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Data Sharing and Access Using Aggregate Key Concept

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Abstract

Cloud Storage is a capacity of information online in the cloud, which is available from different and associated assets. Distributed storage can provide high availability and consistent quality, reliable assurance, debacle free restoration, and reduced expense. Distributed storage has imperative usefulness, i.e., safely, proficiently, adaptably offering information to others. Data privacy is essential in the cloud to ensure that the user's identity is not leaked to unauthorized persons. Using the cloud, anyone can share and store the data, as much as they want. To share the data in a secure way, cryptography is very useful. By using different encryption techniques, a user can store data in the cloud. Encryption and decryption keys are created for unique data that the user provides. Only a particular set of decryption keys are shared so that the data can be decrypted. A public–key encryption system which is called a Key-Aggregate cryptosystem (KAC) is presented. This system produces constant size ciphertexts. Any arrangement of secret keys can be aggregated and make them into a single key, which has the same power of the keys that are being used. This total key can then be sent to the others for decoding of a ciphertext set and remaining encoded documents outside the set stays private. The project presented in this paper is an implementation of the proposed system.

Acknowledgement

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Chapter I: Introduction

Introduction

Cloud computing is the way of providing the resources to a user, as a service over the network. Nowadays, cloud computing is in high demand in the market because data can be made available to a user from any place at any point in time. Distributed storage is a method, which implements cloud computing, where data from a single physical machine is spread across different virtual machines (VM) on the same machine. Due to this distributed storage, the concept of data outsourcing is in high in demand. But data is of the most importance to the cloud service providers, and it must be shared securely so that it does not fall into the wrong hands.

The Internet provides many services to users. Cloud computing is one of the vital services provided on the Internet. It provides an on-demand technology by providing a resource as a service or platform as a service or infrastructure as a service to the user. Using cloud computing a user can access the data and store the data in the cloud storage from anywhere in the world. This is the main advantage of cloud usage. Security is one of the primary concerns of cloud storage in the present scenario. Security is the primary intention to prevent unauthorized users to access the data. The users can store the data in the cloud and access it whenever needed, by storing the data in remote cloud servers. But data confidentiality might be an issue while storing the data on the third-party servers. To avoid this problem, data must be encrypted before it is outsourced to the cloud. Usually, before storing the data in the cloud, the data owner uses some encryption technique to store the data on the cloud servers. Though it provides data confidentiality, it may not offer dynamic data modification and high security (Mahalle & Pawade, 2015). While transferring the data by the data owner to the cloud servers, the intruder may get the data, or he may access and decrypt the data by cryptographic keys (Mahalle & Pawade, 2015). The intruder may modify the data and again store the data in cloud servers. The data owners and the end users may not identify the breach. The data may resemble the original data. The users may think that the data is coming from the data owners and the data owners may think they are sharing the valid data. This may affect the data integrity, data originality, security and data origin point of authentication. Here we can use different encryption schemas like public-key encryption also known as asymmetric key encryption or symmetric key encryption. Using symmetric key encryption, when the data wants to be received by the user, they must provide their private key, which is not desirable in some scenarios. While coming to the public key encryption, there is a difference in the keys being used. It uses two pairs of keys: a public key and the private key. This provides authentication, as the public key used verifies the owner of the paired private key, thereby allowing only the intended owner to decrypt the data. The public key is open, and the private key is only known to the data owner.

In today's era, anyone can apply for free accounts for email, photo storage, file sharing, remote access, etc., and can get a storage space of more than 50GB (this can be increased to more than 1TB by paying some extra money). Because of the advancement in the wireless networks, this stored information can be accessed through a mobile device, from anywhere in the world. Though the cloud storage makes the data more readily available to the user, there are security constraints, which must be implemented before sharing the data so that only the legitimate user can use the data. Even though the data is readily available across different VM's, there might be a problem as data in a target VM could be stolen by instantiating another VM copy with the target one (More & Singh, 2015). On behalf of the data owner, there are a series of cryptographic schemes that allow a third-party auditor to check for a files availability without giving anything about the data, or without compromising the data owner’s privacy (More & Singh, 2015). The cloud server can reduce the responsibility of customers from the overwhelming weight of capacity administration and support. The most prominent contrast of distributed storage from customary in-house stockpiling of data is that the information is exchanged using the Internet and put away in an unverifiable area, not under control of the customers by any stretch of the imagination.

Considering data security, an ordinary way to deal with the objective without question is to rely on upon the server to approve the passageway control after affirmation, which suggests any unanticipated advantage increasing speed will reveal all data. In a shared residency disseminated figuring environment, things end up being significantly more severe. Information from different clients can be encouraged on segregated virtual machines (VMs) be that as it may, harp on a single physical device. Because of this, the cloud users may not have a firm belief that the cloud service providers are providing the confidentiality. For this reason, the cloud users may encrypt their data before storing it in the cloud. This can be explained using a simple example. Using Figure1.1, let us assume there are two users: Alice and Bob. Alice has an account in Dropbox.com. Alice wants to store her photographs in Dropbox.com. But she doesn’t trust the security features provided by Dropbox.com. So, she encrypts all her photos and uploads them to the Dropbox (Chu et al., 2014). Bob who is a friend of Alice requests her to send the photographs that he is present in. If Alice sends them directly to Bob, then Bob cannot view them because they are encrypted with a key. Here there is a constraint as to how the decryption rights should be provided to Bob. Alice can encrypt all the files with one single key and send the key to Bob or encrypt each file and send Bob the respective keys. The first method is not applicable because all the other data can be sent to Bob. In the second method, the number of keys may be more for the number of photos. This becomes complex and requires key storage and sending of all of these keys may not be secure as it requires a secure channel to be sent. So here we can use the Key Aggregation Concept where all the keys are aggregated into one single key of constant size and can be sent through email or any other means securely. This allows Bob to view only his photos, and not Alice's.

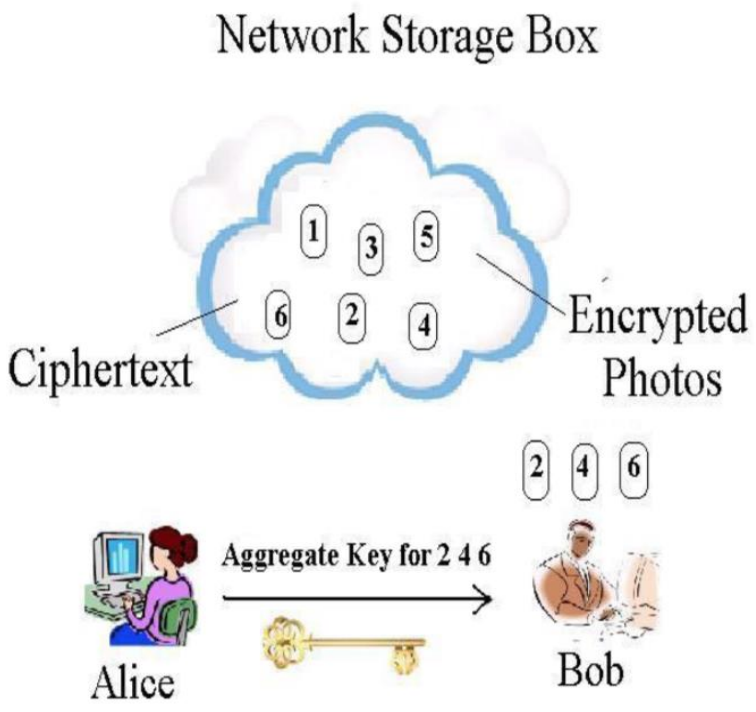


Figure 1. Communication Between Two Users (Chu, Chow, Tzeng, Zhou, & Deng, 2014)

Problem Statement

In the present world, sharing the data between the users without any data leakage becomes a big challenge. Data sharing services are one of the essential services provided in cloud computing. Data in the cloud is of higher importance and needs to be protected from unauthorized access. To avoid any data leakage, usually, the data is stored in an encrypted format. However, the problem comes while sharing the encrypted data and providing the decryption rights to the users. An efficient encryption solution is necessary that provides decryption rights to the users for multiple sets of ciphertext classes using a single key that comprises the power of several individual keys that are combined.

Nature and Significance of the Problem

Data privacy is a critical concern when accounting for a user's requirement. As the decryption rights should be given only for the requested data, the key aggregate system is used.

Objective of the Study

The main aim of the study is to implement how an aggregate key can be used for data sharing and accessing between two or more users. To study the emergence of developing public and private data security in cloud computing. To analyze the architecture, methodology and system design and present the output results to users.

Limitations of the Study

The research has some limitations as follows:

1. The research is limited in analyzing the cloud computing in networking.
2. The study mainly focuses on the implementation of the private and public key using services in cloud technology.
3. The data collection for the research and practical programming may not be accurate.

Summary

In this section, an overview regarding the cloud computing and distributed storage are presented. Also, how data outsourcing plays an important role in the present situation and how the user can store the data in the cloud is explained. Furthermore, the necessity of encrypting the data and how the data is encrypted and the keys for decryption should be shared between the users is discussed. Also, the concept of a key-aggregate cryptosystem is introduced.

Chapter II: Background and Review of Literature

Introduction

In this section, the fundamental concepts of cloud computing, the characteristics and deployment models related to cloud, background related to the problem and various literature reviews of authors are discussed, and the proposed system is presented.

Background Related to the Problem

In the previous section, an example regarding the data sharing between the two users is given. The encrypted data is stored in the cloud, but the problem comes with how to share the keys securely so that all the unnecessary information should not be exposed to the user. If the sender encrypts all the information using a single key and sends it to the receiver, he is exposing all the important information to the receiver, which is a breach of privacy. Also, if he sends each key for the encrypted data, then he needs to send decryption keys for each encrypted data. This is acceptable when the number of keys is small, but for thousands of keys, separate storage needs to be maintained, and these must be sent through a secure channel, where there might be a chance for data leakage. So, to overcome this problem, a key aggregate cryptosystem concept is developed where a single aggregate key of constant size is formed from the set of keys and sent to the receiver (Chu et al., 2014). This also uses the concept of public key encryption, using this makes the decryption is difficult or nearly impossible without the key.

Literature Related to Methodology

In the present scenario, online data sharing, access, and performance are the preliminary requirements for any organization. The data available is shared across geographical boundaries, and it is available to a multitude of users to perform operations on the data. To do so, the data owner ideally must use different encryption mechanisms before they store the data and provide the decryption power for some of the users while retaining the ability to revoke access for any users at any point in time. The efficient solution would be providing decryption rights to different ciphertexts with the use of a single aggregate key, as proposed by (Chu et al., 2014).

According to Cui, Liu, and Wang (2016), the ability to share encoded information via public storage with different clients can significantly reduce the data disclosures in the cloud. To provide that kind of encryption schemas requires excellent management of keys. However, sharing a unique number of selected documents with a different number of users requires different encryption keys to be used for a various number of documents. This implies, a large number of decryption keys to be passed securely and to be stored properly. Also, to perform a search over the data, a large number of keyword trapdoors must be passed to the cloud storage to get the data. This scenario seems to be impractical with the current cloud capacity accessed by millions of users. To address this problem, Cui et al. (2016) proposed the novel concept of Key Aggregate Searchable Encryption (KASE) and instantiated the idea through a concrete KASE scheme. This KASE schema can be applied to any cloud that supports searchable group data sharing. This implies that a user can share a group of files to a group of users and the users can perform the search over the files and retrieve the files they are authorized to access. Efficient key management can be done as follows, the data owner should provide only the aggregate key to the user to share a group of files, and the user needs to provide a single aggregate trapdoor to perform the search over the cloud to get the data.

Recently, Patranabis, Shrivastava, and Mukhopadhyay (2017) proposed Chosen Plaintext Attacks (CPA) and Chosen Cipher Attacks (CCA) secure KAC constructions that can be implemented in cloud environments, which uses elliptical curves, and is a first of its kind. This extended broadcast key aggregate cryptosystem is based on the fundamental KAC proposed by (Chu et al., 2014) and the broadcast encryption proposed by Benaloh (2009). In the broadcast scenario, the single ciphertext is transmitted to different users, and the respective users can decrypt using their allocated private key. While in KAC a single aggregate key will be distributed to multiple users and they can be used to decode the ciphertexts encrypted with reference to different classes. In the broadcast scenario, the focus is on shorter ciphertexts with individual decryption keys and with KAC the focus is on shorter ciphertexts with individual lower head aggregation key (Patranabis et al., 2017). They also described how the standalone KAC scheme could be efficiently combined with broadcast encryption to cater to m data users and M data owners while reducing the secure channel requirement from O(mM). In the standalone case O(m+M) (Patranabis et al., 2017). They proposed a CCA collusion resistant system and the addition and revocation of new users can be easily implemented. Also, the addition of new users is easily handled in the proposed extended KAC construction by generating a new key for each newly added user in the system and ensuring that all future aggregate key broadcast operations consider the access rights of the new users in addition to the existing ones (Patranabis et al., 2017).

The key aggregate cryptosystem is one of the most efficient, scalable and secured techniques that can be implemented in cloud storage. A key aggregate cryptosystem is a public key cryptosystem in which all of the sets of secret keys are aggregated into a single key, and the aggregated key has the power of all the secret keys. Wang and Zhou (2016) proposed a leakage resilient key aggregate cryptosystem with auxiliary input based on the KAC scheme which was proposed by Chu et al. (2014). This method is used to overcome the side channel attacks. Using this attack, the attacker may be able to access a part of the information of the secret key by observing the physical properties like temperature and power usage of a cryptosystem (Wang & Zhou, 2016). To overcome this, they have designed a leakage resistant cryptosystem, even though the attacker may get the leaked bits of the aggregate key, they cannot get the information of the master key. They have used an auxiliary input model which is the best among the other leakage models, which are continuous leakage model and bounded retrieval model. However, this proposed model only protects the master key, and the cost of decryption is high when using this model, which could be an improvement in their future work.

Literature Related to Existing Systems

In this section, the details regarding the existing systems are discussed. There are some public and private cryptographic schemes for online data sharing and some of them concentrate on the key aggregation, although only a few of the systems emphasize on producing constant size keys, to decrypt a random number of encrypted objects (Patranabis, Shrivastava, & Mukhopadhyay, 2015).

Hierarchical encryption. Hierarchical encryption is used to provide access control in cloud storage (Patranabis et al., 2015). This is one of the most prominent methods, which uses a pre-defined hierarchy of secret keys like in a tree structure, where access to the key to any corresponding node provides access to the all of the subtrees consequent to that node. The primary aim of this schema is to reduce the cost for storing the secret keys. Sandhu (1988) proposed the methods that use repeated calculations of a pseudo-random function or block cipher on a fixed secret user to generate symmetric keys in a tree hierarchy. There are few advanced schemes in hierarchical encryption that provide access to acyclic and cyclic graphs. One of the major disadvantages in using a hierarchical encryption scheme is that providing access to one of the branches within a given subtree licenses an increase in the number of secret keys. This increase in the number of keys will in turn expands the size of the shared key. Thus, the hierarchical cryptosystem provides an excellent delegate mechanism when there are files to be shared in a given branch, however its efficiency drops, as the complexity of the key size increases. Using the Figure 2, the hierarchical encryption scheme is explained. The parent node represents the secret, and the child nodes represent the ciphertext classes. The small circles in Figure 2 are the classes which need to be delegated. The rectangle represents the keys to be granted. Every non-leaf node can generate the keys of its child node. Considering an example provided by Kumari and Lakshmi (2014), if a user wants to upload data in the professor category, the child nodes come under the professor class. “Department” and “Classes” are classes under the Rectangle. Using the Figure 2, if Alice wants to share some data in the “Professor” category, the keys need to be only granted for the “Professor” node which will grant and delegate the keys of the descendant nodes, “Department” and “Classes.”

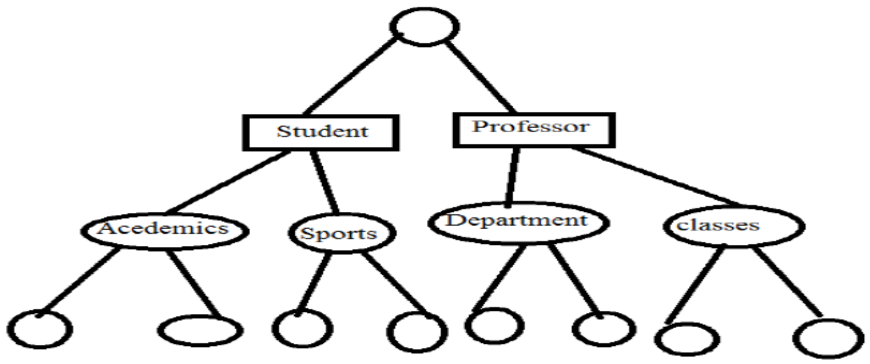


Figure 2. Tree Structure in Hierarchical Encryption (Kumari & Lakshmi, 2014)

Compact key symmetric encryption. In symmetric key setting, compact key encryption was proposed by Benaloh (2009) to solve the problem of quickly transmitting a large number of keys in a broadcast scenario. In this, the basic methodology is to divide the entire cipher-text space into a finite set of classes, thus overcoming the problem of multiclass delegation in hierarchical schemas. According to Patranabis et al. (2015), this method is not always desirable and is practically not applicable for some cloud applications. To overcome this, some other schemas in the symmetric key setting have tried to reduce the key size but the sharing of decryption keys are not aimed at these schemas.

Advantages:

- The size of the ciphertext is constant.
- Easy to construct.
- The size of the decryption key is constant.
- It takes less space to store the ciphertext and keys.

Disadvantages:

- The same key performs the encryption and decryption.
- To encrypt the files, the owner should get the corresponding key.

Compact key identity-based encryption. Identity-based encryption (IBE) is a public key encryption scheme in which the public key corresponds to the identity string related to that user (Bachhav, Chaudhari, Shinde, & Kaloge, 2015). This can be a user's email address or a mobile number. In IBE, each user receives a private key from the Private Key Generator (PKG) based on user's Identity. This PKG holds a master-secret key. In IBE, the content provider uses the public parameter and the user's identity to encrypt the message. The recipient using his private key can decrypt the message. Guo, Mu, and Chen (2007) tried to build IBE using key aggregation scheme. Here the constraint is that all the keys that need to be aggregated come from various “Identity divisions.” While there an exponential number of user identities and thus having many private keys, only a polynomial of them can be aggregated. This leads to an increase in storage cost and transmission of ciphertexts. However, this scenario impractical when it comes to shared cloud storage. In Fuzzy IBE (Sahai & Waters, 2005), a single compact key can be used to decrypt multiple ciphertexts, provided that they should have been encrypted in a close set of identities and this scenario fails to work when arbitrary identities are used.

