ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Impact Factor: 8.206

Volume 8, Issue 4, April 2025

© 2025 IJMRSET | Volume 8, Issue 4, April 2025 |DOI:10.15680/IJMRSET.2025.0804250

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Drop Store: A Secure Backup System using Multi -Cloud and Fog

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ABSTRACT: In the realm of disaster recovery, data backup stands as a critical component. While current cloud-based solutions offer a secure infrastructure, they fall short in guaranteeing data privacy when hosted on a single cloud. Multi-Cloud technologies present an alternative by distributing data across multiple clouds, enhancing privacy. However, this approach demands that edge devices manage various accounts and communications, complicating the process. This complexity has limited the widespread adoption of Multi-Cloud technology.

Enter DropStore: our proposed solution designed to provide an easy-to-use, highly secure, and reliable backup system utilizing cutting-edge Multi-Cloud techniques. By introducing a locally hosted device known as "the Droplet," DropStore simplifies system complexities for the end user, ensuring data privacy without relying on untrusted third parties. This is achieved through the principles of Fog Computing. The uniqueness of DropStore lies in its integration of Multi-Cloud and Fog Computing principles.

Our system is open-source and available online. Performance results demonstrate that DropStore enhances data protection in terms of reliability, security, and privacy preservation, all while maintaining a user-friendly interface with edge devices.

KEYWORDS: Machine Learning, Multi Cloud, FOG Computing and Digital Storage.

I. INTRODUCTION

Digital storage is rapidly being embraced with networking and computing popularity. However, digital data storage poses many threats, such as operation error, security attacks, and hardware failure. Data backup is important for avoiding these threats, and cloud backup systems are commonly used to add protection and disaster recovery. Cloud computing technology has enabled users to use remote computing to the full. Millions of people use different types of cloud services, directly or indirectly. It has become a very big challenge to ensure the protection of their data. Many cloud service providers around the world are available in the market at low cost, and some provide free services. They all deliver different services but are not identical in their system settings, privacy policy, rules, and regulations. Therefore, they do not enforce any uniform policy that will guarantee protection and privacy-preservation of user data.
For these reasons, many researchers adopted the concept of Multi-Cloud to increase the level of data protection. Multi-Cloud is a heterogeneous architecture utilizing various cloud computing and storage facilities, which can come from a public cloud, a private cloud, or as standalone cloudlike on-premise facilities. When Multi-Cloud architecture is used, users are aware of the multiple clouds and are responsible for managing the resources and the services, or a third party is responsible for managing them. There are various reasons to adopt a Multi-Cloud architecture, including reducing dependency on any single provider, cost efficiency, flexibility in choice, and disaster immunity. Many applications benefit from the Multi-Cloud architecture. This includes data storage applications. Depending on the system architecture, there are many advantages of using the Multi-Cloud concept for data storage and backup. The most prominent include

1) Increasing data protection: Due to the isolation of the data between different providers, a violation in one of them only affects a small amount of data which allows simple isolation of attacks.

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2) Increasing flexibility: The use of storage facilities from various providers helps prevent providers' lock-in and improve data reliability by replication.

3) Cost optimization: The ability to provide different storage facilities helps to tailor the cost and the choices.

1.1 MOTIVATION

In today's digital age, the volume of data generated by individuals and organizations is growing exponentially. With this growth comes the increased risk of data loss due to hardware failures, cyberattacks, accidental deletions, and natural disasters. Traditional backup solutions often fall short in providing robust, scalable, and secure data protection. There is a pressing need for innovative backup systems that leverage advanced technologies to ensure data integrity, availability, and security.

1.2 PROBLEM DEFINITION

Conventional backup systems face several challenges:

- Data Security: Ensuring that data is protected against unauthorized access and breaches.
- Scalability: Handling the ever-growing amount of data efficiently without performance degradation.
- Redundancy: Providing multiple layers of backup to prevent data loss in case of failures.
- Accessibility: Ensuring that data can be quickly restored when needed, regardless of the user's location country.

