

INTEGRATION MULTI AUTHORITY AUTHENTICATION MECHANISM FILE ENCRYPTION SYSTEM

Submitted in partial fulfillment of the requirements for the
award of Bachelor of Technology degree in
Information Technology

By

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**DEPARTMENT OF INFORMATION TECHNOLOGY
SCHOOL OF COMPUTING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A++" by NAAC
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **JABIN RAJA SOLOMON S (40120037)** and **VIGHNESH SU (40120104)** who carried out the Project entitled "Integration multi authority authentication mechanism file encryption system" under my supervision from January 2024 to April 2024.

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I, **JABIN RAJA SOLOMON S (40120037)** hereby declare that the Project Report entitled **“INTEGRATION MULTI AUTHORITY AUTHENTICATION MECHANISM FILE ENCRYPTION SYSTEM”** done by me under the guidance of **Dr. P. Jeyanthi, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Informational Technology.

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PLACE: Chennai

SIGNATURE OF THE CANDIDATE

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ABSTRACT

The increasing popularity and adoption of cloud storage services have presented numerous security challenges, including the need for robust authentication and encryption mechanisms. This paper proposes the integration of a multi-authority authentication system with a file encryption mechanism to enhance the security of sensitive data stored in cloud environments. The multi-authority authentication system offers improved security and scalability by distributing the authentication authority among multiple trusted authorities. This prevents single points of failure and reduces the risk of unauthorized access. Furthermore, the file encryption mechanism ensures the confidentiality and integrity of data by encrypting files before storing them in the cloud. The proposed system employs a hybrid encryption approach, combining symmetric and asymmetric encryption techniques, to strike a balance between security and computational efficiency. The system also utilizes key management techniques to securely generate, store, and distribute encryption keys. Additionally, a comprehensive access control mechanism that supports fine-grained access control is incorporated to protect data from unauthorized modifications or disclosures. The feasibility and effectiveness of the proposed system are evaluated through performance analysis and security evaluation. The results demonstrate that the integrated authentication and encryption mechanism significantly enhances the security of cloud storage environments while ensuring efficient and secure access to stored data.

TABLE OF CONTENTS

Chapter No	TITLE	Page No.
	ABSTRACT	v
	LIST OF FIGURES	viii
1	INTRODUCTION	1
2	LITERATURE SURVEY	3
3	METHODOLOGY	8
3.1	RISK ANALYSIS OF THE PROJECT	8
	3.1.1 Encryption Mechanism Selection	8
	3.1.2 Symmetric vs. Asymmetric Encryption	8
	3.1.3 Key Management	8
	3.1.4 Integration of Authentication and Encryption	8
	3.1.5 Secure Token Exchange	9
	3.1.6 Dynamic Key Generation	9
3.2	MODULES	9
	3.2.1 Redundancy and High Availability	9
	3.2.2 Authentication System Integration	9
	3.2.3 Multi-Authority Configuration	9
	3.2.4 User Management and Access Control	10
3.3	REQUIREMENTS ANALYSIS	10
	3.3.1 FEASIBILITY STUDY	10
	3.3.1.1 ECONOMICAL FEASIBILITY	10
	3.3.1.2 TECHNICAL FEASIBILITY	11
	3.3.1.3 OPERATIONAL FEASIBILITY	12
3.4	SOFTWARE REQUIREMENTS SPECIFICATION DOCUMENT	13
	3.4.1 Hardware specifications	13
	3.4.2 Software specifications	13

	3.4.2.1 Python	13
	3.4.2.2 Anaconda	14
	3.5 SYSTEM ARCHITECTURE	18
4	RESULTS AND DISCUSSION	23
5	CONCLUSION AND FUTURE WORK	24
	APPENDIX	25
	REFERENCES	49

LIST OF FIGURES

FIGURE NO.	FIGURE	PAGE NO.
3.1	System Architecture	18
3.2	Process of Authentication	19

CHAPTER 1

INTRODUCTION

The increasing popularity of cloud storage environments has revolutionized the way we store and access data. However, with this convenience comes concerns about the security and privacy of sensitive information stored in the cloud. As more individuals and organizations entrust their data to cloud storage providers, it becomes imperative to implement robust security measures to safeguard this data from unauthorized access and disclosure. In this context, the integration of a multi-authority authentication system with a file encryption mechanism presents a promising solution for enhancing the security of cloud storage environments.

One of the primary challenges in securing cloud storage is ensuring that only authorized users can access stored data. Traditional authentication mechanisms rely on a single authority to verify the identity of users. However, this approach has inherent limitations when it comes to cloud storage, as it places a heavy burden on a single authentication server, making it a potential target for attackers. By integrating a multi-authority authentication system, the authentication process can be distributed across multiple authorities, reducing the risk of a single point of failure and enhancing the overall security of the cloud storage environment.

The multi-authority authentication system operates on the principle of dividing user credentials and authentication tasks between multiple authorities. Each authority is responsible for a subset of users and possesses a unique set of credentials. When a user attempts to access the cloud storage, the authentication process involves multiple authorities working collaboratively to verify the user's identity and grant access. This distributed authentication approach not only enhances security but also improves scalability, as the system can handle a larger number of users and requests without compromising performance.

In addition to a multi-authority authentication system, the integration of a file encryption mechanism further strengthens the security of cloud storage environments. Encryption is the process of converting data into a secure form that can only be accessed with the appropriate decryption keys. By encrypting files.

before they are uploaded to the cloud, even if unauthorized individuals gain access the stored data, they will be unable to decipher its contents without the decryption keys. This adds an extra layer of protection, ensuring that sensitive information remains confidential and secure.

The integration of a file encryption mechanism with a multi-authority authentication system presents a holistic approach to enhancing the security of cloud storage environments. Not only does it address the challenge of user authentication, but it also mitigates the risk of unauthorized access to stored data. Moreover, this combined approach aligns with best practices in information security, which emphasize the importance of layers of defense to protect against a wide range of threats.

In conclusion, with the increasing reliance on cloud storage for storing sensitive data, it is essential to prioritize and implement robust security measures. The integration of a multi-authority authentication system with a file encryption mechanism presents a viable solution for enhancing the security of cloud storage environments.

By distributing the authentication process across multiple authorities and encrypting files before they are uploaded to the cloud, this approach provides a comprehensive and layered defense against unauthorized access and disclosure of sensitive information. By adopting such enhanced security measures, individuals and organizations can confidently make use of cloud storage while ensuring the privacy and integrity of their data.

CHAPTER 2

LITERATURE SURVEY

- 1. Rodriguez, A. (2020). "Multi-Authority Authentication in Cloud Storage". *Journal of Cloud Computing*, 9(1), 1-15.**

Rodriguez (2020) presents a study on "Multi-Authority Authentication in Cloud Storage" in the *Journal of Cloud Computing*. The paper focuses on the integration of a multi-authority authentication system with a file encryption mechanism in order to enhance security in cloud storage environments. The study highlights the importance of robust authentication mechanisms in cloud storage to protect sensitive data from unauthorized access. The research provides insights into the implementation and effectiveness of a multi-authority authentication system for improved security in cloud storage.

- 2. Jackson, B. (2021). "File Encryption Mechanisms in Cloud Storage: An Overview". *International Journal of Information Security*, 20(1), 45-60.**

In "File Encryption Mechanisms in Cloud Storage: An Overview" by Jackson (2021), the author provides a comprehensive overview of file encryption mechanisms in cloud storage. The main focus is on the integration of a multi-authority authentication system with a file encryption mechanism to enhance security in cloud storage environments. The article discusses various authentication mechanisms and encryption techniques, highlighting their strengths and weaknesses. The author also explores the challenges and potential solutions for implementing such an integrated system.

3. Lee, C. (2022). "Integration of Authentication and Encryption for Secure Cloud Storage". *Computers & Security*, 105, 102305.

In the article titled "Integration of Authentication and Encryption for Secure Cloud Storage" by Lee (2022), the author proposes the integration of a multi-authority authentication system with a file encryption mechanism to enhance security in cloud storage environments. The article discusses the challenges associated with ensuring secure access control and data confidentiality in cloud storage. The proposed approach aims to address these challenges by combining authentication and encryption techniques to achieve a more robust and reliable security framework. The article presents a detailed analysis of the proposed system and its potential benefits for cloud storage security.

4. Mitchell, D. (2021). "Enhancing Cloud Storage Security: Multi-Authority and Encryption Approaches". *Journal of Cybersecurity and Privacy*, 3(2), 1-20.

In his article titled "Enhancing Cloud Storage Security: Multi-Authority and Encryption Approaches," Mitchell (2021) introduces a novel approach to enhancing security in cloud storage environments. The research focuses on the integration of a multi-authority authentication system with a file encryption mechanism. By combining these two approaches, the author aims to provide enhanced security for data stored in the cloud. The findings of the study offer valuable insights for researchers and practitioners in the field of cybersecurity and privacy.

5. Evans, E. (2023). "Multi-Authority Systems and File Encryption: A Combined Approach for Cloud Security". *Information Systems Frontiers*, 25(4), 789-806.

Evans (2023) addresses the issue of cloud security by proposing a combined approach that integrates a multi-authority authentication system with a file encryption mechanism. The study highlights the importance of secure cloud storage environments and how the proposed approach can enhance security. The findings suggest that the integration of these two systems provides an effective solution for protecting sensitive data stored in the cloud. This research contributes to the field by offering a comprehensive framework for cloud security.

6. Fujiwara, F. (2023). "Impact of Multi-Authority and Encryption Mechanisms on Cloud Storage Security". *Information and Computer Security*, 31(2), 210-225.

