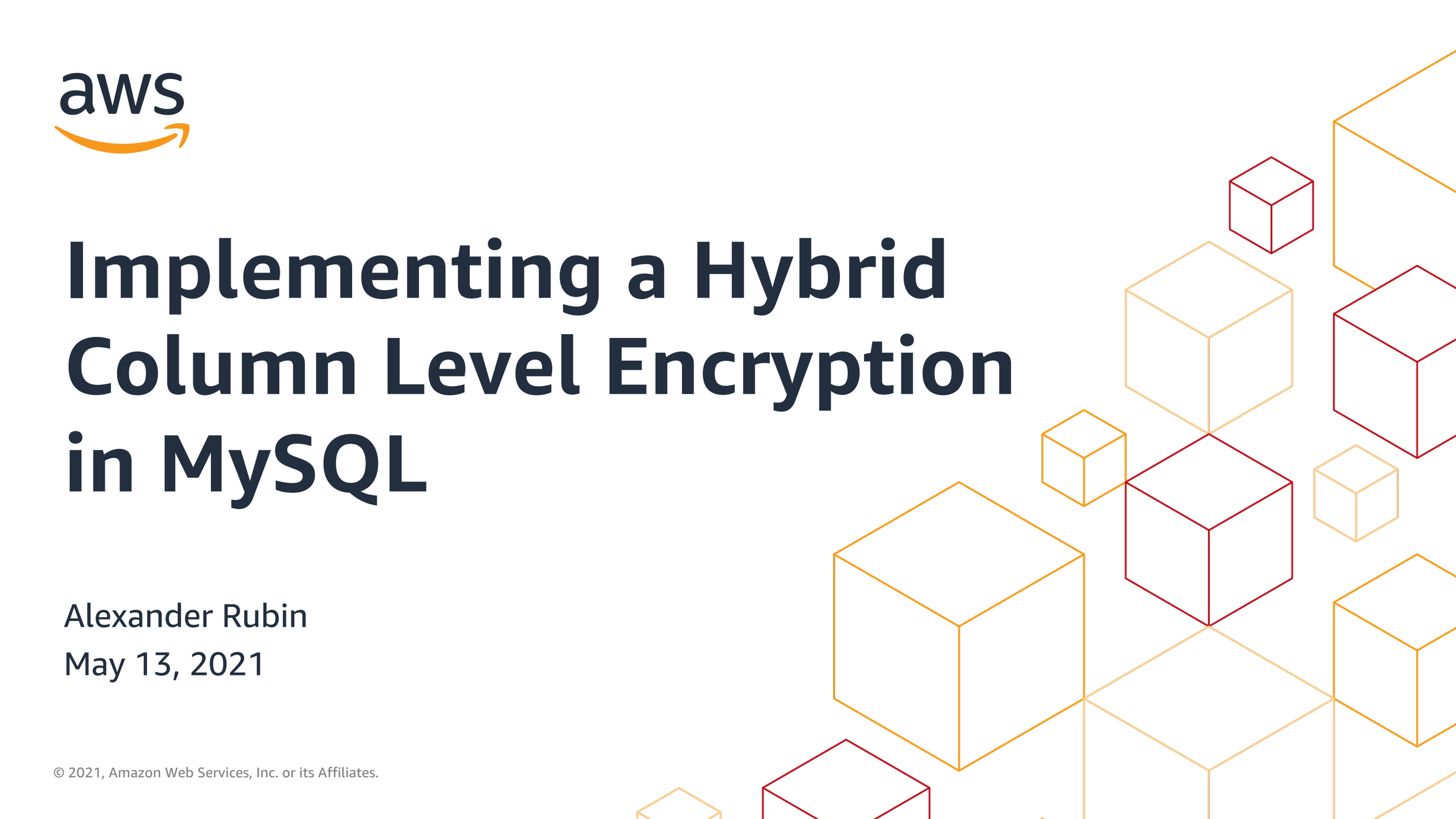

Implementing a Hybrid Column Level Encryption in MySQL

Alexander Rubin

May 13, 2021

About me

Working with MySQL for ~15 years

- Started at MySQL AB 2006
    - Sun Microsystems, Oracle (MySQL Consulting)
    - Percona since 2014
- Joined the Amazon Relational Database Service (RDS) engineering team in 2020

