MySQL™

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Mysteries of the Binary Log

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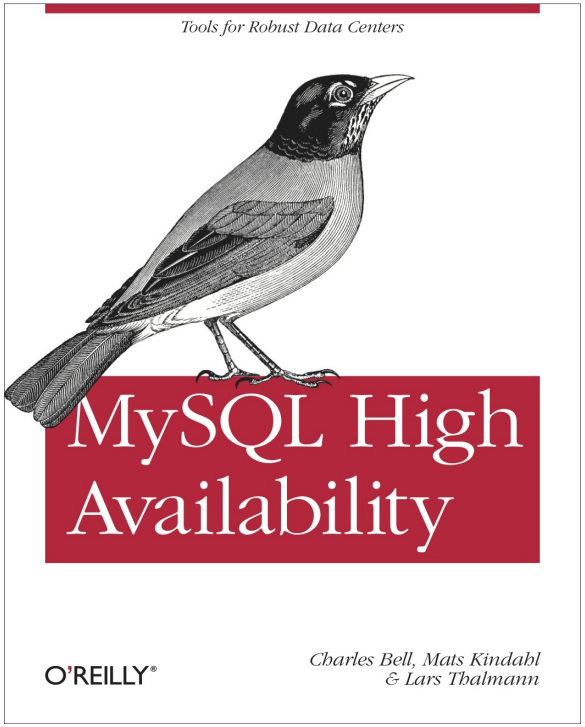
About the Speakers



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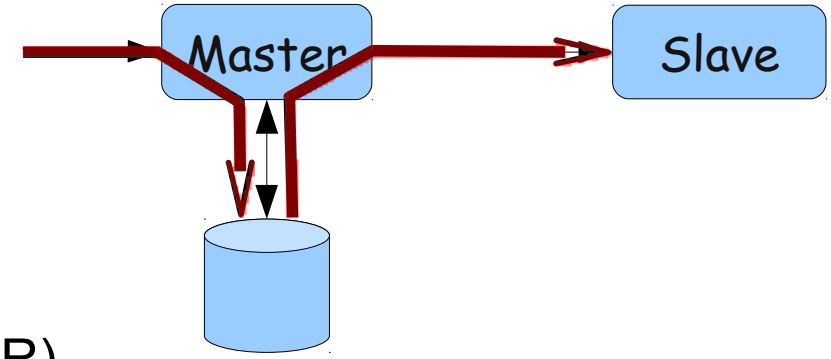
MySQL

What is the binary log?

- Record of changes
- Used for
  - Replication
  - Auditing
  - Point-In-Time Recovery (PITR)

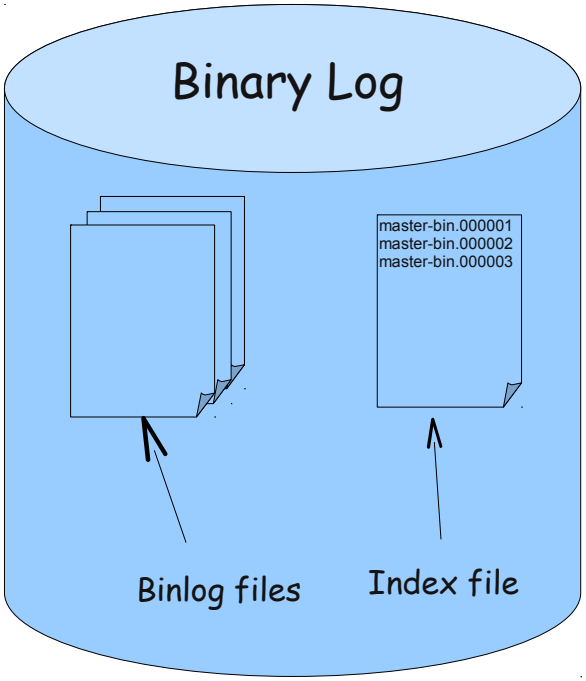


- Slave executes changes with privileges turned off
  - Security implications?
  - “If it is OK to execute on the master, it should be OK to execute on the slave”
  - Not always true (as you will see)

Best Practices

- Manage your log rotations
- Protect your logs
  - Store on secure location
  - Don't store on same disk as data
- Purge old logs
  - PURGE command
  - --expire-log-days
- Use log filters sparingly if point-in-time recovery a priority
- Protect the replication user account from tampering
- Avoid using sensitive data in statements (e.g. passwords)

