

A Fully Distributed Secure Approach using Nondeterministic Encryption for Database Security in Cloud

Mr.Srinu Banothu^{1*} A. Govardhan² Karnam Madhavi³

¹Research Scholar, JNTUH,
Assistant Professor, Dept of CSE, Vignan Institute of Technology and Science, Hyderabad, India

²Professor & Rector, Dept. of CSE, JNTUH, Hyderabad, India

³Professor, Dept of CSE, GRIET, Hyderabad, India
Email: bmadhaviranjan@yahoo.com

*Correspondence Author: Srinu Banothu

Summary:

Database-as-a-Service is one of the prime services provided by Cloud Computing. It provides data storage and management services to individuals, enterprises and organizations on pay and uses basis. In which any enterprise or organization can outsource its databases to the Cloud Service Provider (CSP) and query the data whenever and wherever required through any devices connected to the internet. The advantage of this service is that enterprises or organizations can reduce the cost of establishing and maintaining infrastructure locally. However, there exist some database security, privacy challenges and query performance issues to access data, to overcome these issues, in our recent research, developed a database security model using a deterministic encryption scheme, which improved query execution performance and database security level. As this model is implemented using a deterministic encryption scheme, it may suffer from chosen plain text attack, to overcome this issue. In this paper, we proposed a new model for cloud database security using nondeterministic encryption, order preserving encryption, homomorphic encryption and database distribution schemes, and our proposed model supports execution of queries with equality check, range condition and aggregate operations on encrypted cloud database without decryption. This model is more secure with optimal query execution performance.

Keywords:

Cloud Computing, Database-as-a-Security (DaaS), Cloud Service Provider (CSP), Database Security.

1. INTRODUCTION

Cloud computing is a technology, provides various remote services on a pay and use basis. The cloud services are broadly categorized into three types:

1) Software-as-a-Service (SaaS) 2) Platform-as-a-Service (PaaS) 3) Infrastructure-as-a-Service (IaaS), the prime example of SaaS is Database-as-a-service (DBaaS), it allows organizations and end users to easily outsource their databases and computations and access data whenever and wherever required through any device connected to the internet. DBaaS provides organizations with unlimited data storage services cost-effectively with higher availability and easy deployment.

A) DBaaS Architecture

The cloud database setup is shown in architecture that the cloud database is hosted by various cloud service providers and available over public cloud network to be rented out, use it as a service. The architecture of DBaaS is shown in figure 1, Cloud databases offerings bundle together a package of database management services, where organizations no need to deploy and manage their database servers and infrastructures, databases are hosted and managed by a third party and accessed by users on the cloud across the globe on pay and use basis. In which any organization or individual user run the application and upload or retrieve the data from cloud databases.

B) Benefits of DBaaS

There are many factors, demanded need for cloud database services and the following are benefits of it.

- Highly Scalable: Infinity data storage capacity

- Cost-Effectiveness: this is a major advantage, only pay for what we use, cost of hardware and networking also eliminated
- For businesses struggling to manage their data, the cloud can provide a low cost alternative to investing in the infrastructure to manage it all at their sites
- For DBaaS, the organization pays for what it uses and time it uses, this is also a big advantage to the cloud database service users

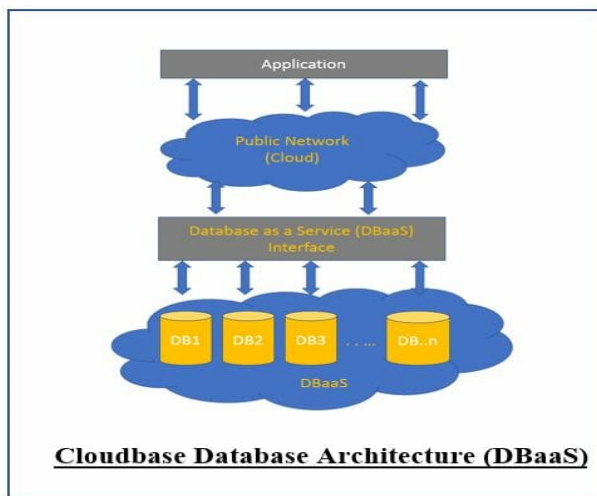


Figure 1. Database as-a-Service Architecture

Along with benefits, there are some challenges also in DBaaS, the biggest challenge is data security and privacy in the cloud environment. Now a day's most organizations or individuals are outsourcing their databases to the cloud environment, the amount of sensitive data stored in the cloud is increasing day by day; hence it should be protected from malicious parties. It introduces new challenges regarding database security and privacy. The major threats to user data are 1) protecting data from external attackers 2) protecting data from cloud service providers. Security and privacy to cloud databases can be provided using 1. Data Distribution Approaches and 2. Data encryption techniques. Authors contributed their work to protect cloud databases from malicious attacks, few of them used data encryption methods and others used data distribution methods. In this paper we proposed a new model for cloud database security using a combination of data encryption and data distribution approaches, the basic idea of our proposed method is initially all the