Interests in:

- IoT / devices
- IT security

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Agenda

1. Existing encryption methods
    - May not provide adequate encryption for sensitive data
2. Proposed method of column level encryption

Protecting Data In MySQL

Background information and existing solutions

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Protecting Data In MySQL: encryption

- Encryption will protect sensitive data
- Required by HIPAA, PCI compliances, etc

Amazon RDS security features:

- Encryption of Data at Rest
- Encryption of Data in Transit

https://aws.amazon.com/rds/features/security/

Some sensitive data may require an additional protection

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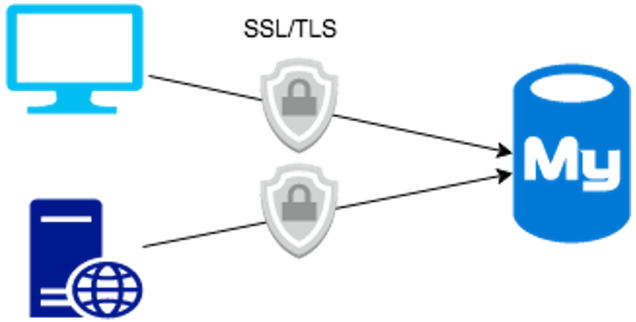
Protecting data in MySQL: types of encryption

1

Data in flight

SSL/TLS



2

Data at Rest

Full disk encryption

Transparent DB Encryption

Field level encryption

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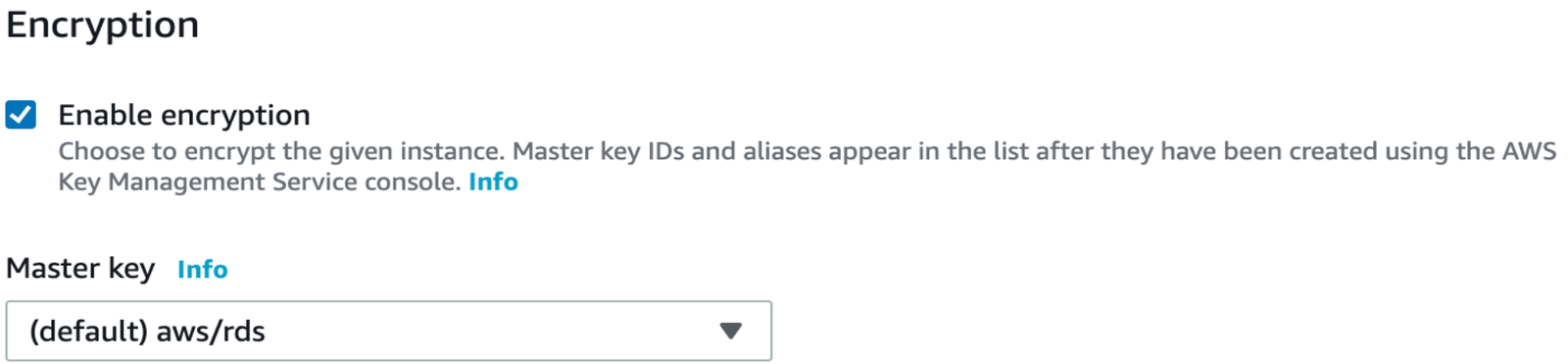
Data at Rest Encryption: full disk encryption options

Data at Rest

Full disk encryption

- Amazon RDS or EC2: Encrypting disk with KMS



- Full disk encryption on Linux: LUKS / etc
- Shared storage encryption

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Data at Rest Encryption: full disk encryption downsides

