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DropStore: Revolutionizing Data Backup with Multi Cloud and Fog Computing for Ultimate Privacy

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Abstract – Data backup plays a crucial role in recovery from disasters. Current cloud provide a secure environment, but they do not ensure data privacy when all data is concentrated in a single cloud. An alternative is the adoption of Multi-Cloud technologies. While distributing data across multiple clouds can enhance privacy, it requires the edge device to handle different accounts and facilitate communication with various clouds. These challenges have resulted in limited use of this technology. In this paper, we introduce DropStore, an user-friendly, highly secure, and dependable backup system that utilizes advanced Multi-Cloud and encryption methods. DropStore incorporates an abstraction layer for users, simplifying the system complexities by using a local device called "the Droplet," which is entirely managed by the user. This design eliminates the need to trust any unreliable third parties. This functionality is made possible through Fog Computing technology. What sets DropStore apart is the integration of Multi-Cloud and Fog Computing principles. The implementation of the system is open source and accessible online. Performance evaluations indicate that the proposed system enhances data protection in terms of reliability, security, and privacy, while offering a straightforward interface with edge devices.

Index Terms – Multi-Cloud, Fog computing, data reliability, disaster recovery, user privacy.

I. INTRODUCTION

The use of digital storage is increasingly common due to the rise of networking and computing. To mitigate these risks, data backup is essential, and cloud backup systems are frequently utilized for enhanced protection and recovery from disasters. Safeguarding their data has become a significant challenge. Numerous cloud service providers operate globally, often at competitive prices, with some even offering free services. To address these issues, many researchers have explored the Multi-Cloud concept to enhance data protection. Multi-Cloud refers to a diverse architecture that leverages multiple cloud computing and storage solutions, which may come from public clouds, private clouds, or even on-premise facilities. When employing a Multi-Cloud architecture, users must manage their resources and services across various clouds, though this can also be handled by third-party managers. The benefits of adopting a Multi-Cloud architecture include reducing reliance on a single provider, achieving cost efficiency, enjoying flexibility in options, and enhancing disaster resilience. Several applications gain advantages from Multi-Cloud architectures, especially those focused on data storage. Depending on the specific system architecture, the Multi-Cloud approach offers numerous benefits for data storage and backup. Among the most notable advantages are:

- **Enhanced data protection:** The segregation of data across different providers means that a breach at one provider impacts only a limited amount of data, facilitating easier isolation of attacks.
- **Increasing flexibility:** Utilizing storage options from different providers helps prevent vendor lock-in and enhances data reliability through replication.
- **Cost optimization:** The availability of various storage solutions allows for customized pricing and selection. While Multi-Cloud storage presents numerous advantages, managing, securing, and distributing data in a cohesive manner can pose difficulties.
- **Different APIs:** Various providers develop distinct API frameworks and employ different programming languages.
- **Compatibility issues:** Storage systems must be consistent across multiple clouds to integrate smoothly into a unified environment. This requires adherence to the same data structures and compatibility with similar resources.
- **Complex management:** Effective management necessitates centralized oversight and service aggregation, including identity and access controls.

Additionally, typical users generally require simpler processes for backing up and securing their data. To tackle many of the challenges associated with Multi-Cloud systems, DropStore uses Fog Computing. The Fog Computing concept was originally created to decrease data access latency between users and the cloud. It offers data processing and networking capabilities at the network's edge. The idea involves placing dedicated servers geographically close to end-users in micro/nano data centers. While Cloud Computing provides resources centralized in the core of the network, Fog Computing delivers services and resources distributed near or at the network edge. This architecture enables very low latency, location awareness, prompt response times, and real-time interactions