tuples of a relation are encrypted using AES-CBC-256 algorithm using random initialization vector and a secret key, it outputs nondeterministic cipher blocks for the same plaintext block and then the relation is partitioned vertically with selected columns into two or more fragments and store these fragments of tables into different database instances of the same cloud environment and also one additional index column is added to each table fragment, index column is encoded with the hash function, to retrieve the tuple values, a query will be sent to all database instances, processed on encrypted database tables, the result returned to the user is in an encrypted format, the user will decrypt the result using a secret key. Our proposed method addresses the data confidentiality and availability issues of the cloud database and reduces the query processing time to access the data from the cloud database. The remaining part of this paper discusses the concepts: section II covers related work, section III explains the proposed model methodology, section IV Results and Implementation and section V covers conclusion and future scope.

2. RELATED WORK

In 1978, Ronald L. Rivest et al. [1] introduced encryption is a well-known technique for preserving the privacy of sensitive data, and also presented the limitations of the model. The authors also demonstrated an application that how to protect and access a small loan company data, which uses a commercial time-sharing system to store the records of loan company data bank. For data encryption, privacy homomorphism techniques are used in their model. Also introduced some sample privacy homomorphism, some of them are weak cryptographically and a "chosen ciphertext" attack may break them.

In 1981, George Davida et al. [2] proposed a model for database encryption using sub-keys, the basic idea of this scheme is database is encrypted using the Chinese Remainder theorem which satisfies some of the required properties such as security, speed, record level encryption, and attribute based data access by users using distinct sub-keys.

In 2002, Hakan Hacigumus et al. [3] proposed a model to address the problem of data to be protected from database service providers and also proposed a technique to execute SQL queries over the encrypted database. Introduced a database encryption algorithm for the full SQL query. The basic concept of the algorithm is first, every tuple of a relation must be encrypted with a secure encryption algorithm, then perform weak encryption to some of the attribute values, it is performed by mapping attribute plain text values into a certain interval and encrypting that interval by a secret permutation. Then these weakly encrypted attribute values are appended to the actual ciphertext. Therefore different plaintext values may be mapped to the same ciphertext. But the information available in the plaintext may be destroyed a little bit, but this is not the same as in an ordinary encryption scheme. With small post-processing, the remaining information (like the number of tuples of the table, or which tuples have similar values in which secret attributes) is sufficient to query the encrypted database.

In 2006, Evdokimov et al. [4] introduced a new security definition for Database Privacy Homomorphism, the idea is the construction of database Privacy Homomorphism based on a searchable encryption scheme, in this scheme initially, create some words, those are strings of the same length and then identify the attributes of the relation. Then bijectively convert the tuples of the given relation to the sets of words or documents. The number of words in each document is the same as the number of attributes in the relation. The globally fixed word length is equal to the length of an attribute identifier plus the length of the longest attribute value. Then documents are stored on a remote server by encrypting using a searchable encryption scheme. To apply an exact select query on the encrypted relation, queries will be converted into the search operation and processed as a search operation, returning a set of encrypted strings. The strings are then decrypted and converted into the corresponding tuples. It is a generic construction for a database PH, this can be proved to be secure in a relaxed way, but still requires rigorous and plausible sense under widely accepted cryptographic assumptions.

In 2012, Dongxi Shenlu Wang et al. [5], contributed work for secure query processing over the encrypted

database, it is named as programmable order-preserving indexing scheme. This scheme is built over simple linear expression of the form $a*x+b$, the form of expression in public, 'x' is the input value and coefficients 'a' and 'b' are kept secret (not known to attackers). By using linear expression the indexing scheme maps input value 'x' to $a*x+b+noise$, where noise is a random value. If noise is carefully selected then the order of input values is preserved. This indexing scheme allows the programmability of basic indexing expressions, in which users can select different linear expressions for different input values for indexing input values. Programmability improves the robustness of the scheme against brute force attacks since there are more indexing expressions. This scheme is used to process range queries over the encrypted database and it only depends on linear expression, so that it is easy to understand by the users. The problem with this scheme is more processing overhead as different linear expressions are used to create indexing for different input values.