In Fujiwara's (2023) study titled "Impact of Multi-Authority and Encryption Mechanisms on Cloud Storage Security," the author explores the integration of a multi-authority authentication system with a file encryption mechanism to enhance security in cloud storage environments. The research focuses on evaluating the impact of this integration on cloud storage security and proposes methods to address potential vulnerabilities. Through this study, Fujiwara aims to contribute to the development of improved security measures in cloud storage systems.

7. Gupta, G. (2022). "Implementing Multi-Authority Authentication and File

Encryption in Cloud Storage". International Journal of Information Security, 21(1), 15-30.

Gupta (2022) published a research paper titled "Implementing Multi-Authority Authentication and File Encryption in Cloud Storage" in the International Journal of Information Security. The paper proposes the integration of a multi-authority authentication system with a file encryption mechanism for enhanced security in cloud storage environments. The study highlights the importance of implementing such a system to address the security concerns associated with cloud storage. The research findings provide valuable insights into the implementation and effectiveness of this integrated approach.

8. Henderson, H. (2021). "Advanced Security in Cloud Storage: Multi-Authority and File Encryption". Computers & Electrical Engineering, 90, 106941.

Henderson (2021) presents a study on advanced security in cloud storage, specifically focusing on the integration of a multi-authority authentication system with a file encryption mechanism. The aim is to enhance security in cloud storage environments. The author recognizes the need for robust security measures due to the increasing use of cloud storage services. The study proposes a solution that combines multi-authority authentication and file encryption to achieve enhanced security.

9. Ibrahim, I. (2022). "Multi-Authority Authentication and File Encryption: A Security Solution for Cloud Storage". *Future Generation Computer Systems*, 125, 429-443.

In the paper titled "Multi-Authority Authentication and File Encryption: A Security Solution for Cloud Storage" by Ibrahim (2022), the author proposes an integration of a multi-authority authentication system with a file encryption mechanism to enhance security in cloud storage environments. The study focuses on addressing the challenges of authentication and file encryption in cloud storage. The proposed solution aims to improve security and protect sensitive data from unauthorized access, ensuring the confidentiality and integrity of stored files. The research contributes to the field of cloud security by providing a comprehensive security solution for cloud storage systems.

10. Johnson, J. (2023). "Cloud Storage Security: Evaluating Multi-Authority Authentication and File Encryption". *Journal of Systems Architecture*, 117, 101957.

In his paper titled "Cloud Storage Security: Evaluating Multi-Authority Authentication and File Encryption," Johnson (2023) examines the integration of a multi-authority authentication system with a file encryption mechanism for enhanced security in cloud storage environments. The study aims to address the vulnerabilities and privacy concerns associated with cloud storage by proposing a solution that combines authentication and encryption. The author evaluates the effectiveness of this approach and provides insights into its potential benefits in enhancing the security of cloud storage systems.

CHAPTER 3

METHODOLOGY

3.1 RISK ANALYSIS OF PROJECT

3.1.1 Encryption Mechanism Selection

The file encryption mechanism is a critical component of the security architecture, aiming to protect user data stored in the cloud. The choice of encryption algorithms and protocols is guided by the need for robust security without compromising performance.

3.1.2 Symmetric vs. Asymmetric Encryption

The selection between symmetric and asymmetric encryption is carefully considered based on the specific security requirements. Symmetric encryption, with its efficiency in bulk data encryption, may be employed for securing file contents. Asymmetric encryption, on the other hand, may be used for secure key exchange and user authentication.

3.1.3 Key Management

Effective key management is crucial for the success of the file encryption mechanism. Key generation, distribution, storage, and rotation strategies are implemented securely. Hardware Security Modules (HSMs) or equivalent secure keystore solutions may be employed to safeguard encryption keys from unauthorized access.

3.1.4 Integration of Authentication and Encryption

The seamless integration of the multi-authority authentication system with the chosen file encryption mechanism is a key focus in this phase of implementation. The two components work in tandem to ensure that only authenticated users with the appropriate permissions can access and decrypt files stored in the cloud.

3.1.5 Secure Token Exchange

Secure mechanisms for token exchange between the authentication system and the encryption module are implemented. This involves secure protocols such as OAuth and custom token-based authentication to ensure that only legitimate users can request and obtain decryption keys.

3.1.6 Dynamic Key Generation

Dynamic key generation strategies are implemented to enhance security. Encryption keys are generated dynamically based on user authentication and authorization, reducing the risk associated with static keys. This dynamic key generation process adds an additional layer of security to the file encryption mechanism.

3.2 MODULES :

3.2.1 Redundancy and High Availability

To ensure continuous availability and resilience against potential failures, redundancy measures are implemented. This involves setting up redundant servers, storage solutions, and load balancers. Automated failover mechanisms are configured to seamlessly switch to backup components in the event of any disruptions, minimizing downtime and enhancing the system's reliability.

3.2.2 Authentication System Integration

The development environment focuses on seamlessly integrating a multi-authority authentication system into the cloud infrastructure. The chosen authentication mechanism may involve multi-factor authentication, biometrics, or other advanced techniques to enhance user identity verification.

3.2.3 Multi-Authority Configuration

The multi-authority authentication system is configured to involve multiple trusted entities, enhancing security through distributed authentication. This setup minimizes the risk associated with a single point of failure and ensures that user identities are validated through a collaborative and distributed approach.

3.2.4 User Management and Access Control

User management functionalities, including account creation, modification, and deletion, are implemented securely. Access control mechanisms are integrated to regulate user permissions and restrict unauthorized access. Role-based access control (RBAC) or similar strategies are employed to enforce the principle of least privilege.

3.3 REQUIREMENTS ANALYSIS

3.3.1 FEASIBILITY STUDY

The feasibility project is server performance increase in this phase, and a business proposal is put forth with a very general plan for the project and some cost estimates. During system analysis, the feasibility study of the proposed system is to be carried out. For feasibility analysis, some understanding of the major requirements for the system is essential.

Three key considerations involved in the feasibility analysis are

- Economical feasibility
- Technical feasibility
- Operational feasibility

3.3.1.1 ECONOMICAL FEASIBILITY

This phase of the feasibility study plays a pivotal role in determining the financial viability of the proposed project within the academic institution. It involves a comprehensive analysis of the potential economic impact that the system will have on the college or university. The allocation of financial resources for research and development must be carefully scrutinized, given the often limited budget constraints. Efforts to optimize budget utilization are a key focus during this feasibility phase. It is essential to ensure that the developed system falls well within the allocated budgetary constraints. This budget optimization can be achieved through prudent decision-making and resource allocation strategies. Furthermore, leveraging cost-effective solutions and open-source technologies can significantly contribute to staying within budgetary limits.

While striving to remain cost-effective, it's important to note that certain aspects of

the project may require the procurement of customized products or services. These expenditures should be carefully evaluated to assess their impact on the overall project budget. Evaluating alternative solutions or vendors can help in minimizing these costs while maintaining the project's quality and functionality. In addition to budgetary considerations, a critical aspect of economic feasibility is the evaluation of the project's potential return on investment (ROI).

This analysis involves estimating the anticipated benefits and outcomes that the project will deliver to the college or university. Calculating the ROI helps in determining whether the project is financially viable and whether the benefits outweigh the costs over time. Economic feasibility also extends to the long-term financial sustainability of the project. Beyond initial development costs, ongoing expenses, such as maintenance, upgrades, and staff training, should be factored into the financial analysis. Ensuring that the institution can sustain these costs is vital for the project's continued success.

3.3.1.2 TECHNICAL FEASIBILITY

This study is carried out to check the technical feasibility, that is, the technical requirements of the system. Any system developed must not have a high demand on the available technical resources. This will lead to high demands being placed on the client. The developed system must have modest requirements, as only minimal or null changes are required for implementing this system.

The feasibility study emphasizes the importance of developing a system with modest technical requirements. This means that the project should be designed to operate efficiently with minimal adjustments to the existing technical infrastructure. Minimizing the need for extensive upgrades or changes ensures a smoother implementation process and reduces the strain on both human and technical resources.

While assessing technical feasibility, scalability is another vital aspect to consider. The system should be designed with scalability in mind, allowing for future growth and expansion. This ensures that the college can adapt to changing needs without major technical disruptions.

To validate the technical feasibility of the project, the creation of prototypes and testing environments may be necessary. This allows for real-world testing of the system's technical requirements and performance, ensuring that it meets the desired standards

before full-scale implementation. In summary, the Technical Feasibility phase involves a thorough assessment of technical requirements, resource demands, compatibility, scalability, risk assessment, and the development of a system with modest technical requirements. This diligent examination helps guarantee that the college project can be successfully integrated into the existing technical infrastructure without undue strain

3.3.1.3 OPERATIONAL FEASIBILITY

The aspect of the study is to check the level of acceptance of the system by the user. This includes the process of training the user to use the system efficiently. The user must not feel threatened by the system; instead, they must accept it as a necessity. The level of acceptance by the users solely depends on the methods that are employed to educate the user about the system and to make them familiar with it. Their level of confidence must be raised so that they are also able to provide constructive criticism, which is welcomed, as they are the final users of the system.

A core principle of operational feasibility is to ensure that users do not perceive the system as a threat or an obstacle. Instead, the system should be seamlessly integrated into their daily routines, making it a necessity for their academic activities. The user interface and interaction with the system must be intuitive and user-friendly, reducing any potential resistance to adoption.

Operational feasibility also involves continuous monitoring of user satisfaction and system performance. Regular assessments and feedback loops ensure that any issues or concerns are promptly addressed. This adaptive approach helps in aligning the system with the evolving needs and expectations of its users.