The centralized nature of cloud computing cannot satisfy the growing number of internet connected devices. Continuing to rely solely on cloud computing may result in network congestion, decreased service quality, and increased latency. Furthermore, some applications that require real-time responses may not function properly. Embracing Fog Computing will facilitate the development of widely distributed applications and services, promoting innovation in location-aware services and real time systems that need rapid responses. It also supports the mobility of edge devices. Additionally, Fog Computing improves energy efficiency, alleviates network congestion, enhances service delivery, and optimizes infrastructure spending. Fog nodes can consist of typical network elements like routers or mid-tier servers located close to end-users. These nodes are capable of executing applications and storing data to provide necessary services and improve user experiences. They connect to the cloud core via high speed links, acting as the cloud's extensions while the central processing occurs within the network. Fog nodes handle local data processing, which helps minimize traffic across the network. For higher-level processing, data is forwarded to the cloud after initial processing by fog nodes. For instance, future planning decisions in intelligent vehicles and smart cities are made by the cloud, which integrates data collected from the fog nodes, whereas fog nodes focus on processing real-time interactions locally. This paper presents DropStore, an innovative data backup solution that leverages Multi-Cloud and Fog Computing. The system harnesses the benefits of Multi-Cloud storage to guarantee the protection and reliability of users' data while addressing the challenges associated with Multi-Cloud through the Fog Computing framework. Users can conveniently and securely back up, restore, and modify their data without having to manage the complex tasks involved in data security on Multi-Cloud platforms. The proposed system offers several advantages compared to existing solutions, highlighted as follows:

• It is the first system to integrate the benefits of both Multi-Cloud and Fog Computing paradigms.

• It provides rapid backups and an enhanced user experience..

• It eliminates reliance on untrusted third parties for security management. Section II provides a brief review of earlier work on Multi-Cloud backup systems and research in Fog Computing based storage. Section III outlines the architecture of the DropStore system. In Section IV, we assess the system's performance. Finally, Section V concludes with a discussion of possible future enhancements.

II. LITERATURE SURVEY

Dropstore is a safe and easy-to-use backup solution that utilizes multi-cloud storage and fog computing to overcome the drawbacks of traditional systems.

- **Multi-cloud storage** involves spreading data across various cloud service providers to boost security and reliability while preventing vendor lock-in. In dropstore, user data is encrypted and divided into smaller segments, which are then distributed among different cloud servers. This approach guarantees that no single cloud provider can access the entire dataset, thereby improving privacy and security.
- **Fog computing** takes cloud computing to the network's edge, bringing computation and storage closer to the users. Dropstore incorporates a locally hosted device known as the droplet, which serves as an intermediary between the user and the cloud services. The droplet manages the

processes of data encryption, chunking, and distribution across multiple clouds, while also facilitating communication with the cloud servers.

- **Encryption techniques** are employed to protect data by transforming it into an unreadable format. Dropstore uses advanced encryption algorithms, such as AES, to secure user data before it is fragmented and distributed among various clouds. The droplet locally manages the encryption keys, ensuring that only authorized users can access the data.
- **Abstraction layer** the droplet is a locally hosted device that streamlines the user experience by concealing the complexities of multi-cloud storage and encryption. It acts as a single point of interaction for users, managing all aspects of data backup, encryption, and communication with the cloud. Users only need to engage with the droplet, which takes care of the underlying processes.

The data are sliced based on the Permutation Ordered Binary (POB) numbering system and stored on multiple cloud servers. The key information is divided into multiple random shares based on the Chinese Remainder Theorem (CRT) and saved to multiple servers. Whereas the key can be restored from k servers out of n servers, where k is less than n, the data can be restored only if all the shares are available. Therefore, this system will not survive in the case of cloud service provider lockouts. Triviback is a chunking based backup system that minimizes the storage needs using the sec cs data structure for deduplication of flat contents. It offers Multi-Cloud storage for the generated backups. Whereas the storage is efficiently used, this comes at the expense of data reliability and immunity against lockouts. TrustyDrive is a document storage system on multiple cloud providers. It tries to preserve user anonymity and document anonymity. Although the focus was on saving and securing document files only, the system does not provide an interactive or easy way to share and view the saved documents.