1.3 OBJECTIVE OF THE PROJECT

The primary objective of the Dropstore project is to develop a secure backup system using fog and multi-cloud technologies that addresses the aforementioned challenges. The system aims to:

- Enhance Data Security: Implement state-of-the-art encryption and access control mechanisms to protect data.
- Improve Scalability: Utilize fog computing to distribute data storage and processing closer to the data source, reducing latency and improving performance.
- Ensure Redundancy: Leverage multiple cloud providers to store redundant copies of data, ensuring high availability and fault tolerance.
- Optimize Costs: Implement cost-effective strategies for data storage and transfer, balancing performance with affordability.
- Facilitate Accessibility: Provide a user-friendly interface and efficient data retrieval processes to ensure quick and reliable access to backup data.and reduced costs.
-

II. LITERATURE SURVEY

"Scientific cloud computing: Early definition and experience" [2008].

Authors: L. Wang, J. Tao, M Kunze, A.C. Castellanos, D.Kramer, and W.Karl.
Cloud computing emerges as a new computing paradigm which aims to provide reliable, customized and QoS guaranteed computing dynamic environments for end-users. This paper reviews recent advances of Cloud computing, identifies the concepts and characters of scientific Clouds, and finally presents an example of scientific Cloud for data centers.

"A Secured cost-effective multi-cloud storage in cloud computing" [2011].

Authors: Y. Singh, F. Kandah, and W. Zhang.
The end of this decade is marked by a paradigm shift of the industrial information technology towards a pay-per-use service business model known as cloud computing. Cloud data storage redefines the security issues targeted on

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customer's outsourced data (data that is not stored/retrieved from the costumers own servers). In this work we observed that, from a customer's point of view, relying upon a solo SP for his outsourced data is not very promising. In addition, providing better privacy as well as ensuring data availability, can be achieved by dividing the user's data block into data pieces and distributing them among the available SPs in such a way that no less than a threshold number of SPs can take part in successful retrieval of the whole data block. In this paper, we propose a secured cost-effective multi-cloud storage (SCMCS) model in cloud computing which holds an economical distribution of data among the available SPs in the market, to provide customers with data availability as well as secure storage. Our results show that, our proposed model provides a better decision for customers according to their available budgets.

''Fog computing: A comprehensive architectural survey'' [2020].

Authors: P. Habibi, M. Farhoudi, S. Kazemian, S. Khorsandi, and A.Leon-Garcia
Fog computing is an emerging technology to address computing and networking bottlenecks in large scale deployment of IoT applications. It is a promising complementary computing paradigm to cloud computing where computational, networking, storage and acceleration elements are deployed at the edge and network layers in a multi-tier, distributed and possibly cooperative manner. These elements may be virtualized computing functions placed at edge devices or network elements on demand, realizing the "computing everywhere" concept. To put the current research in perspective, this paper provides an inclusive taxonomy for architectural, algorithmic and technologic aspects of fog computing. The computing paradigms and their architectural distinctions, including cloud, edge, mobile edge and fog computing are subsequently reviewed. Practical deployment of fog computing includes a number of different aspects such as system design, application design, software implementation, security, computing resource management and networking. A comprehensive survey of all these aspects from the architectural point of view is covered. Current reference architectures and major application-specific architectures describing their salient features and distinctions in the context of fog computing are explored. Base architectures for application, software, security, computing resource management and networking are presented and are evaluated using a proposed maturity model.

''Fog computing: Survey of trends, architectures, requirements, and research directions" [2018].

Authors: R.K.Naha,S.Garg,D.Georgakopoulos,P.P.Jayaraman,L.Gao,Y.Xiang, and R. Ranjan.
Emerging technologies like the Internet of Things (IoT) require latency-aware computation for real-time application processing. In IoT environments, connected things generate a huge amount of data, which are generally referred to as big data. Data generated from IoT devices are generally processed in a cloud infrastructure because of the on-demand services and scalability features of the cloud computing paradigm. However, processing IoT application requests on the cloud exclusively is not an efficient solution for some IoT applications, especially time-sensitive ones. To address this issue, Fog computing, which resides in between cloud and IoT devices, was proposed. In general, in the Fog computing environment, IoT devices are connected to Fog devices. These Fog devices are located in close proximity to users and are responsible for intermediate computation and storage. Fog computing research is still in its infancy, and taxonomy-based investigation into the requirements of Fog infrastructure, platform, and applications mapped to current research is still required. This paper starts with an overview of Fog computing in which the definition of Fog computing, research trends, and the technical differences between Fog and cloud are reviewed. Then, we investigate numerous proposed Fog computing architecture and describe the components of these architectures in detail. From this, the role of each component will be defined, which will help in the deployment of Fog computing. Next, a taxonomy of Fog computing is proposed by considering the requirements of the Fog computing paradigm. We also discuss existing research works and gaps in resource allocation and scheduling, fault tolerance, simulation tools, and Fog-based microservices. Finally, by addressing the limitations of current research works, we present some open issues, which will determine the future research direction.