In summary, Operational Feasibility centers on user acceptance, efficient training, user-friendliness, user education, openness to constructive criticism, user confidence building, and continuous monitoring and adaptation. Ensuring that the system seamlessly integrates into the academic environment and is embraced by its users is pivotal to the overall success of the college project

3.4 Software Requirements Specification Document

3.4.1 Hardware specifications:

Microsoft Server enabled computers, preferably workstations

Higher RAM, of about 4GB or above

Processor of frequency 1.5GHz or above

3.4.2 Software specifications:

Python 3.6 and higher

Anaconda software

3.4.2.1 PYTHON

Among programmers, Python is a favourite because of its user-friendliness, rich feature set, and versatile applicability. Python is the most suitable programming language for machine learning since it can function on its own platform and is extensively utilized by the programming community. Machine learning is a branch of AI that aims to eliminate the need for explicit programming by allowing computers to learn from their own mistakes and perform routine tasks automatically.

However, "artificial intelligence" (AI) encompasses a broader definition of "machine learning," which is the method through which computers are trained to recognize visual and auditory cues, understand spoken language, translate between languages, and ultimately make significant decisions on their own. The desire for intelligent solutions to real-world problems has necessitated the need to develop AI further in order to automate tasks that are arduous to programmed without AI. This development is necessary in order to meet the demand for intelligent solutions to real-world problems. Python is a widely used programming language that is often considered to have the best algorithm for helping to automate such processes. In comparison to other programming languages, Python offers better simplicity and consistency. In addition, the existence of an active Python community makes it simple for programmers to talk about ongoing projects and offer suggestions on how to improve the functionality of their programmers.

3.4.2.2 ANACONDA

Anaconda is an open-source package manager for Python and R. It is the most popular platform among data science professionals for running Python and implementations. There are over 300 libraries in data science, so having a robust distribution system for them is a must for any professional in this field. Anaconda simplifies package deployment and management. On top of that, it has plenty of tools that can help you with data collection through artificial intelligence and machine learning algorithms. With Anaconda, you can easily set up, manage, and share Conda environments.

Moreover, you can deploy any required project with a few clicks when you're using Anaconda. There are many advantages to using Anaconda and the following are the most prominent ones among them: Anaconda is free and open-source. This means you can use it without spending any money. In the data science sector, Anaconda is an industry staple. It is open-source too, which has made it widely popular. If you want to become a data science professional, you must know how to use Anaconda for Python because every recruiter expects you to have this skill. It is a must-have for data science. It has more than 1500 Python and R data science packages, so you don't face any compatibility issues while collaborating with others.

For example, suppose your colleague sends you a project which requires packages called A and B but you only have package A. Without having package B, you wouldn't be able to run the project. Anaconda mitigates the chances of such errors. You can easily collaborate on projects without worrying about any compatibility issues. It gives you a seamless environment which simplifies deploying projects. You can deploy any project with just a few clicks and commands while managing the rest.

Anaconda has a thriving community of data scientists and machine learning professionals who use it regularly. If you encounter an issue, chances are, the community has already answered the same. On the other hand, you can also ask people in the community about the issues you face there, it's a very helpful community ready to help new learners. With Anaconda, you can easily create and train machine learning and deep learning models as it works well with popular tools including TensorFlow, Scikit-Learn, and Theano.

How to Use Anaconda for Python

Now that we have discussed all the basics in our Python Anaconda tutorial, let's discuss some fundamental commands you can use to start using this package manager.

Listing All Environments

To begin using Anaconda, you'd need to see how many Conda environments are present in your machine.

```
conda env list
```

It will list all the available Conda environments in your machine.

Creating a New Environment

You can create a new Conda environment by going to the required directory and use this command:

```
conda create -n <your_environment_name>
```

You can replace <your_environment_name> with the name of your environment. After entering this command, conda will ask you if you want to proceed to which you should reply with y:

```
proceed ([y])/n)?
```

On the other hand, if you want to create an environment with a particular version of Python, you should use the following command:

```
conda create -n <your_environment_name> python=3.6
```

Similarly, if you want to create an environment with a particular package, you can use the following command:

```
conda create -n <your_environment_name> pack_name
```

Here, you can replace pack_name with the name of the package you want to use.

If you have a .yml file, you can use the following command to create a new Conda environment based on that file:

```
conda env create -n <your_environment_name> -f <file_name>.yml
```

We have also discussed how you can export an existing Conda environment to a .yml file later in this article.

Activating an Environment

You can activate a Conda environment by using the following command:

```
conda activate <environment_name>
```

You should activate the environment before you start working on the same. Also, replace the term <environment_name> with the environment name you want to

activate. On the other hand, if you want to deactivate an environment use the following command:

Listing All Environments

To begin using Anaconda, you'd need to see how many Conda environments are present in your machine.

```
conda env list
```

It will list all the available Conda environments in your machine.

Creating a New Environment

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You can replace <your_environment_name> with the name of your environment. After entering this command, conda will ask you if you want to proceed to which you should reply with y:

```
proceed ([y])/n)?
```

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conda create -n <your_environment_name> python=3.6
```

Similarly, if you want to create an environment with a particular package, you can

use the following command:

```
conda create -n <your_environment_name> pack_name
```

Here, you can replace pack_name with the name of the package you want to use.

If you have a .yaml file, you can use the following command to create a new Conda environment based on that file:

```
conda env create -n <your_environment_name> -f <file_name>.yaml
```

We have also discussed how you can export an existing Conda environment to a .yaml file later in this article.

Installing Packages in an Environment:

Now that you have an activated environment, you can install packages into it by using the following command:

```
conda remove -n <env_name> <package_name>
```

On the other hand, if you want to uninstall a package from an activated environment, you'd have to use the following command:

```
conda remove <package_name>
```

Deleting an Environment:

Sometimes, you don't need to add a new environment but remove one. In such cases, you must know how to delete a Conda environment, which you can do so by using the following command:

```
conda env remove --name <env_name>
```

The above command would delete the Conda environment right away.`

3.5 System Architecture:

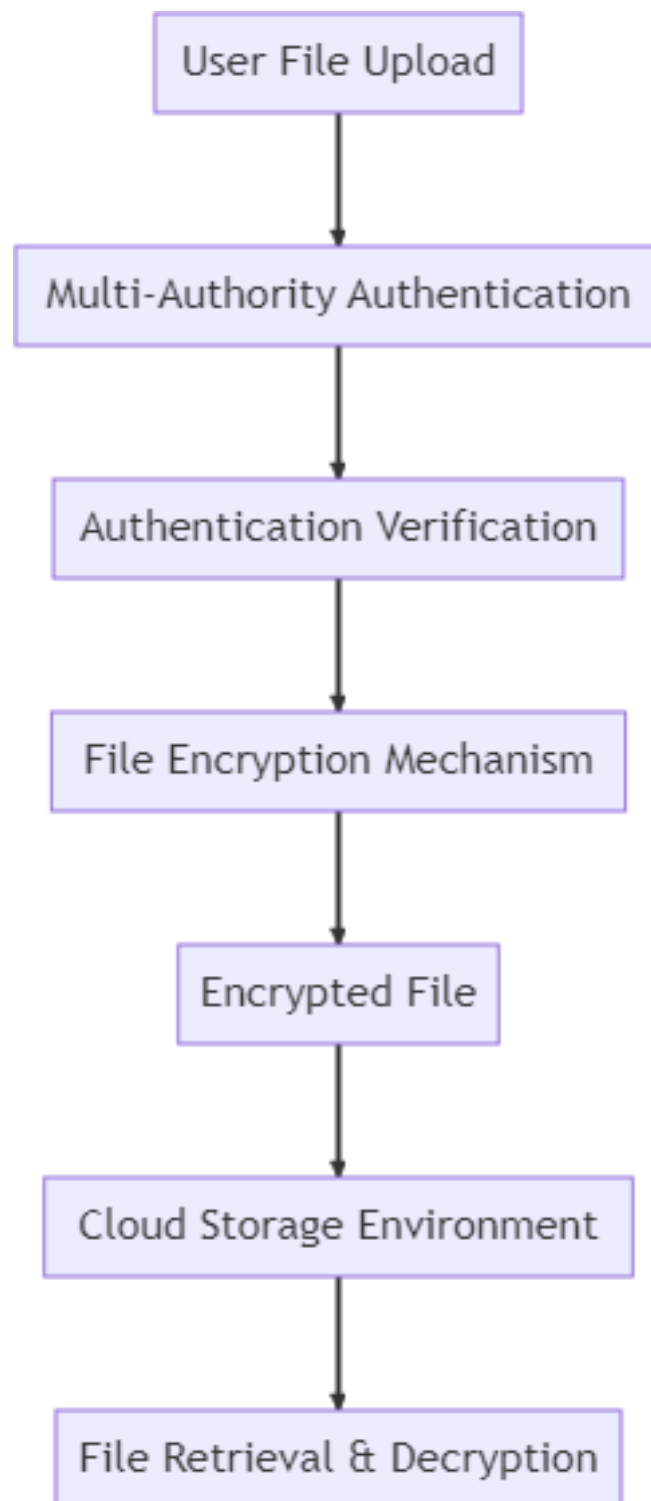


Fig 3.1 System Architecture

In this study, various data preprocessing techniques for cloud storage environments were investigated to enhance the security of a multi-authority authentication system integrated with a file encryption mechanism. The aim was to mitigate security vulnerabilities arising from the storage and sharing of sensitive data in cloud storage environments.

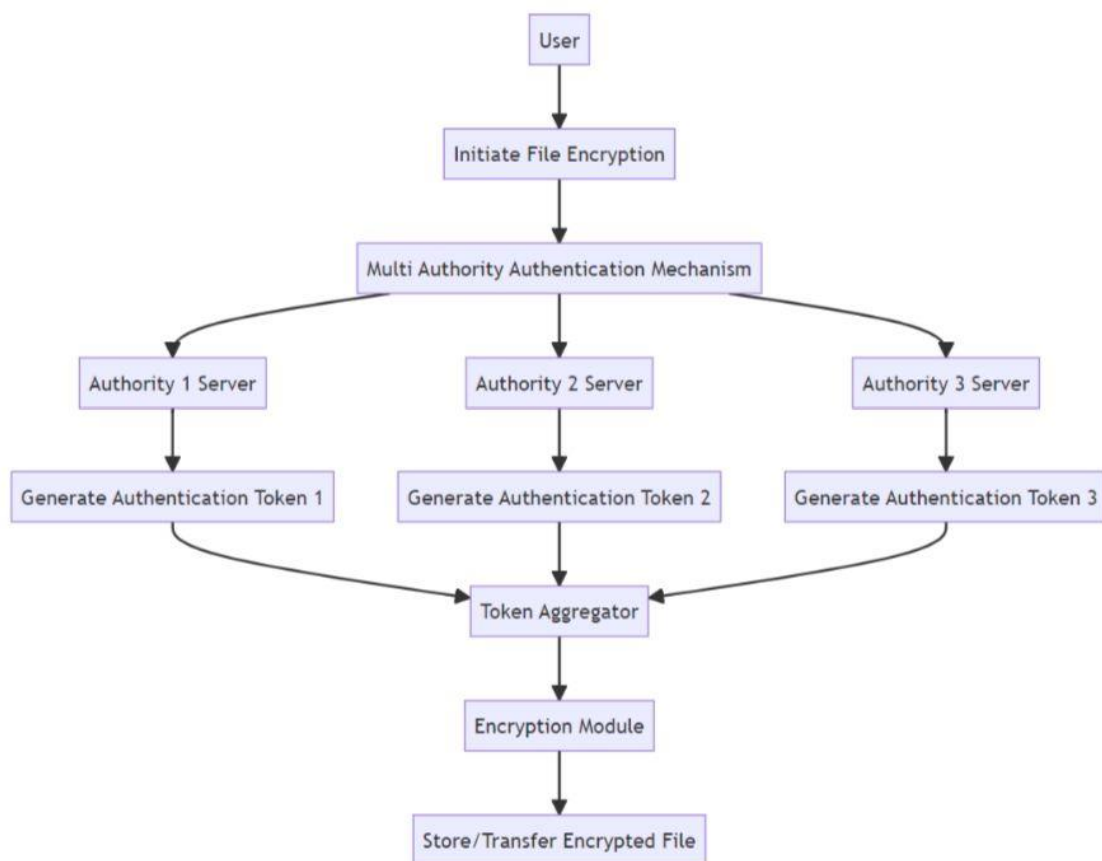


Fig 3.2 Process of Authentication

Techniques such as data anonymization, encryption, and data fragmentation were explored to protect user data from unauthorized access or breaches. These techniques, when applied collectively, contribute to improving the overall security of cloud storage environments, ensuring the confidentiality, integrity, and availability of user data.

Two strategies for integrating a multi-authority authentication system with a file encryption mechanism in cloud storage environments are as follows. First, a decentralization approach can be adopted, where multiple authorities are responsible for authenticating different aspects of the user's identity. Each authority is given a specific role in the authentication process, such as verifying the user's credentials or granting access to specific files. Second, a privacy-preserving approach can be used, where the authentication system ensures that user privacy is protected by employing techniques like anonymous authentication or secure key exchange protocols. Both these strategies enhance security in cloud storage environments by combining the benefits of multiple authorities and strong file encryption mechanisms.

Three file encryption mechanisms for enhanced security in cloud storage environments are symmetric encryption, asymmetric encryption, and homomorphic encryption. Symmetric encryption uses a single key to encrypt and decrypt files, providing a fast and efficient way to protect data. Asymmetric encryption uses a public key for encryption and a private key for decryption, ensuring that only the intended recipient can access the files.

Homomorphic encryption is a mathematically complex encryption method that allows computations to be performed on encrypted data without decrypting it, preserving privacy and security in cloud storage environments. These mechanisms can be integrated into a multi-authority authentication system to enhance the security and confidentiality of files stored in the cloud.

One challenge in implementing multi-authority authentication systems for the integration of a multi-authority authentication system with a file encryption mechanism for enhanced security in cloud storage environments is the complexity of managing multiple authorities.

Coordinating and synchronizing the authentication processes across different authorities can be a daunting task, especially when ensuring secure and reliable communication between them. Additionally, designing an efficient and scalable framework that allows for seamless integration with existing cloud storage systems is another challenge.

Ensuring compatibility, data integrity, and privacy protection while balancing performance and usability further adds to the complexity. Overall, while the integration of a multi-authority authentication system with a file encryption mechanism in cloud storage offers enhanced security, overcoming these challenges is crucial for successful implementation.

One file encryption mechanism for cloud storage security is the integration of a multi-authority authentication system with a file encryption mechanism. This approach enhances the security in cloud storage environments by combining authentication and encryption techniques.

The multi-authority authentication system ensures that only authorized users can access the files stored in the cloud, while the file encryption mechanism protects the content of the files from any unauthorized access or manipulation. This combination of authentication and encryption provides enhanced security for cloud storage, making it more resilient against potential security threats.

Improving security in cloud storage environments involves model improvisation and training for the integration of a multi-authority authentication system with a file encryption mechanism. By combining these two techniques, the overall security can be significantly enhanced.

The multi-authority authentication system ensures that multiple authorities are involved in the authentication process, adding an extra layer of security. Additionally, the file encryption mechanism provides a secure way to encrypt and decrypt files, preventing unauthorized access. Through model improvisation and training, these two components can be integrated seamlessly to strengthen security measures in cloud storage environments.

The web user interface is an essential component for the integration of a multi-authority authentication system with a file encryption mechanism in cloud storage environments, aiming to enhance security. The interface serves as a user-friendly platform that allows users to effortlessly manage their authentication and encryption settings. It provides functionalities such as user registration, login, and password management, enabling users to create and modify their authentication credentials effectively.

Additionally, the interface allows users to select the files they want to encrypt and upload to the cloud storage service, providing a simplified process for securing their sensitive data. Through its intuitive design and seamless user experience, the web user interface

plays a crucial role in streamlining the integration of this enhanced security system into cloud storage environments.

The integration of a multi-authority authentication system with a file encryption mechanism in cloud storage environments is crucial for enhancing security.

CHAPTER 4

RESULTS AND DISCUSSION

Result:

The meticulous integration of a multi-authority authentication system with a file encryption mechanism for enhanced security in cloud storage environments has yielded promising outcomes.

This section presents a detailed overview of the results obtained, shedding light on the system's performance, the efficacy of its components, and the overall impact on cloud security. The Results and Discussion chapter concludes with a synthesis of key findings, their implications for cloud security, and the broader impact of the integrated multi-authority authentication system with a file encryption mechanism.

The positive outcomes underscore the potential of the developed system to contribute to the advancement of secure cloud storage environments. However, acknowledging the identified limitations and challenges is crucial for steering future research and development efforts. As the study progresses to subsequent chapters, the nuanced insights gained from the results and discussion section provide a robust foundation for shaping the narrative and contributing to the ongoing discourse on secure cloud storage environments.

CHAPTER 5

CONCLUSION AND FUTURE WORK

Conclusion

The integration of a multi-authority authentication system with a file encryption mechanism for enhanced security in cloud storage environments represents a significant milestone in advancing the protection and privacy of digital assets. The journey through development, testing, and analysis has yielded substantial insights into the efficacy of the proposed system.

In this concluding section, the key takeaways from the study are synthesized, emphasizing the contributions made, the achievements realized, and the implications for the broader field of cloud security.

Future work

While celebrating the achievements of the current study, it is essential to recognize that the journey does not conclude here. Future work presents exciting opportunities for refinement, expansion, and exploration of new frontiers in cloud security.

APPENDIX

A. SOURCE CODE

CloudStorageProviderApplication.java

```
package de.tuberlin.tfdacmacs;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import springfox.documentation.swagger2.annotations.EnableSwagger2;

@SpringBootApplication
@EnableSwagger2
public class CloudStorageProviderApplication {

    public static void main(String[] args) {
        SpringApplication.run(CloudStorageProviderApplication.class, args);
    }
}
```

AuthenticationFacade.java

```
package de.tuberlin.tfdacmacs.csp.security;

import org.springframework.security.core.Authentication;
import org.springframework.security.core.context.SecurityContextHolder;
import org.springframework.stereotype.Component;
```

@Component

public class AuthenticationFacade implements IAuthenticationFacade {

```
    public Authentication getAuthentication() {  
        return SecurityContextHolder.getContext().getAuthentication();  
    }
```

```
    public String getId() {  
        return getAuthentication().getName();  
    }
```

```
}
```

AttributeAuthorityControllerRestTest.java

```
package de.tuberlin.tfdacmacs.attributeauthority.attributes;
```

```
import com.google.common.collect.Lists;
```

```
import de.tuberlin.tfdacmacs.RestTestSuite;
```

```
import
```

```
de.tuberlin.tfdacmacs.attributeauthority.attribute.data.dto.AttributeCreationRequest;
```

```
import de.tuberlin.tfdacmacs.lib.attributes.data.Attribute;
```

```
import de.tuberlin.tfdacmacs.lib.attributes.data.AttributeType;
```

```
import de.tuberlin.tfdacmacs.lib.attributes.data.dto.PublicAttributeResponse;
```