Data at Rest

Full disk encryption

- Only protect from physical access to disk (or reusing images)
- If MySQL is running:
  - data in MySQL files ***can be seen as unencrypted***
    - ***It is encrypted only when volume(s) are not mounted***

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Data at Rest Encryption: TDE

Data at Rest

Transparent DB Encryption

Transparent Database Encryption (TDE): encrypting db files

1. **InnoDB files:** tablespaces, redo logs, undo logs
2. **Binary logs, relay logs:** for MySQL replication
3. **Tmp files**

Data at Rest Encryption: field/column level encryption

Data at Rest

Field level encryption

Application code encrypts needed fields.
For example:

- PII information
- Medical (PHI) information
- Etc

Issues:

- Key rotation
- Searches in MySQL - range search does not work
- Order by searches
- Indexes

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Data at Rest Encryption options: comparison

Encryption option	PROs	CONs
Full disk	• No application changes needed • Lowest overhead	• When **system** is running data is decrypted • Does not protect from **copying database files**
TDE	• No application changes needed • Low overhead	• When **MySQL** is running data is decrypted • Does not protect from **exporting data** (i.e. mysqldump)
Field / column	• Best protection • Can be combined with other options	• Require some application changes • Overhead can be significant

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Field Level Encryption

Implementation options

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Field/column level encryption: common approach

Application encrypt/decrypt data (code)

- Data is *already* encrypted
  - In flight (from app to MySQL)
  - At rest (when MySQL stores it on disk)

Field/column level encryption: problems

1. Application needs to implement encryption
    - What if we have a legacy application?
2. Need to store and rotate encryption key
3. Complicate MySQL queries:
    - Range scan / order by will not work inside MySQL

Field Level Encryption

Possible approach for MySQL

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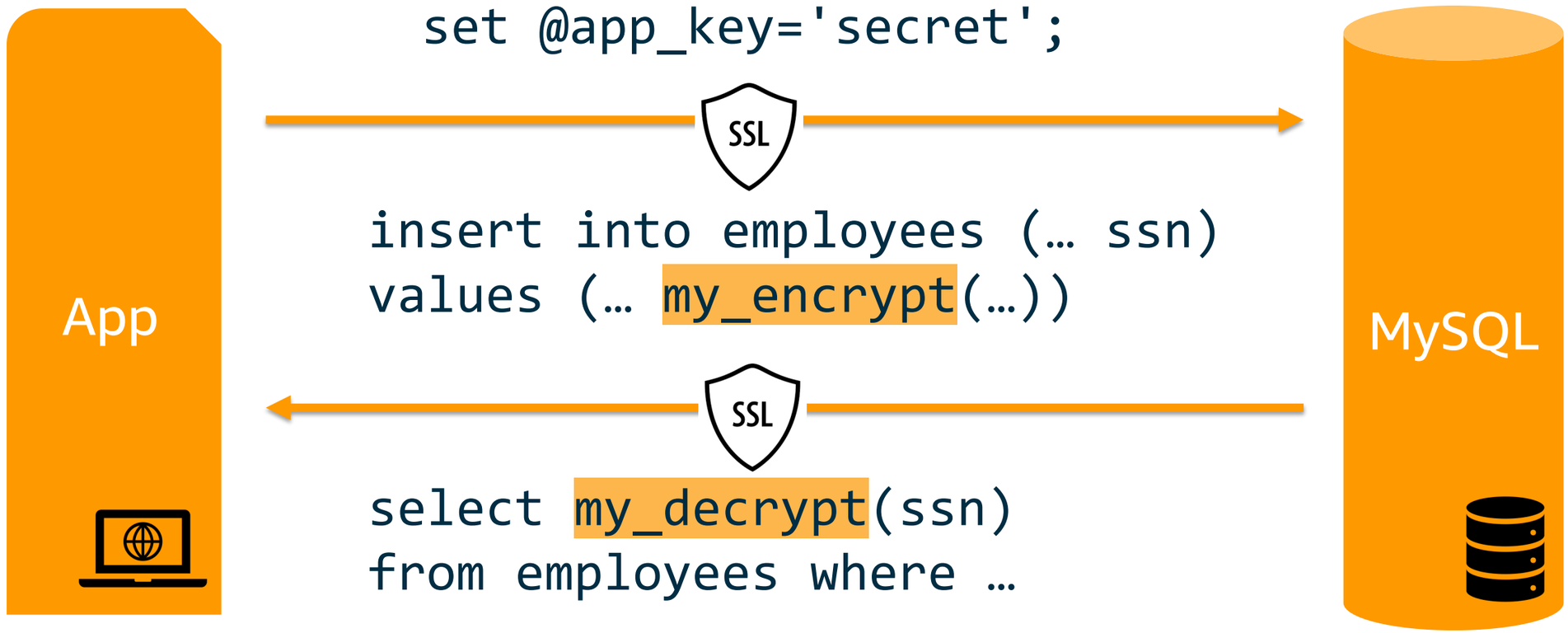
Field/column level encryption for legacy application