''A survey of fog computing: Concepts, applications and issues'' [2015].

Authors: S.Yi,C.Li,andQ.Li.
Despite the increasing usage of cloud computing, there are still issues unsolved due to inherent problems of cloud computing such as unreliable latency, lack of mobility support and location-awareness. Fog computing can address those problems by providing elastic resources and services to end users at the edge of network, while cloud computing are more about providing resources distributed in the core network. This survey discusses the definition of fog

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computing and similar concepts, introduces representative application scenarios, and identifies various aspects of issues we may encounter when designing and implementing fog computing systems. It also highlights some opportunities and challenges, as direction of potential future work, in related techniques that need to be considered in the context of fog computing.

"Theoretical modelling of fog computing: A green computing paradigm to support IoT applications" [2016].

Authors: S. Sarkar and S. Misra.
In this study, the authors focus on theoretical modelling of the fog computing architecture and compare its performance with the traditional cloud computing model. Existing research works on fog computing have primarily focused on the principles and concepts of fog computing and its significance in the context of internet of things (IoT). This work, one of the first attempts in its domain, proposes a mathematical formulation for this new computational paradigm by defining its individual components and presents a comparative study with cloud computing in terms of service latency and energy consumption. From the performance analysis, the work establishes fog computing, in collaboration with the traditional cloud computing platform, as an efficient green computing platform to support the demands of the next generation IoT applications. Results show that for a scenario where 25% of the IoT applications demand real-time, low-latency services, the mean energy expenditure in fog computing is 40.48% less than the conventional cloud computing model.

''A hierarchical distributed fog computing architecture for big data analysis in smart cities" [2015].

Authors: B. Tang, Z. Chen, G. Hefferman, T. Wei, H. He, and Q. Yang.
The ubiquitous deployment of various kinds of sensors in smart cities requires a new computing paradigm to support Internet of Things (IoT) services and applications, and big data analysis. Fog Computing, which extends Cloud Computing to the edge of network, fits this need. In this paper, we present a hierarchical distributed Fog Computing architecture to support the integration of massive number of infrastructure components and services in future smart cities. To secure future communities, it is necessary to build large-scale, geospatial sensing networks, perform big data analysis, identify anomalous and hazardous events, and offer optimal responses in real-time. We analyze case studies using a smart pipeline monitoring system based on fiber optic sensors and sequential learning algorithms to detect events threatening pipeline safety. A working prototype was constructed to experimentally evaluate event detection performance of the recognition of 12 distinct events. These experimental results demonstrate the feasibility of the system's city-wide implementation in the future.

''Fog computing for vehicular ad-hoc networks: Paradigms, scenarios, and issues'' [2016].

Authors: K. Kai, W. Cong, and L. Tao.
Vehicular Ad-hoc networks (VANETs) are kinds of mobile Ad-hoc networks (MANETs), which consist of mobile vehicles with on-board units (OBUs) and roadside units (RSUs). With the rapid development of computation and communication technologies, peripheral or incremental changes in VANETs evolve into a revolution in process. Cloud computing as a solution has been deployed to satisfy vehicles in VANETs which are expected to require resources (such as computing, storage and networking). Recently, with special requirements of mobility, location awareness, and low latency, there has been growing interest in research into the role of fog computing in VANETs. The merging of fog computing with VANETs opens an area of possibilities for applications and services on the edge of the cloud computing. Fog computing deploys highly virtualized computing and communication facilities at the proximity of mobile vehicles in VANET. Mobile vehicles in VANET can also demand services of low-latency and short-distance local connections via fog computing. This paper presents the current state of the research and future perspectives of fog computing in VANETs. Moreover, we discuss the characteristics of fog computing and services based on fog computing platform provided for VANETs. In this paper, some opportunities for challenges and issues are mentioned, related techniques that need to be considered have been discussed in the context of fog computing in VANETs. Finally, we discuss about research directions of potential future work for fog computing in VANETs. Within this article, readers can have a more thorough understanding of fog computing for VANETs and the trends in this domain.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

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''Distributed multi cloud storage system to improve data security with hybrid encryption'' [2020].