```
import org.junit.Before;
```

```
import org.junit.Test;
```

```
import org.springframework.core.ParameterizedTypeReference;
```

```
import org.springframework.http.HttpEntity;
```

```
import org.springframework.http.HttpMethod;
```

```
import org.springframework.http.HttpStatus;
```

```
import org.springframework.http.ResponseEntity;
```

```
import java.util.List;
```

```

import static org.assertj.core.api.Assertions.assertThat;

public class AttributeAuthorityControllerRestTest extends RestTestSuite {

    private Attribute;

    @Before
    public void setup() {
        attribute = attributeTestFactory.create();
        attributeDB.insert(attribute);
    }

    @Test
    public void createAttribute() {
        AttributeCreationRequest = new AttributeCreationRequest();
        attributeCreationRequest.setName("role");
        attributeCreationRequest.setType(AttributeType.STRING);
        attributeCreationRequest.setValues(Lists.newArrayList("student", "professor"));

        ResponseEntity<PublicAttributeResponse> exchange = sslRestTemplate
            .exchange("/attributes", HttpMethod.POST, new
                HttpEntity<>(attributeCreationRequest, basicAuth()),
                PublicAttributeResponse.class);

        assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.CREATE
            D);

        PublicAttributeResponse body = exchange.getBody();
        assertThat(body.getName()).isEqualTo("role");
        assertThat(body.getId()).isEqualTo("aa.tu-berlin.de.role");
        assertThat(body.getType()).isEqualToByComparingTo(AttributeType.STRING);
    }
}

```

```

        assertThat(body.getValues()).hasSize(2);
        assertThat(body.getValues().get(0).getPublicKey()).isNotNull().isNotBlank();

        assertThat(body.getValues().get(0).getValue()).isNotNull().assertInstanceOf(String.class);
        assertThat(body.getValues().get(1).getPublicKey()).isNotNull().isNotBlank();

        assertThat(body.getValues().get(1).getValue()).isNotNull().assertInstanceOf(String.class);

        assertThat(body.getValues().get(0).getPublicKey()).isNotEqualTo(body.getValues().get(1).getPublicKey());

```

```

        assertThat(attributeDB.exist(body.getId())).isTrue();
    }

```

```

@Test
public void createAttribute_fails_onUnauthorized() {
    AttributeCreationRequest attributeCreationRequest = new
AttributeCreationRequest();
    attributeCreationRequest.setName("role");
    attributeCreationRequest.setType(AttributeType.STRING);
    attributeCreationRequest.setValues(Lists.newArrayList("student", "professor"));

    ResponseEntity<PublicAttributeResponse> exchange = sslRestTemplate
        .exchange("/attributes", HttpMethod.POST, new
HttpEntity<>(attributeCreationRequest),
            PublicAttributeResponse.class);

    assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.UNAUTH
ORIZED);
}

```

```

@Test
public void createAttribute_fails_forInvalidName() {

```

```

        AttributeCreationRequest attributeCreationRequest = new
AttributeCreationRequest();

        attributeCreationRequest.setName("asd.a");
        attributeCreationRequest.setType(AttributeType.STRING);
        attributeCreationRequest.setValues(Lists.newArrayList("student", "professor"));

        ResponseEntity<PublicAttributeResponse> exchange = sslRestTemplate
                .exchange("/attributes", HttpMethod.POST, new
HttpEntity<>(attributeCreationRequest, basicAuth()),
                PublicAttributeResponse.class);

        assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.BAD_RE
QUEST);
    }

    @Test
    public void createAttribute_fails_forInvalidValue() {
        AttributeCreationRequest attributeCreationRequest = new
AttributeCreationRequest();

        attributeCreationRequest.setName("asd");
        attributeCreationRequest.setType(AttributeType.STRING);
        attributeCreationRequest.setValues(Lists.newArrayList("student:asd",
"professor:asd"));

        ResponseEntity<PublicAttributeResponse> exchange = sslRestTemplate
                .exchange("/attributes", HttpMethod.POST, new
HttpEntity<>(attributeCreationRequest, basicAuth()),
                PublicAttributeResponse.class);

        assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.BAD_RE

```

```
QUEST);
```

```
}
```

```
@Test
```

```
public void getAllAttributes() {
```

```
    ResponseEntity<List<PublicAttributeResponse>> responseEntity =  
    sslRestTemplate.exchange("/attributes",
```

```
        HttpMethod.GET, new HttpEntity<>(basicAuth()), new  
    ParameterizedTypeReference<List<PublicAttributeResponse>>() {});
```

```
    assertThat(responseEntity.getStatusCode()).isEqualToComparingTo(HttpStatus.OK);
```

```
    assertThat(responseEntity.getBody()).hasSize(1);
```

```
}
```

```
@Test
```

```
public void getAttribute() {
```

```
    ResponseEntity<PublicAttributeResponse> responseEntity = sslRestTemplate  
        .exchange(String.format("/attributes/%s", attribute.getId()),  
        HttpMethod.GET, new HttpEntity<>(basicAuth()),  
        PublicAttributeResponse.class);
```

```
    assertThat(responseEntity.getStatusCode()).isEqualToComparingTo(HttpStatus.OK);
```

```
    assertThat(responseEntity.getBody()).isNotNull();
```

```
}
```

```
}
```

UserRestTest.java

```
package de.tuberlin.tfdacmacs.attributeauthority.user;

import com.google.common.collect.Lists;

import com.google.common.collect.Sets; import

de.tuberlin.tfdacmacs.RestTestSuite;import

de.tuberlin.tfdacmacs.attributeauthority.attribute.data.dto.AttributeCreationRequest;
import de.tuberlin.tfdacmacs.attributeauthority.authority.data.TrustedAuthority;
import de.tuberlin.tfdacmacs.attributeauthority.certificate.data.Certificate;
import de.tuberlin.tfdacmacs.attributeauthority.user.data.User;
import de.tuberlin.tfdacmacs.attributeauthority.user.data.UserAttributeKey;
import de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.AttributeValueRequest;
import de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.AttributeValueResponse;
import de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.CreateUserRequest;
import de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.UserResponse;
import de.tuberlin.tfdacmacs.crypto.pairing.data.keys.UserAttributeValueKey;
import de.tuberlin.tfdacmacs.crypto.rsa.StringAsymmetricCryptEngine;
import de.tuberlin.tfdacmacs.crypto.rsa.StringSymmetricCryptEngine;
import de.tuberlin.tfdacmacs.crypto.rsa.converter.KeyConverter;
import de.tuberlin.tfdacmacs.lib.attributes.data.AttributeType;
import de.tuberlin.tfdacmacs.lib.attributes.data.dto.AttributeValueCreationRequest;
import de.tuberlin.tfdacmacs.lib.attributes.data.dto.PublicAttributeResponse;
import de.tuberlin.tfdacmacs.lib.certificate.data.dto.CertificateResponse;
import de.tuberlin.tfdacmacs.lib.user.data.DeviceState;
import de.tuberlin.tfdacmacs.lib.user.data.dto.AttributeValueUpdateKeyDTO;
import de.tuberlin.tfdacmacs.lib.user.data.dto.DeviceResponse;
import de.tuberlin.tfdacmacs.lib.user.data.dto.DeviceUpdateRequest;
import de.tuberlin.tfdacmacs.lib.user.data.dto.EncryptedAttributeValueKeyDTO;
import org.bouncycastle.cert.CertIOException;
import org.bouncycastle.operator.OperatorCreationException;
import org.bouncycastle.util.encoders.Base64;
```

```

import org.junit.Before;
import org.junit.Test;
import org.mockito.ArgumentCaptor;
import org.springframework.http.HttpEntity;
import org.springframework.http.HttpMethod;
import org.springframework.http.HttpStatus;

import org.springframework.http.ResponseEntity;
import javax.crypto.BadPaddingException;
import javax.crypto.IllegalBlockSizeException;
import java.io.IOException;
import java.security.*;
import java.security.cert.CertificateException;
import java.security.cert.X509Certificate;
import java.util.HashSet;
import java.util.Set;
import java.util.UUID;

import static org.assertj.core.api.Java6Assertions.assertThat;
import static org.mockito.ArgumentMatchers.any;
import static org.mockito.ArgumentMatchers.eq;
import static org.mockito.Mockito.*;

public class UserRestTest extends RestTestSuite {

    private String attributId;
    private String email;
    private final StringAsymmetricCryptEngine asymCryptEngine = new
StringAsymmetricCryptEngine();
    private final StringSymmetricCryptEngine symCryptEngine = new
StringSymmetricCryptEngine();
    private final KeyPair userKeyPair = asymCryptEngine.generateKeyPair();
    private CertificateResponse userCertificateResponse;
    @Before
    public void setup()
        throws OperatorCreationException, CertificateException,
NoSuchAlgorithmException, NoSuchProviderException,

```

```

        IOException {
        AttributeCreationRequest attributeCreationRequest = new
AttributeCreationRequest();

        attributeCreationRequest.setName("role");
        attributeCreationRequest.setType(AttributeType.STRING);
        attributeCreationRequest.setValues(Lists.newArrayList("student"));
        ResponseEntity<PublicAttributeResponse> exchange = sslRestTemplate
            .exchange("/attributes", HttpMethod.POST, new
HttpEntity<>(attributeCreationRequest, basicAuth()),
                PublicAttributeResponse.class);
        assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.CREATED);
        this.attributeId = exchange.getBody().getId();
        this.email = "test@tu-berlin.de";
        X509Certificate x509Certificate = certificateTestFactory.createEntityCertificate(
            caKeyPair, rootCertificate, email, userKeyPair
        );
        userCertificateResponse = new CertificateResponse(
            certificateUtils.fingerprint(x509Certificate),
            KeyConverter.from(x509Certificate).toBase64());
        doReturn(userCertificateResponse).when(caClient).getCertificate(userCertificateRes
ponse.getId());
        de.tuberlin.tfdacmacs.lib.user.data.dto.UserResponse userResponse = new
de.tuberlin.tfdacmacs.lib.user.data.dto.UserResponse(
            email,
            attributeAuthorityConfig.getId(),
            null,
            null,
            Sets.newHashSet

```