Our Plan

1. Identify fields that require field/level encryption
2. Create encrypt /decrypt function (stored function or UDF)
3. Use MySQL rewrite plugin (+ triggers) to “inject” encryption
4. Use application encryption keys

Implementation diagram



my_encrypt() my_decrtypt(): stored functions we will create

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Field/column level encryption for legacy application

Pre-requisites

1. Data in flight encryption:
    - application connects to MySQL with SSL/TLS
2. Application stores its key securely

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Field/column level encryption for legacy application

Implementation 1:

create MySQL stored functions to encrypt / decrypt

```
use secret_schema;
create function my_encrypt(str text character set utf8)
returns text binary
return aes_encrypt(str, @app_key);

create function my_decrypt(str text binary)
returns text character set utf8
return aes_decrypt(str, @app_key);
```


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Field/column level encryption for legacy application

```
mysql> set @app_key='secret';
Query OK, 0 rows affected (0.00 sec)

mysql> select hex(my_encrypt('test’));
+-----------------------------------+
| hex(my_encrypt('test'))           |
+-----------------------------------+
| 1356CAC477BA0A814054243FDBE2398F  |
+-----------------------------------+

mysql> select my_decrypt(my_encrypt('test'));
+-------------------------------+
| my_decrypt(my_encrypt('test')) |
+-------------------------------+
| test                          |
+-------------------------------+
```

Application sets this key

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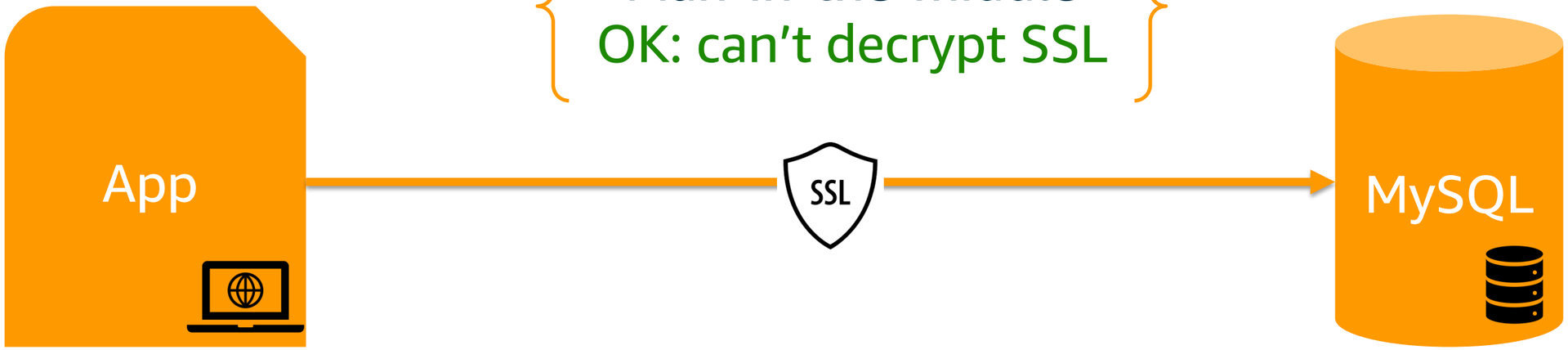
Security

App: Attacker Need key to decrypt data Vulnerable?