III. METHODOLOGY

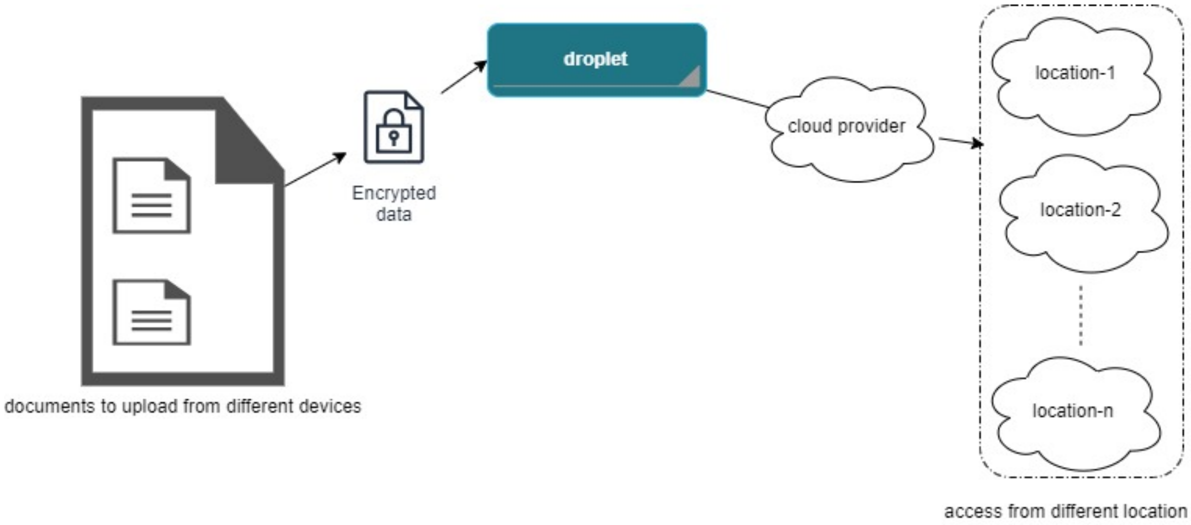

droplet
Encrypted data
documents to upload from different devices
cloud provider
location-1
location-2
location-n
access from different location

Fig 1: Dropstore Architecture

In the era of remote work and global collaboration a secure cloud storage solution is indispensable for providing secure anytime anywhere access to critical documents.

- Document upload from different devices users upload documents from various devices such as laptops tablets or smartphones these documents can contain sensitive information that requires secure handling.
- Documents are encrypted before being transmitted providing a robust security measure that prevents unauthorized access and ensures the confidentiality of sensitive data during storage and transfer.
- Droplet storage processing the encrypted documents are sent to a droplet which serves as a virtual computing instance for managing file storage and processing this droplet is responsible for handling file encryption managing access controls and facilitating cloud synchronization.
- By interacting with a cloud provider the droplet leverages secure cloud storage to safeguard encrypted files minimizing the risk of data loss through robust redundancy backup mechanisms and high availability.
- Multi-location access the system is designed for accessibility from multiple locations location-1 location-2 location-n authorized users can retrieve their files securely from different locations ensuring flexibility and remote accessibility.
- By leveraging this architecture organizations can benefit from a robust document management solution that provides enhanced data security efficient scalability secure remote access and high availability through cloud-based redundancy.

IV. PERFORMANCE EVALUATION

- **System Implementation** DropStore was developed and tested to assess its efficiency in secure data backup and storage. The system was configured to establish communication between user devices and the cloud using the Secure File Transfer Protocol (SFTP). This protocol ensures encrypted data transmission and user authentication, making it compatible with different devices. To strengthen security and prevent unauthorized modifications, SFTP Jail was implemented, restricting users to access only their own data. A customized version of Duplicity, an open-source backup tool, was modified to improve data distribution across multiple cloud platforms. This enhanced version introduced dynamic redundancy to balance storage more effectively. To simplify the user experience, an intuitive installation interface was created, which automated software setup, account configuration, and backup restoration.
- **Dataset and Backup Strategy** To replicate real-world conditions, a variety of file types, including images, text documents, and videos, were used for testing. The system was set to perform automated daily backups during low-traffic hours to optimize bandwidth usage and minimize user disruptions.

Evaluation Metrics

Several key metrics were used to assess the system's performance:

- **Cloud Server Utilization:** Measured the effect of distributed storage on backup efficiency.
- **Data Chunk Size:** Analyzed how chunk size impacts compression and storage efficiency.
- **Replica Count:** Evaluated the balance between redundancy and storage consumption.

- **Network Latency:** Assessed the delay in data transfer based on internet speed.
- **User Data Size:** Measured the efficiency of data storage and retrieval.

Most tests were conducted on local servers, with final evaluations performed in cloud environments for accurate results.

Storage Efficiency DropStore reduces storage demands by employing compression and incremental backup techniques:

- Increasing the number of replicas proportionally raised storage usage.
- A single-replica setup consumed less storage due to compression, significantly reducing the original file size.
- Text-based files experienced up to 80% reduction in storage needs, demonstrating the system's effectiveness.