Authors: S.U.Zaman,R.Karim,M.S.Are n,andY.Morimoto.
Data security of cloud storage is one of the major concerns right now. Usually, cloud storage providers store user data in a single location to achieve better maintainability. Beside some advantages, this approach has drawbacks also. The government of the country can legally order the cloud storage provider to let them access their stored data and in such situation, a user who is from another part of the world can not stop the provider. In a system it is very likely to have system vulnerability and the hacker is going to take its advantages as soon as he discovers it. The storage design approach described in this paper aimed to reduce the unauthorized access to end-user data. Our goal is to design a storage system which is a combination of some major cloud storage service providers. Our experimental results indicate that proposed approach provided the end user better control on his data in cloud storage with minimum cost and performance effect. Our system ensures user data privacy from anyone including government or cloud service provider itself.

III. SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

In recent years, Multi-Cloud Storage has gained considerable interest because it has the potential to offer high availability, strong security, and prevent service provider lockouts. For example, Zaman et al. [9] designed a distributed MultiCloud storage system that uses hybrid encryption to secure the data. The user data are encrypted offline, then divided into chunks and distributed to multiple cloud servers. The solution deployment depends on a third-party cloud service provider, which will keep track of the chunk sequence and addresses. Also, it needs a separate key management server to take care of the encrypted keys. The system did not implement any redundancy technique to ensure data reliability, and no explicit versioning is used to reduce the storage needs. In addition, the third-party cloud service provider, which will deploy the system, is a vulnerable bottleneck and a single point of failure.

3.1.1 DISADVANTAGES OF EXISTING SYSTEM

- Complexity in Management.
- Data Privacy Concerns.
- Latency Issues.
- Reliability.

3.2 PROPOSED SYSTEM

Singh et al. proposed a secure data deduplication technique using secret sharing schemes. 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.

3.2.1 ADVANTAGES OF PROPOSED SYSTEM

- Enhanced Security.
- Improved Performance.
- Increased Resilience.
- Vendor Lock-in Reduction.
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© 2025 IJMRSET | Volume 8, Issue 4, April 2025 |DOI:10.15680/IJMRSET.2025.0804250

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IV. SYSTEM DESIGN

DropStore is a secure backup system leveraging the synergy of multi-cloud storage and fog computing. This innovative design aims to address challenges such as data reliability, availability, scalability, and security while ensuring cost efficiency and reduced latency for users.

Devices like smartphones, laptops, or desktops, acting as the entry point for users to upload and access their backups. Fog computing layer provides a decentralized intermediary between user devices and the cloud. Multi-cloud storage layer ensures high availability and fault tolerance by distributing data across multiple cloud providers. Security features include encrypting data before transmission to the cloud, using unique encryption keys for each fragment.

Data flow or workflow goes like Users upload data via the DropStore client or dropstore edge-node. Uploaded data is encrypted and compressed at the fog layer. Encrypted data fragments are distributed across multiple cloud providers.Data fragmentation is done in such a way that the encrypted data is split into multiple fragments to prevent unauthorized access to the complete dataset. Distributed fragments add an additional layer of security.Access controls include Multi-factor authentication (MFA) for user accounts and Role-based access controls for managing privileges.
Fault tolerance has Redundant storage that ensures data availability even in the event of cloud provider failures. Fog nodes act as fail-safes during temporary connectivity issues. Horizontal scaling of fog nodes to accommodate increased user demand and Dynamic allocation of cloud storage resources. The proposed system design focuses on flexibility, robust, security, reliability and scalability while ensuring that users can safely store their data without any concerns about reliability and security.

4.1 SYSTEM ARCHITECTURE

The architecture of DropStore is designed to provide a secure, scalable, and efficient data backup and recovery system. It integrates fog computing and multi-cloud storage to ensure low latency, high availability, and robust data security.This application can be accessed using any device(smartphones, laptops,tablet).It enables users to upload data for backup. Displays notifications about backup status and alerts.Preprocessing module encrypts, compresses, and fragments data before it is sent to the cloud.Multi-cloud storage layer manages data distribution across multiple cloud providers.