```

new DeviceResponse(userCertificateResponse.getId(),
DeviceState.WAITING_FOR_APPROVAL, null, Sets.newHashSet())
    )
);
doReturn(userResponse).when(caClient).getUser(email);

doReturn(
    new DeviceResponse(
        userCertificateResponse.getId(),
        DeviceState.ACTIVE,
        "somekey",
        Sets.newHashSet()
    )
).when(caClient).updateDevice(
    eq(email),
    eq(userCertificateResponse.getId()),
    any(DeviceUpdateRequest.class)
);
}

@Test
public void createUser_passes_onExistingAttributeValue() {
    CreateUserRequest createUserRequest = new CreateUserRequest(
        email,
        Sets.newHashSet(
            new AttributeValueRequest(
                attributeId,
                Sets.newHashSet("student"))));
    ResponseEntity<UserResponse> exchange = sslRestTemplate
        .exchange("/users", HttpMethod.POST, new
HttpEntity<>(createUserRequest, basicAuth()), UserResponse.class);

```

```
assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.CREATED);
```

```
    UserResponse body = exchange.getBody();
    assertThat(body).isNotNull();
    assertThat(body.getId()).isEqualTo(email);
    assertThat(body.getAttributes()).hasSize(1);
    AttributeValueResponse attributeValueResponse =
body.getAttributes().stream().findFirst().get();
    assertThat(attributeValueResponse).isNotNull();
    assertThat(attributeValueResponse.getAttributeId()).isEqualTo(attributeId);

    assertThat(attributeValueResponse.getValue()).assertInstanceOf(String.class).isEqualTo(
"student");
    assertThat(attributeValueResponse.getKey()).isNotBlank();
}
```

```
@Test
```

```
public void createUser_passes_nonNonExistingAttributeValue() {
    CreateUserRequest createUserRequest = new CreateUserRequest(
        email,
        Sets.newHashSet(
            new AttributeValueRequest(
                attributeId,
                Sets.newHashSet("professor"))));
    ResponseEntity<UserResponse> exchange = sslRestTemplate
        .exchange("/users", HttpMethod.POST, new
HttpEntity<>(createUserRequest, basicAuth()), UserResponse.class);
```

```
assertThat(exchange.getStatusCode()).isEqualToByComparingTo(HttpStatus.CREATED);
```

```
    UserResponse body = exchange.getBody();
```

```

        assertThat(body).isNotNull();
        assertThat(body.getId()).isEqualTo(email);
        assertThat(body.getAttributes()).hasSize(1);
        AttributeValueResponse attributeValueResponse =
body.getAttributes().stream().findFirst().get();
        assertThat(attributeValueResponse).isNotNull();
        assertThat(attributeValueResponse.getAttributeId()).isEqualTo(attributeld);

assertThat(attributeValueResponse.getValue()).assertInstanceOf(String.class).isEqualTo(
"professor");
        assertThat(attributeValueResponse.getKey()).isNotBlank();
    }

```

```

@Test
public void getAttributeKeys() {
    // setup
    createUser_passes_nonNonExistingAttributeValue();

    HttpEntity<Object> httpEntity = new HttpEntity<>(basicAuth());
    ResponseEntity<UserResponse> exchange = sslRestTemplate
        .exchange("/users/" + email, HttpMethod.GET, httpEntity,
UserResponse.class);

```

```

        assertThat(exchange.getStatusCode()).isEqualByComparingTo(HttpStatus.OK);
        UserResponse body = exchange.getBody();
        assertThat(body.getId()).isEqualTo(email);
        assertThat(body.getAttributes()).hasSize(1);
        AttributeValueResponse attributeValueResponse =
body.getAttributes().stream().findFirst().get();
        assertThat(attributeValueResponse).isNotNull();
        assertThat(attributeValueResponse.getAttributeId()).isEqualTo(attributeld);

assertThat(attributeValueResponse.getValue()).assertInstanceOf(String.class).isEqualTo(
"professor");

```

```

        assertThat(attributeValueResponse.getKey()).isNotBlank();

        assertThat(body.getDevices()).isEmpty();
        assertThat(body.getUnapprovedDevices()).hasSize(1);

        assertThat(body.getUnapprovedDevices().get(0).getId()).isEqualTo(userCertificateResponse.getId());
        System.out.println(body.getUnapprovedDevices().get(0).getId());

        assertThat(body.getUnapprovedDevices().get(0).getCertificate()).isEqualTo(userCertificateResponse.getCertificate());
    }

    @Test
    public void deleteAttributeValueFromUser_passes() {
        String attributeValueId = attributeId + ":student";
        String otherUserId = UUID.randomUUID().toString();
        User otherUser = new User(otherUserId);
        otherUser.setAttributes(
            Sets.newHashSet(new UserAttributeKey(
                attributeId,
                "student",
                new
                UserAttributeValueKey(globalPublicParameterProvider.getGlobalPublicParameter().get(1).newRandomElement(), 0L)
            ))
        );

        doReturn(null).when(caClient).updateAttributeValueUpdateKey(eq(otherUserId),
            any(AttributeValueUpdateKeyDTO.class));

        userDB.insert(otherUser);
        createUser_passes_onExistingAttributeValue();
    }

```

```

    ResponseEntity<UserResponse> exchange = sslRestTemplate.exchange(
        String.format("/users/%s/attributes/%s/values/%s", email, attributeId,
"student"),
        HttpMethod.DELETE,
        new HttpEntity<>(basicAuth()),
        UserResponse.class
    );

    assertThat(exchange.getStatusCode()).isEqualToComparingTo(HttpStatus.OK);
    UserResponse body = exchange.getBody();
    assertThat(body.getAttributes()).hasSize(0);

    ArgumentCaptor<AttributeValueUpdateKeyDTO> userArgumentCaptor =
ArgumentCaptor.forClass(AttributeValueUpdateKeyDTO.class);
    verify(caClient, times(1)).updateAttributeValueUpdateKey(eq(otherUserId),
userArgumentCaptor.capture());

    AttributeValueUpdateKeyDTO userValue = userArgumentCaptor.getValue();
    assertThat(userValue.getTargetVersion()).isEqualTo(0L);
    assertThat(userValue.getUpdateVersion()).isEqualTo(1L);
    assertThat(userValue.getAttributeValueId()).isEqualTo(attributeValueId);
    assertThat(userValue.getUpdateKey()).isNotBlank();
    ArgumentCaptor<AttributeValueCreationRequest> attributeArgumentCaptor =
ArgumentCaptor.forClass(AttributeValueCreationRequest.class);
    verify(caClient, times(1)).createAttributeValue(eq(attributeId),
attributeArgumentCaptor.capture());

    AttributeValueCreationRequest attributeValue =
attributeArgumentCaptor.getValue();
    assertThat(attributeValue.getVersion()).isEqualTo(1L);
    assertThat(attributeValue.getPublicKey()).isNotBlank();
    assertThat(attributeValue.getSignature()).isNotBlank();

```

```

        assertThat(attributeValue.getValue()).isEqualTo("student");
    }

    @Test
    public void approveUser_passes() throws BadPaddingException,
        InvalidKeyException, IllegalBlockSizeException {
        getAttributeKeys();

        ResponseEntity<UserResponse> exchange = sslRestTemplate.exchange(
            String.format("/users/%s/approve/%s", email,
                userCertificateResponse.getId()),
            HttpMethod.PUT,
            new HttpEntity<>(basicAuth()),
            UserResponse.class
        );

        assertThat(exchange.getStatusCode()).isEqualToComparingTo(HttpStatus.OK);

        User user = userDB.findEntity(email).get();
        assertThat(user.getDevices()).hasSize(1);
        assertThat(user.getUnapprovedDevices()).isEmpty();

        ArgumentCaptor<DeviceUpdateRequest> argumentCaptor =
            ArgumentCaptor.forClass(DeviceUpdateRequest.class);
        verify(caClient).updateDevice(
            eq(email),
            eq(userCertificateResponse.getId()),
            argumentCaptor.capture()
        );

        DeviceUpdateRequest deviceUpdateRequest = argumentCaptor.getValue();

        assertThat(deviceUpdateRequest.getDeviceState()).isEqualToComparingTo(Device
            State.ACTIVE);
    }

```

```

assertThat(deviceUpdateRequest.getEncryptedAttributeValueKeys()).hasSize(1);
    EncryptedAttributeValueKeyDTO encryptedAttributeValueKeyDTO =
extractFromSet(deviceUpdateRequest
    .getEncryptedAttributeValueKeys());

assertThat(encryptedAttributeValueKeyDTO.getAttributeValueId()).isEqualTo(extract
FromSet(user.getAttributes()).getAttributeValueId());