Advantages:

- This is a public key encryption schema.
- A dependent party that grasps the secret key.
- The secret key is delivered based on identity.
- Decryption key size is constant.

Disadvantages:

- The transmission of cipher-texts and storage is costly.
- The size of cipher-text is not constant.

Attribute-based encryption. Attribute-based encryption scheme allows every user to be identified over a set of attributes (Patranabis & Mukhopadhyay, 2016). Only the user who has access privileges for the corresponding secret key will be able to decrypt the encrypted file stored in the cloud storage. The secret key will be provided via a secure channel to the user, who satisfies the access control policies set by the data owner. The primary disadvantage of this scheme is that, whenever the user access rights are revoked, the cipher-text in the cloud must be re-encrypted. One of the major drawbacks of ABE is collusion resistance.

Advantages:

- ABE uses public key encryption.
- The size of the ciphertext is constant.

Disadvantages:

- The size of the key increases linearly with the increase in the number of attributes.
- The size of the decryption key is not constant.
- It requires more storage to store keys, and it is expensive to maintain keys.

Proxy re-encryption. To provide fine-grain access control and for scalable user revocation in unreliable clouds, proxy re-encryption is used. In this mechanism, the semi-trusted proxy cloud and the data owner shares a secret key in advance. Because of sharing of the secret key, on behalf of the data owner, the proxy cloud is delegated and can be able to re-encrypt the data. Using the public key of the data owner the semi-trusted proxy converts the data into a file and using the secret key of the client the file can be decrypted. In this overall process, the proxy has no knowledge regarding the data being sent. An addition to this technique is that the cloud servers can re-encrypt the data without any external triggers, using the internal clocks. The drawback of proxy re-encryption is that it transfers the responsibility of the key storage to the semi-trusted proxy and it may be vulnerable to collusion attacks. Here, the transformation key of the proxy should be well protected, and every time interaction is required with the proxy regarding the decryption which is undesirable in some of the applications in the cloud. Table 1 shows the comparison of KAC with related schemas, regarding the type of encryption used in each schema, the size of ciphertext and the size of the decryption key produced.

Table 1

Comparison of KAC with Related Schemes (Kate & Potdukhe, 2014)

	Size of Cipher Text	Size of Decryption Key	Type of Encryption
Key assignment schemas	constant	non-constant	symmetric or public key
Symmetric key encryption with compact key	constant	constant	symmetric key
Identity based encryption with compact key	non-constant	constant	public key
Attribute based encryption	constant	non-constant	public key
KAC	constant	constant	public key

Concepts of Cloud Computing

Cloud computing is evolving as the latest trend in various fields related to information technology, academic fields, health and for personal use. In cloud computing the user connects to the "cloud" which appears as a single entity although it resides on multiple servers, where the user can upload, access, share and can modify the data remotely. They are allowed to access multiple services from a shared pool of configurable computing resources. This pay-per-use model in cloud services brings savings to users and offers flexibility and scalability in terms of capacity and performance. Using the distributed storage provided by the cloud service providers (CSP), users can store their data. Although the storage is secure, this allows the CSP to have control over a user's data (Vanitha & Elavarasi, 2014).

Characteristics of cloud. According to NIST, cloud computing has the following main characteristics (Mell & Grance, 2009):

- Measured Service: The cloud is built on the pay-per-use model. Cloud computing can efficiently monitor use, and customers can dynamically access the use of cloud services. The measurement is used to bill the customers on pay as you use model. The resource usage can be monitored, reported and controlled so that there exists transparency between the user and the provider.
- On-demand self-service: Without any human interaction with the CSP, the cloud customer can utilize the resources provided by the CSP. In addition to this, the user can schedule, manage and timely deploy any of the cloud services like computational storage and server time. This helps in the reduction of personnel overhead and the cut in the cost of the offered services.
- Broad Network Access: The cloud services are readily available and are accessed by the users over the network via standardized interfaces that can be deployed quickly not only on the complex devices like personal computers but also on the lightweight devices like smartphones. High level of utilization of resources is provided because of the lowered cost of high-bandwidth of network communication to the cloud provider.
- Location independent resource pooling: The virtualization concept of the cloud allows the CSP to pool multiple resources using a multi-tenant model. This resource pooling helps to share multiple virtual and physical resources to multiple customers and can be dynamically assigned and reassigned on customer demand. In general, the resource provided to the customer satisfies the characteristics of location

independence as the customer has no control over resource location (Mell & Grance, 2009).

- Rapid Elasticity: The ability to quickly allocate and reallocate the resources efficiently and effectively to the user to meet the self-service goal of cloud computing by an automated process that the procurement time is decreased when in need and prevents the abundant use of the computing power when the need is finished.
- Peer to Peer service: Cloud computing also provides a peer to peer model with a distributed architecture that there is no need for central coordination. Another advantage of cloud computing is that it allows for a cloud sandbox, which is an isolated environment in which, the file, program, or the code can run without affecting the application. Amazon web services provide this usage. Grid computing is provided by the cloud, which is a form of distributed and parallel computing, where it creates a virtual supercomputer connected over a network with loosely coupled computers acting in accordance to perform huge tasks.

Cloud service models. Cloud service providers provide many services to the user. The primary service models offered by the cloud are infrastructure-as-a-service (IaaS), platform-as-a-service(PaaS) and software-as-a-service (SaaS), which are categorized by the Software, Platform, and Infrastructure (SPI) model.

- Infrastructure-as-a-Service (Iaas): It is a service model which provides the infrastructure like network equipment, storage, computational servers as a service using which the platform to develop and execute the application which is set. Using this model reduces the infrastructure cost of buying software and hardware components. Instead, services can be accessed to virtualized objects and using an interface to control them. When there is a need for additional storage, the consumer can request the services and will be billed according to their pay per use model. Examples include Amazon EC2, Rackspace, etc.

- Platform-as-a-Service (PaaS): In this services delivery model, using a platform by which the applications can be developed and deployed, is provided as a service. The platform usually consists of the programming environment, databases, web servers using where the development takes place, and the consumers have the full access to the environment settings. This model reduces the cost of buying software, hardware components and managing them. The developers can later be able to deploy their developed apps into the cloud very quickly. Examples include Microsoft Azure and AWS elastic beanstalk.
- Software-as-a-Service (SaaS): In this service delivery model, one or more services or applications and the computational resources that are required for the working of the application are delivered. This service model reduces the cost of software development, infrastructure components, and maintenance operations. The software provided by the service provider usually resides on their infrastructure or are hosted by third-party vendor's infrastructure and the consumer can access the service using a web application like a browser. This mechanism is implemented using a licensing model, and the service can be provided to a user or group of users or an organization. Here, the security necessities are managed by the service provider and the consumer

will not be controlling or having access to the underlying infrastructure. An example is Microsoft Office 365.

Deployment models in cloud.

- Private Cloud: The Private cloud infrastructure is solely implemented for an organization, either operated by a third-party service provider or resides in an internal data center and can be hosted externally or internally. Only the authorized people who have authentication and belong to that organization can be able to access the data in the cloud. Efficient security policies must be implemented by the organization while deploying a private cloud. By using the private cloud, the organization will have an advantage over the infrastructure, computational resources and consumers data than on a public cloud (Jansen & Grance, 2011).
- Public Cloud: Contrary to the private cloud, a public cloud is accessible to everyone and users can use them to store their data and access the data anytime, using the Internet. Anyone can use the computational power and infrastructure services provided by it. It is owned and operated by cloud service providers, and it is external to any organization. SkyDrive, Google Drive, Dropbox, etc., are some of the public clouds available.
- Community Cloud: Community cloud can sometimes be referred as a mix of public and private clouds. It is implemented between two or more organizations that share similar security and privacy policies, rather than a single organization (Jansen & Grance, 2011). It is identical to a private cloud, but the computational power, resources and the infrastructure are exclusive to both the organizations involved.

- Hybrid Cloud: The Hybrid cloud infrastructure is a mix of two or more clouds, that is used to perform distinct functions within an organization. These clouds can be a combination of either public cloud, private cloud or a community cloud and are bound together by a standardized proprietary technology that enables application portability (Mell & Grance, 2009). An example for the use of hybrid cloud implementation is that an organization that implements hybrid cloud may store the clients' sensitive data in the private cloud application and interconnect that application to a business intelligence application running on a public cloud, as software as a service (Hybrid cloud, n.d.).

Cloud storage requirements. With the advent of cloud computing, data sharing is one of the prominent uses of the cloud. Cloud sharing has gained interest in the organizational sector, health care systems, social users because of the services provided by it. The data is distributed across many servers and can be accessed at any given time. Many organizations outsource their data and store it in the cloud because they do not need to maintain physical storage, which cuts the cost and they are still able to share the data with other business organizations. Social users like to save their photos, videos, and documents in the cloud, provided by the CSP, as there is no loss of data occurs in the cloud compared to storing data in a physical location on a device, which once lost it is lost forever.

One more advantage is data sharing, where the user can share their data whenever wherever and with whomever they want, with the access to the Internet. Cloud computing is the underlying technology for many of the everyday applications that are used, and which can be accessed from a browser. However, with the vast benefits provided there are security concerns regarding the use of the cloud. One of the concerns is the data stored in the cloud should be protected from unauthorized access. Recently, the ICloud leak of celebrities' photos are an example. Another concern is the data stored in the cloud is available to the CSP. The access to the data and the data should be protected from the CSP. The following are the requirements for data sharing while using the cloud.

- Data confidentiality: Including the CSP, the data in the cloud should be protected from unauthorized access, at any given time. Data should remain confidential during the transfer of data, at an idle state or as backup data. Only the authorized users should be provided access to the data at any given time.
- User revocation: If the data in the cloud is authorized to a user and later the rights are revoked, the user shouldn't have access to the data when the new change is implemented. Also, the revocation of a particular user should not affect the authorization provided to other users. An example for this is if a group of users are authorized to access a project in team foundation server, and later for one user access is revoked to that project, then the remaining people should still be able to access the project except the revoked user.
- Scalability and efficiency: Cloud allows for a large storage of data. An enormous number of users access cloud on a daily basis and their count and usage is unpredictable. Many of them join and leave, so it is necessary that the system should be efficient and scalable (Kumar, 2015).
- Collusion between the entities: In the cloud, data sharing services should be provided in such a way that even when malicious users try to collude, the data access should be

efficient such that it should be granted only to authorized users. To provide proper authorization to access the data or resources access control mechanisms should be implemented. Access control is a security model that allows the users to access or deny or restrict permissions. Access control mechanism is very useful in tracking the users who have been provided access and also maintains a list of attempts made by a user before accessing a system or a resource.

- User-based access control: Using UBAC the system applications and services are restricted at a user level. UBAC permissions are implemented with a combination of login and password, which are stored in the access control list which either grants or rejects the user to access a resource. Companies with high-security concerns implement this access control and because it has high management overhead and as the number of users accessing the cloud is high, this is not a feasible approach to implement in the cloud.
- Role-based access control: RBAC is a control mechanism in which the users are provided access according to their assigned roles. This can be implemented for a system, network or cloud, using roles assigned to individual which users can then access data according to their roles. The access can be referred to as the user’s ability to view, create or modify the data and perform some operations. An example of this in an enterprise setting, the director of the organization can have access to the files of all the employees and while a manager can have access to the people under them. The requested data can be accessed, only when the role constraint is satisfied. It is easy to assign or remove or modify roles using this mechanism. There are other access

control mechanisms like mandatory access control (MAC) and discretionary access control (DAC). MAC, DAC, RBAC—all of these mechanisms come under the umbrella of Identity-based access control models (Kumar, 2015).

- Attribute-based access control (ABAC): ABAC is a mechanism in which the access is provided on the basis of attributes assigned to the user on a set of policies. The access to the data stored in the cloud is provided after satisfying the policy for the provided attributes. ABAC is based on the evaluation of subjects (users), objects (resources) and sometimes environmental conditions and the access policy for the rules satisfying the subject-object attributes. Using only the access control mechanisms in the cloud for data privacy and security can lead to privilege escalation attacks as the data in the cloud comes from multiple users and exists on the same server (Patranabis et al., 2017). The data in the cloud should be protected from unauthorized access and as well as the cloud service providers. The CSP provides data security, however, they also have access to the data. To overcome this, the data must be encrypted by the user using different cryptographic schemes before it is outsourced to the cloud, which provides data confidentiality. The cloud storage system should be effective in such a way that the users can also be able to search a part of the stored encrypted data. The cloud storage system should be able to return the searched data, and they should be unaware of what portion of the searched data is returned (Kumar, 2015). Data sharing in the cloud is a significant concern. The most prominent challenge in the cloud is how to share the encrypted data to users. The traditional way is the users can download the encrypted data, decrypt it and then share it with others. However, using the cloud this way loses the usage of cloud service. The data sharing service should be effective in such a way that the user should be provided with the access rights of data to others so that they can download the data directly from the server. Using simple encryption and decryption techniques are not sufficient to achieve this. Complex encryption schemes should be applied, which makes the use of keys and a proper and secure key management system is necessary, as keys are very important for data retrieval. Adequate encryption schemes should be applied to data while it is transmitted over networks, while it is at rest or in a backup state. This is done to protect the data from the malicious cloud service providers and unauthorized users. Efficient key management which includes key storage and access to the key storage should be securely implemented as loss of keys may compromise the stored encrypted data. Key management refers to the storage of keys, access to the keys, transportation of keys, activation and deactivation of keys and the creation or deletion of keys (Kumar, 2015). The data usually is encrypted by the user and the CSP before the data is stored. So, both the encryption and key management is necessary to protect and share data in the cloud securely. The requirements of proper key management are discussed below (Kumar, 2015).

- Secure key stores: Key storage is the storage space where all the keys related to encryption or decryption will be stored. A proper security mechanism should be used to prevent the malicious users from gaining access. If the access to the storage is compromised, they can gain access to the keys related to encrypted data and to corresponding decryption keys. To avoid this, the key stores should protect themselves from malicious users, while in storage, in transit or on a backup media.

- Access to key stores: Proper access control mechanism should be implemented while providing access to the key stores. Limited access should be given to access the key stores, for the users who have access to the data. Access control should be provided based on the roles, and the entity that uses the given key should not be the one to store keys (Kumar, 2015). As key stores contain essential information related to the keys, proper safety measures should be taken, otherwise the loss of data will occur.
- Recoverability and backup of keys: Data is usually stored in an encrypted form. Keys help convert the plaintext into ciphertext. This encrypted data gets shared with others. So, the loss of keys makes the decryption process difficult or sometimes impossible. Proper key recovery and backup mechanisms should also be implemented. Loss of keys eventually leads to loss of data. Proper key recoverability and backup mechanisms should be applied by the cloud service providers, or if not, the access to data will be lost.

Types of attacks on the cloud. Cloud provides a distributed service of data where many people across the world can access it. Although cloud is secure and different security mechanisms are implemented it is still prone to privacy and security attacks by hackers. Some of the attacks are discussed below (Kumar, 2015).

- Law enforcement request: Users store the data on a cloud provided by the CSP. When the government or any government agency requests the data regarding the user, most of the time, a CSP will not have a choice to deny their request. Because of this, there is a loss of confidentiality of the data.

- Data-stealing attacks: This attack refers to stealing data from a user by any means, gaining access to a user account and password information using techniques like brute force or over the shoulder techniques. This is a threat to user confidentiality and could lead to a breach of data. To overcome this, one of the security mechanisms that can be implemented is using authenticator application or two-factor authentication, where a message is received with a code to verify the authenticity of the user. Many organizations apply this method to provide authorized access.
- Flooding attacks: In this kind of attack the malicious user sends a request to the cloud. The attacker then overloads the server by sending bogus data requests to the server, thereby increasing the workload of the services and utilizing all of the available resources and potentially crashes the server.
- Denial-of-service attacks: In this kind of attack, malicious code is injected into browsers which opens multiple windows, and this then denies services to the authorized user. These kinds of attack can often be seen while using the browser.
- Cross-site scripting attacks: In this kind of attack, the attacker injects a malicious piece of payload into the legitimate website or web application. In this way, the attacker is not affecting the victim directly, but by making use of the vulnerability in the application, the user would visit (Acunetix, n.d.).

- XML signature wrapping attacks: Using this kind of attack, the attacker, can get administrative rights of the cloud user and can create, delete or modify the information of the user.

Proposed System

Technology is emerging rapidly day-by-day, and cloud storage has become a predominant source of storage and sharing of data and is where a large amount of user data is stored. There is a high possibility of data leakage in this process of storing and sharing of data. To avoid this, the proposed system is based on the aggregate key concept. Using this, the successful delegation of decryption rights for a set of ciphertext classes are provided to the receiver. In this system, multiple encryption operations are performed, and an aggregate key is generated. This aggregate key is passed on to the delegate and using this key the decryption is performed to obtain the original text. This system guarantees a secure data exchange between the sender and receiver, and only the authorized user will be able to decrypt and thus view the shared information.

Chapter III: Methodology

Introduction

In this section, the details regarding the methodology used in the key aggregate cryptosystem is explained. Also, the framework, the modules involved in design, the algorithm used and applications of KAC are presented.

Key aggregate cryptosystem. The key aggregate cryptosystem is a public key cryptosystem which is implemented in cloud storage for successful delegation of keys, to decrypt the data. The users not only encode the message under an open key but also under an identifier of ciphertext called a class. The ciphertexts again are classified into classes. Anybody can encrypt the message using their public keys and can choose which ciphertext class is related to the plaintext message to be encoded. The information owner holds the master key pair which can be used to generate secret keys for the set of classes. The produced key is an aggregate key, which is compacted as a secret key for a single class but possesses the power of many such secret keys which are combined. By providing this key, the user, for the authorized set of classes is be able to decrypt the information and the rest out of the set stay private.