Fog nodes and cloud storage can scale horizontally to handle increasing user demands. Access control system manages role-based access and multi-factor authentication (MFA) in order to ensure only authorized access to data. Multi-cloud redundancy prevents data loss from individual provider failures.Here, End user devices serve as access points for backup services throught the process. This modular and layered architecture ensures that DropStore is secure, efficient, and reliable, capable of meeting the diverse needs of its users.

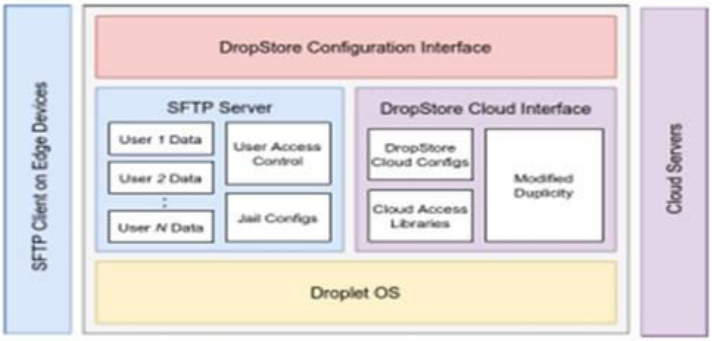

Fig 1: System Architecture

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4.2 UML DIAGRAMS

UML stands for Unified Modeling Language. UML is a standardized general- purpose modeling language in the field of object-oriented software engineering. The standard is managed, and was created by, the Object Management Group. The goal is for UML to become a common language for creating models of object oriented computer software. In its current form UML is comprised of two major components: a Meta-model and a notation. In the future, some form of method or process may also be added to or associated with, UML. The Unified Modeling Language is a standard language for specifying, Visualization, Constructing and documenting the artifacts of software system, as well as for business modeling and other non-software systems.

UML was created as a result of the chaos revolving around software development and documentation. In the 1990s, there were several different ways to represent and document software systems.

The UML represents a collection of best engineering practices that have proven successful in the modeling of large and complex systems. The UML is a very important part of developing objects oriented software and the software development process. The UML uses mostly graphical notations to express the design of software projects.

4.2a GOALS:

The Primary goals in the design of the UML are as follows:

1. Provide users a ready-to-use, expressive visual modeling Language so that they can develop and exchange meaningful models.
2. Provide extendibility and specialization mechanisms to extend the core concepts.
3. Be independent of particular programming languages and development process.
4. Provide a formal basis for understanding the modeling language.
5. Encourage the growth of object oriented tools market.
6. Support higher level development concepts such as collaborations, frameworks, patterns and components.
7. Integrate best practices.

V. RESULTS

The following figures present the sequence of screenshots of the results.