Structure of the Binary Log



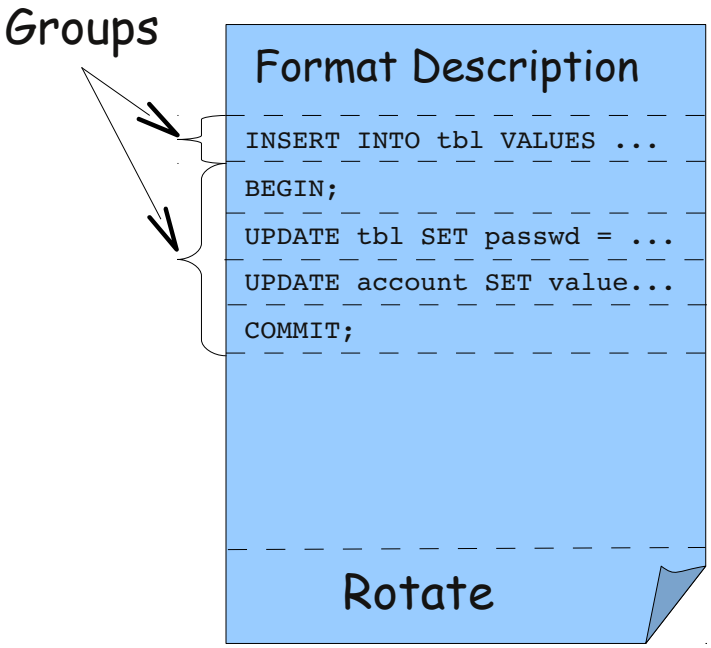
Binlog files

- Option `log-bin`
- Default `master-bin.000001`
- Content of binary log

Binlog index

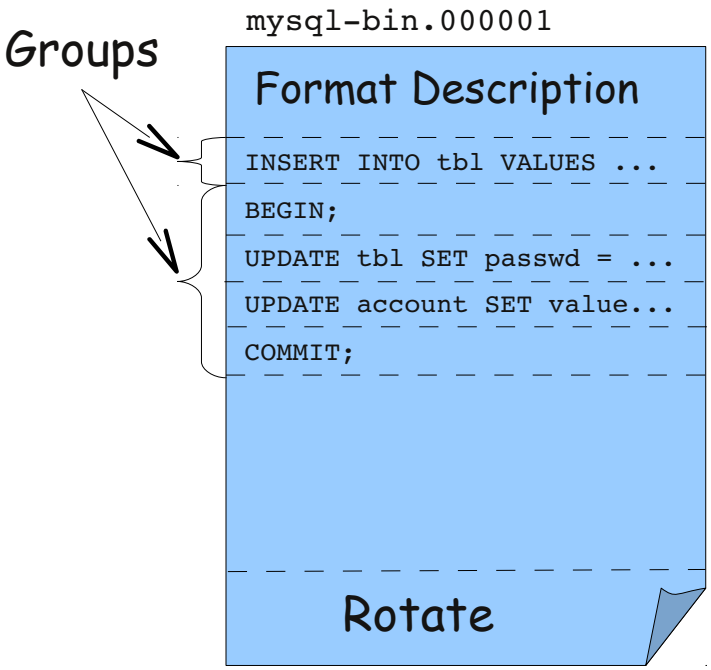
- Option `log-bin-index`
- Default `master-bin.index`
- Index over binlog files

Binlog file structure



- Format Description Event
  - File-specific data
  - Binlog Format Version
  - Server Version
- Rotate
  - Terminate binlog file
  - Next file in sequence
- Binlog Events
  - Organized in groups
  - MySQL 5.1 have 26 different event types

Binlog file structure



- Binary Log Coordinate
  - File name
  - File position

Investigating Binary Log

- `SHOW BINLOG EVENTS`
  - `IN` *`file`*
  - `FROM` *`position`*
  - `LIMIT` *`events`*
- Shows contents of first binlog file (!)
  - **Not** contents of last binlog file

```
mysql> SHOW BINLOG EVENTS;
+------------------+-----+-------------+-----------+-------------+-----------------------------------------------+
| Log_name         | Pos | Event_type  | Server_id | End_log_pos | Info                                          |
+------------------+-----+-------------+-----------+-------------+-----------------------------------------------+
| mysql-bin.000001 |   4 | Format_desc |         1 |         106 | Server ver: 5.1.37-1ubuntu5.1-log, Binlog ver: 4 |
| mysql-bin.000001 | 106 | Query       |         1 |         250 | use `test`; CREATE TABLE book (id INT UNSIGNE... |
| mysql-bin.000001 | 250 | Query       |         1 |         373 | use `test`; CREATE TABLE author (name VARCHAR... |
+------------------+-----+-------------+-----------+-------------+-----------------------------------------------+
3 rows in set (0.00 sec)
```

Size = End_log_pos - Pos

Purging Binlog Files

- `PURGE BINARY LOG TO` *`filename`*

  Deletes all binary log files before the named file.

- `PURGE BINARY LOG BEFORE` *`datetime`*

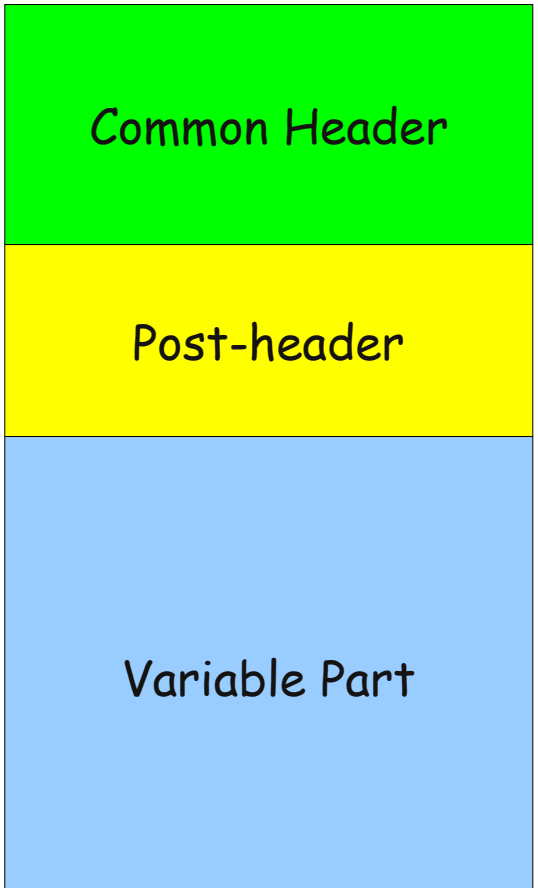
  Purge will always delete complete files. This means that if there is at least one event in the log file that has a time stamp after datetime, the file is not deleted.