Framework

The key aggregate encryption scheme consists of five polynomial time algorithms (Chu et al., 2014). They are as follows:

1. Setup (1λ, n): In this step, the data owner registers on a server which is untrusted. Here the $1\ \lambda$ is the security level parameter and n is the set of ciphertext class for which a public param is generated.

2. KeyGen: In this phase, a random master key and public key pair are generated by the dataowner(pk, msk).
3. Encrypt (pk, i, m): In this encrypt phase, the encryption operation is performed, and it takes the input as a public key(pk), a message (m), and index I each of the ciphertext classes.
4. Extract (msk, S): In this phase the delegating power or the decryption rights for the receiver who satisfies for the set of indices I are provided. For this, it takes the input as master secret key and set of ciphertext classes and it outputs an aggregate key Ks.
5. Decrypt (Ks, S, I, C): In this final step, the delegate who receives the aggregate key Ks, which is obtained in the Extract phase, takes the key Ks as input along with the index I for a set of indices S and the ciphertext classes C are generated, to decrypt and obtain the original message m (Kate & Potdukhe, 2014).

Sharing the data. The main usage of KAC is to share data efficiently. The aggregation property is useful when the delegation to be provided is efficient and flexible. Using KAC schemes, the data owner can share the data in a secure, confidential and selective way, by providing each authorized user a single aggregate key, with a small ciphertext expansion. The data sharing between two users Alice and Bob using KAC is explained with an example shown in Figure 3. Suppose, if user Alice wants to share her data {m1,m2,m3…..mn}, she first performs the setup (1λ,n) to get the public system parameter 'param.' Then she executes the KeyGen to generate a public master-secret key pair (pk,msk). The 'param' and the public key 'pk' can be made public, but Alice should hide the master secret key. Anyone can encrypt each of Alice's messages by doing Encrypt (pk, i, mi) to produce ciphertext Ci. This encrypted data can be uploaded to the server. Once Alice wants to share her set 'S' of data to user Bob, Alice can perform Extract (msk, S) to produce an aggregate key Ks. The aggregate key generated is of a constant size and can be securely transferred in the email. After receiving the key, Bob can download the data set for which the authorization is provided. For each i ϵ S, Bob can download the Ci from the server and be using the aggregate key Ks; decryption can be performed using Decrypt (Ks, S, I, Ci) for each i ϵ S

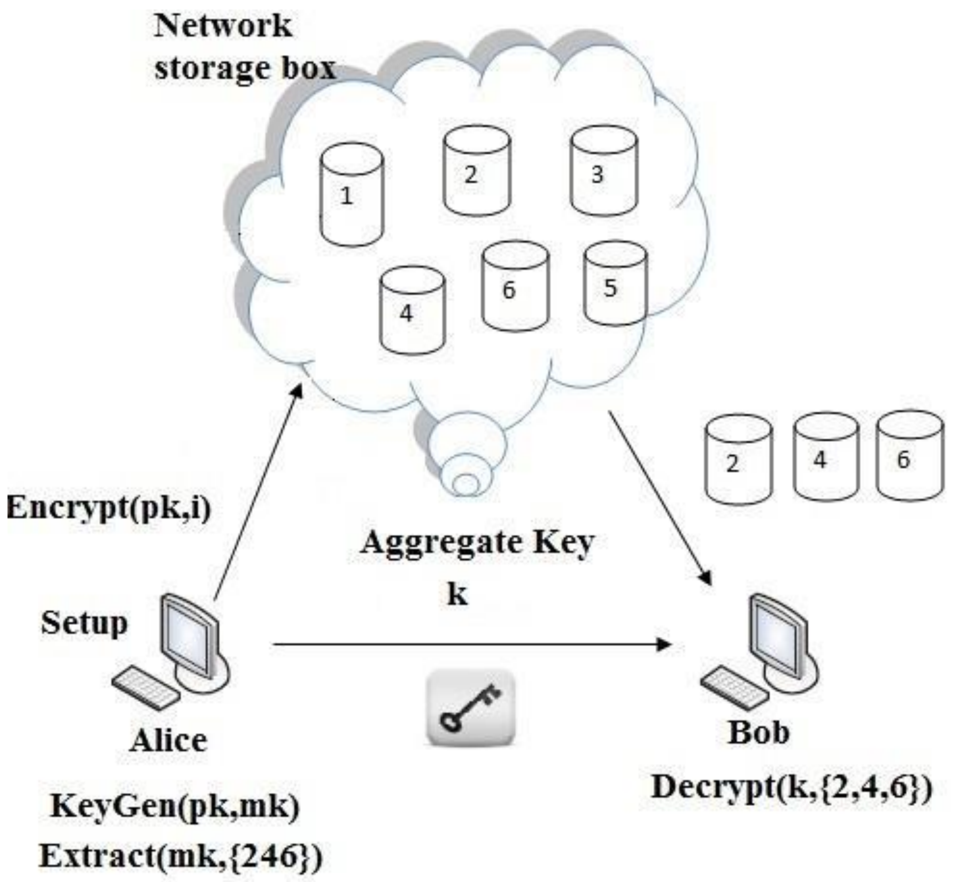


Figure 3. Data Sharing Using KAC (Jadhav & Nargundi, 2014)

Modules Design

The design phase is to ensure that the project gets developed according to the requirements. The entire design is divided into five modules and each module has a specific functionality, and it is related to other modules. Following are the five modules:

- Registration of user and authentication
- Key generation
- Encryption and storage
- Data sharing using aggregate key
- Decryption and view content

Registration of user and authentication. The registration module allows users to register on the application. Users can then create accounts by providing their details regarding username, email id, password, etc. A new user should go through the registration process. Any registered user can log in to the application by entering the details that are provided during the registration process. This module also checks for already existing usernames, during registration, to avoid duplication and a unique id is assigned to each user (Revathi & John, 2016).

The authentication mechanism ensures that only eligible users are provided access, by comparing the credentials with the values stored in the database. Implementing a proper authentication reduces the risk of data leakage. After the login, a user has various options using which they can search, share messages, view messages and log out of the application. Figure 4shows the registration and authentication process.

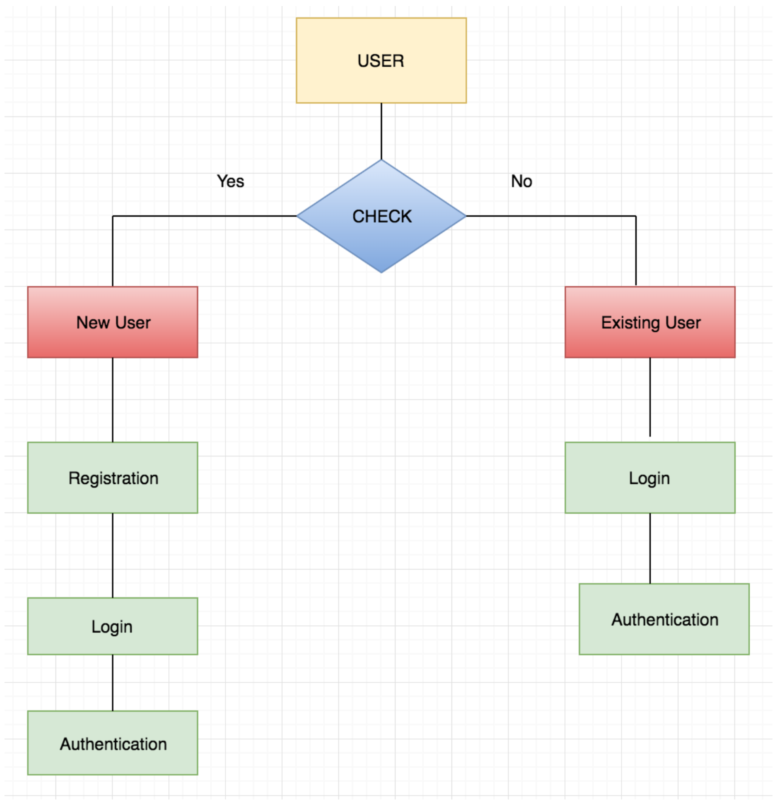


Figure 4. Registration and Authentication

Key generation. Key generation is a process of producing cryptographic keys. Figure 5 shows the process of key generation. When a user is registered with the application, the public key and private key are generated for each user and assigned to them. These keys are stored for the particular user profile and can be retrieved at a later point. After login, the user has the option to share the message with the other users.

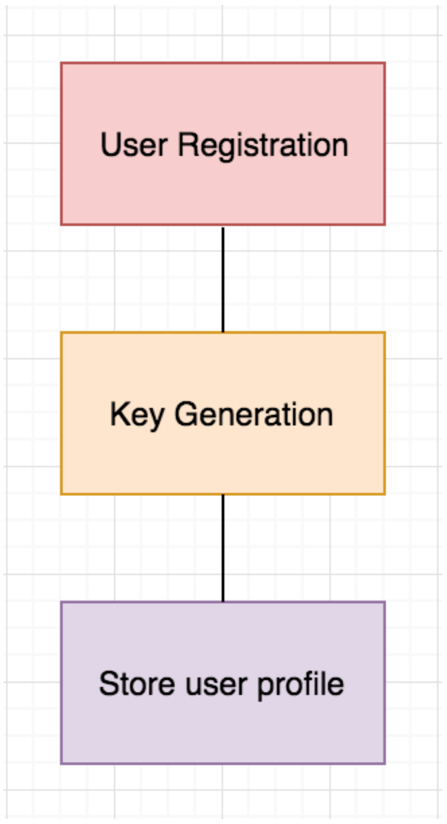


Figure 5. Key Generation

Encryption and storage. Encryption is a process of scrambling the contents of the message where only the authorized person can be able to access it, by providing the secret key. This module describes the encryption process that happens after a successful login of a user. The encryption operation is needed before sharing any data. After a user registers and is successfully authenticated, he can share the information with another user only if it is properly encrypted. When the sender sends a message to the receiver, the sender's message gets encrypted using symmetric encryption. This symmetric encryption generates symmetric ciphertexts. The encrypted values are stored in the database, and a unique identifier or a master key is assigned for this set of information. This unique identifier is encrypted using ElGamal encryption, which generates ciphertexts and these are aggregated and passed to the receiver. Figure 6 shows the encryption process.

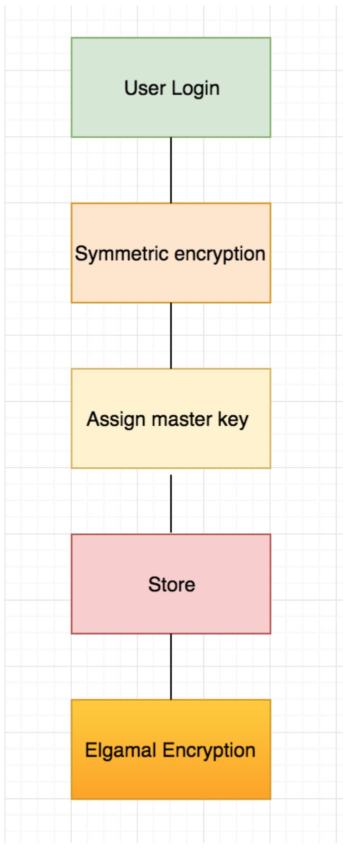


Figure 6. Encryption and Storage

Data sharing using aggregate key. Using ElGamal encryption, the unique message identifier is encrypted. This encryption process produces a set of ciphertexts. These ciphertexts c1 and c2 are combined to generate an aggregate key. This aggregate key has the decryption power on the set of symmetric generated ciphertexts. This aggregate key is passed along with the symmetrically encrypted ciphertexts. Figure 7 displays the process of aggregate key data sharing.

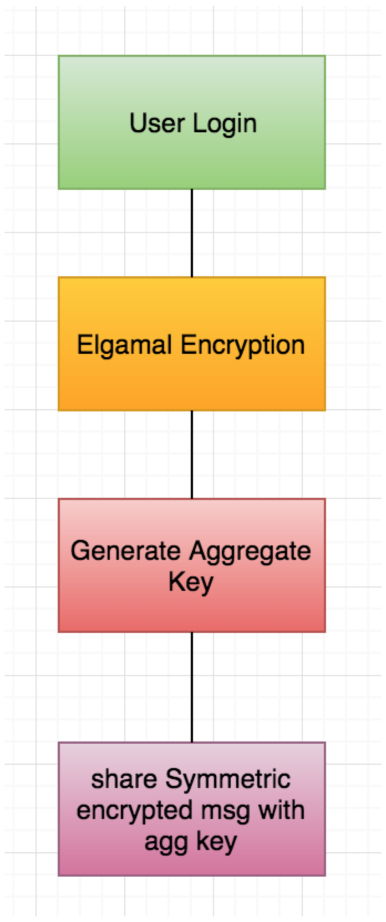


Figure 7. Data Sharing Using Aggregate Key

Decryption and viewing content. The encrypted message is shared from the sender to the receiver. When the receiver logs in, they receive the encoded message along with the aggregate key. By using this key, the individual ciphertexts c1 and c2 are extracted. Using the ElGamal decryption, which takes the c1 and c2 values as input, the unique message identifier is calculated. As the unique identifier is associated with the symmetrically encrypted ciphertexts, the ciphertexts are retrieved and using the symmetric decryption, and the original values are displayed to the receiver. Figure 8 shows the decryption process.

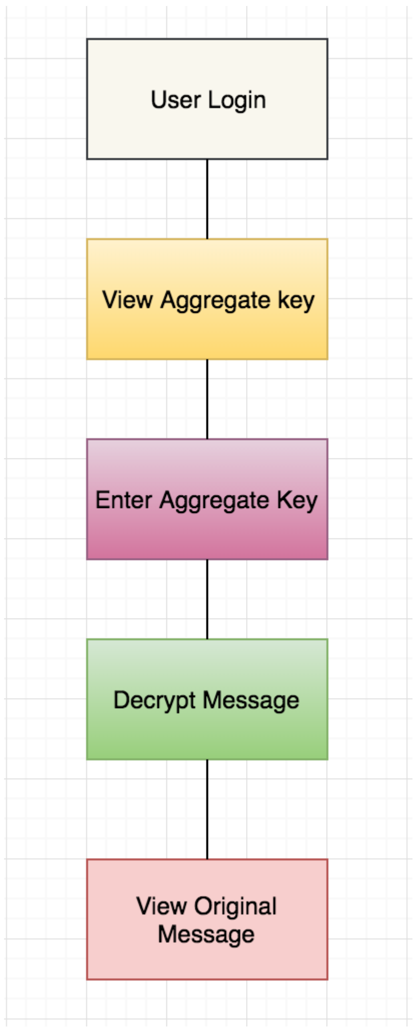


Figure 8. Decryption and Content View

Algorithm Used

The ElGamal algorithm is one of the best practices to achieve secure encryption and decryption process of sharing information. There are three components: (a) key generation, (b) encryption, and (c) decryption.

Key generation: The key generator works as follows:

1. Peter generates an efficient description of a multiplicative cyclic group **G** and pick a prime **p** with generator **g**

2. Peter chooses a random **x** from **{0 …… p-1}**

3. Peter computes $\mathbf{y = g^x}$

4. Peter publishes **y**, along with the description of **G**, **p**, **g** as his **public key**. Peter retains **x** as his **private key** which must be kept secret

Encryption: The encryption algorithm works as follows:

To encrypt a message m to Peter under his public key **(G, p, g, y)**

1. David chooses a random **i** from **{1 …… p-2}** then calculates $\mathbf{c_1 = g^y}$

2. David calculates the shared secret $\mathbf{s = y^i}$

3. David converts his secret message **m** into an element **m'** of **G**

4. David calculates $\mathbf{c_2 = m'.s}$

5. David sends the ciphertext to Peter $\mathbf{(c_1, c_2) = (g^i.m'.y^i) = (g^i.m'.(g^x)^i)}$

Decryption: The decryption algorithm works as follows:

To decrypt a ciphertext $\mathbf{(c_1, c_2)}$ with his private key **x**

1. Peter calculates the shared secret $\mathbf{s = c_1{}^x}$

2. Then he will calculate plaintext message **m**, by converting $\mathbf{c_2.s^{-1}}$

   Where $\mathbf{c_2 = m'.y^i}$, $\mathbf{S= y^i}$ and. $\mathbf{y = g^x}$

   $\mathbf{c_2.s^{-1} = m'.y^i.(g^{xi})^{-1}}$

   $\mathbf{= m'.g^{xi}.g^{-xi}}$

   $\mathbf{= m'. (g^{xi}/ g^{xi})}$

   $\mathbf{= m'}$

Applications of KAC

Some of the applications in which KAC can be implemented are as follows (Patranabis & Mukhopadhyay, 2016).

1. Patient Controlled Encryption (PCE): Patient controlled encryption (PCE) is a recently introduced concept. PCE allows the patients (users) to upload their individual medical records onto the cloud and allow them to provide the delegation of rights for the decryption of data, to only authorized health care personnel and as per their requirements. The KAC concept can be used here, by which users can create their own hierarchy of medical data and provide the decryption rights on this data to different specialists or organizations, using the concept of the aggregate key. As the health records of individuals are considered as sensitive data, storing them on a local or physical machine is not a viable solution and the cloud is a best alternative for the storage of data and KAC provides a two-way advantage in this scenario. It not only allows different users across the globe to store their data efficiently, but also allows them to gain the support of different health personnel across the globe, by providing them access to their data securely using the aggregate key.
2. Distribution of product licenses or activation keys: Aggregate key concept can be implemented for an organization that allocates product licenses to its users. For example, consider that an organization has large number of products and wants to distribute the licenses or activation files of the products to different users. Using KAC, the license files can be encrypted and stored in the cloud. The aggregate key associated with multiple licenses for different products can be shared to customers to

legally authenticate them, as per their requirements (Patranabis & Mukhopadhyay, 2016). The legal authentication is provided to the users who buys the products from the company and an authentication key is given to the user. Using the aggregate key user can be able to decrypt the license file for each product. Since the keys produced are of a constant size, distributing a single aggregate key is easier than sharing multiple keys for the licenses (Patranabis & Mukhopadhyay, 2016).

Chapter IV: Technology Stack

Introduction

In this section, the various technologies that are used to implement the project and a brief overview regarding each of them are presented. The software and hardware requirements required for the application is provided.

