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MySQL Connector/J BOF

Internals and Optimization

CREATE
THE
FUTURE

Jess Balint
Java Specialist Principal Software Developer
MySQL Connectors Team
Sept 30, 2014

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Program Agenda

1. Connector/J Introduction
2. Internal Interfaces
3. Feature Support
4. Optimization
5. Resources

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What is Connector/J?

- Type-4 JDBC Driver, etc, etc
- Supports most major JDBC features
  - Prepared statements, BLOBs, etc
- A.k.a. C/J for short
- 5.1 branch stable for several years
  - Frequent maintenance releases

Sample of Interesting Connector/J Features

- Client and server prepared statements
  - Client-side aka “emulated” prepared statements
- Load-balanced connections
  - Supports replication, cluster, master-master, etc
  - JMX reporting and management
- Client-side batch insert rewrite
- Hugely configurable via properties, interceptors, custom APIs

Recently Introduced Features

- Pluggable authentication (MySQL 5.5)
  - SHA-256 using SSL or RSA (requires OpenSSL server)
- Support for MySQL Fabric
  - 5.1.30/5.1.31 supports Fabric 1.4
  - 5.1.32+ supports Fabric 1.5
- Connection attributes (MySQL 5.6)
  - Configurable via `connectionAttributes` property
  - Accessible via `performance_schema.session_connect_attrs`

Other Recent Improvements

- Load-balancing improvements
  - Live management of replication connections via JMX or `com.mysql.jdbc.ReplicationConnectionGroupManager` interfaces
  - Multi-master load-balanced connections with `address=(host=hostname)(type=[master|slave])` URL syntax
- Set read-only status on server (MySQL 5.6)
  - `set session transaction read only`
- Several low-level performance improvements in strings and arrays

4 Things You Might Not Know

But should!

- Connector/J supports UTF-8 by default – no special configuration
  - More on this later
- Exceptions are classified by error type
  - C/J-specific classes of JDBC4 exception classes
- Troubleshooting help and profiling facilities are integrated
  - Usage advisor, slow query explanations
- Several extension points available for customization
  - Exception, statement, connection interceptors

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Core Classes

Client/server connections

- com.mysql.jdbc.MysqlIO
  - Lowest-level communication with MySQL server
  - Implements client/server wire protocol
- com.mysql.jdbc.ConnectionImpl
  - Builds on MysqlIO to implement connection
  - Contains all properties allowed on connection
    - E.g. getAllowMultiQueries()
    - Inherits from ConnectionPropertiesImpl
  - Creates statements
  - Executes queries (via MysqlIO)

Core Classes

JDBC APIs

- com.mysql.jdbc.DatabaseMetaData
  - Implements JDBC metadata APIs using MySQL “SHOW” commands
  - DatabaseMetaDataUsingInfoSchema
    - Using SQL standard INFORMATION_SCHEMA
    - Enable with `useInformationSchema` property
- com.mysql.jdbc.StatementImpl
  - JDBC Statement operations and functionality used by prepared statements
  - com.mysql.jdbc.PreparedStatement implements client-side prepared statements
  - com.mysql.jdbc.ServerPreparedStatement implements server-side prepared statements
- com.mysql.jdbc.ResultSetImpl

Logical Connection Classes

Replication & Load-balancing

- com.mysql.jdbc.LoadBalancingConnectionProxy
  - JDK dynamic proxy
  - Implements load-balanced connections
  - Proxies JDBC objects (statements, result sets)
- com.mysql.jdbc.LoadBalancedMySQLConnection
  - Connection object used internally to avoid proxy overhead
- com.mysql.jdbc.ReplicationConnection
  - Implements master/slave selection logic

Internal Interfaces

Connection Properties

- com.mysql.jdbc.ConnectionProperties
  - Getter/setter interface for all connection properties
- com.mysql.jdbc.ConnectionPropertiesImpl
  - Private member for each property
    - Property values accessed with accessor/mutator methods
  - Property definitions
  - Base class for most connection classes

Internal Interfaces

Connections

- com.mysql.jdbc.Connection
  - Vendor-specific extension to JDBC Connection interface
  - Documented & stable
- com.mysql.jdbc.MySQLConnection extends ConnectionProperties
  - Internal interface all connection classes implement
  - Exposes all operations internals need to perform on connections
  - Implemented different for physical direct connections (ConnectionImpl) than for logical connections such as load-balanced connections (LoadBalancedMySQLConnection)