- `RESET MASTER`
  - Deletes all binary log files listed in the index file, resets the index, and creates a new binlog file.

Purging Binlog Files

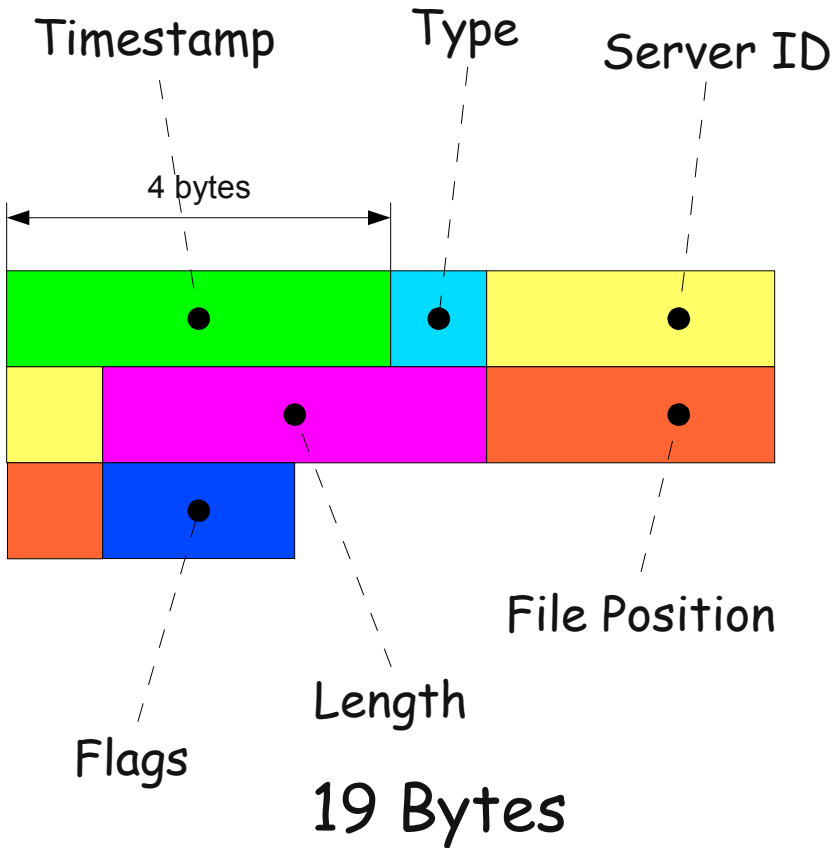
- Automatically purge logs
  - Server_variable: `expire_logs_days`
  - Removes the binlog files that are at least that old
  - The removal happens at server start or log flush

Binlog Event Structure



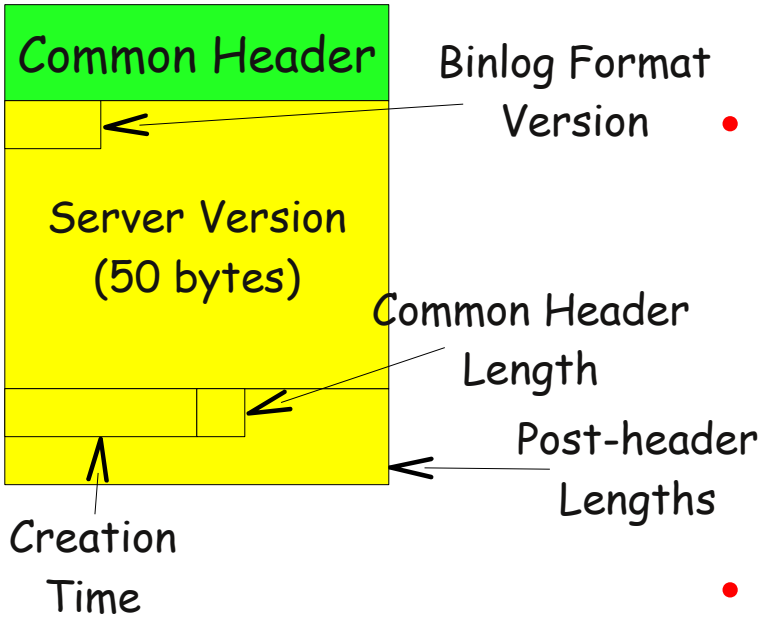
- Common header
  - Generic data
  - Fixed size
- Post-header
  - Event-specific data
  - Fixed size
- Variable part
  - Event-specific data
  - Variable size