Technologies Used

Various technical stacks are used to develop this application. Some of them are:

- Java 1.8
- J2EE technologies like JSP, Servlet, JDBC
- MySQL database
- Eclipse IDE
- Tomcat Application Server
- HTML and CSS

About Java. Java is a programming language widely used to develop platform independent applications. Since it has a wide variety of predominant features like Graphical User Interface (GUI) systems and Java 2 Platform Enterprise Edition (J2EE) libraries, most of the applications are developed in Java. Many web applications have risk factors with different kinds of security and portability issues: Java resolves these issues using bytecode which is executed by the Java compiler with a highly optimized set of instructions that are designed in Java Virtual Machine (JVM). Since bytecode is highly optimized, it enables JVM to run and execute programs faster. Any Java program can be run when a runtime exists for a system. Java programs can be translated into bytecodes which enables it to run it in a wide variety of environments easily.

Java progressively handles memory compared to other programming languages which makes it more dynamic and easy to run code across a network. Java is an enhanced version of C++, but Java uses an entirely different approach to problem-solving. Java provides APIs for developing web applications with I/O, XML parsing, database connections, client-based utilities. Java has a wide variety of J2EE frameworks like Spring, Struts, Hibernate, GWT, Maven, JSF, etc., which makes the development process easier for an application. Java is more stable and predictable hence it enables cross-platform development.

***Advantages of Java*.**

1. Simple: Easy to learn if you know the object-oriented programming language, it is based on the C and C++ programming languages.
2. Secure and Portable: Since the Java program translates into bytecode it is more secure and can run on any platform.
3. Robust: Java is more robust because of its capability to do runtime and compile time error checks.
4. Multithreaded: Running one or more threads simultaneously in the same program is called multithreading, Java allows a program to run in a multithreaded environment.
5. High performance: Java uses the Just-In-Time (JIT) compiler to compile, which enables high performance.

6. Distributed: Most of the J2EE and web applications which runs on the Internet are distributed, and Java has great flexibility to develop the distributed system without any constraints.

J2EE technologies. J2EE provides a variety of services to build large-scale, distributed, multi-tier applications. The codes are written once and run on different platforms. J2EE is comprised of a wide variety of technologies like Java Servlets, JSP, JDBC, etc. Major advantages include: (a) different platforms support applications developed using J2EE, and (b) most application servers that support J2EE are portable.

Java servlets. Servlets are programs run on a web application server. It handles HTTP requests. It is a technology that creates web applications, provides interfaces and classes, used to implement the interfaces, and is deployed on the servers. They can be created using **javax.servlet** and **javax.servlet.http** packages. Servlet lifecycle includes three paths from initiation till destruction: (a) initialization by **init( )**, (b) **Service( )** method to process the HTTP request, and (c) destruction or termination by **destroy( )**. Service() method is used to process HTTP request and perform the task. This includes receiving requests from clients and responding back to the requests. A new thread gets created whenever a request is received. Different types of HTTP methods are used during the service phase such as doGet, doPost, doPut, doDelete, etc. throughout the lifecycle. Figure 9 shows the architecture diagram for the servlet. Figure 10 shows the lifecycle diagram for servlets.

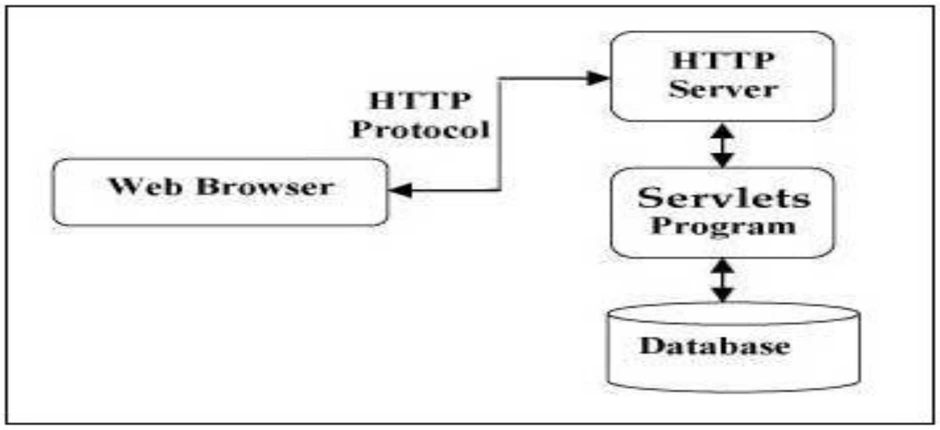


Figure 9. Servlet Architecture (Tutorials Point, n.d.-a)

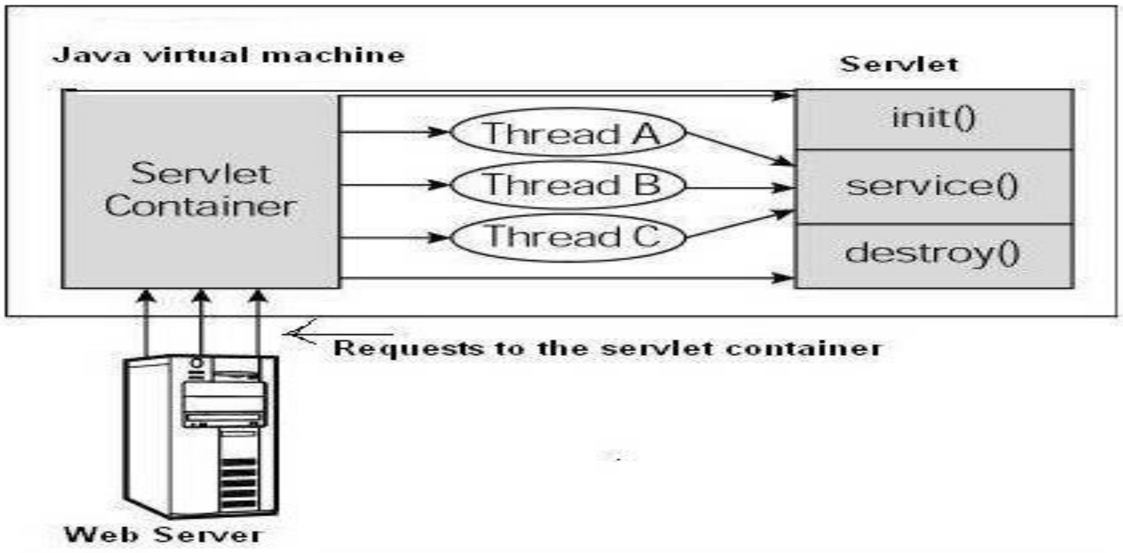


Figure 10. Servlet Lifecycle Diagram (Tutorials Point, n.d.)

MYSQL database. A database is used to store the collection of data with subsequent relational mappings to the tables. To do any CRUD (Create, Read, Update and Delete) operations on any database we use Structured Query Language (SQL). MySQL is one among the many prevalent open-source DBMS (Database Management Systems) which is provided by Oracle. Because of fast performance, high usability and its user-friendly nature most of the web/J2EE applications use MySQL. Initially, it is developed and supported by MySQL AB. MySQL provides a MySQL Workbench (GUI), which is made for the user to execute SQL, create or drop schemas and tables.

Java database connectivity (JDBC). JDBC is a Java API for database dependent connections between Java programs and databases. JDBC is often used for SQL and Procedural Language SQL (PL/SQL) statements to send to different databases. An API (Application Programming Interface) consists of all the features related to a product in a documented form. Figure 11 shows the JDBC Architecture and how it consists of two layers

a) JDBC API: Connection between Application to JDBC

b) JDBC Driver API: Connection between JDBC and Driver

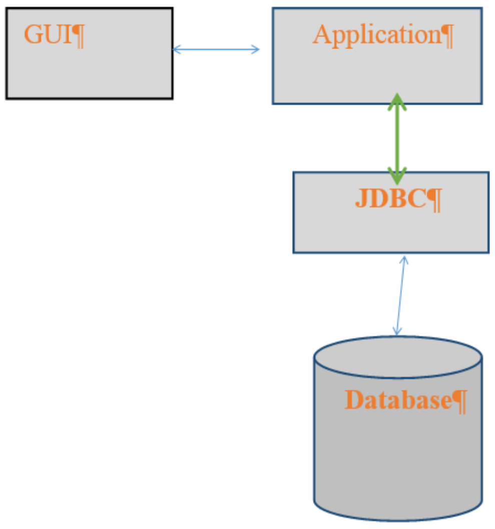
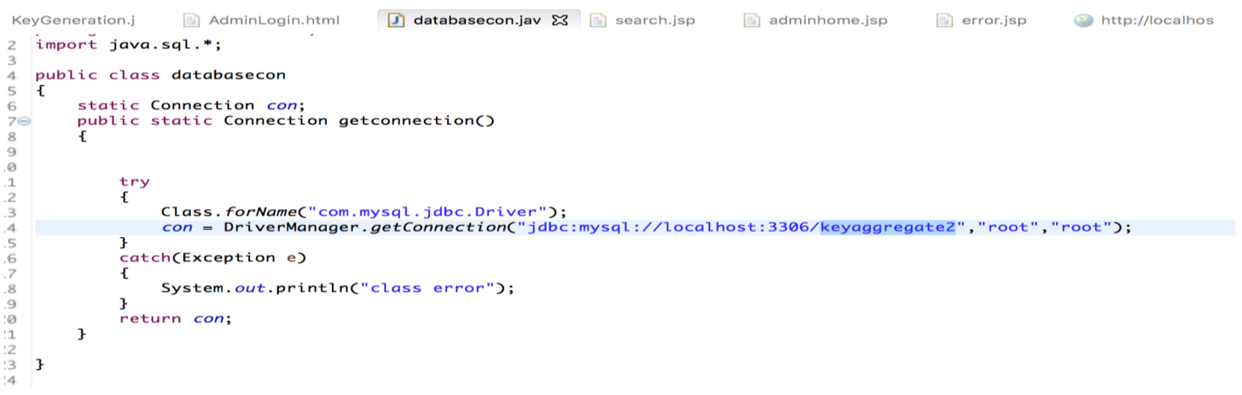


Figure 11. JDBC Connectivity

To process a query (SQL statement) using JDBC, the following steps are followed: (a) establish a connection, (b) create statement, (c) execute queries, (d) process result set, and (e) close the connection.

Figure 12 shows the code snap shot for connecting to a database using JDBC.



```
import java.sql.*;

public class databasecon
{
    static Connection con;
    public static Connection getconnection()
    {


        try
        {
            Class.forName("com.mysql.jdbc.Driver");
            con = DriverManager.getConnection("jdbc:mysql://localhost:3306/keyaggregate2","root","root");
        }
        catch(Exception e)
        {
            System.out.println("class error");
        }
        return con;
    }

}
```

Figure 12. JDBC Code Snippet

Java server pages (JSP). For developing web applications, JSPs are often used. It is a very significant technology which is an extension of Java servlet, which has scripting, form actions and directive elements in the form of static (HTML, CSS, etc.) as wells as dynamic code. JSPs are used for developing presentation layer or client-side applications.

There are three types of scripting elements that can be used in JSP:

- Declaration element (tag: <%! %>)
- Expression element (tag: <%= >)
- Scriptlet element (tag: <% %>)

Life Cycle methods of a JSP:

- Pre-translated: Before compiled to Servlet
- Translated: Compiled to Servlet
- Initialized: Before handling the service requests
- Servicing: Services the client requests
- Out of Service: Completing the services or calls the jspDestory() method

Hypertext markup language (HTML). Web pages are designed using different structures, HTML is a language used to describe various structures of web pages using markups. It uses tags to format the code. The tags are enclosed in angle braces <Tag name>. HTML consists of elements, the codes are written with opening tags <abc> and closing tags </abc> and using various content. Elements comprise an opening tag, content, and closing tags. Attributes contain information related to elements using additional symbols, as described below:

- <h> : Used for headings
- <p> : Used for paragraphs
- <ul> or <ol> : Used to create menus
- <div> : Used to create containers for parts
- <a href> : Used to create links
- <img> : Used to link images

HTML comprises a header and a body. The header consists of the title of the document and the body consists of the main content (code). Images and tables can also be created using HTML pages (HTML Basics, n. d.). HTML uses a variety of properties to define elements such as text color, fonts, size, formatting (Special functions) and alignment, etc. Links are created using anchor tags <a> for web pages or other source documents, and email links are also created using HTML.

Cascading style sheets (CSS). CSS is interlinked with HTML as it helps in applying styles to elements in HTML documents. CSS consists of a set of rules in a code format. Every HTML file consists of a CSS with different codes needed to style the pages. CSS consists of two different types of attributes like type (used for text) and media (used for screens, projections, etc.). CSS consists of three different types:

- Internal Stylesheets: This includes insertion of CSS code within the HTML file.
- External Stylesheets: Text created in notepad and saved as a .css file and linked to a HTML file.
- Inline Style: Used to style single elements.

Different kinds of tags are used in the layout of the content such as:

Eg: h1 {

```
Color: #Red;
}
```

Eclipse IDE. Eclipse provides an integrated Development Environment (IDE). It is the most widely used IDE tool for development of J2EE and web applications. It is an open source software and user-friendly development tool available in the market. It has great features to support and develop the application in commonly used programming languages. Eclipse provides a structured workbench with all subsystems included by means of implementing one or more plugins. For developing the current system, the Eclipse neon version is used.

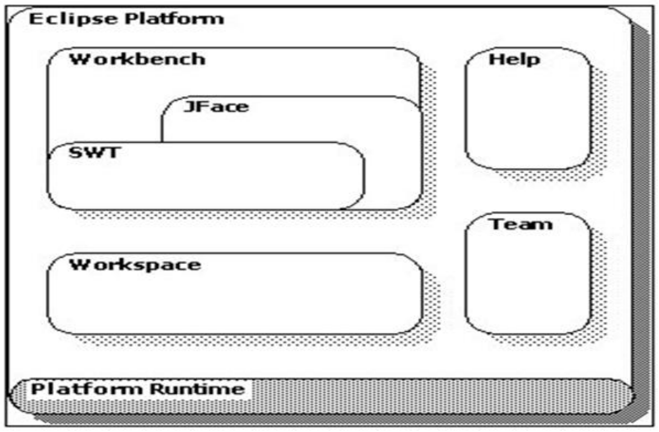


Figure 13. Eclipse Platform Overview

Tomcat application server. Application servers are used to maintain service-oriented components like Servlets and JSP's. They are used to gather data from the database and to apply business tools for an application to have full control over the user sessions. On a web server, an application server clustering (loosely coupling on a network) is performed for high scalability and load balancing. The Apache Tomcat Application Server is a product of Apache Software Foundation which is an open source application to implement J2EE and web applications. It has a Servlet container which is specifically used to run Servlets and JSPs. Tomcat can be used for exposing the business logic and dynamic content to the client using HTTP protocol. Tomcat 8.0 is used in the current system implementation.

Software and Hardware Requirements

Hardware requirements include any system processor, not before Pentium IV and RAM of 2GB or above and hard disk space not less than 30 GB is sufficient to deploy the application.

Software requirements:

- Operating system: Windows, macOS, Linux

- Programming language: JAVA 1.8
- IDE: Eclipse JEE (Neon version)
- Server: Apache Tomcat Server 8
- Database: MYSQL
- Front End: HTML, CSS, JSP

Chapter V: Implementation

Introduction

In this section software used for the execution of the application, installation process and the environment setup are discussed. Also, the implemented application screenshots and a description of each screenshot is presented.

Installation Procedure

For achieving the implementation of the system, the below steps are followed:

Java Installation: In developing the system, JRE 1.8 version is used, which is available on Oracle site as an open source application. Steps to follow include:

- Download JRE 1.8 from the Oracle site.
- Set the environment variable by adding JAVA_HOME path in system variables. JAVA_HOME path would be the JRE location that has been downloaded.
- Add %JAVA_HOME%\bin to environment path variable.

To check if JRE installed in the system, open CMD, and type for “java -version” or “java -help.”

Eclipse Neon Installation: In developing the application, Eclipse Neon 4.6 version is used, which can be obtained from www.eclipse.org/downloads, it is open source software available in the market. Steps to get Eclipse installed are as follows:

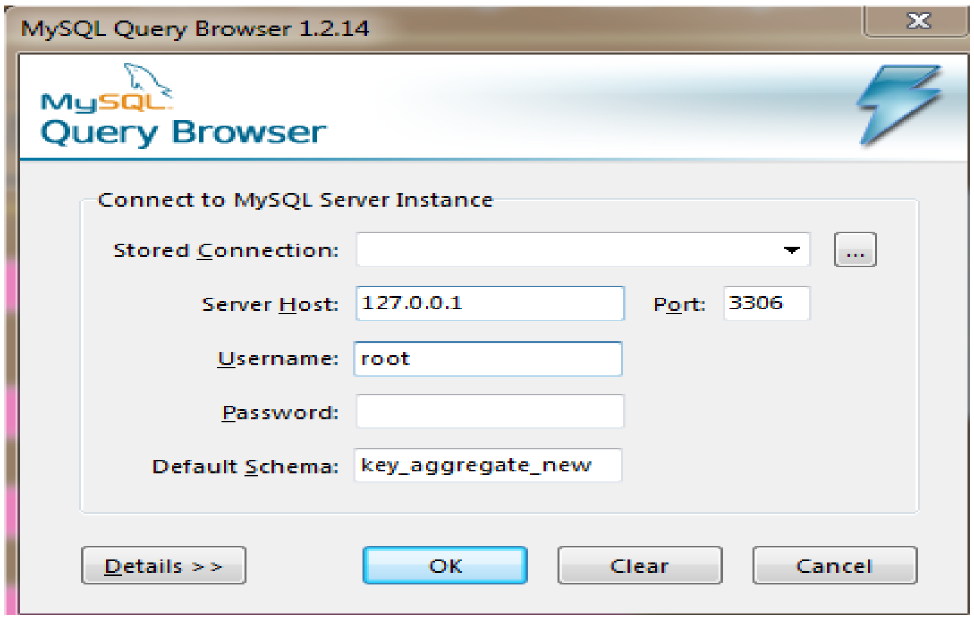
For Windows:

- Choose 64-bit or 32-bit Eclipse IDE for Java EE Developers Neon version and click on download.
- Unzip the downloaded Eclipse zip folder and click on the Eclipse executable icon.

For Mac:

- Choose Eclipse IDE for Java EE Developers Neon version for Mac and click on download.
- Unzip the downloaded Eclipse zip folder and click on the Eclipse executable icon.