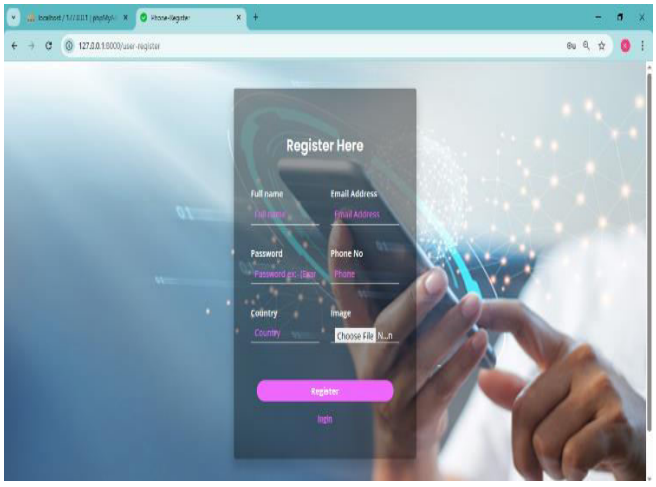

Fig 2a: Registration Page

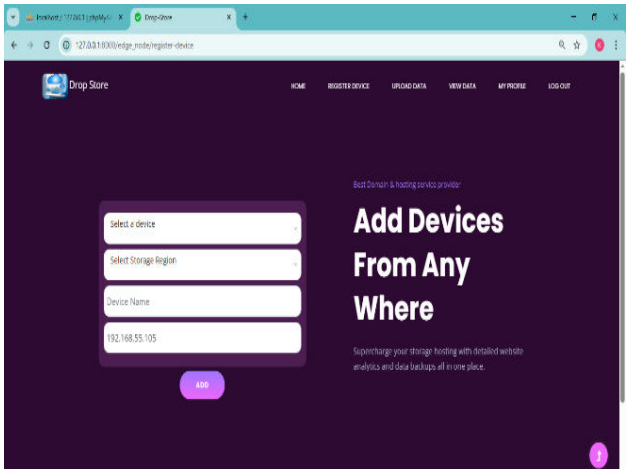

Fig 2b: register your device page

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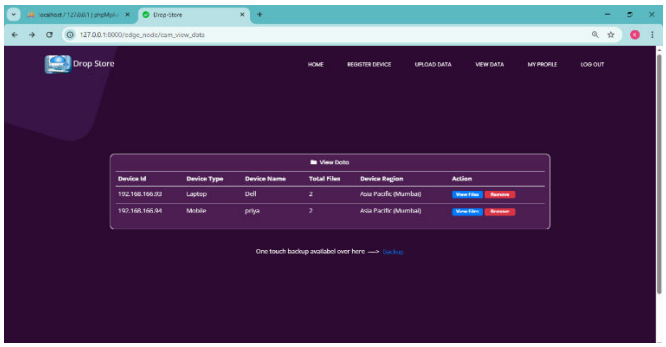

Fig 2c: backup your file.

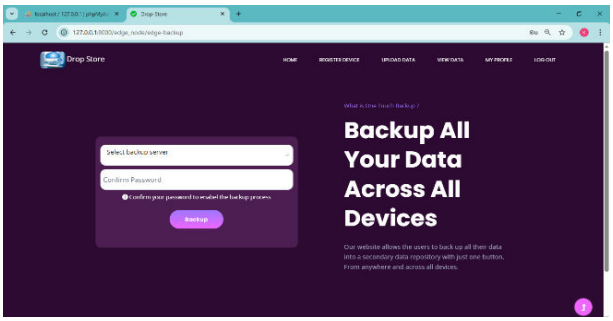

Fig 2d: Backup all your data across all devices

VI. CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSIONS

In this paper, we proposed DropStore, a new backup solution to tackle the problem of data security and reliability. The solution is based on Multi-Cloud and Fog Computing paradigms. Data security and user privacy are maintained by encryption and data partitioning on Multi-Cloud Storage. The solution abstracts the individual users from the system complications and improves the backup experience by utilizing Fog Computing advantages. We have built the system and ran many experiments on real-world scenarios. We have implemented two versions of DropStore. The first implementation is based on a low-cost single-board computer (Droplet node). The second implementation is based on a more powerful personal laptop. We have shown the DropStore can store and retrieve the data reliably using the two implementations. DropStore enables securing the user data with minimal complexity at the edge side. In the future, better scheduling strategies for data uploading to the cloud will be explored. The new scheduling strategies need to consider the QoS parameters and the remaining storage at each CSP. To improve the system's error detection and correction capabilities, linear block codes for data replication will be developed instead of entire data block repetition.
In conclusion, DropStore presents a robust and secure backup system leveraging the combined strengths of multi-cloud and fog computing. By implementing end-to-end encryption, distributed data storage, and edge-level processing, DropStore effectively addresses the challenges of modern data backup, offering enhanced security, reliability, and performance.

6.2 FUTURE WORK

While the DropStore system design provides a strong foundation for a secure and efficient backup solution, several avenues for future work can further enhance its capabilities and address evolving user needs.

Advanced Data Management & Intelligence:

- **AI-Powered Data Classification:**

✓ Enable intelligent storage tiering and backup policies based on data classification.
✓ Improve search and retrieval capabilities through semantic analysis.

- **Predictive Backup and Resource Allocation:**

✓ Optimize resource allocation in fog and cloud layers by predicting workload fluctuations.
✓ Implement smart scheduling to minimize network congestion and backup times.

- **Enhanced Data Deduplication and Compression:**

✓ Explore more advanced deduplication algorithms, such as content-defined chunking and delta compression, to further reduce storage footprint.
✓ Implement adaptive compression techniques that optimize compression ratios based on file types and content.

Security and Privacy Enhancements:

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- **Blockchain Integration for Data Integrity:**

✓ Utilize blockchain technology to create an immutable audit trail for data backups and access logs.

✓ Enhance data integrity verification and prevent unauthorized modifications.

By pursuing these future work areas, DropStore can evolve into a highly sophisticated and versatile backup solution, catering to the diverse needs of individuals and organizations in an increasingly data-driven world.

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