Binlog Event Common Header



- Data common to all events
- File Position
  - *End* of event
- Timestamp
  - Statement *start* time
- Flags
  - Binlog-in-use
  - Thread-specific
  - Suppress “use”
  - Artificial
  - Relay-log event

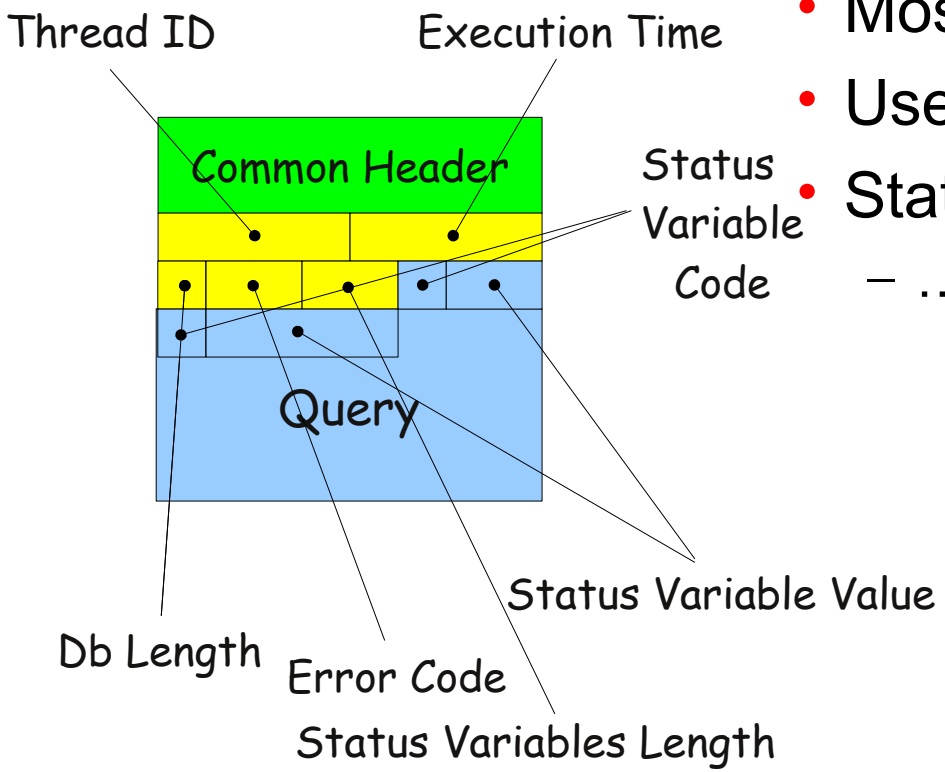
Format Description Event



- Describes file information
  - Different files can have different information
  - Design for extensibility
    - Common header length
    - Post-header lengths
- Fixed size!

```
mysql> SHOW BINLOG EVENTS;
+------------------+-----+-------------+-----------+-------------+-----------------------------------------------+
| Log_name         | Pos | Event_type  | Server_id | End_log_pos | Info                                          |
+------------------+-----+-------------+-----------+-------------+-----------------------------------------------+
| mysql-bin.000001 |   4 | Format_desc |         1 |         106 | Server ver: 5.1.37-1ubuntu5.1-log, Binlog ver: 4 |
| mysql-bin.000001 | 106 | Query       |         1 |         250 | use `test`; CREATE TABLE book (id INT UNSIGNE... |
| mysql-bin.000001 | 250 | Query       |         1 |         373 | use `test`; CREATE TABLE author (name VARCHAR... |
+------------------+-----+-------------+-----------+-------------+-----------------------------------------------+
3 rows in set (0.00 sec)
```

Query Event



- Most common event
- Used for statements
- Statement logged literally
  - … in almost all cases

Handling Statement Context

- SQL_MODE
- Time functions
  - NOW(), CURDATE(), CURTIME(), UNIX_TIMESTAMP()
  - SYSDATE()
- Auto-increment handling
  - Insert into AUTO_INCREMENT column
  - Using LAST_INSERT_ID()
  - @@auto_increment_increment
  - @@auto_increment_offset
- User-defined variables
- Seed for RAND()
- Character set

Status Variables

- Added in query event
  - Only when needed

- SQL_MODE
- Catalog
- auto_increment_increment
- auto_increment_offset
- Character Set
- Time Zone

Time Functions

- Execution start time is saved for session
  - Recorded in binlog event
- Some functions use statement start time
  - NOW(), CURTIME(), CURDATE(), UNIX_TIMESTAMP() OK
- Some functions call *time(2)* directly
  - SYSDATE() Warning!