Internal Interfaces

Fabric & Load-balanced Connections

- com.mysql.jdbc.LoadBalancedConnection
  - Extends MySQLConnection
  - Interface for load-balanced connections
  - Add/remove hosts
- com.mysql.fabric.jdbc.FabricMySQLConnectionProperties
  - Extends ConnectionProperties
  - Adds additional Fabric-specific connection properties
- com.mysql.fabric.jdbc.FabricMySQLConnection
  - Adds operations relevant to Fabric connections
  - Documented for application use

Extensions

- com.mysql.jdbc.StatementInterceptorV2
  - Allows altering statement execution
  - Pre/post process statement
    - If result is returned in pre-processing, query execution is skipped
  - Callbacks implemented in MysqlIO
- com.mysql.fabric.jdbc.ConnectionLifecycleInterceptor
  - Interceptor receives events at transaction boundaries and connection open/close
- Others
  - ExceptionInterceptor
  - LoadBalanceExceptionChecker
  - BalanceStrategy (load-balancing)

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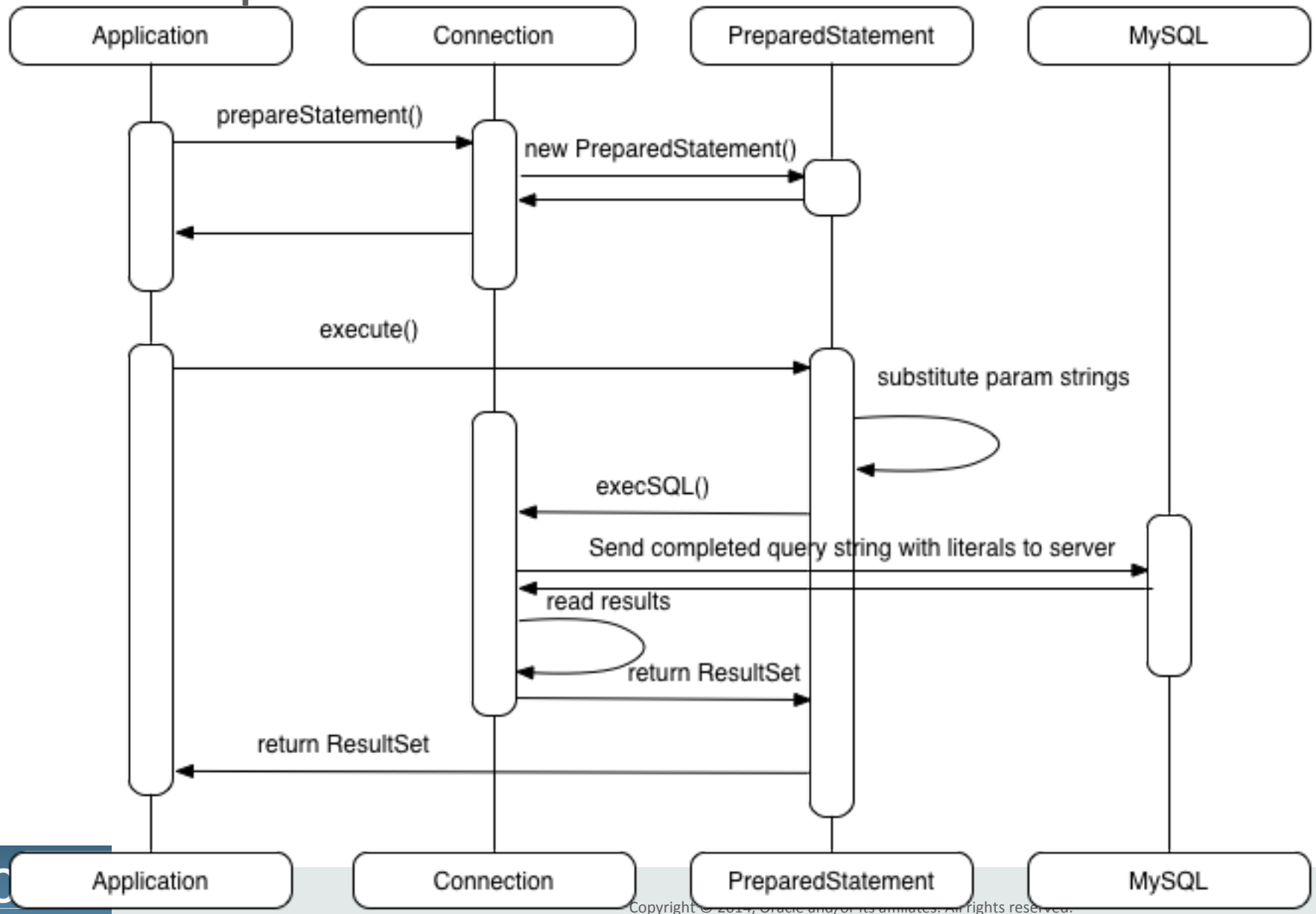
Client-side Prepared Statements and the Text Protocol