Authors in [6] proposed a model for cloud database security in Database-as-a-Service; it provides data privacy and security using data distribution techniques instead of data encryption. This technique is used by the existing netDB2 service. It is based on the multiple service providers and secret sharing algorithm, the basic idea of secret sharing method is to distribute data to multiple servers to ensure the privacy of user queries. If the user wants to outsource data from a data source (D) to database service providers (DBS1, DBS2, ..., DBSn), data is partitioned into n shares and n shares will be stored in n DBS. If the user wants to retrieve the data from DBS, the query will be sent to all DBS and data received from all DBS will be merged and the result will be sent to the user. To reconstruct secret value V_s at data source D, the knowledge of any K can refer to V_s besides some secret information X that is known only to the data source. Therefore with the full knowledge of $(K-1)$, DBS will not have any knowledge of V_s , even if X is known to them. In this model, data source (D) selects a random polynomial equation $q(x)$ of degree $(K-1)$, where the constant is V_s . Each DBS has constant V_s and X which is a set of n random points. The problem with this model is the availability of all DBS. If any one of the service provider's server is down, data cannot be retrieved and

another problem is the computational complexity of n random polynomial equations for different n values. Another issue identified in this model is authors only considered numeric data for encryption, doest talk about non-numeric data.

In 2017, authors in [7] recently proposed a model for cloud database security to improve security level, this model provides security to a cloud database using a combination of data distribution and data encryption techniques. This model uses two types of clouds one is master cloud and another is slave cloud, the master cloud stores the entire database encrypted using some encryption algorithms and the slave cloud stores the extended columns (i.e. vertically fragmented columns) of relation. Keys are not revealed to master cloud service providers. In this model, when a relation for master cloud is created, one additional column is added for storing the indexes of each tuple in that relation. The index column stores the indexes of the tuple in plain text format so that the user can query the relation through that index to access the desired tuples. The index is replicated in each fragment stored in the slave cloud. Here master cloud is a private cloud because it is available within the enterprise limits, it actslike a proxy server, the task of the proxy server is to create relations, insert, delete, encrypt, decrypt and process the queries. The problem with this model is that since it maintains a private cloud locally in the enterprise environment, the same infrastructure has to be established and maintained locally as public cloud, so there is no benefit of cloud service reflected. Another issue is all slave cloud servers must always be available to retrieve the data by users. If any one of the slave cloud servers is down data can't be retrieved, so losing on-demand cloud service. And also increases query processing time to access the data as the query has to be split forwarded to all the slave clouds.

3. METHODOLOGY

In our model, three entities are involved 1. Data Owner 2. Data user and 3. Cloud Service Provider (CSP) or Cloud vendor and the basic architecture of secure Database-as-a-Service (DaaS) modelis shown in figure 2, in which the Data owner outsources databases encrypted using the secure secret key to CSP, then data owner

shares the secret key securely to data users through a secure channel, CSP stores the encrypted database, and process the query requests received from data owner or user on an encrypted database. Data users send the query to process on the encrypted database without decryption to CSP, then CSP processes the query and returns the results to the data user.

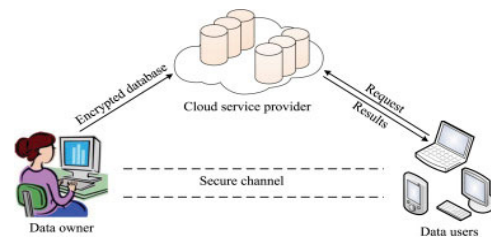


Figure 2: Basic Architecture of Secure Database-as-a-Service (DaaS) model.

In our proposed model we are using the following database encryption schemes in combination with the data distribution approach for enhancing database security in the cloud.

A. Encryption Schemes

Traditional Encryption schemes provide strong security guarantees, such as symmetric encryption algorithms like AES, DES, etc. However, when these traditional encryption schemes are used for database encryption, leads to unavoidable database search and processing problems, those are mainly three types: Equality check, Order Checking and Computability.

Equality Checking: Whenever plaintext data in the database are encrypted using a traditional encryption scheme, the same plaintext blocks may be mapped to different ciphertext blocks if different keys or initialization vectors are used. So that it is very difficult to search text.