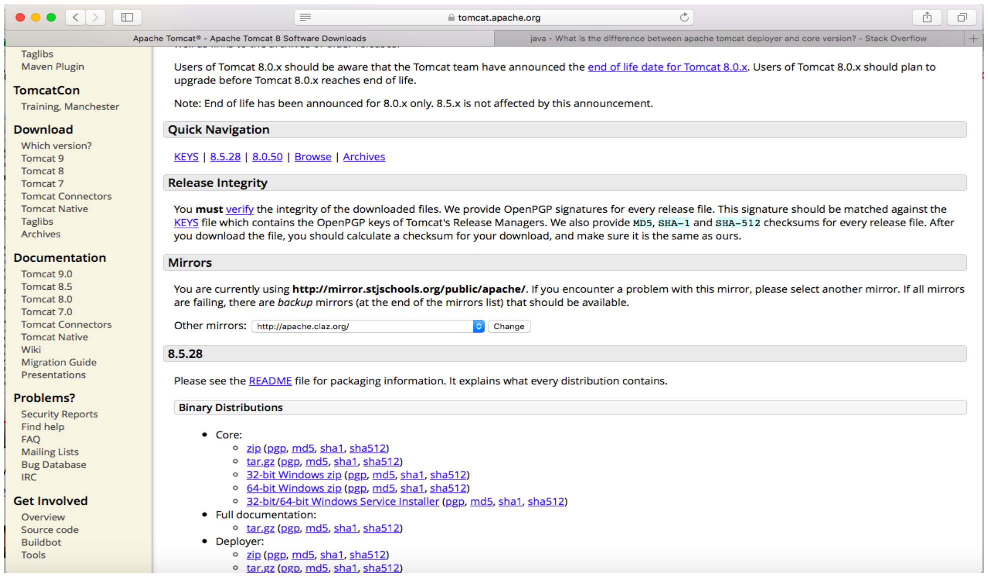
MySQL installation: Download MySQL community installer, which is an open source available on the MySQL site. For a better user interface, MySQL provides MySQL Workbench. MySQL Workbench is a rich interface to work on SQL operations such as DDL (Data Definition Language), DML (Data Manipulation Language) and DCL (Data Control Language). MySQL Workbench is used to connect to Oracle databases by providing server host, port, username, password, and schema information. Figure 14 shows the schema connection.



Stored Connection:
Server Host: 127.0.0.1
Port: 3306
Username: root
Password:
Default Schema: key_aggregate_new

Figure 14. Schema Connection

Installing Tomcat Application Server: Eclipse provides the option to use the tomcat application server. To get the Tomcat Application Server, you must go to the apache site (https://tomcat.apache.org/download-80.cgi). For this system, apache tomcat 8.5 server is used. Figure 15 shows the screenshot of the tomcat site where tomcat server is downloaded.



Users of Tomcat 8.0.x should be aware that the Tomcat team have announced the end of life date for Tomcat 8.0.x. Users of Tomcat 8.0.x should plan to upgrade before Tomcat 8.0.x reaches end of life.

Note: End of life has been announced for 8.0.x only. 8.5.x is not affected by this announcement.

Quick Navigation

KEYS | 8.5.28 | 8.0.50 | Browse | Archives

Release Integrity

You **must** verify the integrity of the downloaded files. We provide OpenPGP signatures for every release file. This signature should be matched against the KEYS file which contains the OpenPGP keys of Tomcat's Release Managers. We also provide `MD5`, `SHA-1` and `SHA-512` checksums for every release file. After you download the file, you should calculate a checksum for your download, and make sure it is the same as ours.

Mirrors

You are currently using **http://mirror.stjschools.org/public/apache/**. If you encounter a problem with this mirror, please select another mirror. If all mirrors are failing, there are *backup* mirrors (at the end of the mirrors list) that should be available.

Other mirrors: http://apache.claz.org/ Change

8.5.28

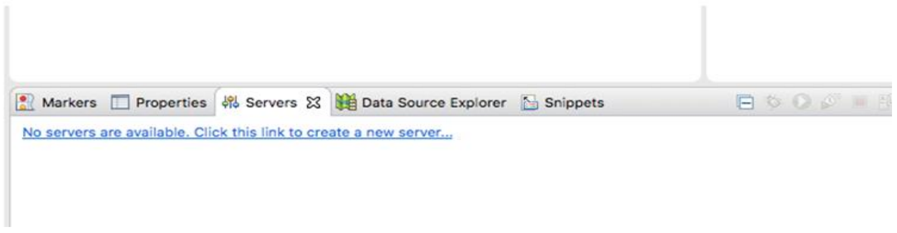
Please see the README file for packaging information. It explains what every distribution contains.

Binary Distributions

- Core:
  - zip (pgp, md5, sha1, sha512)
  - tar.gz (pgp, md5, sha1, sha512)
  - 32-bit Windows zip (pgp, md5, sha1, sha512)
  - 64-bit Windows zip (pgp, md5, sha1, sha512)
  - 32-bit/64-bit Windows Service Installer (pgp, md5, sha1, sha512)
- Full documentation:
  - tar.gz (pgp, md5, sha1, sha512)
- Deployer:
  - zip (pgp, md5, sha1, sha512)
  - tar.gz (pgp, md5, sha1, sha512)

Figure 15. Tomcat Apache Download Page

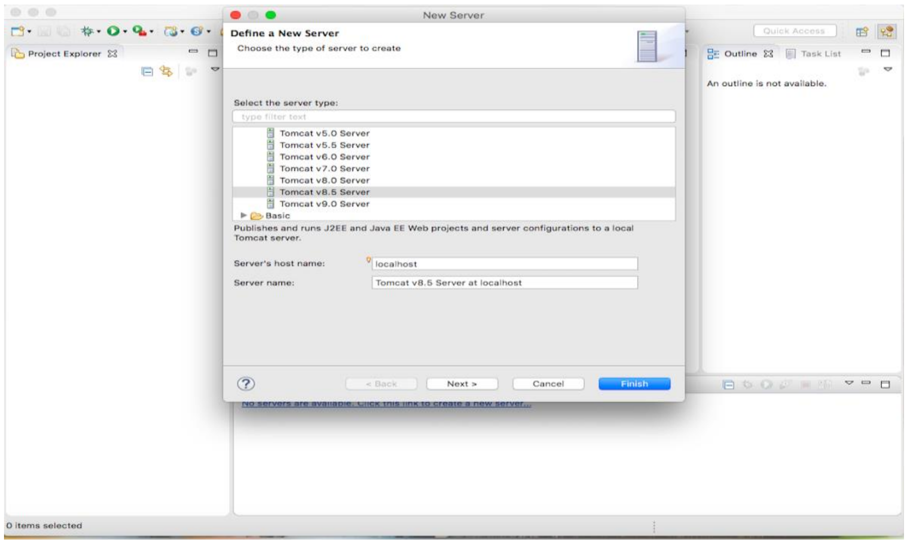
Once Tomcat Server 8.5 is downloaded, extract the zip file and place that folder in a specific location. Now open Eclipse and click on the link to create a new server. Figure 16 shows the Eclipse server page to add a server.



No servers are available. Click this link to create a new server...

Figure 16. Eclipse Servers Page

This opens the screen depicted in Figure 17 where the list of servers is displayed. Select Tomcat v8.5 server and click on finish. Figure 17 shows the available tomcat servers listed in Eclipse.



Define a New Server
Choose the type of server to create

Select the server type:

Tomcat v5.0 Server
Tomcat v5.5 Server
Tomcat v6.0 Server
Tomcat v7.0 Server
Tomcat v8.0 Server
Tomcat v8.5 Server
Tomcat v9.0 Server
Basic

Publishes and runs J2EE and Java EE Web projects and server configurations to a local Tomcat server.

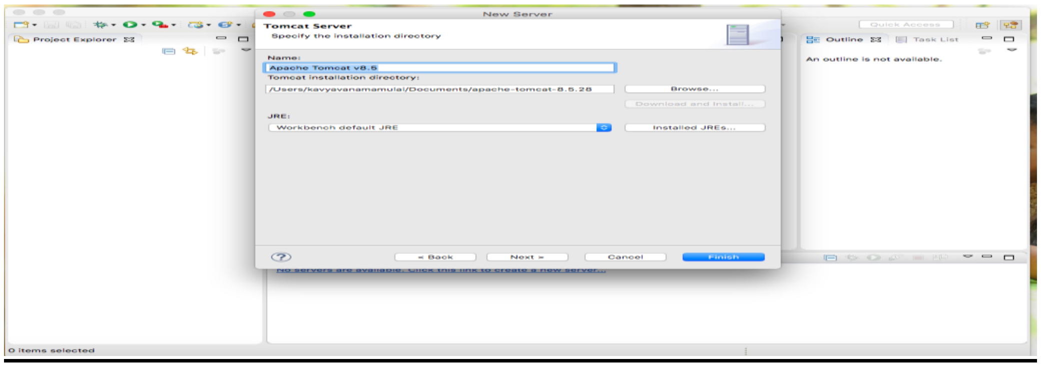
Server's host name: localhost

Server name: Tomcat v8.5 Server at localhost

An outline is not available.

Figure 17. Tomcat Server List in Eclipse

It will prompt a dialog box to specify the installation directory for tomcat server. Now browse to the directory where you copied the downloaded tomcat v8.5 core installation package. And select the installed JRE in the system then click finish. Figure 18 shows the process to add a tomcat server.



Tomcat Server
Specify the installation directory

Name: Apache Tomcat v8.5

Tomcat installation directory: /Users/kavyavanamamulal/Documents/apache-tomcat-8.5.28

JRE: Workbench default JRE

An outline is not available.

Figure 18. Adding Tomcat Server

This is the final step for installing tomcat application server through Eclipse. This allows a user to add or remove the application from the Tomcat application server. To add on to the server, select the application and click on the finish button, the app gets deployed. To run the server, right click and choose “Run” to run the application. Figure 19 shows how to add an application to the server and run it.

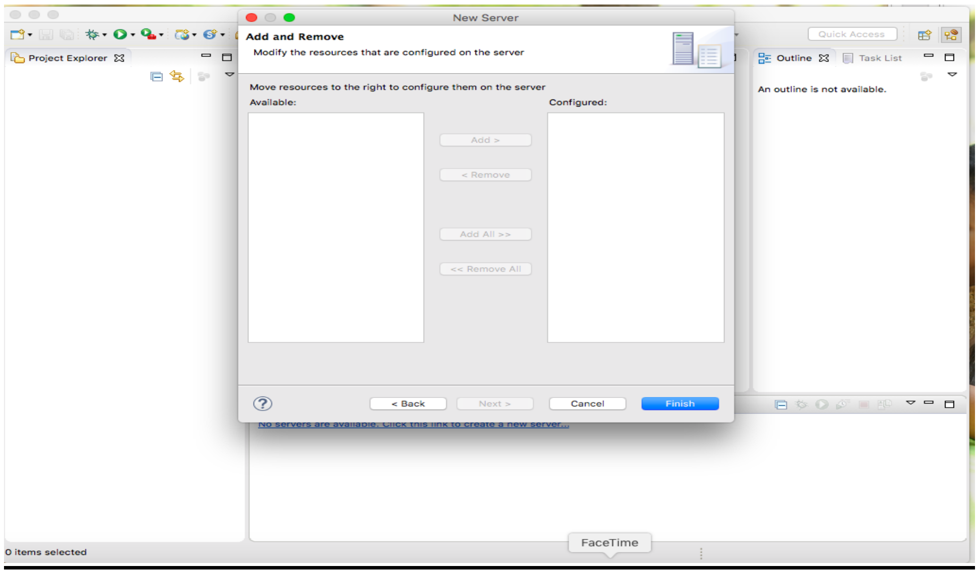

New Server
Add and Remove
Modify the resources that are configured on the server
Move resources to the right to configure them on the server
Available:
Configured:
Add >
< Remove
Add All >>
<< Remove All
< Back
Next >
Cancel
Finish
Project Explorer
Outline
Task List
Quick Access
An outline is not available.
No servers are available. Click this link to create a new server...
0 items selected
FaceTime

Figure 19. Add or Remove Application

Application Screen Shots

Registration page: Initially, the user must register in the application by providing their details regarding the name, email id, password, gender, and location to send secure messages to other users. While registering their details, a unique public key and the private key is generated to every user, using key generation and these details are saved. Figure 20 shows the registration page.

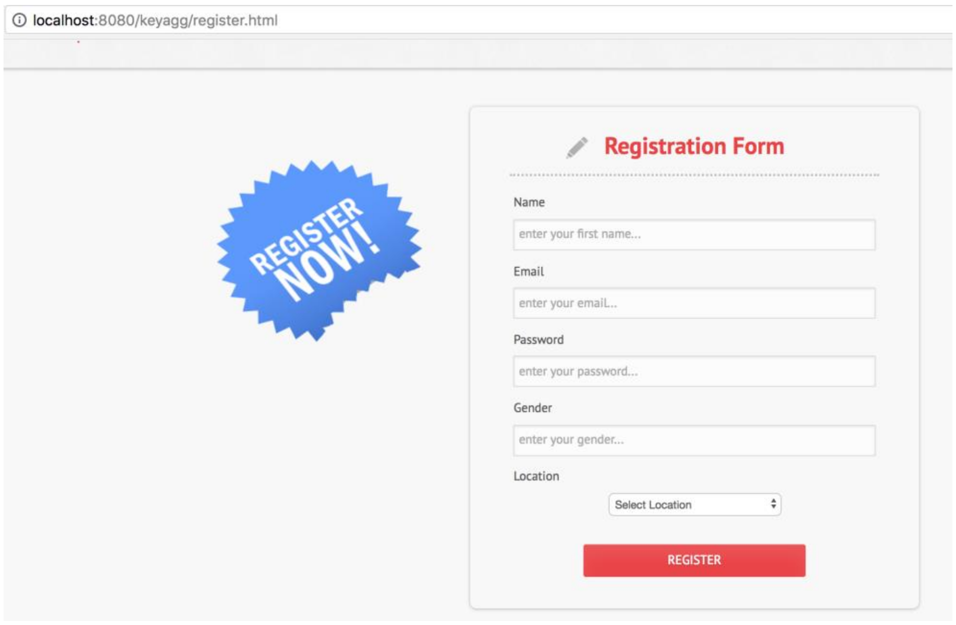


Figure 20. Registration Page

Admin login page: is screen is the admin login page. Here the admin must log in with their user credentials to manage the application. Figure 21 shows the admin login page, and Figure 22 shows the admin landing page.

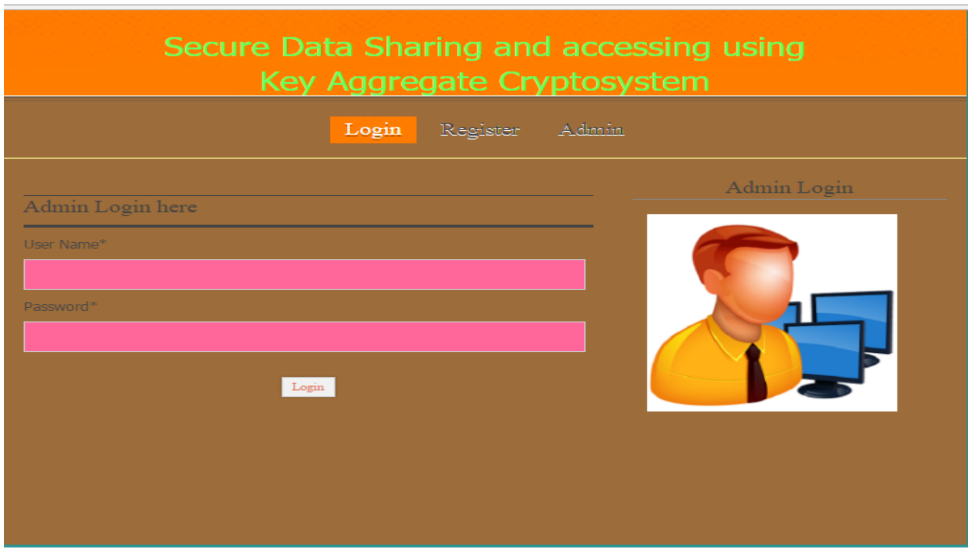
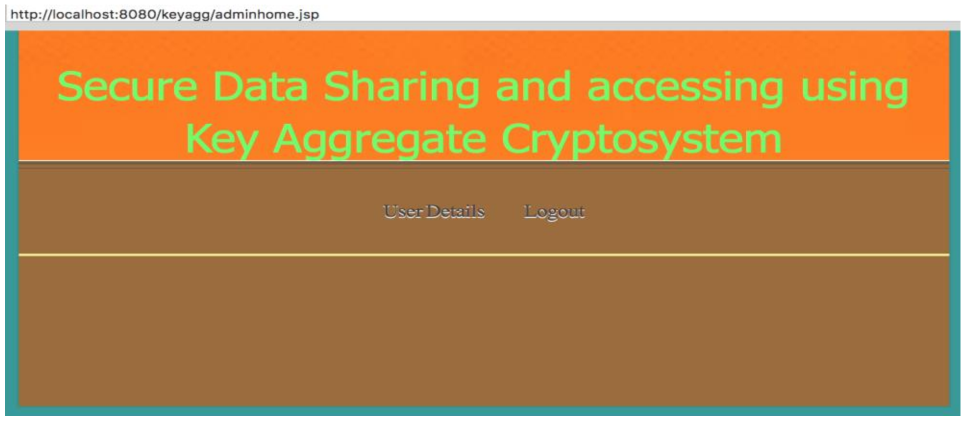


Figure 21. Admin Login Page

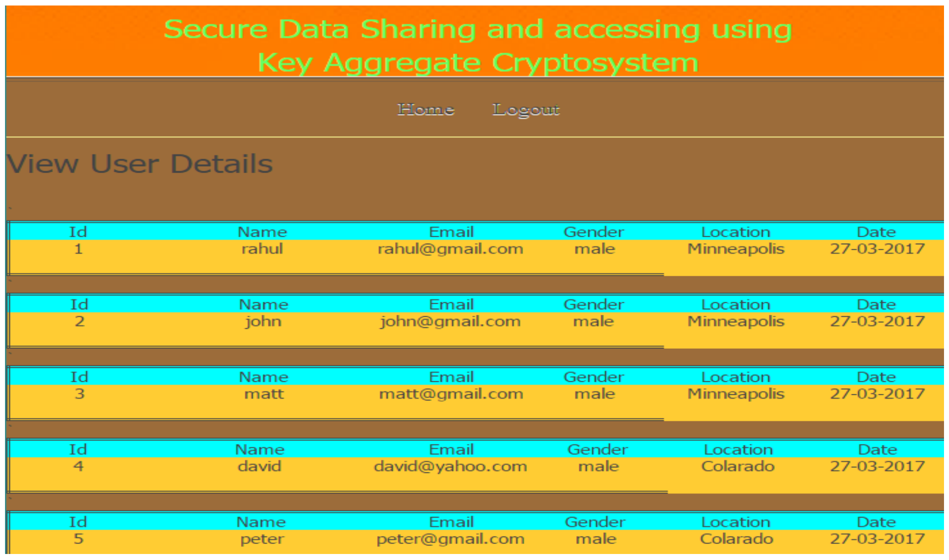


http://localhost:8080/keyagg/adminhome.jsp

Secure Data Sharing and accessing using Key Aggregate Cryptosystem

Figure 22. Admin Landing Page

Admin view page: This screen shows the what the admin sees after their login. Users need to register to use and share the messages. The admin is able to see the information regarding the list of users who are registered with the application and when they were registered. Admin has privileges to manage the list of users. They also have access to the home and logout button. Figure 23 shows the admin view page.