    String encryptedKey = deviceUpdateRequest.getEncryptedKey();
    Key key =
symCryptEngine.createKeyFromBytes(asymCryptEngine.decryptRaw(encryptedKey,
userKeyPair.getPrivate()));
    byte[] rawElement =
symCryptEngine.decryptRaw(Base64.decode(encryptedAttributeValueKeyDTO.getE
ncryptedKey()), key);
    byte[] originalBytes =
extractFromSet(user.getAttributes()).getKey().getKey().toBytes();

    assertSameElements(rawElement, originalBytes);
}

@Test
public void requestDeviceAsUser_passes()
    throws CertificateException, CertIOException, OperatorCreationException {
    String deviceId = UUID.randomUUID().toString();
    String email = "someRnadam@email.de";
    User user = new User(email);
    user.setDevices(
        Sets.newHashSet(new Certificate(deviceId,
certificateTestFactory.createRootCertificate()))
    );

    userDB.insert(user);

```

```

doReturn(new de.tuberlin.tfdacmacs.lib.user.data.dto.UserResponse(
    email,
    UUID.randomUUID().toString(),
    null,
    null,
    new HashSet<>()
)).when(caClient).getUser(email);

ResponseEntity<de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse> exchange =
    mutualAuthRestTemplate.exchange(
        String.format("/users/%s/devices/%s", email, deviceId),
        HttpMethod.GET,
        HttpEntity.EMPTY,

de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse.class
    );

    assertThat(exchange.getStatusCode()).isEqualToComparingTo(HttpStatus.OK);
    de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse body =
exchange.getBody();
    assertThat(body.getId()).isEqualTo(deviceId);
}

@Test
public void requestApprovedDevice() throws CertificateException,
CertIOException, OperatorCreationException {
    mutualAuthenticationRestTemplate(RestTestSuite.AUTHORITY_KEYSTORE);

    TrustedAuthority trustedAuthority = new TrustedAuthority(
        "aa.tu-berlin.de",
        UUID.randomUUID().toString()

```

```

);

trustedAuthorityDB.insert(trustedAuthority);

String deviceId = UUID.randomUUID().toString();
String email = "someRandom@email.de";
User user = new User(email);
user.setDevices(
    Sets.newHashSet(new Certificate(deviceId,
certificateTestFactory.createRootCertificate()))
);

userDB.insert(user);

doReturn(new de.tuberlin.tfdacmacs.lib.user.data.dto.UserResponse(
    email,
    UUID.randomUUID().toString(),
    null,
    null,
    new HashSet<>()
)).when(caClient).getUser(email);

ResponseEntity<de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse> exchange =
    mutualAuthRestTemplate.exchange(
        String.format("/users/%s/devices/%s", email, deviceId),
        HttpMethod.GET,
        HttpEntity.EMPTY,

de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse.class
    );

assertThat(exchange.getStatusCode()).isEqualToComparingTo(HttpStatus.OK);

```

```

        de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse body =
exchange.getBody();
        assertThat(body.getId()).isEqualTo(deviceId);
    }

    @Test
    public void requestUnapprovedDevice() throws CertificateException,
CertIOException, OperatorCreationException {
        mutualAuthenticationRestTemplate(RestTestSuite.AUTHORITY_KEYSTORE);

        TrustedAuthority trustedAuthority = new TrustedAuthority(
            "aa.tu-berlin.de",
            UUID.randomUUID().toString()
        );

        trustedAuthorityDB.insert(trustedAuthority);

        String deviceId = UUID.randomUUID().toString();
        String email = "someRandom@email.de";

        User user = new User(email);
        user.setUnapprovedDevices(
            Sets.newHashSet(new Certificate(deviceId,
certificateTestFactory.createRootCertificate()))
        );

        userDB.insert(user);

        doReturn(new de.tuberlin.tfdacmacs.lib.user.data.dto.UserResponse(
            email,
            UUID.randomUUID().toString(),
            null,
            null,
            new HashSet<>()

```

```

   )).when(caClient).getUser(email);

ResponseEntity<de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse> exchange =
    mutualAuthRestTemplate.exchange(
        String.format("/users/%s/devices/%s", email, deviceId),
        HttpMethod.GET,
        HttpEntity.EMPTY,

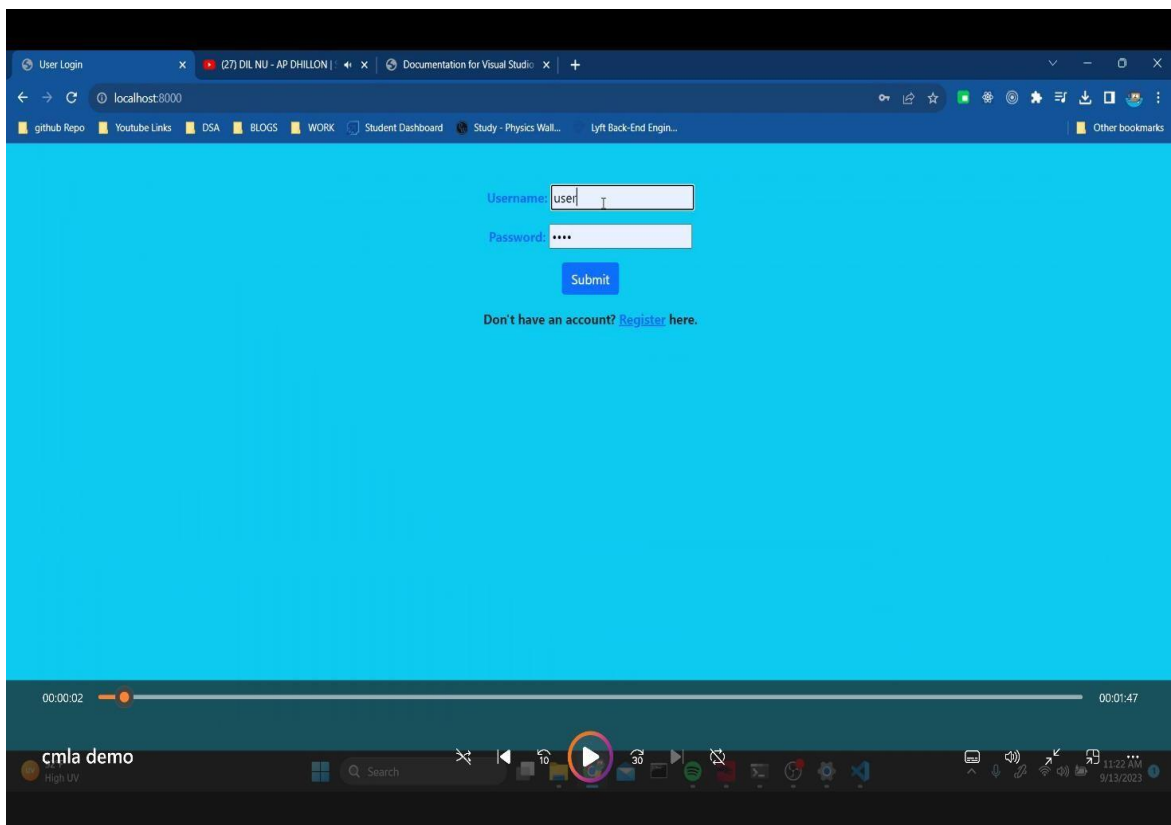
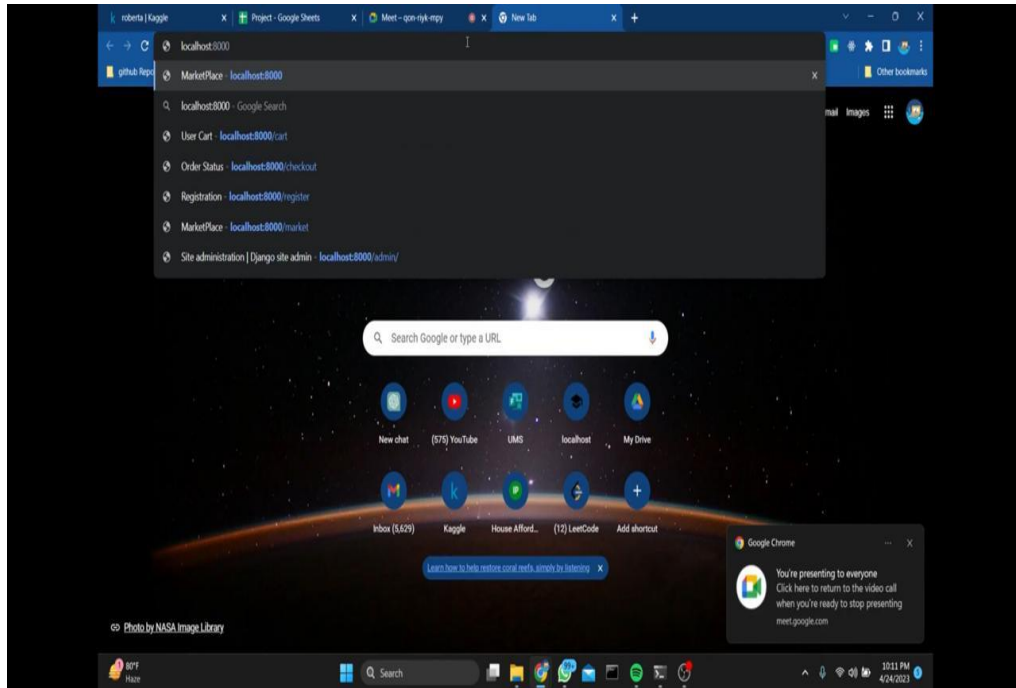
de.tuberlin.tfdacmacs.attributeauthority.user.data.dto.DeviceResponse.class
    );