Order Checking: When numeric data values are encrypted using a traditional encryption scheme, it losses the order of numeric data, so it is very difficult to search order of data, due to this range queries cannot be applied tothe database.

Computational problem:When plaintext data is encrypted using traditional encryption algorithms, we

cannot perform operations like addition or multiplication on ciphertext data. Due to this queries with aggregate functions cannot be applied to the database.

To overcome the above issues, we are using three categories of algorithms in our proposed model, so that we can execute range and aggregate queries on encrypted cloud databases without decrypting the database tables.

- Nondeterministic Encryption
- Order Preserving Encryption
- Homomorphic Encryption

Nondeterministic Encryption: The non-deterministic encryption scheme maps the same plaintext blocks to different ciphertext blocks, whenever plaintext is encrypted using traditional encryption algorithms like AES-CBC-256 using a secret key and a random initialization vector value using Cipher Block Chaining (CBC) or Cipher Feedback (CFB) modes. So that it is protected from Chosen Plaintext Attack (CPA). In our proposed model, we used the AES-CBC-256 algorithm for database table encryption, since it is more secure and efficient.

Order Preserving Encryption: The order preserving encryption scheme is used for encrypting numeric data in database relations because it preserves the order of data in the ciphertext. For example if v_1, v_2 are two integer values and if $v_1 < v_2$, then it holds the order that $\text{Enc}(k, v_1) < \text{Enc}(k, v_2)$, where 'k' is a secret key and $\text{Enc}(k, v_1)$ is the encrypted values of v_1 using secret key 'k'. So that range queries can be executed efficiently and securely on the encrypted database without decrypting. It avoids the order checking problem. We used the most popular order preserving encryption scheme used in [8-10], in our model for numeric data encryption.

Homomorphic Encryption: Cipher outputs from homomorphic encryption are more secure and all aggregate operations like sum, sub, min, max and average operations are performed on them without decrypting. For example, if x_1, x_2 are two plaintext values then $E(k, x_1) * E(k, x_2)$ is equal to $E(k, (x_1 * x_2))$ and $D(k, E(x_1 * x_2))$ is equal to $x_1 * x_2$, where $E(k, x)$ is the encryption of plaintext values using secret key 'k' and $D(k, C)$ is the decryption of ciphertext C using secret key 'k'. So it holds the multiplicative homomorphic property. This encryption scheme is designed for executing aggregate SQL queries on ciphertext blocks

without decrypting them. In our model, we used the homomorphic encryption scheme in [7]. This homomorphic scheme is very efficient

B. Proposed model Methodology

First, database relations are encrypted using appropriate encryption schemes, then relations are vertically fragmented with selected columns of relations (i.e. column selection for table partition is based on data sensitivity level) and stored in cloud databases. Two types of databases are used, one is a master database and another is a slave cloud database, master database is used to store the metadata information in the data owner environment, slave cloud databases are used to store the fragmented tables. The metadata in the master database includes the relations with fields like relation name, column names and database name; this is required for data owners and data users for easy retrieval of data from cloud databases. For data encryption, AES-256-CBC uses a secret key and a random initialization vector is used for nondeterministic ciphertext blocks so that the same plaintext blocks are mapped to different ciphertext blocks using the same secret key. It provides very good data confidentiality and high security to the data with optimal database encryption time, and we used Order Preserving Encryption (OPE) scheme for executing range queries over encrypted cloud database, homomorphic encryption for aggregate query execution over encrypted cloud database and also used the hashing encryption scheme for equality condition checking i.e. blind index, this model is called as fully secure distributed approach (FSDA) using the blind index. The methodology of my proposed model:

- First, additional columns are added in cloud database relations, one for the blind index for equality check, one column for storing the values encrypted using Order preserving encryption for range condition checking and another column for storing domain values encrypted using homomorphic encryption for aggregate query processing.
- The data owner encodes the primary key column domain values of the table using the hash encoding scheme and stores them in the blind index column of the cloud database table, here the SHA-256 encoding scheme is used.