Secure Data Sharing and accessing using Key Aggregate Cryptosystem

View User Details

Id	Name	Email	Gender	Location	Date
1	rahul	rahul@gmail.com	male	Minneapolis	27-03-2017
2	john	john@gmail.com	male	Minneapolis	27-03-2017
3	matt	matt@gmail.com	male	Minneapolis	27-03-2017
4	david	david@yahoo.com	male	Colarado	27-03-2017
5	peter	peter@gmail.com	male	Colarado	27-03-2017

Figure 23. Admin View Page

User login page: After the user has registered with the application, the user needs to log in with their credentials that were provided during the registration time. If they provide only the correct credentials, then they will be allowed to log in. Figure 24 shows the user login page.

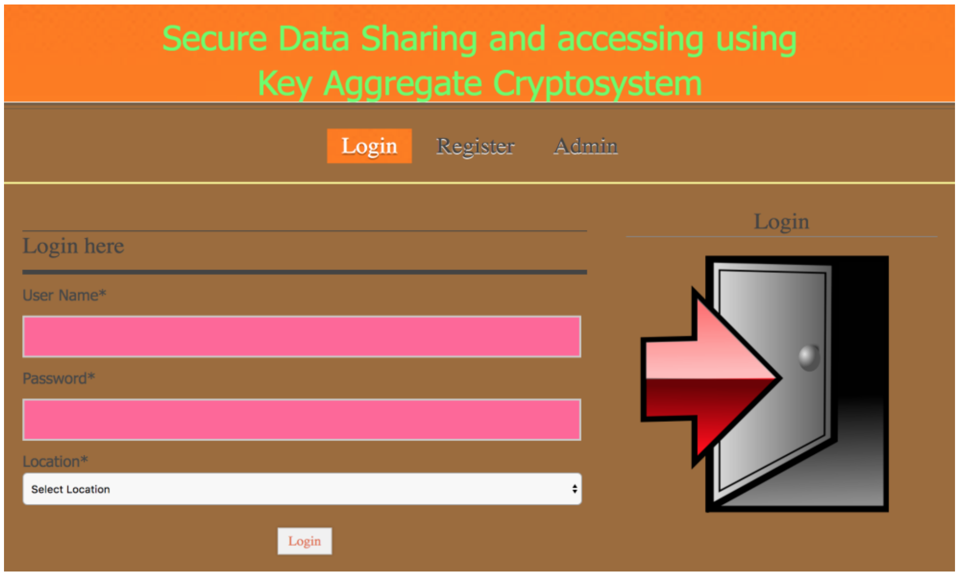
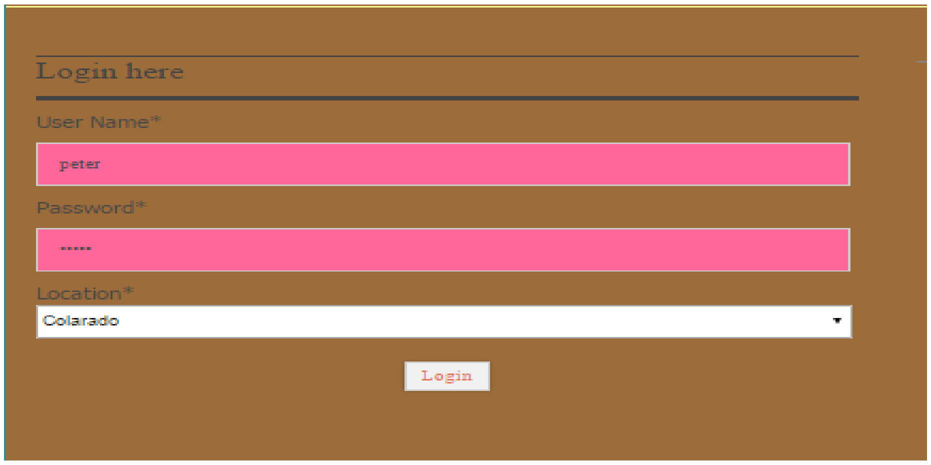


Figure 24. User Login Page

Below is the login for a user named Peter.

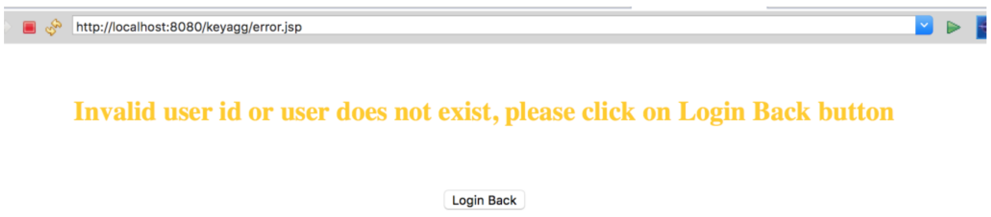

Login here

User Name*: peter

Password*: ••••••

Location*: Colarado

Verify user credentials: If Peter user enters incorrect login credentials, then he will not be provided access to the application. His credentials are compared with the values that are stored in the DB, and an error message is thrown, and the user will be redirected to the login page, by clicking on the login back button. Only the authorized users are provided access. Figure 25 shows the error message that is thrown.

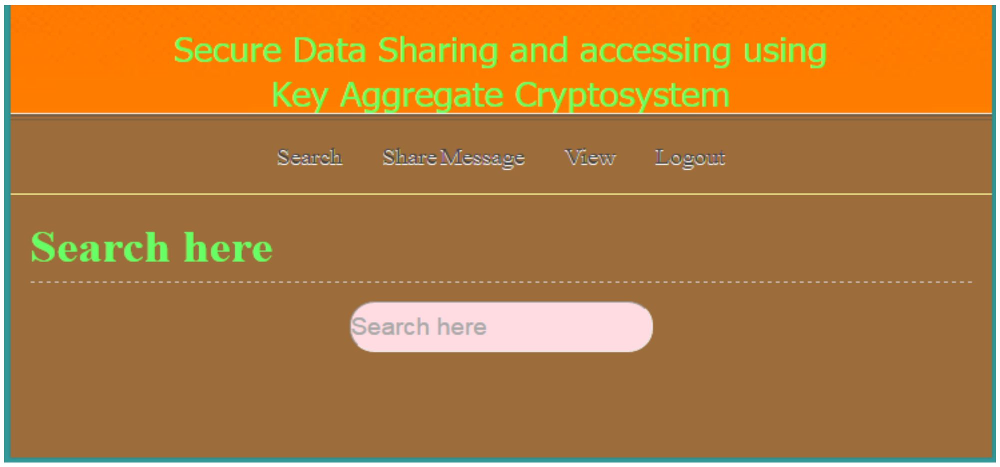


http://localhost:8080/keyagg/error.jsp

Invalid user id or user does not exist, please click on Login Back button

Figure 25. Verify User Credentials

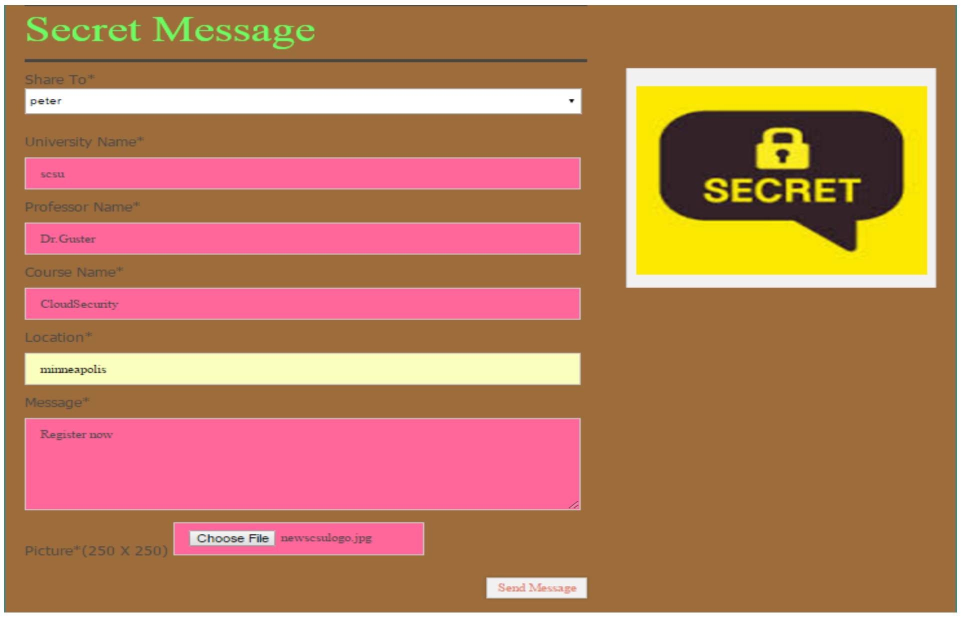
After login options: When a user successfully logs in using proper authentication, Figure 26 is the landing page. There they have various options to search, share, view and log out. Figure 26 shows after the login options page. Search is used to search for the received username. ShareMessage button is used to share the information regarding different fields to another user. The View message is to check the received messages.



Secure Data Sharing and accessing using
Key Aggregate Cryptosystem
Search
ShareMessage
View
Logout
Search here
Search here

Figure 26. User Landing Page

Secret message sharing values: Let us consider an example regarding the sharing of information between two users Peter and David. The user David wants to share some information regarding the university name, professor name, course name, location, and message this to Peter. The details can be seen below in the Figure 27. To send the message he must click on share message option. Once he clicks on the share message button, a secret message screen appears, and he can provide the required details in the secret message screen with a message or image that he wants to share.


Secret Message

Share To*: peter

University Name*: scsu

Professor Name*: Dr.Guster

Course Name*: CloudSecurity

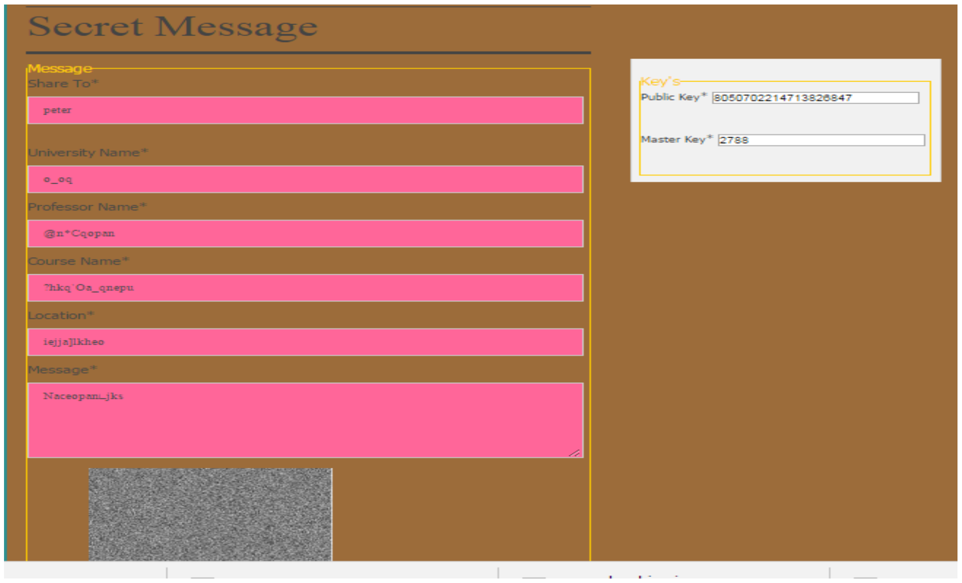
Location*: minneapolis

Message*: Register now

Picture*(250 X 250): newscsulogo.jpg

Figure 27. Secret Message Sharing Values

Secret message encryption: When David clicks the "Send Message" button, the information that he provided will be encrypted using symmetric encryption, and ciphertext classes are generated, and these ciphertext classes are then stored in the database. These cipher text classes are represented by integer message id 'M' and by using ElGamal encryption algorithm, this message id is converted into ciphertext and an aggregate cipher key is generated and it is sent to Peter. Figure 28 shows the message encryption.



Secret Message

Message

Share To*

peter

University Name*

o_oq

Professor Name*

@n*Cqopan

Course Name*

?hkq`Oa_qnepu

Location*

iejjajlkheo

Message*

Naceopan_jks

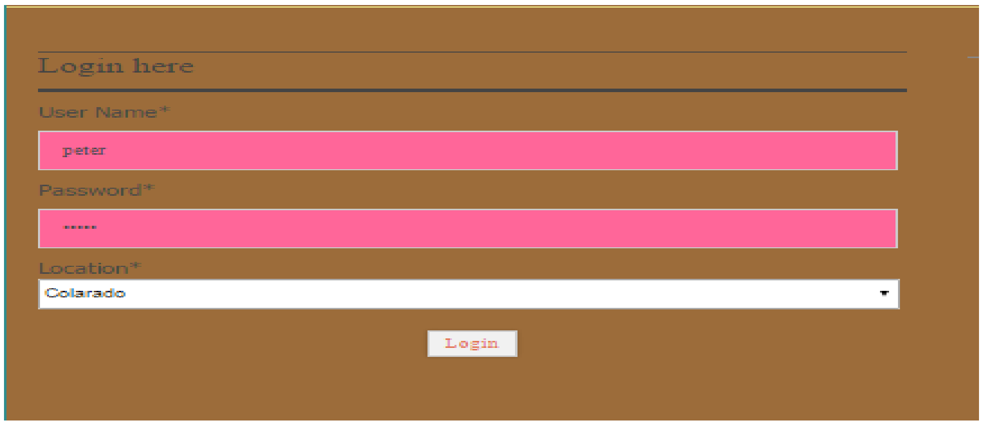
Key's

Public Key* 805070221471382684

Master Key* 2788

Figure 28. Secret Message Encryption

View shared details: Figure 29 shows Peter logging in to see the received message.



Login here

User Name*

peter

Password*

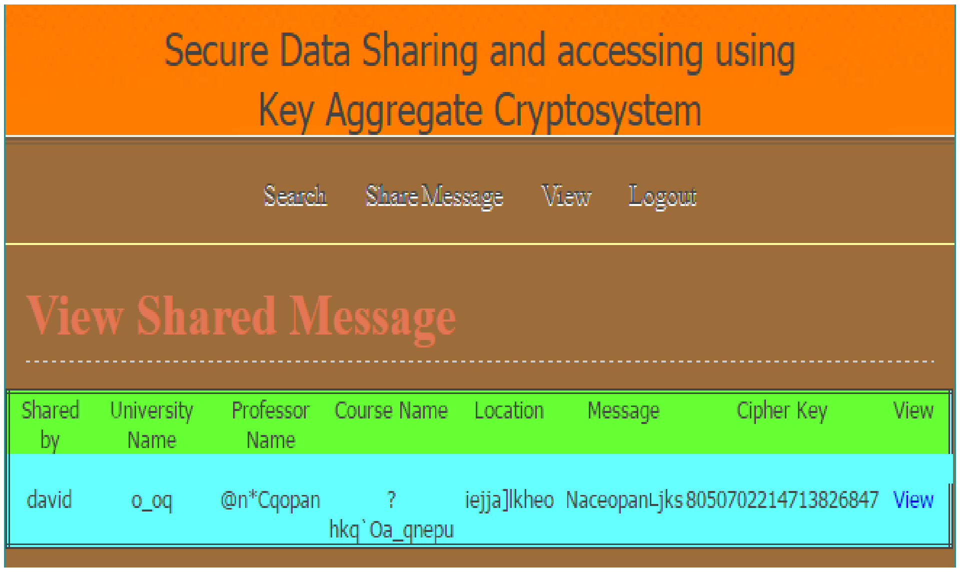
••••••

Location*

Colarado

Figure 29. User Peter Login

After logging in, the receiver is able to view the shared message. Figure 30 displays the view of the message. The information that David sent in the message, and which he received will be in an encrypted format. By clicking the view link in the message, he will be redirected to a new page where he needs to enter the key.