MySQL DBA can't decrypt exported data OK

Man-in-the-middle OK: can't decrypt SSL



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Vulnerable points

Application level: key needs to be protected

On disk - store in secure storage. I.e.:

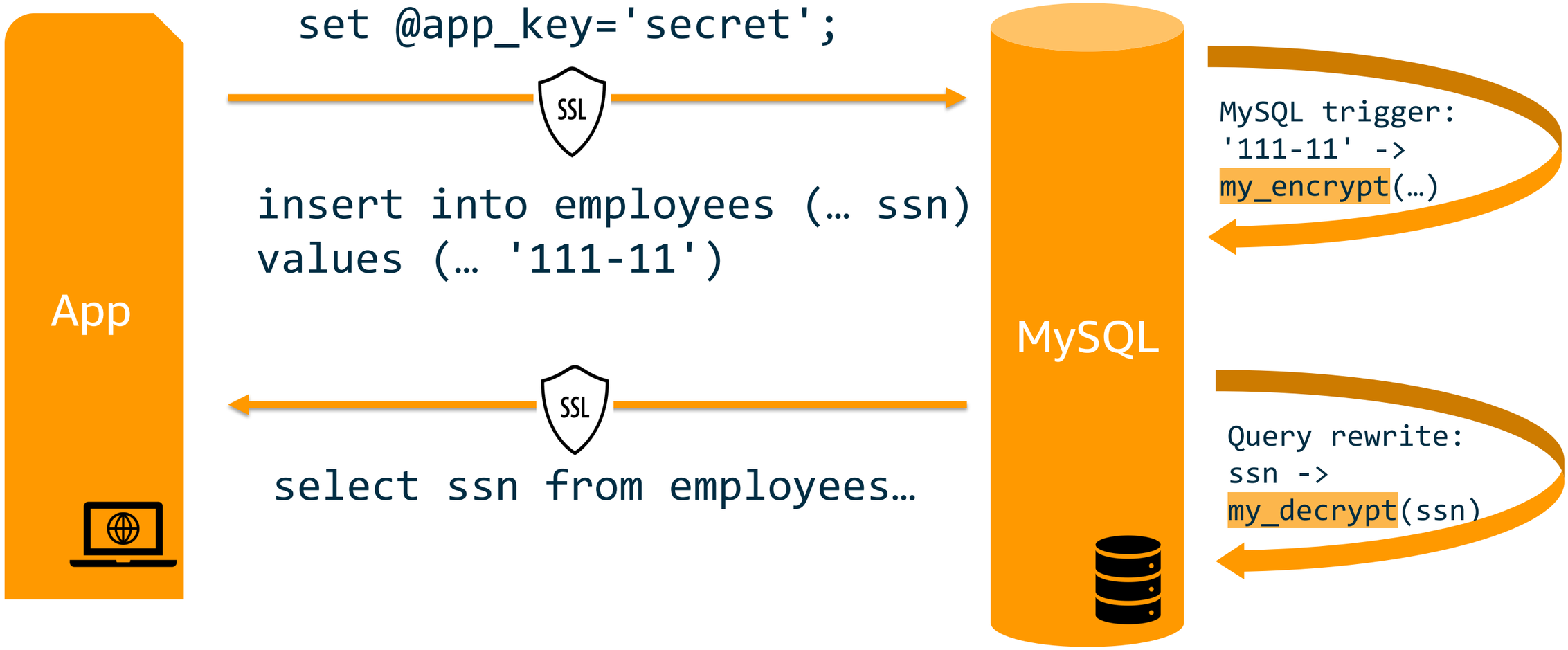
- AWS Secrets Manager: https://docs.aws.amazon.com/secretsmanager/latest/userguide/intro.html
- Vault