- Then all numeric column domain values are encrypted using the Order Preserving Encryption scheme [7] and stored in additionally added columns of cloud database for executing range queries over encrypted database table without decryption.
- Data owner also encrypts the domain values of columns using a homomorphic encryption scheme on which aggregate queries are to be processed and store them in additionally created columns in the cloud database.
- Finally, the data owner encrypts all the column values of a relation in a database using AES-256-CBC encryption algorithm, a secret encryption key and a random initialization vector (IV), this key is known only to the data owner and it should be securely shared to the data users.
- Then the encrypted database tables or relations are vertically partitioned into two or more fragments with selected columns by considering data sensitivity criteria and also add index column for each vertically fragmented relations, this index value must be replicated in all fragments for the tuple of un-partitioned relation so that the user can retrieve the tuple data easily and reduces the query execution time.
- Uploads the encrypted and vertically fragmented table in multiple database instances of the same cloud service provider environment.
- Data owner maintains metadata in the owner-private environment to know the locations of fragments stored in cloud databases.
- Data owners must authenticate users to perform operations on a cloud database, for authentication users must register with the data owner with their details.
- The data owner will share the user credentials with cloud service providers (CSP), so that CSP verify the user credentials with credentials already shared by the data owner to CSP, if a user is valid then CSP grant permissions to the user to access data.
- Data users can send the query request to the data owner for the metadata information.
- The data user can retrieve the encryption key from the data owner and perform operations on databases like selection, insertion, deletion and updating.

- The data owner or user retrieves the data from the cloud database in encrypted form only and performs decryption at the client environment using the secret key. So CSP doesn't have any knowledge about the data stored in the cloud.
- When the user sends the SELECT query to retrieve the data from the database, it must include the JOIN clause with a predicate on the index column.

C) Proposed Model summary steps

Database outsourcing process:

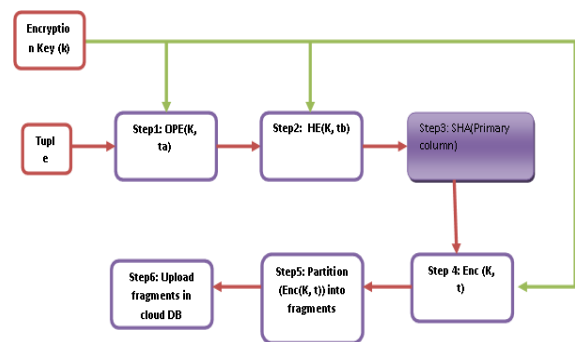


Figure 3: Shows the steps for secure outsourcing of database to cloud environment

Let $R(A_1, A_2, A_3 \dots A_n)$ be a relation schema of relational database, where R represents relation, A_1, A_2, A_n , are columns in relation R . let A_a be a column with numerical values on which range queries are to be executed and A_b be a column on which aggregate queries are to be executed and K represents the encryption key of length 256 bit length.

Steps for secure outsourcing of database to cloud environment:

- Step1: Encrypt tuple column t_{a1} value using OPE algorithm i.e. $OPE(K, t_a)$.
- Step2: Encrypt tuple column t_{a2} value using Homomorphic algorithm $HE(K, t_b)$.
- Step3: Find the hash of primary key column using SHA256 hash algorithm for equality check.
- Step 4: Encrypt tuple data using AES-256-CBC using $Enc(K, t(a_1, a_2 \dots a_j, a_k, \dots, a_n))$
- Step 5: Distribute the encrypted tuple values into multiple database instances.

Step 6: Insert distributed column values into fragmented table columns of cloud databases.

Step 7: Repeat steps 1-5 until all records are uploaded in cloud database tables.

So the advantage of our proposed cloud database security model is that 1) it is strongly protected from Chosen Plaintext Attack(CPA) because, in this model we used a random initialization vector in AES-CBC-256 Algorithm for database relation encryption, it maps the same plaintext into different ciphertext blocks. 2) As database relations are partitioned vertically and distributed into multiple database instances if the attacker compromises the data in one fragment, cannot get the complete information. The cloud service providers will be unaware of the data stored in the database because all attribute values of records in database relations are stored in ciphertext format.

4. IMPLEMENTATION AND RESULTS

A. Cloud Computing Tools

For simulation of our model, we designed an application using PHP and My-SQL server, also used HTML for front end design, for this installed the XAMPP tool and application is deployed on local system. Then we created a public cloud computing account at cloud clusters.io, which provides an open-source cloud computing service. We have created a My-SQL server managed with PhpMyadmin for experimental purposes and then created two slave databases in the cloud for storing fragments of database relation. The configurations of servers created on the cloud are 3(core) Processors, 4GB RAM, 100GB SSD. Then run my application on my local system configured with Intel Core i5 processor, 10GB RAM and 360GB hard disk space. The network speed is 150mbps.

