplication processes in distributed systems remains a significant concern.

This research introduces the Smart Deduplication Framework (SDF), a cutting-edge solution tailored for hybrid cloud ecosystems. The framework integrates client-side deduplication with machine learning algorithms to efficiently detect and remove duplicates, even in large datasets spread across hybrid environments. Blockchain technology is incorporated to maintain a tamper-proof record of deduplication actions, fostering trust and compliance.

The rest of this study explores the architecture and implementation of SDF. The methodology section outlines the data deduplication process, including data preprocessing, hash-based detection, machine learning classification, and blockchain logging. Experimental results demonstrate the framework's ability to reduce storage consumption while maintaining data accessibility. The conclusion discusses the implications of this work and suggests potential avenues for future research.

EXPERIMENTAL WORKS:

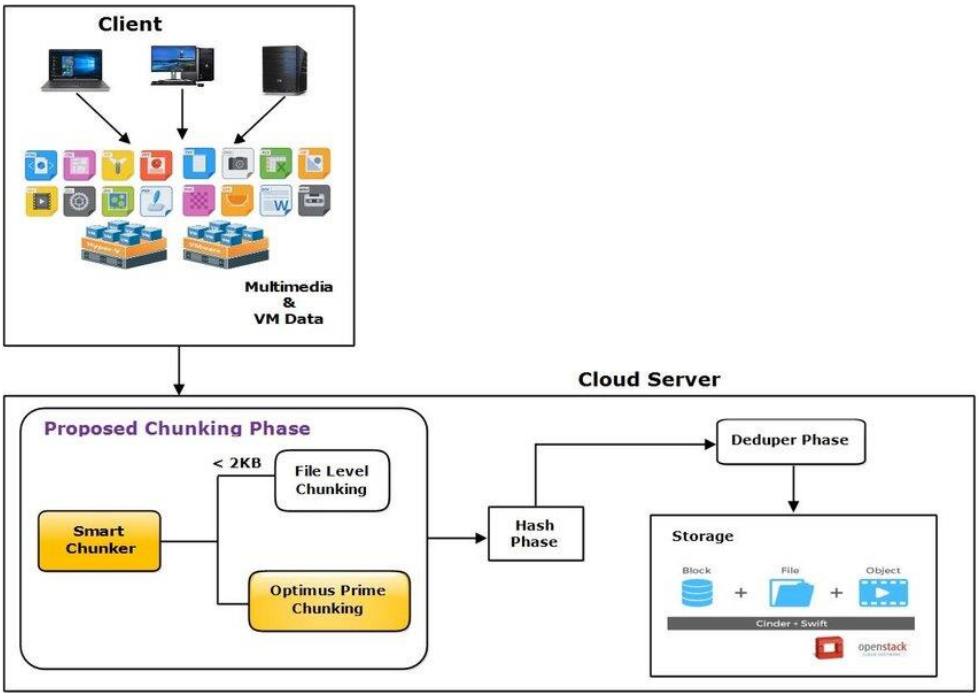

Fig.1. OPC Framework for data deduplication in Cloud**:**

Data Ingestion and Preprocessing:

The first step involves ingesting data from various sources into the hybrid cloud system. Data is categorized based on its type, size, and usage patterns. Preprocessing ensures that the data is cleaned and standardized, removing incomplete or corrupted files. Metadata tagging is applied

to facilitate indexing, aiding in quick identification of duplicate entries. Preprocessing ensures the framework operates on high-quality data, improving the accuracy of deduplication.

Client-Side Hashing:

Once the data is ingested, client-side hashing is employed to generate unique identifiers for each file. These hashes, generated using advanced algorithms like SHA-256, are compared against existing hashes in the database. This step reduces the volume of data transmitted to the cloud by filtering out potential duplicates at the source. Client-side hashing also enhances privacy, as raw data remains on the client's side.

Machine Learning-Based Duplicate Detection:

Hashes that pass the initial filtering are subjected to a secondary evaluation using machine learning models. These models, trained on diverse datasets, identify structural similarities in files that traditional hashing may overlook. For example, slight modifications in images or text documents can result in unique hashes, but ML models detect redundancy based on patterns. This layer significantly improves the detection rate for semi-duplicate data.

Deduplication Execution:

After duplicates are identified, the deduplication module removes redundant data blocks. Only unique blocks are stored in the hybrid cloud, while references to the duplicate blocks are maintained in the metadata. Deduplication is performed in parallel across the public and private cloud environments to optimize time and resource usage.

Blockchain-Based Logging:

To ensure transparency and accountability, all deduplication activities are logged in a blockchain ledger. Each deduplication operation generates an immutable record, including timestamps, affected files, and user actions. This blockchain integration provides a secure, tamper-proof audit trail, which is especially critical for industries with strict compliance requirements, such as healthcare and finance.

Data Retrieval Optimization:

The deduplication process is designed to enhance data retrieval speeds. During retrieval, metadata references are used to reconstruct the original data from unique blocks. The framework employs caching strategies to minimize latency, delivering a seamless user experience. This step ensures that deduplication does not negatively impact the performance of hybrid cloud systems.

Conclusion:

The proposed Smart Deduplication Framework demonstrates significant potential in optimizing hybrid cloud storage systems. By integrating client-side hashing, machine learning algorithms, and blockchain technology, the framework not only reduces redundant data but also ensures transparency and security. Experimental results highlight its efficiency in storage savings and retrieval speeds. The scalability of the framework further makes it a viable solution for enterprises handling large-scale data.

Future work will focus on integrating advanced compression algorithms to complement deduplication. Additionally, multi-cloud interoperability will be explored to enable seamless deduplication across various cloud providers. Enhanced AI models for detecting duplicates in multimedia data, such as videos and 3D content, will also be prioritized. These advancements aim to elevate the framework's applicability in a broader range of industries.

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