- Connection creates a PreparedStatement object on prepareStatement()
- Upon execution:
  - Bound parameters are converted to strings and placeholders in the query string are substituted with string representations
  - Query is sent to the server without any placeholders
- Results are read as text and parsed/converted when requested by the application
  - E.g. resultSet.getInt(1)

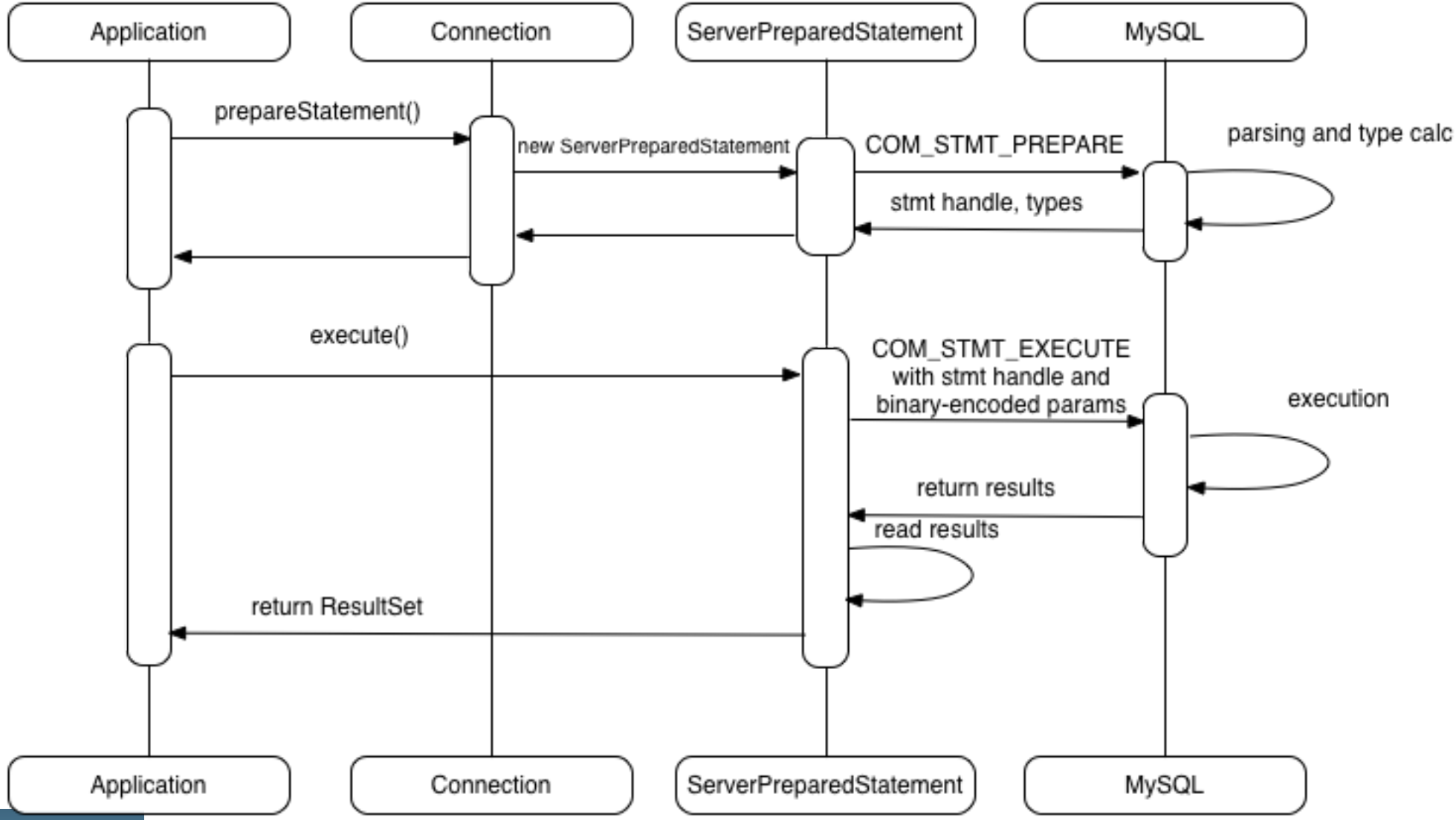
Client-side Prepared Statement Execution



Server-side Prepared Statements and the Binary Protocol

- Connection creates a ServerPreparedStatement object on prepareStatement()
  - Statement object sends the query text with placeholders to the server for parsing
  - Reads statement handle and inferred parameter and result types as response
- Upon execution:
  - Bound parameters are binary-encoded and sent with statement handle for exec
- Results are read in the same binary format as the parameters

Server-side Prepared Statement Execution



JDBC 3 and JDBC 4 – One Jar!