B. Results and Performance Evaluation

For our experimental work, we have taken employee datasets and stored them in cloud databases. For simulation purposes, we have created two database relations on our local system one for storing metadata and another for storing employee records with

fields id, emp_id, emp_name, emp_email, emp_salary, and emp_age., this is called data at data owner side, we also created two slave databases in cloud environment each one for storing fragmented relations and also note that we can create more number of slave databases, which may be equivalent to several fields in data owner base table. We have created a fragmented table schema in slave database1 with fields id, emp_id, emp_name, emp_email and blindindex, here the blindindex column is used to store the hash encoded values of emp_id field, and here we have taken emp_id field as the primary key. Also created another fragmented table in slave database2 with two columns i.e. emp_salary, and emp_age. Then 1000 records of employees are encrypted using a suitable encryption scheme and inserted into the cloud databases, the results are shown in figures. Figure 4 shows the data stored in the data owner local system, it is in plain text format. Figure 5 shows the data stored in a vertically fragmented table in cloud database server 1, in which field values emp_id, emp_name and emp_email are encrypted by data owner using the AES-256-CBC algorithm and secure encryption key and stored in cloud, blindindex column values are encoded values of emp_id column using an SHA-256 encoding scheme, blindindex column values are required for executing select queries with equality check condition on encrypted database relation without decryption in the cloud environment. Figure 6 shows the data stored in a vertically fragmented table in cloud database server2, these column values are encrypted by the data owner using the AES-256-CBC algorithm and secure encryption key and stored in the cloud.

Emp ID	Employee Name	Email Id	Salary	Age
emp_01	Manoj	manoj@gmail.com	24000	34
emp_02	Jasmita	jasmita@gmail.com	15000	21
emp_03	srinu	srinu@gmail.com	34000	40
emp_04	padma	padma@gmail.com	18000	32
emp_05	praveen	praveen@gmail.com	29000	39
emp_06	venkat	venkat@gmail.com	40000	40
emp_07	raju	raju@gmail.com	45000	45
emp_08	rasi	rasi@gmail.com	12000	40
emp_09	sonu	sonu@gmail.com	33000	34
emp_10	JUNDAIDASHRAF SOFI	JUNDAIDASHRAF.02018@GMAIL.COM	54000	28
emp_100	NANAPUTI VARSHITHA	varshitha@gmail.com	108000	53
emp_101	NIDRA UDAYA SREE	nidrapaemaah123@gmail.com	110000	51
emp_102	NIMMALA GANESH	ganesh@gmail.com	111100	49
emp_103	NYAVANANDI SURAJ	suraj@gmail.com	113000	47
emp_104	NYELLANCHERU V ALEKHYA	venkateshreddy1854@gmail.com	114000	45
emp_105	PAMIREDDY MONIKA	mrdunada464@gmail.com	116000	43
emp_106	SEEMA TABASSUM	mrdunada464@gmail.com	29178	41
emp_107	SHRIYA GURRAM	SHRIYA@GMAIL.COM	26476	39
emp_108	THATIKONDA AKHIL KUMAR	thakarshar@gmail.com	67327	60
emp_109	ALAMPALLY NIKHIL	rkomar@gmail.com	90296	32
emp_11	ANDELA RAHUL	RY118129@GMAIL.COM	52000	34
emp_110	ALE VINAY	vinay99@gmail.com	26388	31
emp_111	ALLUGULA HARSHA VARDHAN REDDY	matreddy24@gmail.com	24053	39
emp_112	ARRAGONI BALARAM	balaram99@gmail.com	53633	62
emp_113	AYYALASOMAYAJULA ADITYA SUDEEP SAI	sudeep380700@gmail.com	75638	43
emp_114	BHUTI ASHRETH	bhuti_bh43@rediffmail.com	48321	49
emp_115	BOLISETTY NIKHIL GUPTA	NIKHILGUPTA@GMAIL.COM	20726	28
emp_116	GUNUPUDI VENKATAPANA NMANIDEEP	nmanideep@gmail.com	50676	63
emp_117	BATULA ASHISH GOPI	goppy99@gmail.com	60966	36
emp_118	REDDY L S ADASHILA REDDY	lreddy@rediffmail.com	48136	47