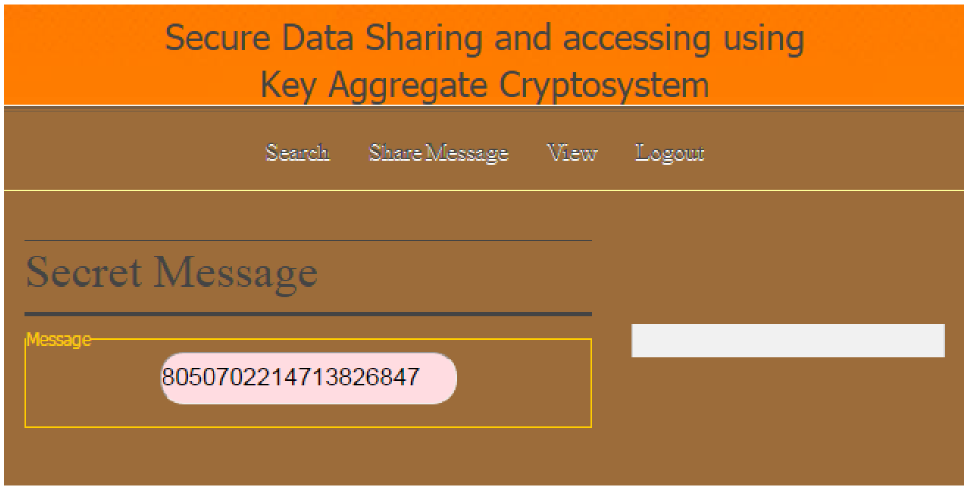

Secure Data Sharing and accessing using
Key Aggregate Cryptosystem
Search
Share Message
View
Logout

View Shared Message

Shared by	University Name	Professor Name	Course Name	Location	Message	Cipher Key	View
david	o_oq	@n*Cqopan	? hkq`Oa_qnepu	iejja]lkheo	NaceopanLjks	8050702214713826847	View

Figure 30. View Shared Details

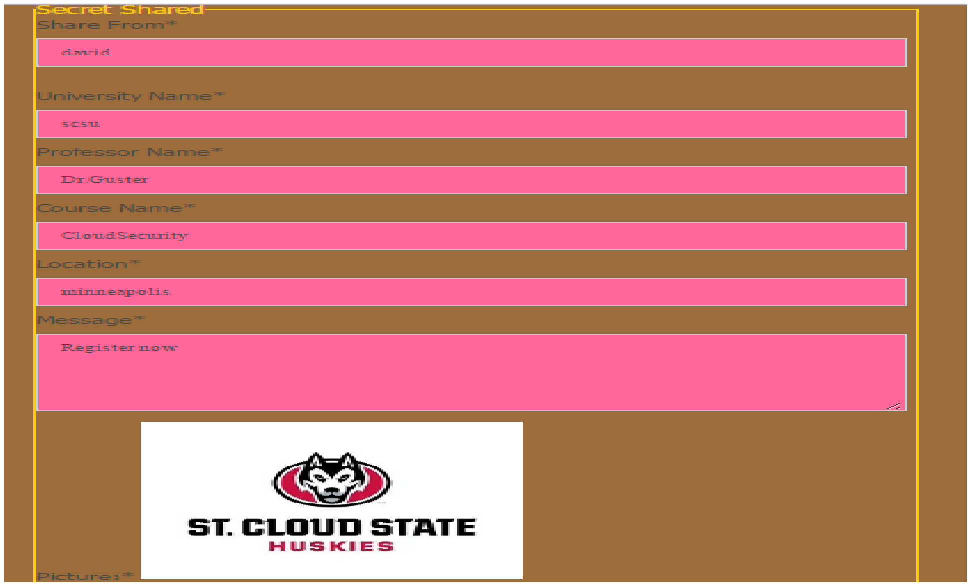
Decryption of data by the key: Peter needs to enter the aggregate key information that he has received in the message. When he enters the key in the secret message text field, it takes the input and the ElGamal decryption algorithm kicks in and the ciphertext of the message id ‘M' is converted into plaintext message id ‘M'. As the ciphertext classes are identified by this value ‘M', after the ElGamal decryption, these ciphertext classes are decrypted using the symmetric key decryption and the original plaintext details are received. Figure 31 shows the decryption of the details by the key.


Secure Data Sharing and accessing using Key Aggregate Cryptosystem
Search
Share Message
View
Logout
Secret Message
Message

8050702214713826847

Figure 31. Decryption of Data by the Key

Decrypted details: Figure 32 shows the information that is displayed after decryption. When user Peter enters the aggregate key, the decryption algorithm kicks in, and the encrypted data which is sent by David to Peter is decrypted, and the plaintext text information is displayed to Peter and the message is readable.



Share From*
david

University Name*
scsu

Professor Name*
Dr.Guster

Course Name*
CloudSecurity

Location*
minneapolis

Message*
Register now

Figure 32. Decrypted Details

Performing search: Users can also perform a search in the application using the names from which they have received the messages. To access the search page, the user needs to click on the search option provided in the user landing page. Figure 33 is an example where user Peter is performing a search by the name to see the received messages.

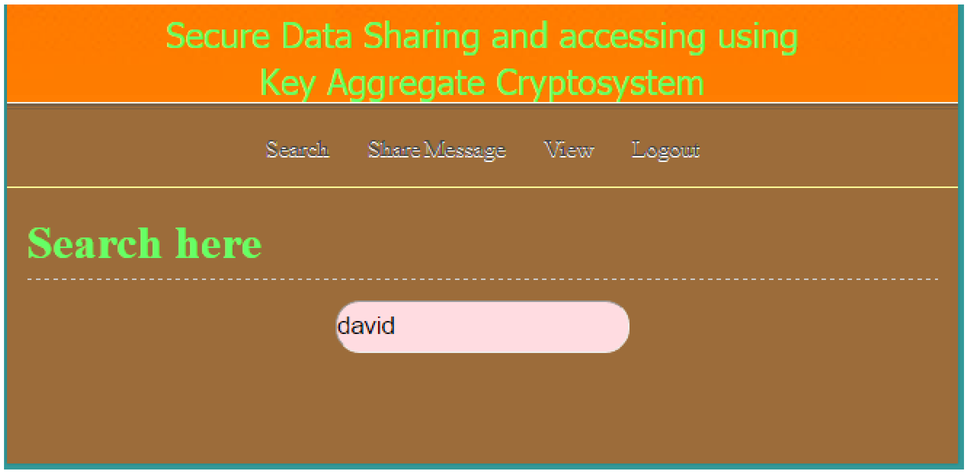
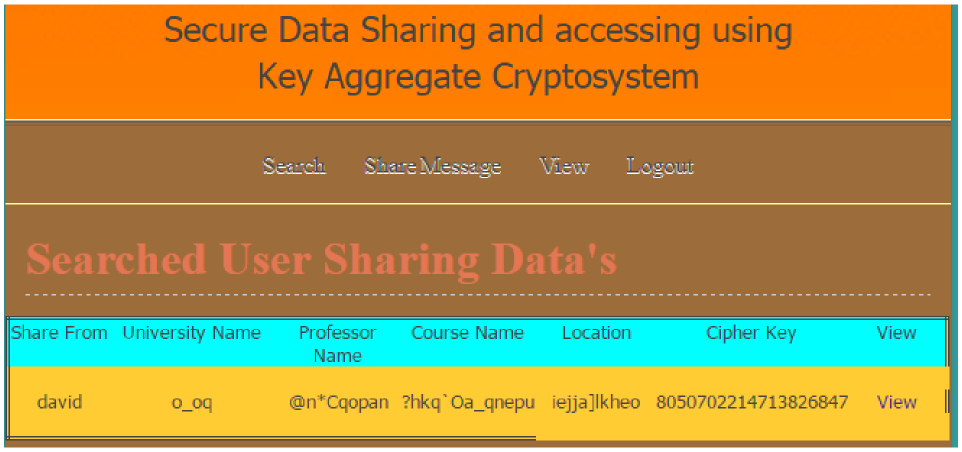

Secure Data Sharing and accessing using
Key Aggregate Cryptosystem
Search
Share Message
View
Logout
Search here
david

Figure 33. Performing Search

Search results page: Users can perform the search by providing the name in the search text box. If there are no received messages from the searched username or if there are any received messages from the searched username, in both the scenarios the user will be redirected to the search results page. Figure 34 shows the search results page of user Peter. In the search results page, the encrypted message that they received from other users is displayed. To decrypt the received message, the user needs to click on the “View” button, and when clicked they will be redirected to a new page, where they need to enter the aggregate key to decrypt and view the original message. Figures 30 and 31 are the screenshots that follow after clicking the “View” button.


Secure Data Sharing and accessing using
Key Aggregate Cryptosystem
Search
Share Message
View
Logout
Searched User Sharing Data's

Share From	University Name	Professor Name	Course Name	Location	Cipher Key	View
david	o_oq	@n*Cqopan	?hkq`Oa_qnepu	iejja]lkheo	8050702214713826847	View

Figure 34. Search Results Page

Chapter VI: System Design

UML Diagrams

UML Stands for Unified Modeling Language. UML is helpful in understanding and visualizing any system. The system can be a software program or a non-software unit. It helps in designing, modeling and getting the artifacts required for a system before it is developed or during the development process. It helps to understand the architecture, structural, and behavioral implementations of a software program. It can be applied in any phase of a software development lifecycle which helps to identify the requirements and to get the resources that are needed. It is a pictorial language that allows creating software blueprints (Tutorials Point, n.d.-b n.d.). It helps the business analysts, software architects, and developers to specify, describe, visualize, design and to document the existing or new business scenarios and to get the structural and behavioral artifacts related to the system. UML diagrams are classified into two types: based on the static behavior and dynamic behavior. In this section, the implementation using the diagrams like activity diagrams, sequence diagrams, and use case diagrams is also discussed along with the architectural design and the data flow of the system.

Architecture diagram. The architecture diagram shows the various components that are involved in the system and their dependency on each other. The users, admin, and database are the components that are involved, and each component performs a specific operation. The users exchange messages between themselves. The information and keys are stored in the database, and the admin can control users and view user details using the database. Figure 35 shows the architecture of the system.

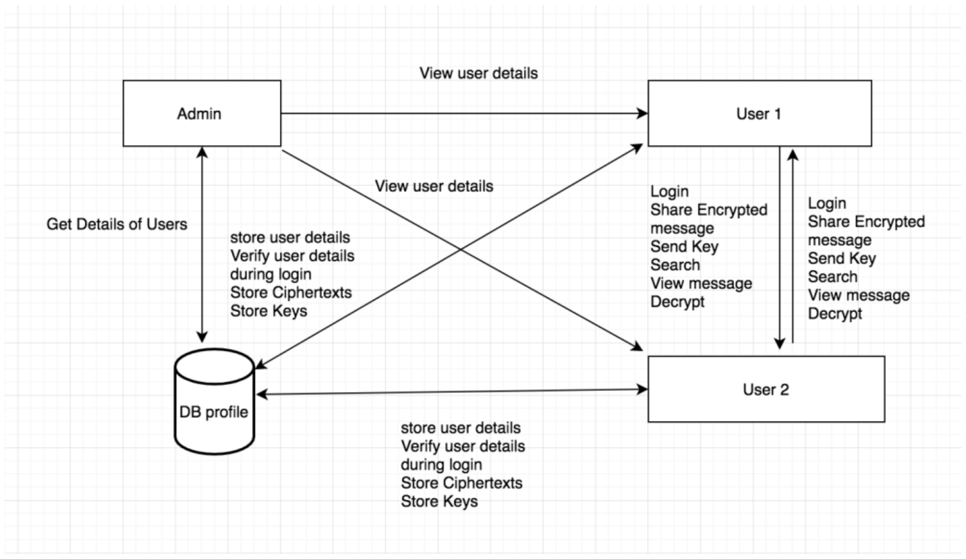


Figure 35. Architecture Diagram

Data flow diagram. Data flow diagram (DFD) is used to model a new system or an existing system. DFD is a graphical representation of the flow of data for a particular system or process (Data flow diagram, n.d.). It is also known as a bubble chart. It helps to visually represent things that are hard to explain in words and thus can be used for technical and non-technical people (Data flow, n.d.). It is used to identify various components that are present in the system and their interactions with each other and layout external entities that interact with the system and to map the flow of data in a system. Figure 36 describes the data flow for a sender. A sender after successful registration and login can send the encrypted message to the receivers along with the aggregate key. Figure 37 describes the data flow for the receiver. A receiver receives the encrypted message along with the aggregate key, shared by the sender. The user enters the key, followed by the decryption mechanism, which displays the original message to the user.

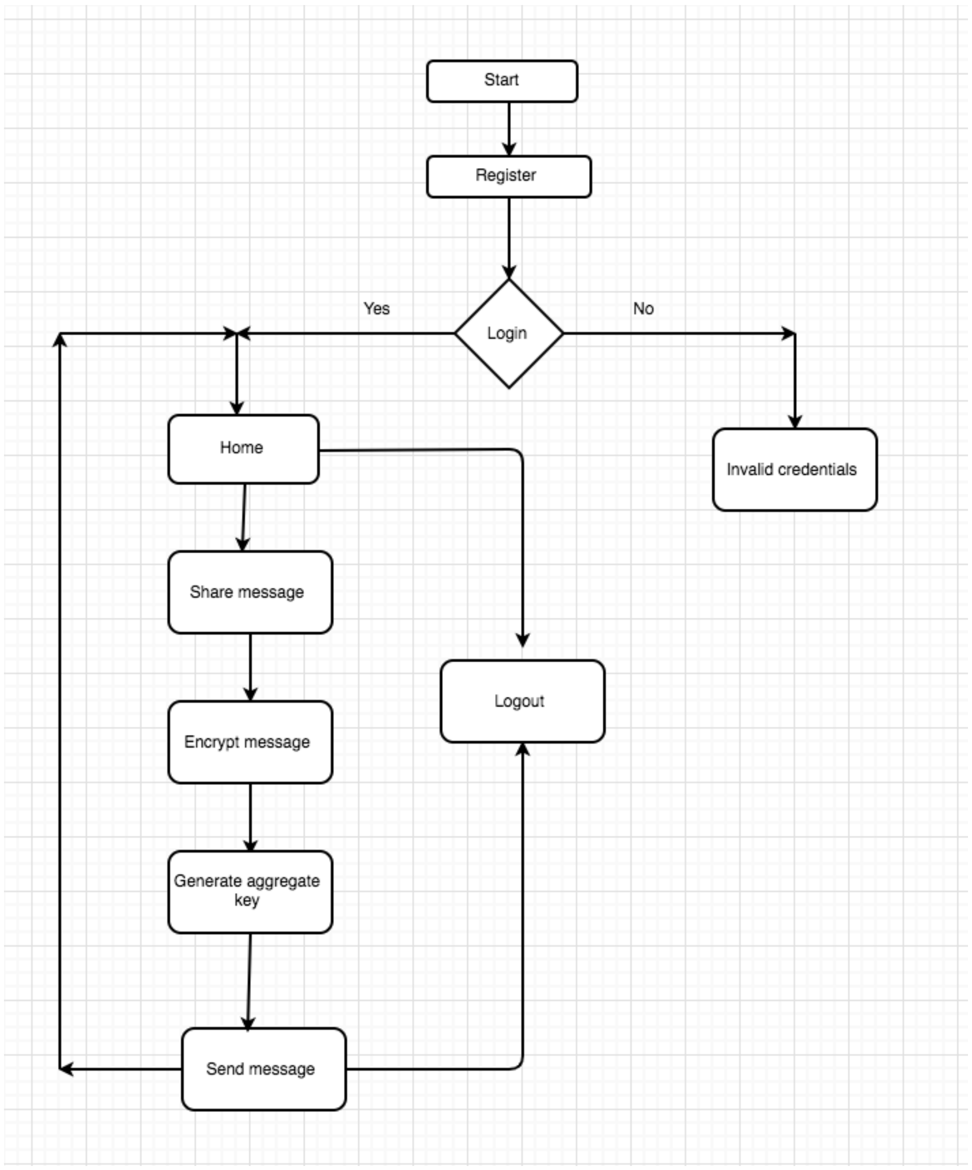


Figure 36. Data Flow Sender

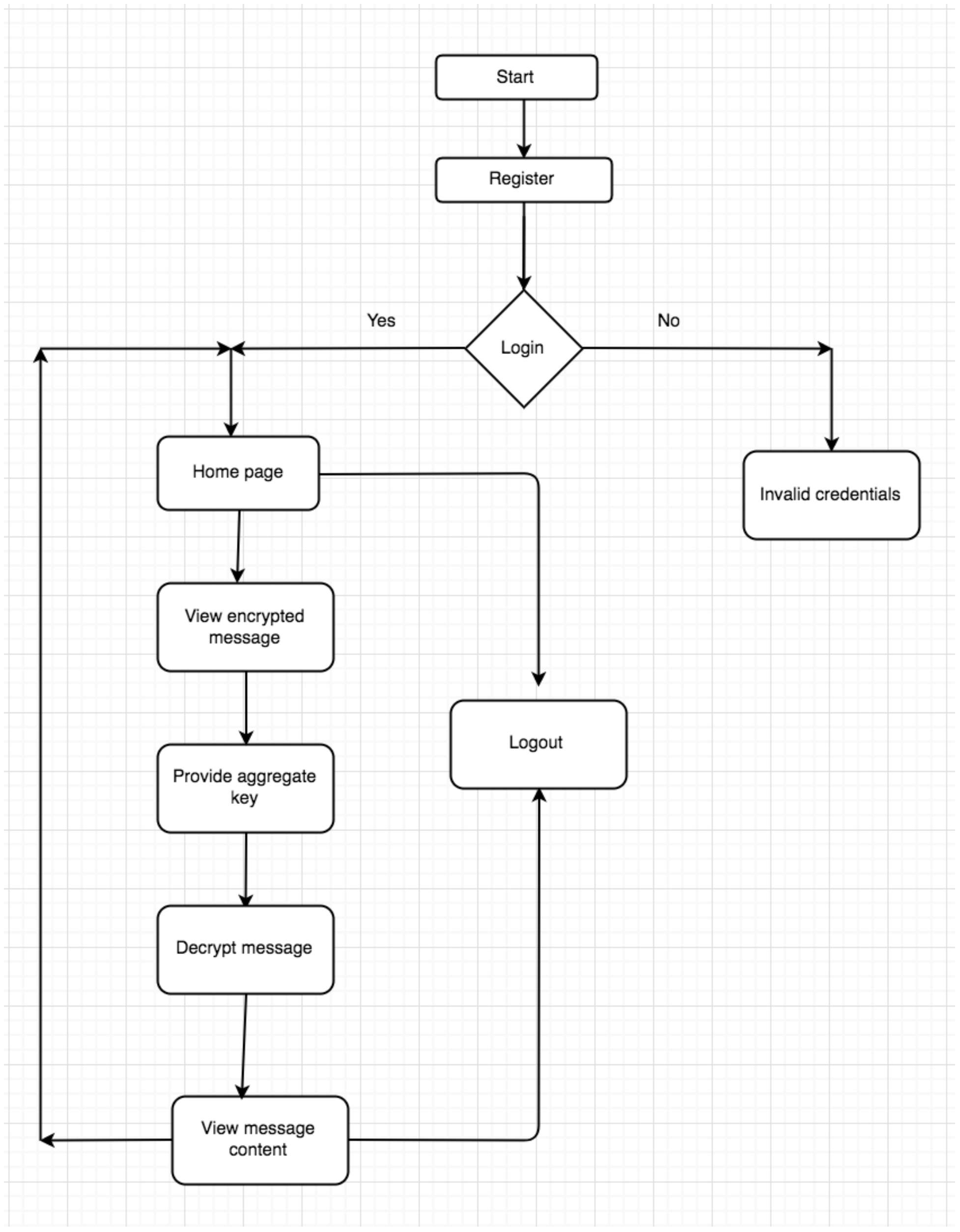


Figure 37. Data Flow Receiver

Use case diagram. A use case diagram is used to model the functionality of a system using use cases and actors. A use case diagram is a simple representation of a system which shows the relation between users and the use cases and the use cases in which the user is involved, interacting with the system. A use case diagram can be useful to design a system from the end user's perspective. It only summarizes the relationship between the use cases, actors, and the system but not show the internal mechanism or steps involved. The scope of the use case diagram is to capture (Tutorials Point, n.d.-c) requirements of a system, validate a systems architecture and to specify the context of the system involved. The use case diagram consists of the following components:

- Actor: An actor is the one who interacts with the system using some use cases. In a use case diagram, the actor is represented using a stick figure.
- Use case: A use case is a methodology used in which the system requirements are analyzed and gathered. Every actor involved in the use case diagram is linked to a specific use case.