Storage Load Balancing The system ensures even storage distribution across multiple cloud providers. Regardless of the replica count or chunk size, DropStore prevents overloading any single provider, enhancing both reliability and data accessibility.

Metadata Overhead Metadata storage in DropStore is minimal, occupying only 1% of the total storage. This ensures that metadata management does not significantly impact the overall cloud storage efficiency.

Backup and Recovery Performance

Backup Time Analysis The time required to back up 200MB of data varied based on the hardware configuration:

- **Raspberry Pi 3 Setup:** Took approximately 150 seconds.
- **Intel Core i7 Setup:** Completed the backup in around 20 seconds.

The backup process included encryption, data partitioning, and replication. While cloud upload speeds depended on internet connectivity, they had minimal impact on overall performance.

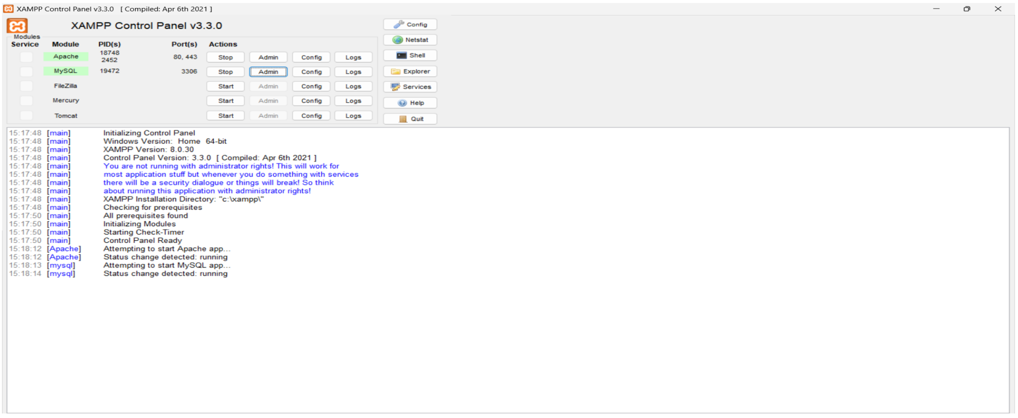
Data Recovery Performance Efficient data recovery is a key feature of DropStore. Tests revealed the following recovery times:

- **Raspberry Pi 3 Setup:** Restored 800MB of data in approximately 300 seconds.
- **Intel Core i7 Setup:** Significantly reduced recovery time to 30 seconds.

The recovery process involved reconstructing backup chains, decrypting data, and decompressing files. Hardware specifications played a crucial role in optimizing recovery speed.

V. RESULTS

Below explains the execution process for backup system using fog computing and multi cloud for ultimate privacy


XAMPP Control Panel v3.3.0 [Compiled: Apr 6th 2021]

XAMPP Control Panel v3.3.0

Service	Module	PID(s)	Port(s)	Actions			
	Apache	18748 2452	80, 443	Stop	Admin	Config	Logs
	MySQL	19472	3306	Stop	Admin	Config	Logs
	FileZilla			Start	Admin	Config	Logs
	Mercury			Start	Admin	Config	Logs
	Tomcat			Start	Admin	Config	Logs

```
15:17:48 [main]      Initializing Control Panel
15:17:48 [main]      Windows Version:  Home  64-bit
15:17:48 [main]      XAMPP Version: 8.0.30
15:17:48 [main]      Control Panel Version: 3.3.0  [ Compiled: Apr 6th 2021 ]
15:17:48 [main]      You are not running with administrator rights! This will work for
15:17:48 [main]      most application stuff but whenever you do something with services
15:17:48 [main]      there will be a security dialogue or things will break! So think
15:17:48 [main]      about running this application with administrator rights!
15:17:48 [main]      XAMPP Installation Directory: "c:\xampp\"
15:17:48 [main]      Checking for prerequisites
15:17:50 [main]      All prerequisites found
15:17:50 [main]      Initializing Modules
15:17:50 [main]      Starting Check-Timer
15:17:50 [main]      Control Panel Ready
15:18:12 [Apache]    Attempting to start Apache app...
15:18:12 [Apache]    Status change detected: running
15:18:13 [mysql]     Attempting to start MySQL app...
15:18:14 [mysql]     Status change detected: running
```