Context Events

- Context events are used for:
  - User-defined variables
  - RAND() seeds
  - AUTO_INCREMENT
  - LAST_INSERT_ID()
- Context event(s) before Query event
  - There can be several context events before a Query
- Context event(s) + Query event = Binlog Group

Rand Event: RAND()

- For statements that use `RAND()` function

```
INSERT INTO tbl VALUE (RAND())
```

- RAND event precedes query
- Hold two seed values used by `RAND()` on slave

```
master> SHOW BINLOG EVENTS IN 'mysqld1-bin.000004' FROM 336;
+------------+-----+------------+-----------+-------------+-----------------------------------------------
| Log_name   | Pos | Event_type | Server_id | End_log_pos | Info
+------------+-----+------------+-----------+-------------+-----------------------------------------------
| mysqld1... | 336 | RAND       |         1 |         371 | rand_seed1=677022992,rand_seed2=870104260
| mysqld1... | 371 | Query      |         1 |         465 | use `test`; INSERT INTO tbl VALUES (RAND())
+------------+-----+------------+-----------+-------------+-----------------------------------------------
2 rows in set (0.00 sec)
```

Intvar Event: AUTO_INCREMENT

- Inserting into an AUTO_INCREMENT column

```
INSERT INTO book(title)
       VALUES("MySQL High Availability")
```

- Type = INSERT_ID
- Value = *integer*

```
mysql> SHOW BINLOG EVENTS FROM 373;
+----------+-----+------------+-----------+-------------+---------------------------------+
| Log_name | Pos | Event_type | Server_id | End_log_pos | Info                            |
+----------+-----+------------+-----------+-------------+---------------------------------+
| mysql... | 373 | Intvar     |         1 |         401 | INSERT_ID=1                     |
| mysql... | 401 | Query      |         1 |         522 | use `test`; INSERT INTO book... |
+----------+-----+------------+-----------+-------------+---------------------------------+
2 rows in set (0.00 sec)
```

Intvar Event: AUTO_INCREMENT

- Using LAST_INSERT_ID()

```
INSERT INTO author(name, book_id) VALUES
  ('Charles Bell', LAST_INSERT_ID()),
  ('Mats Kindahl', LAST_INSERT_ID()),
  ('Lars Thalmann', LAST_INSERT_ID());
```

- Type = LAST_INSERT_ID
- Value = *integer*

```
mysql> SHOW BINLOG EVENTS FROM 522;
+----------+-----+------------+-----------+-------------+---------------------------------+
| Log_name | Pos | Event_type | Server_id | End_log_pos | Info                            |
+----------+-----+------------+-----------+-------------+---------------------------------+
| mysql... | 522 | Intvar     |         1 |         550 | LAST_INSERT_ID=1                |
| mysql... | 550 | Query      |         1 |         746 | use `test`; INSERT INTO auth... |
+----------+-----+------------+-----------+-------------+---------------------------------+
2 rows in set (0.00 sec)
```

User_var Event: User-Defined Variables

- Using user variable

```
SET @LID = LAST_INSERT_ID();
SET @OReilly = "O'Reilly Media";
UPDATE book SET publisher = @OReilly
 WHERE id = @LID;
```

- Typed: STRING, REAL, INT, DECIMAL

```
mysql> SHOW BINLOG EVENTS FROM 1021;
+----------+------+------------+---------+-------------+-----------------------------------------+
| Log_name | Pos  | Event_type | Serv... | End_log_pos | Info                                    |
+----------+------+------------+---------+-------------+-----------------------------------------+
| mysql... | 1021 | User var   |       1 |        1048 | @`LID`=1                                |
| mysql... | 1048 | User var   |       1 |        1102 | @`Pub`=_latin1 0x4F... COLLATE latin1_swedish |
| mysql... | 1102 | Query      |       1 |        1217 | use `test`; UPDATE book SET publisher = @P... |
+----------+------+------------+---------+-------------+-----------------------------------------+
3 rows in set (0.00 sec)
```

Security and the Binary Log

- The replication user with the REPLICATION SLAVE privilege can read everything
- You must protect this account from exploitation
- Precautions
  - Prohibit login from outside the firewall
  - Audit the account and place log on a secure location
  - Use encrypted connection (e.g. SSL)
- But... even if you heed these precautions, it isn't enough if the data in the binary log is compromised
- Avoid sensitive data in the binary log like passwords

Securing Sensitive Data

- This is bad:

```
UPDATE employee SET pass = PASSWORD('foobar')
 WHERE email = 'mats@example.com';
```

- Rewrite the statement to use user-defined variables.
- This is good:

```
SET @password = PASSWORD('foobar');
UPDATE employee SET pass = @password WHERE email =
'mats@example.com';
```

- SET statement is not replicated
- No password written to the binary log

Stored Programs

- Stored Procedure
  - `CREATE PROCEDURE`
  - `CALL`
- Stored Function
  - `CREATE FUNCTION`
- Triggers
  - `CREATE TRIGGER`
- Events
  - `CREATE EVENT`

- Logging
  - Stored Program Definitions?
  - Stored Program Executions?