Load key in Application memory on start

MySQL level

key can be recorded in logs (i.e. slow log, audit log etc)

Dealing with legacy applications



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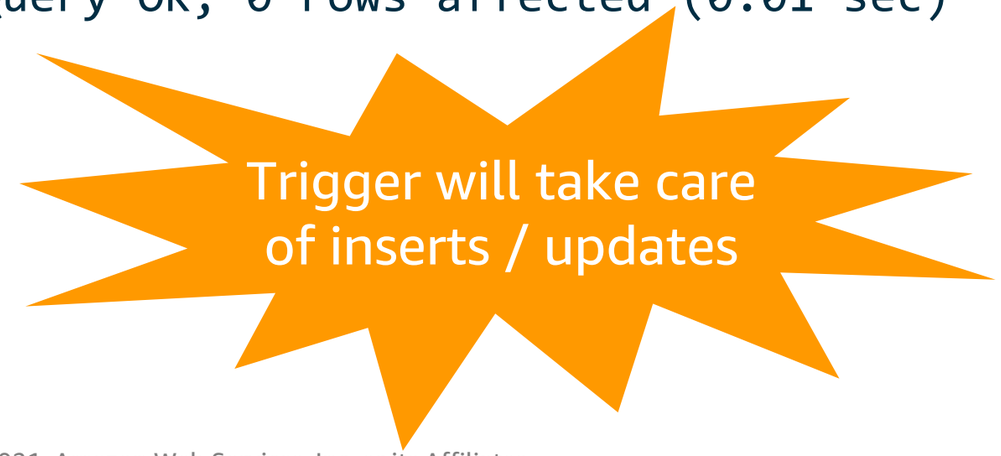
Dealing with legacy applications: implementation

```
mysql> CREATE TABLE `employees` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
   ...
  `ssn` blob,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB;

mysql> CREATE TRIGGER encr
       BEFORE INSERT on employees
       FOR EACH ROW
       set NEW.ssn=my_encrypt(NEW.ssn);
Query OK, 0 rows affected (0.01 sec)
```




```
mysql> insert into employees(ssn)
       values('111-11-111');
Query OK, 1 row affected (0.00 sec)

mysql> select * from employees;
+----+------------------+
| id | ssn              |
+----+------------------+
|  1 | !=9Ll..V.        |
+----+------------------+
1 row in set (0.00 sec)

mysql> select my_decrypt(ssn)
       from employees;
+-----------------+
| my_decrypt(ssn) |
+-----------------+
| 111-11-111      |
+-----------------+
1 row in set (0.00 sec)
```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Dealing with legacy applications: implementation

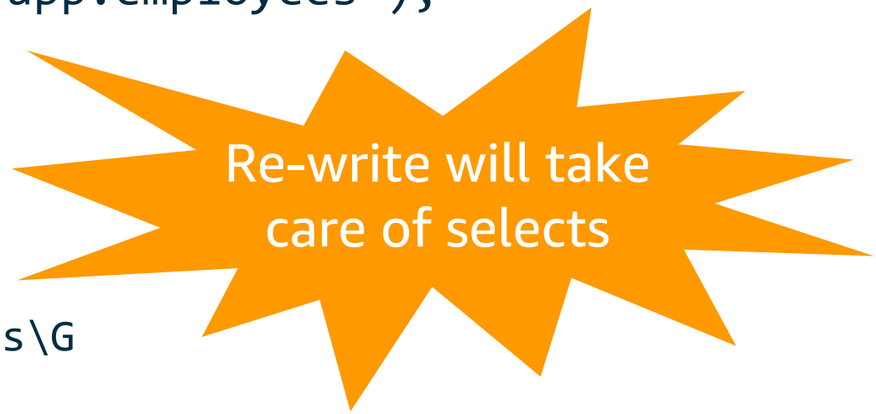
Install re-write plugin:

** Query rewrite plugin is not available currently on Amazon RDS*

https://dev.mysql.com/doc/refman/8.0/en/rewriter-query-rewrite-plugin-usage.html

```
mysql> INSERT INTO query_rewrite.rewrite_rules (pattern, replacement)
       VALUES('SELECT ssn from app.employees',
              'SELECT secret_schema.my_decrypt(ssn) from app.employees');
Query OK, 1 row affected (0.00 sec)

mysql> CALL query_rewrite.flush_rewrite_rules();
Query OK, 0 rows affected (0.00 sec)
```




```
mysql> select ssn from app.employees;
+-------------------------------+
| secret_schema.my_decrypt(ssn) |
+-------------------------------+
| 111-11-111                    |
+-------------------------------+
1 row in set, 1 warning (0.00 sec)
```

```
mysql> show warnings\G

  Level: Note
   Code: 1105
Message: Query 'select ssn from app.employees' rewritten
to 'SELECT secret_schema.my_decrypt(ssn) from
app.employees' by a query rewrite plugin
1 row in set (0.00 sec)
```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Other operations on encrypted columns

```
mysql> alter table employees change ssn ssn varbinary(255),
       add key (ssn);
Query OK, 0 rows affected (0.02 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> set @app_key='secret';
Query OK, 0 rows affected (0.00 sec)

mysql> set @app_key='secret’;
       select id, secret_schema.my_decrypt(ssn)
       from employees
       where ssn=secret_schema.my_encrypt('111-11-111');
+----+------------------------------+
| id | secret_schema.my_decrypt(ssn) |
+----+------------------------------+
|  2 | 111-11-111                   |
+----+------------------------------+
```

Use this query so MySQL can use index

```
           id: 1
  select_type: SIMPLE
        table: employees
         type: index
          key: ssn
      key_len: 258
            …
        Extra: Using where;
               Using index
```

Re-write CAN take care of this as well

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Other operations on encrypted columns: order by

```
mysql> select id, secret_schema.my_decrypt(ssn), secret_schema.my_decrypt(last_name)
from employees order by secret_schema.my_decrypt(last_name) limit 10;
...
10 rows in set (29.79 sec)

mysql> alter table employees add key (last_name);

mysql> explain select id, secret_schema.my_decrypt(ssn),
                          secret_schema.my_decrypt(last_name)
        from employees
        order by secret_schema.my_decrypt(last_name) limit 10\G
             …
        table: employees
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
         rows: 1045875
     filtered: 100.00
        Extra: Using temporary; Using filesort
```

Order by queries will not use indexes and will be slow

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Performance considerations: benchmark

Without trigger:

```
mysql> insert into employees_copy
       select * from employees;
Query OK, 300024 rows affected (3.73 sec)
Records: 300024  Duplicates: 0  Warnings: 0
```

With trigger:

```
mysql> insert into employees_copy_with_trigger
       select * from employees;
Query OK, 300024 rows affected (7.15 sec)
Records: 300024  Duplicates: 0  Warnings: 0
```

- Negligible / hard to measure for single inserts
- ~2x slower for bulk inserts

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Field Level Encryption Implementation: Pros/Cons

PROs	CONs

• Higher level of security for sensitive data
  • Data is encrypted even when database is running
• Compatible with other encryption methods
• No application changes needed
  • Need to set the app key on connection
	• Limits on SELECT quires:
	  • Slow ORDER BY
	  • Slow range queries
	• Performance for bulk inserts/updates can be 2x worse
	• Key rotation will require re-encryption
	• Query text can be recorded in logs (i.e. slow log general_log, performance_schema, etc)

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Other options

Using MySQL keyring SECRET and Asymmetric Encryption
https://mysqlserverteam.com/using-a-mysql-keyring-secret-and-asymmetric-encryption/