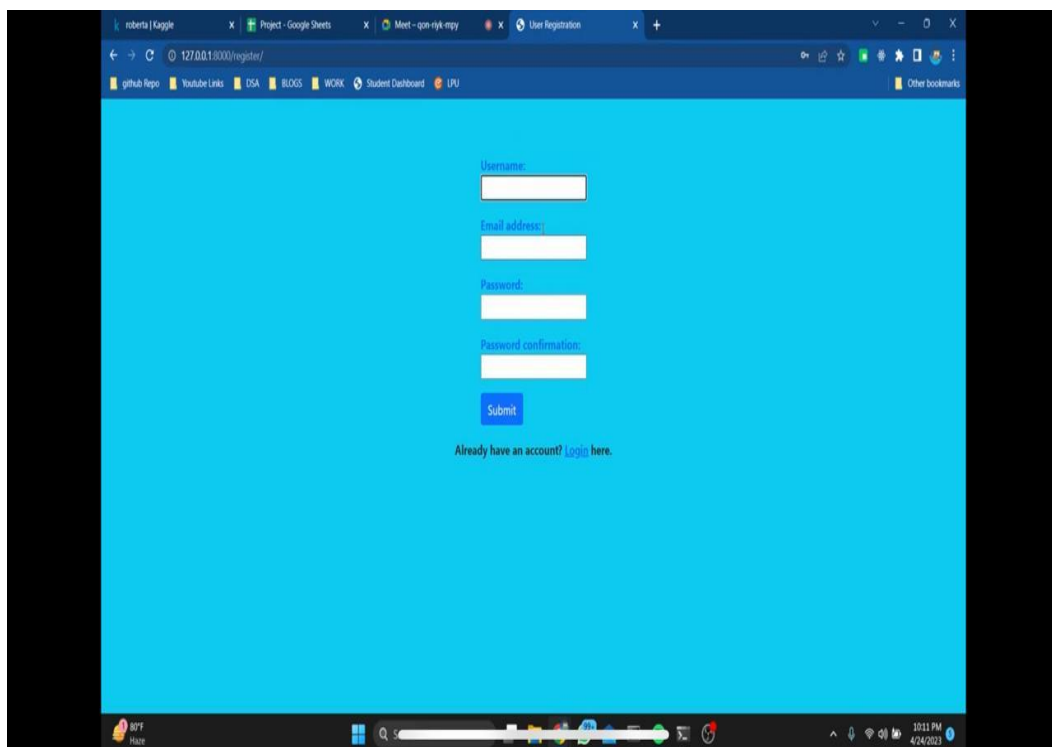
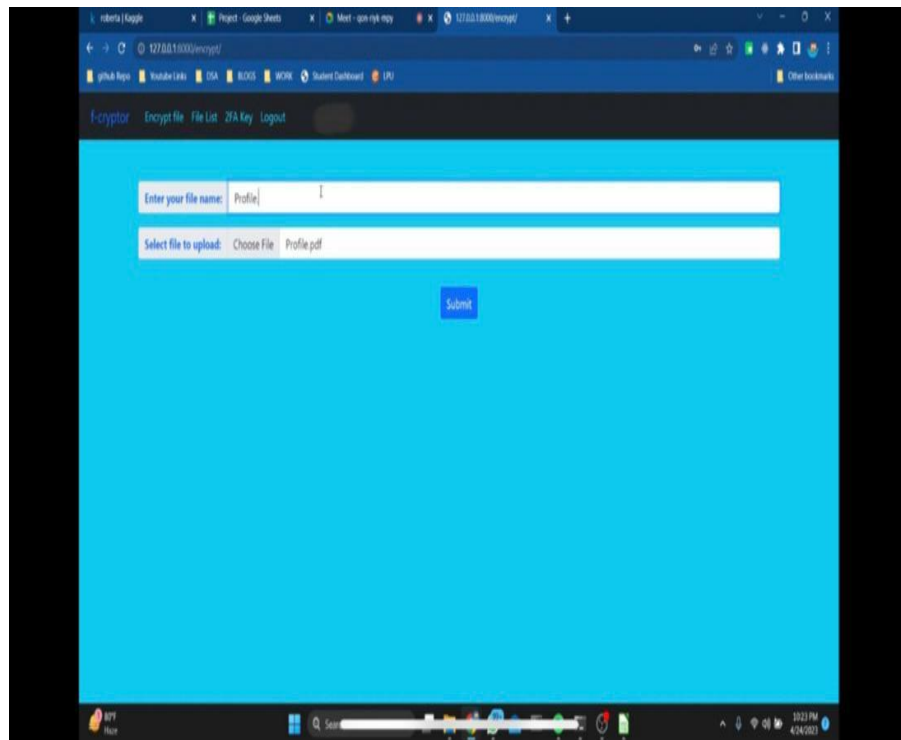
assertThat(exchange.getStatusCode()).isEqualToComparingTo(HttpStatus.NOT_FOUND);
    }

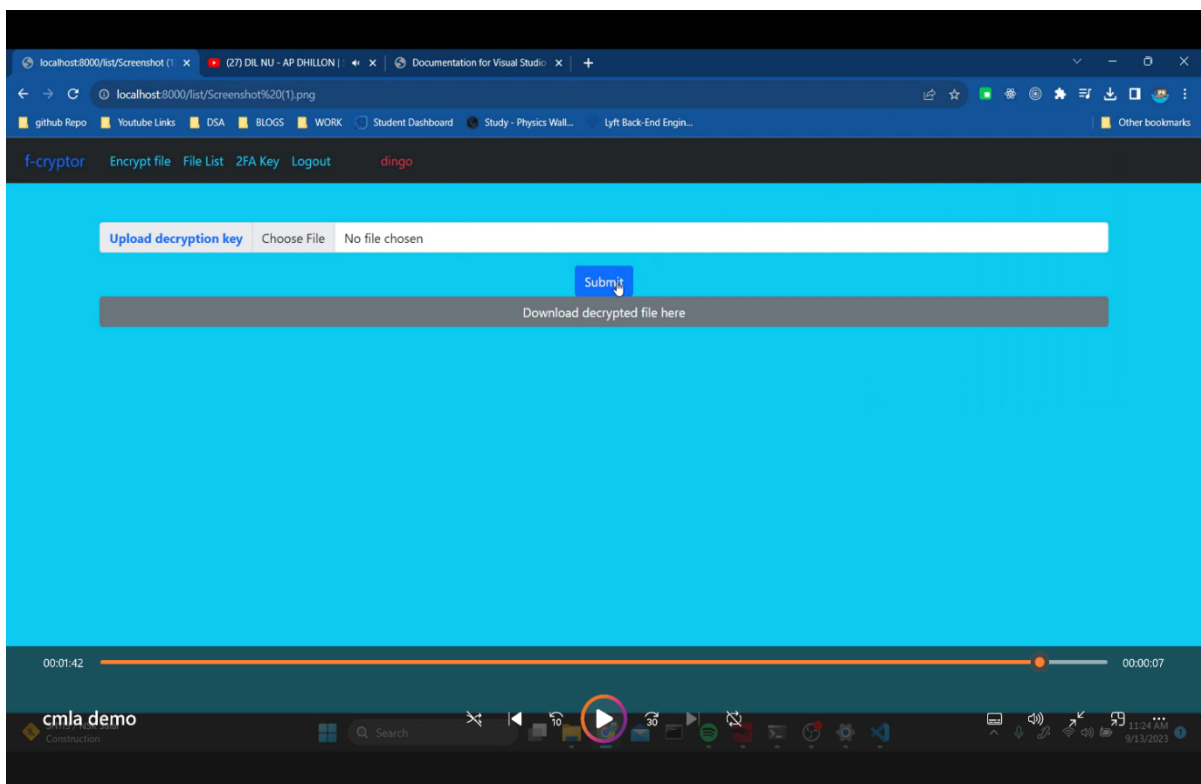
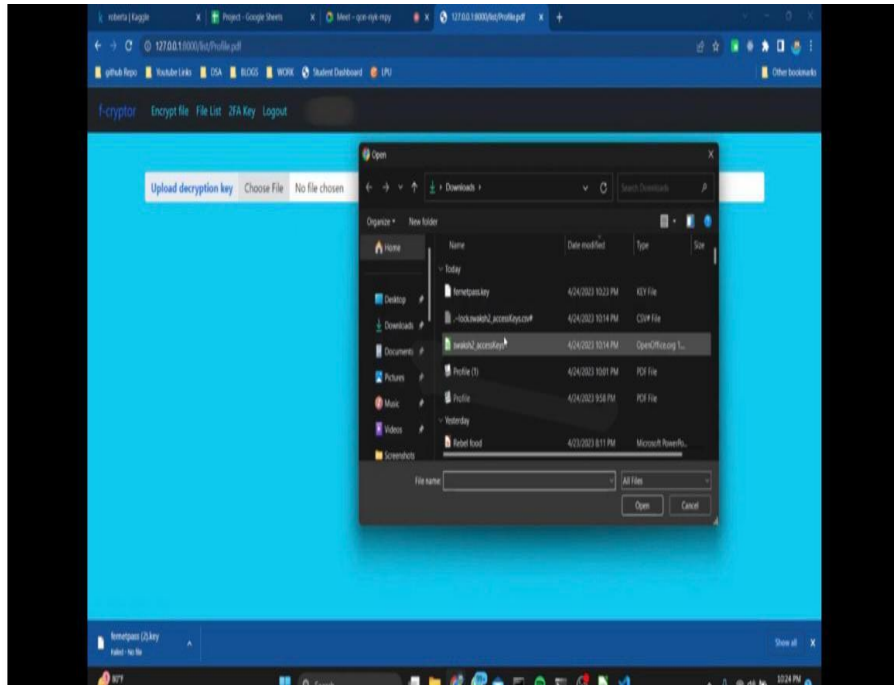
    private <T> T extractFromSet(Set<T> set) {
        return set.stream().findFirst().get();
    }
}

```

B.SCREENSHOTS:







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