Fig 2: XAMPP Control Panel

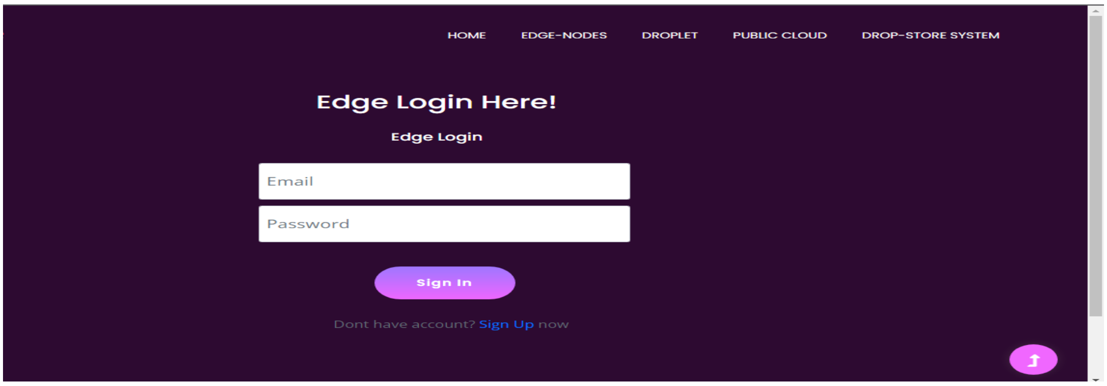
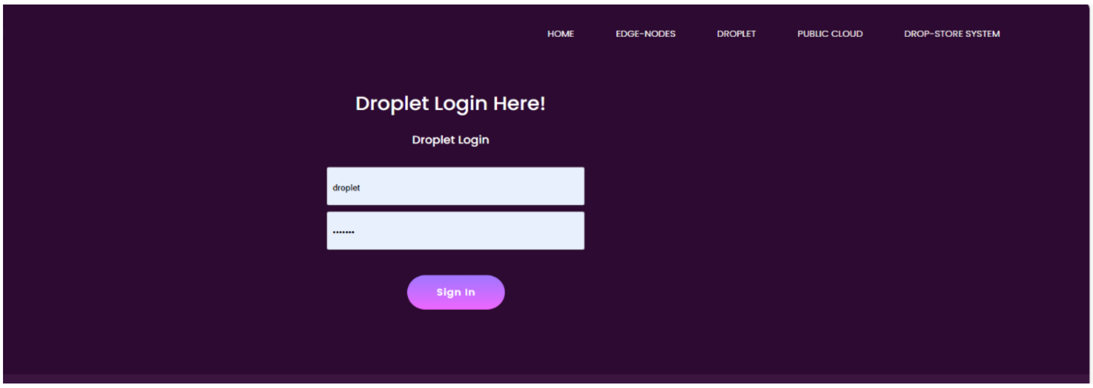


Fig 3: Edge-Node



droplet

•••••••

Fig 4: Accept the pending details

IV. V. CONCLUSION AND FUTURE WORK

DropStore is a novel backup system designed to enhance data security and reliability by integrating Multi-Cloud storage and Fog Computing. The system ensures user privacy and data protection through encryption and partitioning across multiple cloud providers. By leveraging Fog Computing, DropStore simplifies the backup process for users, reducing complexity while improving performance. To evaluate its effectiveness, DropStore was implemented in two different setups:

1. A cost-effective single-board computer (Droplet node).
2. A more powerful personal laptop.

Experiments conducted in real-world scenarios confirmed that DropStore efficiently stores and retrieves data in both configurations. The system provides a secure backup solution with minimal resource consumption on edge devices, making it an ideal choice for users requiring reliable and automated cloud backups.

To further improve DropStore, several enhancements are planned:
✓ **Optimized Cloud Upload Scheduling:** Future updates will incorporate smarter scheduling algorithms to manage data uploads based on network conditions, Quality of Service (QoS) requirements, and available storage capacity at each cloud service provider (CSP).
✓ **Advanced Error Detection and Correction**: Instead of simple data block replication, linear block codes will be implemented to improve data integrity and fault tolerance during cloud storage and retrieval. By implementing these improvements, DropStore aims to enhance efficiency, scalability, and security, making it a more robust backup solution for diverse user environments.

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