This is a different setup with 2 database users

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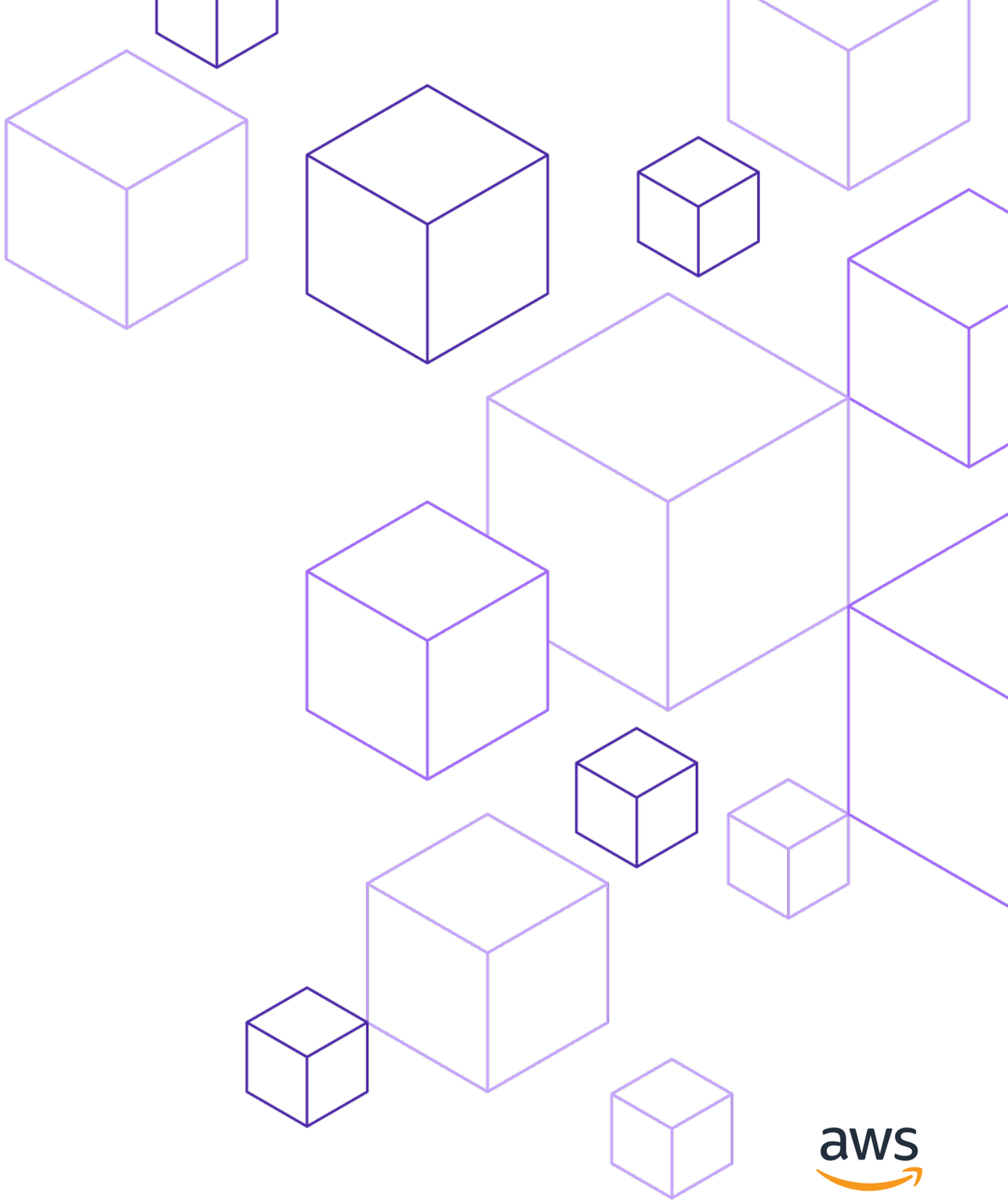
Summary

1. Discussed field level data encryption implementation
2. PRO: Transparent to the application
    - Better security
    - No/minimal application changes needed
3. CON: some queries will be slower, need to test/bechmark

Q&A

Alexander Rubin



Thank you!