Stored Procedures Definition

- Always written as statement
- Requires one of
  - DETERMINISTIC
  - NO SQL
  - READS SQL DATA
- There is no check that you follow protocol!

```
CREATE PROCEDURE add_author(
  book_id INT,
  name VARCHAR(64)
)
  DETERMINISTIC
  SQL SECURITY INVOKER
BEGIN
  INSERT INTO author
     VALUES (book_id, name);
END
```

Stored Procedure Call

- Slave execute with privileges off
  - "`CALL my_exploit(@@server_id = 1)`"
  - Security Issue?
- Execution is unrolled
  - Actual statements executed are written to binary log
  - Procedure parameters replaced using NAME_CONST

```
mysql> CALL add_author(1, 'Mats Kindahl');
Query OK, 1 row affected (0.00 sec)

mysql> SHOW BINLOG EVENTS FROM 3457;
+----------...-----------------------------------------------------------------+
| Log_name ... | Info                                                           |
+----------...-+---------------------------------------------------------------+
| mysqld1-b... | use `test`; INSERT INTO author VALUES ( NAME_CONST('book_id',1), ... |
+----------...-+---------------------------------------------------------------+
1 row in set (0.00 sec)
```

Stored Procedures Definition

- What about definer?
  - Statement executed by slave thread
- User on slave thread?
  - Not normally
  - Who's definer on slave?
- Rewritten using DEFINER

```
CREATE PROCEDURE add_author(
  book_id INT,
  name VARCHAR(64)
)
  DETERMINISTIC
  SQL SECURITY DEFINER
BEGIN
  ...
END
```

```
mysql> SHOW BINLOG EVENTS FROM 3672;
+------...-+-------------------------------------------------------------------------------+
| Log_n... | Info                                                                          |
+------...-+-------------------------------------------------------------------------------+
| mysql... | use `test`; CREATE DEFINER=`mats`@`localhost` PROCEDURE `add_author`(... END |
+------...-+-------------------------------------------------------------------------------+
2 rows in set (0.00 sec)
```

Triggers and Events

Definitions:

- Similar to stored procedure definitions, trigger and event definitions use DEFINER clause
- Event *definitions* are replicated to the slave as slave-side-disabled
  - If you want the replicated events enabled on the slave, you need to enable them manually

Execution:

- Event *execution* effects are replicated

Trigger Execution

```
CREATE TABLE employee (name VARCHAR(64));
CREATE TABLE log (name VARCHAR(64));
CREATE TRIGGER tr_employee BEFORE UPDATE ON employee
FOR EACH ROW
  INSERT INTO log VALUES
    (CONCAT(OLD.name, " changed to ", NEW.name))
```

- What about this statement?

```
INSERT INTO employee VALUES ("Chuck")
```

- What is in the binary log with respect to the trigger?
  - Nothing
  - Trigger definitions can be different on master and slave
    - … even non-existent on master or slave
  - Trigger effects do not have to be replicated
    - … because trigger fires on the slave

Stored Function Execution

```
CREATE FUNCTION get_employee(who VARCHAR(64))
  RETURNS VARCHAR(64)
BEGIN
  DECLARE result VARCHAR(64);
  SELECT name INTO result FROM employee WHERE name = who;
  RETURN result;
END
```

- Consider this statement

```
INSERT INTO authors
  VALUES (get_employee("Chuck"));
```

- Statement is logged as entered by user
  - Similar to triggers
  - Definitions can be different on master and slave

Stored Function Execution

```
CREATE FUNCTION get_employee(who VARCHAR(64))
  RETURNS VARCHAR(64)
  SQL SECURITY INVOKER
BEGIN
  DECLARE result VARCHAR(64);
  IF @@server_id = 1 THEN
    SELECT name INTO result FROM employee WHERE name = who;
  ELSE
    SELECT name INTO result FROM secret_agents LIMIT 1;
  END IF
  RETURN result;
END
```

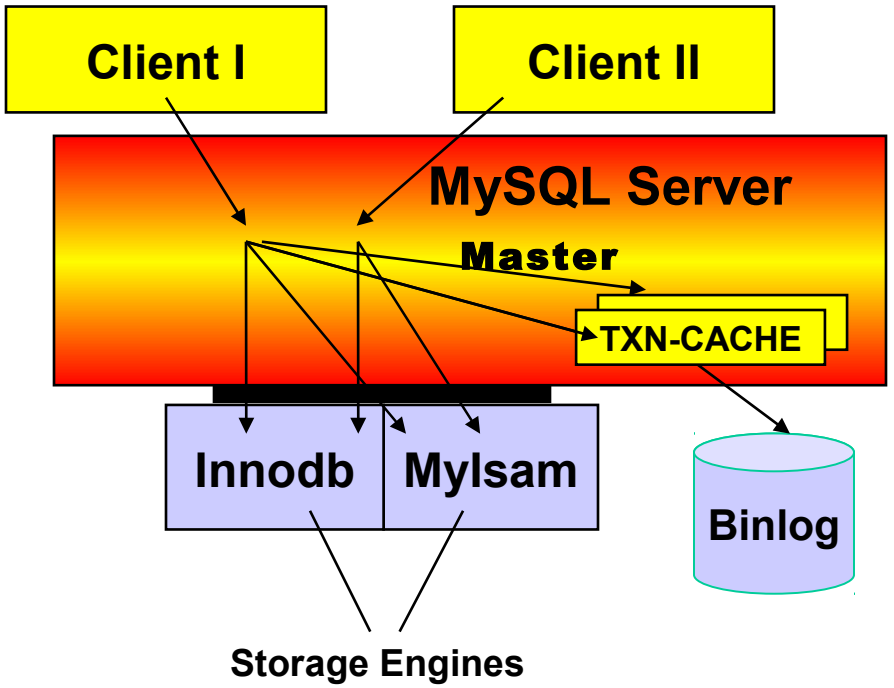
- Consider this statement:

```
INSERT INTO author
  VALUES (get_employee("Chuck"));
```