Figure 4. Data to be outsourced by the data owner

emp_id	emp_name	emp_email	emp_salary
1	Manoj	manoj@gmail.com	24000
2	Jasmita	jasmita@gmail.com	15000
3	srinu	srinu@gmail.com	34000
4	padma	padma@gmail.com	18000
5	praveen	praveen@gmail.com	29000
6	venkat	venkat@gmail.com	40000
7	raju	raju@gmail.com	45000
8	rasi	rasi@gmail.com	12000
9	sonu	sonu@gmail.com	33000
10	JUNDAIDASHRAF SOFI	JUNDAIDASHRAF.02018@GMAIL.COM	54000
100	NANAPUTI VARSHITHA	varshitha@gmail.com	108000
101	NIDRA UDAYA SREE	nidrapaemaah123@gmail.com	110000
102	NIMMALA GANESH	ganesh@gmail.com	111100
103	NYAVANANDI SURAJ	suraj@gmail.com	113000
104	NYELLANCHERU V ALEKHYA	venkateshreddy1854@gmail.com	114000
105	PAMIREDDY MONIKA	mrdunada464@gmail.com	116000
106	SEEMA TABASSUM	mrdunada464@gmail.com	29178
107	SHRIYA GURRAM	SHRIYA@GMAIL.COM	26476
108	THATIKONDA AKHIL KUMAR	thakarshar@gmail.com	67327
109	ALAMPALLY NIKHIL	rkomar@gmail.com	90296
11	ANDELA RAHUL	RY118129@GMAIL.COM	52000
110	ALE VINAY	vinay99@gmail.com	26388
111	ALLUGULA HARSHA VARDHAN REDDY	matreddy24@gmail.com	24053
112	ARRAGONI BALARAM	balaram99@gmail.com	53633
113	AYYALASOMAYAJULA ADITYA SUDEEP SAI	sudeep380700@gmail.com	75638
114	BHUTI ASHRETH	bhuti_bh43@rediffmail.com	48321
115	BOLISETTY NIKHIL GUPTA	NIKHILGUPTA@GMAIL.COM	20726
116	GUNUPUDI VENKATAPANA NMANIDEEP	nmanideep@gmail.com	50676
117	BATULA ASHISH GOPI	goppy99@gmail.com	60966
118	REDDY L S ADASHILA REDDY	lreddy@rediffmail.com	48136

Figure 5. Fragmented data stored in cloud database server1

id	emp_salary	emp_age
1	24000	34
2	15000	21
3	34000	40
4	18000	32
5	29000	39
6	40000	40
7	45000	45
8	12000	40
9	33000	34
10	54000	28
100	108000	53
101	110000	51
102	111100	49
103	113000	47
104	114000	45
105	116000	43
106	29178	41
107	26476	39
108	67327	60
109	90296	32
11	52000	34
110	26388	31
111	24053	39
112	53633	62
113	75638	43
114	48321	49
115	20726	28
116	50676	63
117	60966	36
118	48136	47

Figure 6. Fragmented data stored in cloud database server2

id	Emp (Age)
1	316016311391535898557933318185370136982049778993833328
2	79160751973529423147514371130309678563218422527954492
3	1510297374311394472905632820067136347267468191965027
4	699940471148791057361236134899530948290533583574404115046
5	51024983949540166980155563224561686077892247380578936614
6	94785782237674399752319854946267385788228238506405039957150
7	792108591135282804302924462767983830261193649148222460
8	511829506997488159307057738865797581674312039624997
9	428997090594472014149607603358932672701812267053736321
10	65392142419229447367574829076900436732610378474087903
11	352114953641189502250458399807560165466905687247
12	07886381595304174354435955536693627019968436540969011
13	737097646635114092259119770632399124055160353671103038
14	2329339437116213028208

Figure 7. Emp_age field values encrypted using homomorphic encryption

id	OPE(K,Salary)
1	656206284
2	1309397157
3	1634916838
4	980842854
5	1181804128

Figure 8. Emp_salary encrypted using Order Preserving Encryption

Figure 7 shows the emp_age column values using a homomorphic encryption scheme by the data owner and stored in a cloud database for executing SQL queries with aggregated functions in an encrypted cloud database without decryption. Figure 8 shows the emp_salary column values encrypted using an order preserving encryption scheme by the data owner and stored in a cloud database for executing SQL queries with range conditions on encrypted cloud database without decryption. In our proposed model, these records are retrieved using an isolated cloud server, these records are retrieved using an isolated column values in each fragmented table.

We evaluated the performance in terms of a time delay to encrypt and upload the data in cloud databases and to retrieve from a cloud database, decrypt at the client-side and show the result to the user. The performance of our method is compared with the existing methods. For performance testing of our proposed model, the first 106 records are encrypted and inserted in cloud databases then 206,306,406,506 and 606.