Figure 38 shows the use case diagram, showing the interaction of two users with the system and the set of use cases involved.

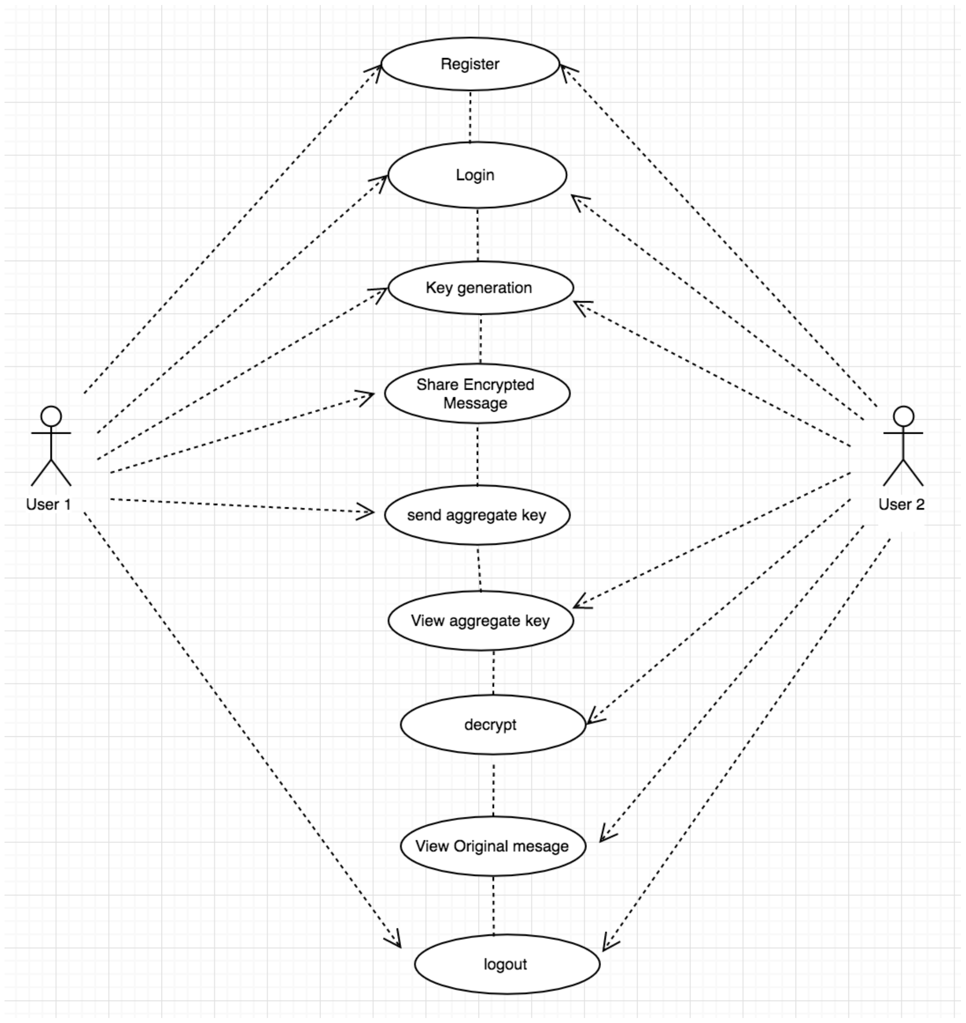


Figure 38. Use Case Diagram

Sequence diagram. A sequence diagram is used to show the high-level interaction between the objects that are present in a system and how the operations are carried out within a time sequence. It is a type of interaction diagram. Sequence diagrams are useful for the business and developers to understand the requirements of a new system or an existing one. These are sometimes referred as event diagrams or event scenarios. Different parts combine to form a sequence diagram.

- Actors: Actors are the entities or persons that interact with a system and are external to a system.
- Objects: Objects are the instances of a class which are arranged horizontally. Usually, they represented by a rectangle box with a name and followed by a semicolon
- Lifeline: Lifeline is represented by a downward line that projects the sequential events that happen to an object during the interactions.
- Activation: Activation is represented by a solid rectangle box on the lifeline, which shows the active time of the objects where it interacts with the system.
- Messages: The arrow lines between the objects, where objects interact with each other either synchronously or asynchronously. All of these components constitute the sequence diagram. Figure 39 shows the sequence diagram where different objects are interacting with each other.

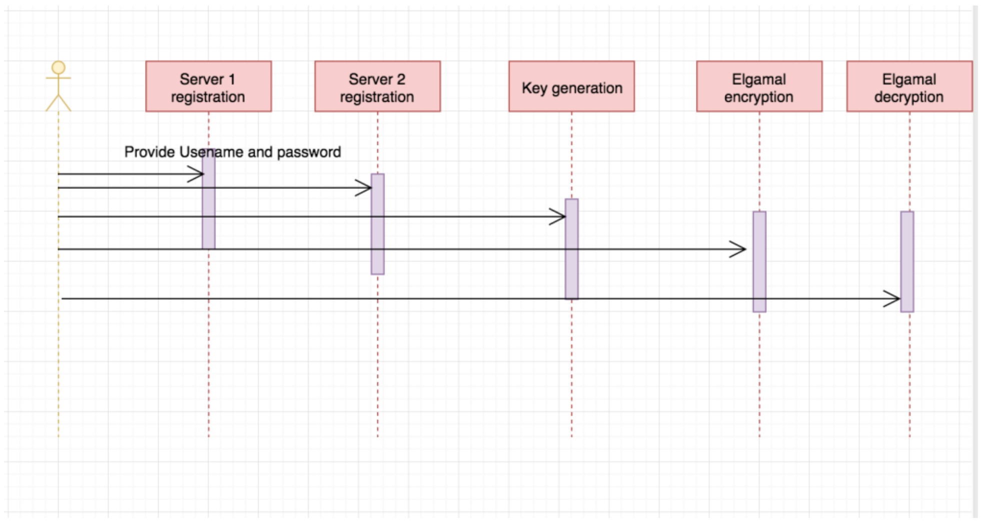


Figure 39. Sequence Diagram

Activity diagram. Activity diagrams are used to represent step-by-step the flow of a working of a system. They also serve dynamic aspects of a system. These are an advanced form of flow charts. They are used to represent the flow of data between one operation to another operation. They are primarily used to describe the complete flow of operations in a system and what happens after one operation and then another. Activity diagrams are constructed using a limited number of shapes where the rounded rectangle represents the action state, the black circle represents the start of a process, and the encircled black circle represents the final node or end of the process. The bars that are used to describe the fork and join operations that happen in a system.

Figure 40 shows the activity diagram and the activities that happen after a user is registered. After successful registration, the key generation takes place and keys are generated for each user, followed by the ElGamal encryption and decryption process to generate the aggregate key.

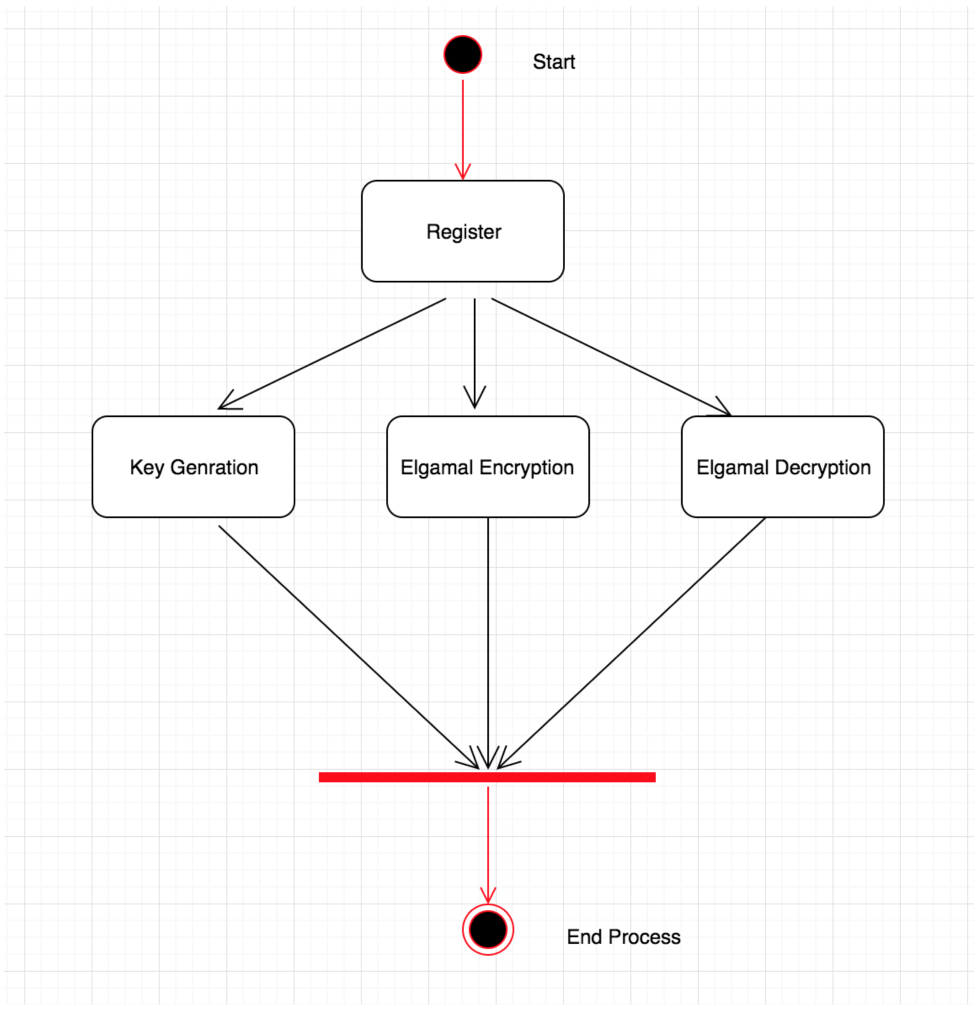


Figure 40. Activity Diagram

Chapter VII: Testing

Any application that is developed needs to be tested before it is used in the real world. Testing is essential to make sure that the developed application is working according to the desired requirement. Testing ensures the quality and suitability of the application. It helps to identify the defects, which are not found during the development phase by the programmers. This helps them to correct the code and making sure that the application is fit for use. Testing is a continuous verification and validation process.

Testing Types

There are many testing types, where each of them is used during a particular time of the development process or after that. Some of the testing types are as follows:

- Unit Testing
- Integration testing
- Functional testing
- Black box testing
- White box testing
- Stress testing
- Performance testing
- Usability testing
- Acceptance testing
- Regression testing

Each of the above testing types has their advantage and helps to identify the bugs. A brief overview regarding these is as follows:

- Unit testing. Unit testing is performed by the developer, during the development process of a feature. Developers perform the unit testing using the testing snippet for a function, to make sure that it is working correctly, by providing a valid input and thereby verifying the desired output. Performing unit testing is a best practice, and it also makes sure that there is 100% code coverage. Unit testing falls into the category of white-box testing.
- Integration testing**.** Integration testing ensures that all of the developed individual components when combined work accordingly. This testing is also performed by developers to ensure that all the components of an application work properly when combined and there is no breakage of code. An example for this is, when a request is passed to a web-service for any feature, it produces a response as an output. When the database is queried to access the data related to the same functionality, the information presented should be identical. This kind of testing is essential to test the modules that are present in different networks. Integration testing is a form of both black box testing and white box testing.
- Functional testing. Functional testing ensures that the functionality of a developed function is working correctly. To verify this, input data which is accepted by that function is passed and an expected output is desired. Functional testing is an example of white box testing.
- White box testing. White box testing mainly focuses on the internal mechanism of a system and verifies all the functions in the system works as expected. It is also known as glass box testing or transparent testing or structural testing. It validates the internal

code of the system. The appropriate input paths are chosen from the code base for the application and testing will be done according to that.

- Black box testing. Black box testing, in contrast to white box testing, neglects the internal workflow of the system and concentrates on the output of the system. The name is given because, the internal software or code is like a black box to the tester, which they cannot see. The black box testing can be classified into functional and non-functional tests, but most of the time they are functional. The advantage of the black box testing is that they can be done irrespective of the developer's area and there is no bias. Also, the tester does not need programming language knowledge to test and it can be tested from the users' perspective according to specifications and listed objectives. They can start working when a component is developed. To summarize, white box testing is used for verification, and black box testing is used for validation.
- Stress testing. Stress testing is a form of black box testing, and it is mainly used to test an application under immense pressure by providing unfavorable conditions like substantial input, more overload, and continuous requests. Many e-commerce sites use this mechanism to see how their application works when a large number of users access the site for a given period and at the same time.
- Performance testing. Performance testing is used to test the effectiveness, speed and fast data retrieval of a system and to check whether the system is generating results within a specific time period which meets its performance requirements. Load testing,

stress testing, endurance testing, and spike testing are types of performance testing. This comes under black box testing.

- Usability testing. Usability testing is a type of black box testing, to ensure how the developed product is easy to use. Testing is done from the end user's perspective to test the ease of use, ability to learn and understand, the design of the application, the attractiveness of the GUI and operational capability. This is very useful to check whether the developed application meets the client's requirements.
- Regression testing**.** Regression testing is essential testing that is performed in the software environment. It is mainly used to check any new enhancements, modifications or fixes have not broken the existing code and to check everything works accordingly. It can be done during any phase of the testing process. It does not involve writing new test cases, but the old ones are rerun to see if there are any changes. Regression tests help to identify the coverage area of the tests. In an agile IT environment, regression testing is of high value. Usually, there are many automation tools which are available, and they are used to do the testing. Daily, weekly, and monthly regression runs are performed, the reports are generated, and the results are analyzed.
- Acceptance testing. Acceptance testing is done by the end users where the developed project is according to the business requirements. It is also referred to as user acceptance testing. It is the last level of testing performed. The end users may conduct themselves or customers of the organization or internal members of an organization.

Testing Implemented for the Project

1. Tested the UI fields accepting input for the username and password.
2. Tested the UI fields accepting input for the admin login and password.
3. Tested proper login, logout mechanism for admin and users.
4. Tested proper authentication of admin and users and displaying error messages.
5. Tested the data workflow between different pages.
6. Tested user options and pages displayed for each user.
7. Tested admin view options and pages that need to be displayed.
8. Tested proper database connection with inputs properly stored and displayed.
9. Tested fields in the pages available for users to provide data.
10. Tested encryption mechanism when user shares the data.
11. Tested generation of keys happening when the user shares the data.
12. Tested incoming messages, when user shares the message.
13. Tested decryption mechanism is happening when the user enters the appropriate key.
14. Tested the search functionality of the user to search using a different username.
15. Tested the application functionality in negative and positive scenarios.

All the scenarios have passed the tests and are working according to their designed functionality.

Chapter VIII: Conclusion

Conclusion

In the present world, the sharing of the data between the users without any data leakage has become a big challenge. Data sharing services are one of the essential functions provided in cloud computing. Data in the cloud is of greater importance and needs to be protected from unauthorized access. In this paper an efficient method is analyzed to avoid any data leakage. Usually, the data is stored in an encrypted format, which will make the data storage in the cloud more secure. However, the problem comes while sharing the encoded data and providing the decryption rights to the users. An analysis and implementation are provided to share the encrypted data to the end user. In this proposed implementation, encryption processes are done at two places one at the time of storing and another at the time of sharing. The users who share their secret messages should also need to know the decryption process. In the proposed paper, a set of decryption keys are aggregated and sent to the end user. One must decrypt the data with the aggregate key to see the original text. By this policy of encryption and decryption, it will effectively increase the secure manner of communication and provides successful delegation of decryption rights to the intended user over the ciphertexts that they are authorized to view. The implemented application has been tested in various scenarios and executed successfully.

Limitations and Future Work

The limitation of the implemented system is that the aggregate key is sent directly to the intended receiver along with the shared encrypted message. Although the key will only be sent to the authorized user, an improvement for this can be transmitting the key through a secured channel like an email. One of the limitations is the predefined bound concerning the maximum number of ciphertext classes. For future work, enough ciphertext classes should be reserved because when it is implemented in cloud storage, the number of ciphertexts increase rapidly. In this implemented system, the ElGamal algorithm is used for encryption and decryption. In future, more secure and efficient algorithms can be used to cope up with the speed and security requirements. User revocation and access controls are important security measures implemented in the cloud. An aggregate key system incorporated with user revocation (Gan, Wang, & Wu, 2017) provides enhanced security to the existing system. However, storing the assigned keys in a mobile device with no trusted software may result in the disclosure of the key. Designing a leakage resilient cryptosystem (Wang & Zhou, 2016) which provides efficient access of keys is another area of future work. An Intrusion Detection System (IDS) can also be used to monitor the network and to detect security breaches while sharing the data. Implementing a key aggregate cryptosystem with an IDS is also an interesting direction of future work that can be investigated (Kumari & Lakshmi, 2014).

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