- Executed without privileges on slave!
  - … and executes different code on master and slave!
- `CREATE FUNCTION` requires `SUPER` privileges

```
--log-bin-trust-function-creators
```

Replication Architecture



Mixing InnoDB and MyISAM changes in the same transaction can cause slave to be inconsistent with the master

- **MyISAM changes are visible immediately when statement ends**
- **Transactional cache is flushed at commit time**

Mixing Engines in Transactions #1

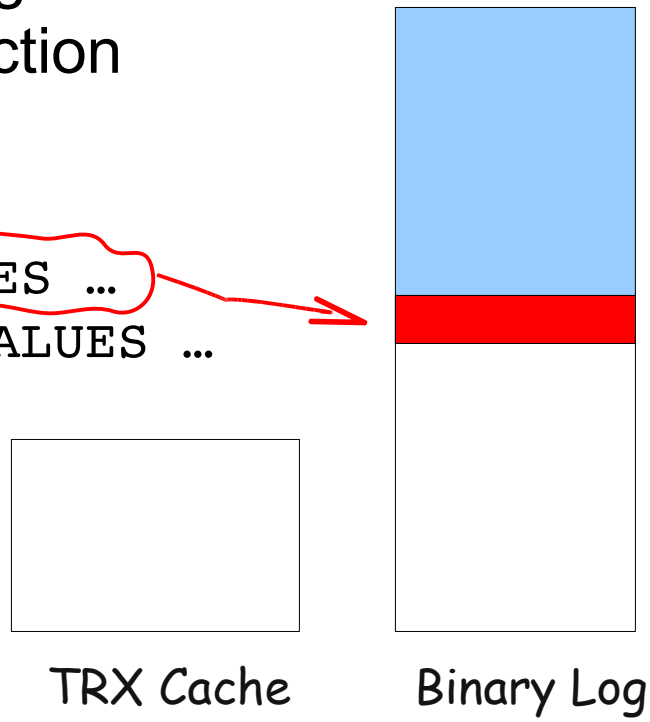
- Non-transactional change outside a transaction go directly to binary log

```
INSERT INTO myisam VALUES …
BEGIN;
INSERT INTO my_innodb VALUES …
    .
    .
    .
COMMIT;
```

Mixing Engines in Transactions #2

- Non-transactional statement goes directly to binary log if transaction cache is empty

```
BEGIN;
INSERT INTO myisam VALUES …
INSERT INTO my_innodb VALUES …
    .
    .
    .
COMMIT;
```



Mixing Engines in Transactions #3

- Non-transactional statement goes to transaction cache if not empty

```
BEGIN;
INSERT INTO my_innodb VALUES …
INSERT INTO myisam VALUES …
    .
    .
    .
COMMIT;
```

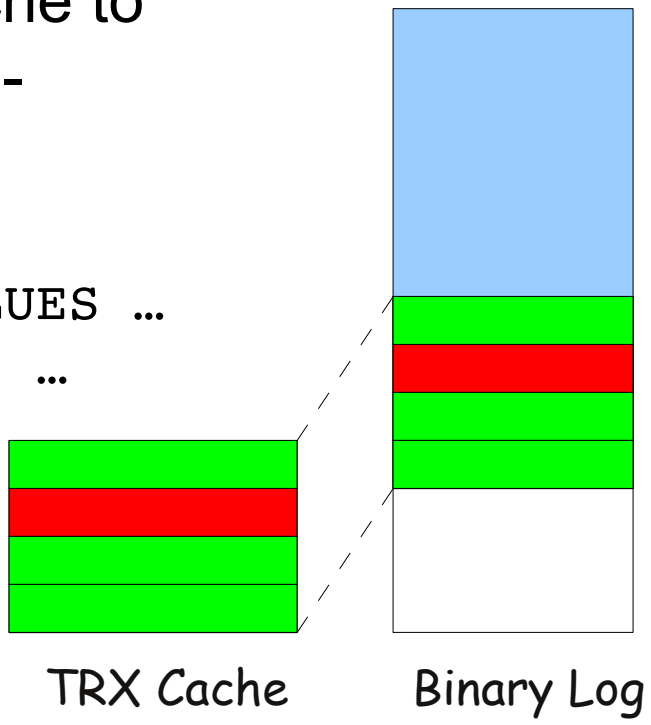
MYSQL 5.5

--binlog-direct-non-transactional-changes

Mixing Engines in Transactions #4

- Rollback writes transaction cache to binary log if it contains any non-transactional changes