Table 1:Time delay in seconds to encrypt and insert the records in cloud databases

Time delay to upload Data in Cloud database(Seconds)		
No. of Records	SCA(sec)	FDSA(sec)
106	58.87	87.39
206	114.22	184.69
306	177.63	265.06
406	243.00	349.15
506	297.23	442.66
606	423.89	473.61

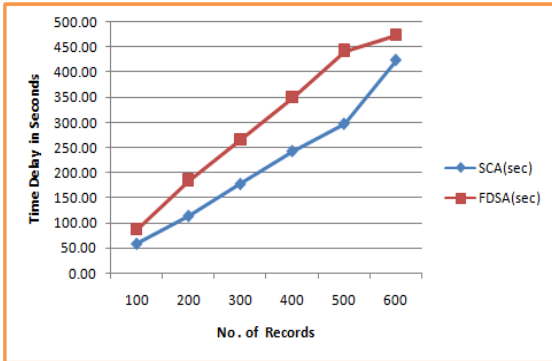


Figure 9:Time delay in seconds to encrypt and insert the records in cloud databases of FDSA and SCA models

Table 1:shows the performance in terms of the time delay of Secure Centralized Approach (SCA) and Fully Distributed Secure Approach (FDSA) using nondeterministic encryption (i.e. our proposed model) for encrypting and inserting the records in cloud databases. The data recorded in table 1 are used to compare the time delay of the existing model with our proposed model for encrypting and executing

INSERT/UPDATE query to insert or update data in the cloud database.

Figure 9: shows that our proposed model performance in terms of time delay for encrypting and inserting the data in cloud database is a little bit slower than the existing model, but as security is a concern our model is more secure than the existing models.

Table 2:Time delay for Select query execution to retrieve all records from cloud database and data decryption at client side

Time delay to Retrieve Data from cloud database (seconds)		
No. of Records	SCA(sec)	FDSA(sec)
106	1.02	1.04
206	1.89	1.82
306	2.74	2.76
406	3.50	3.03
506	4.29	4.18
606	4.62	5.18

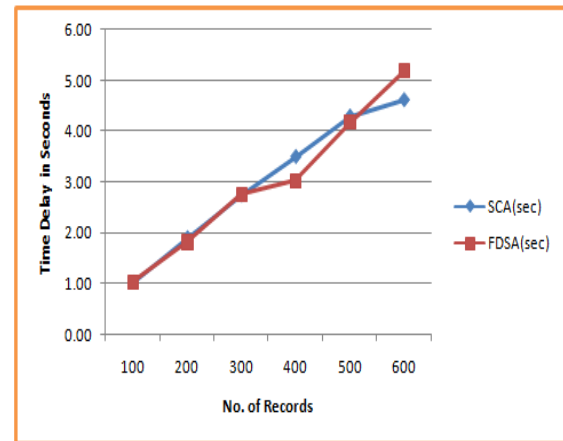


Figure 10:Shows time delay for Select query execution to retrieve all records from cloud database and data decryption at client side of SCA and FDSA models

Table 2: shows the data recorded for testing the performance in terms of time delay for SELECT query execution to retrieve all records from cloud database and data decryption at the client-side with a varied number of

records such as 106,206,306,406,506 and 606 records of our proposed model and SCA models.

Figure 10: shows that our proposed model performance in terms of time delay for SELECT query execution on cloud database servers and decrypting the results returned by the query at the user side is almost the same as the existing model, but as security is a concern our model is more secure than the existing models.

5. CONCLUSION AND FUTURE SCOPE

In this paper, we proposed a model for cloud database security using data distribution and nondeterministic encryption approach, in our model we used AES-256-CBC algorithm, order-preserving encryption and homomorphic encryption schemes for database encryption and distributed database vertical fragmentation technique is used for data distribution, in which database tables are vertically partitioned with selected columns based on the data sensitivity level. For implementing our model, designed a web application using PHP and My-SQL, we run our application using the XAMPP tool on the local machine and created a database server on open source cloud service provider cloudcluster.io and evaluated the performance of SELECT query execution with equality check, range check predicates in WHERE clause on encrypted cloud databases and measured the time delay to access the data from the cloud. In our research, we have compared the performance of our model with existing methods and found our model is more secure with optimal query execution time. Our future research is to introduce novel methods to further enhance the data upload performance.

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