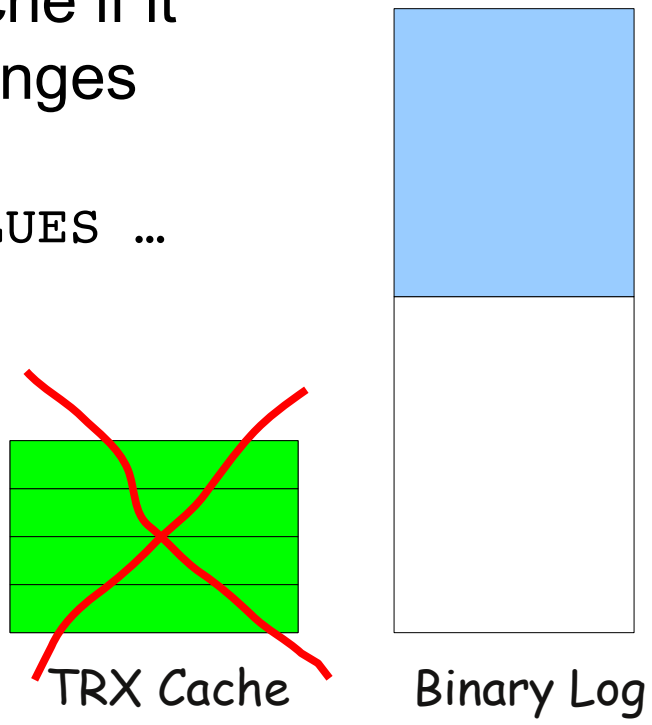
```
BEGIN;
INSERT INTO my_innodb VALUES …
INSERT INTO myisam VALUES …
    .
    .
    .
ROLLBACK;
```



Mixing Engines in Transactions #5

- Rollback clears transaction cache if it contains only transactional changes

```
BEGIN;
INSERT INTO my_innodb VALUES …
    .
    .
    .
ROLLBACK;
```



Mixing Engines in Statements

```
CREATE TABLE employee (name VARCHAR(64)) ENGINE=InnoDB;
CREATE TABLE log (name VARCHAR(64)) ENGINE=MyISAM;
CREATE TRIGGER tr_employee BEFORE UPDATE ON employee
FOR EACH ROW
  INSERT INTO log VALUES
    (CONCAT(OLD.name, " changed to ", NEW.name))
```

- What about this statement?

```
UPDATE employee SET name = "Charles"
 WHERE name = "Chuck";
```

- Transactional or non-transactional?
  - If a statement contain any non-transactional changes, it is considered non-transactional

Mixing Transactional and Non-transactional statements

- You can do this, but it has consequences
- Considerations
  - Non-transactional statements inside the transaction are committed implicitly – and written to the binary log
  - If the transactional statements fail, they are not written to the binary log
- Implicit commits
  - CREATE, ALTER
  - Modifications to mysql database (post 5.1.3)
  - Pragmatic causes (e.g., LOAD DATA INFILE)
- Avoiding the problem
  - Place non-transactional statements first
  - If you need values from these statements, use temporary tables or variables

Questions?

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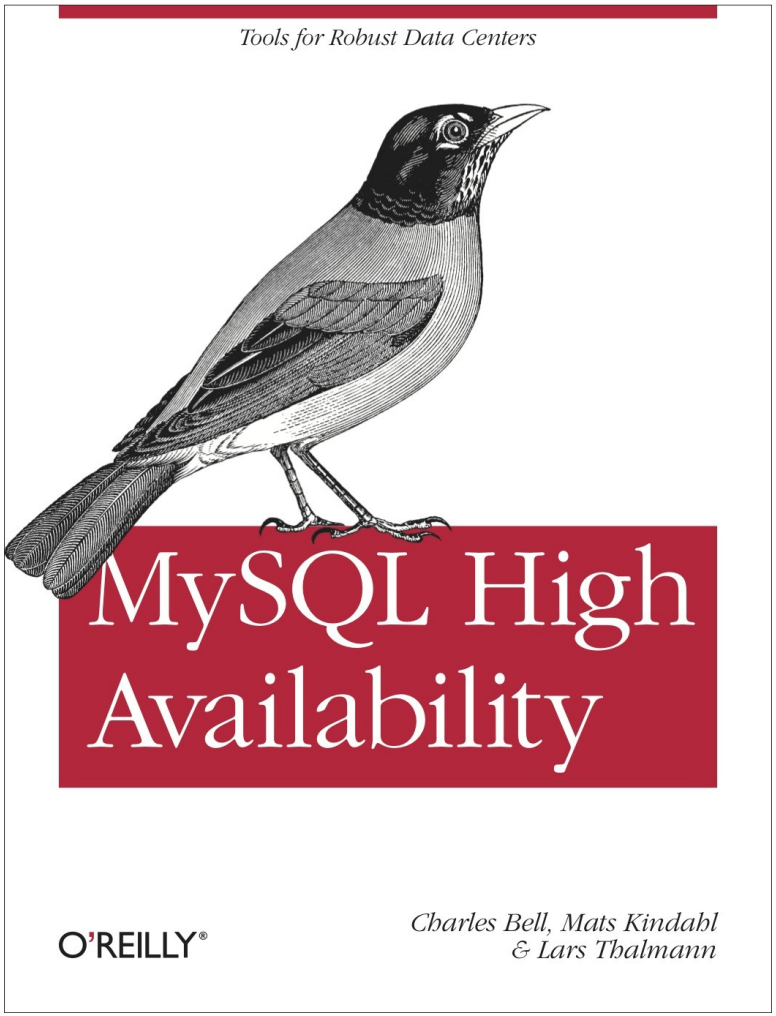
June 2010



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