- Classloader unable to resolve JDBC 4 classes if loaded in JDBC 3 env
- Two-stage build
  - JDBC 3 classes compiled with Java 5
  - JDBC 4 classes compiled with Java 6/7/8
- JDBC 4 implementations are subclasses of JDBC 3 implementations
- Runtime selection of implementation via reflection

Internal Caching Opportunities

- Result set metadata cache
  - Types of results indexed by query text
- Prepared statement and callable statement cache
  - Avoids re-preparing same statements across connections
- Server configuration cache
  - Server configuration needed by driver indexed by

Load-balanced Connections

- Logical connection
  - One or more physical connections contained in logical connection
- Evaluates and possibly replaces “current” physical connection at transaction boundaries
  - Configurable balancing strategies
- Statement objects delegate to this logical connection which delegates to the “current” physical connection
- Created statements, result sets, etc are proxied to intercept errors which may trigger failover (changing the physical connection)

Replication Connections

- Logical connection
  - Does NOT implement MySQLConnection
- Uses load-balanced connections internally
  - Both master and slave
- Connection selection is based on readOnly mode of the logical connection
- Runtime configurable via JMX and public methods
  - No separate interface
  - Delegates to runtime configurability of load-balanced connections

Logical Connection Behavior

- Load-balanced connections maintain state on the client (db, tx isolation, etc)
  - Propagated to physical connection when made “current”
- Load-balanced connections are transparent to statements
  - Statements are executed on current physical connection
- Replication connections are NOT transparent to statements
  - Statements are pinned to master/slave connection upon creation

Contributions Encouraged!

- Technical issues can be discussed in the Connector/J forum on forums.mysql.com
- Extensive regression test suite in src/testsuite
- Patches for bugs or small improvements should be submitted on bugs.mysql.com for review
  - Must sign the OCA (Oracle Contributor Agreement)

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How to Optimize?

- Awareness of application performance bottlenecks
- C/J and server both profile several useful tools
- Different strokes for different folks
  - Network vs CPU vs memory concerns

What to Optimize?

- Figure out where time is spent
  - Narrow by use case
- C/J and MySQL server both can log slow queries
  - C/J can include an query plan from EXPLAIN
    - `logSlowQueries`, `explainSlowQueries`
- C/J usage advisor can help narrow bottlenecks
  - Find unclosed JDBC objects (connections, statements)
  - Find short-lived connections, single-use prepared statements
  - Find large result sets, unused columns, unnecessary type conversions

Reducing Network Traffic (1)

- Goal is to reduce round-trips and amount of data transferred
- Server-prepared statements
  - Avoid sending query text for repeatedly executed queries
  - Pinned to the physical connection
- Eliminate unnecessary server communication
  - Caching of configuration information (cacheServerConfiguration)
  - Disable/minimize connection attributes (MySQL 5.6+)
- Employ JDBC batching
  - Optionally with rewrites (doesn't help when using server-prepared statements)

Reducing Network Traffic (2)

- Don’t send auto-commit or transaction isolation levels
  - elideSetAutoCommits, useLocalSessionState, useLocalTransactionState, alwaysSendSetIsolation=false
- Use compressed protocol
- Use connection pooling
  - Can generate additional statements
- Use ping for connection pool validation

Reducing Network Traffic
(3)

- Use connection pool PreparedStatement cache

- Use common sense
  - Don’t retrieve more data than necessary – rows OR fields
  - Push data aggregation and filtering to the server
  - Keep transaction size reasonable

Reducing Memory Footprint

- Goal is to reduce the amount of data stored on the client
- Streaming result sets
  - com.mysql.Statement.enableStreamingResults()
- Server-prepared statements (useServerPrepStmts)
- Connection pool configuration
  - Minimize idle connections
- Caching server configurations
- Don’t cache prepared statements unless necessary

Reducing CPU Usage

- Goal is to reduce the amount of work done
- Don’t use compression
- Cache result set metadata
- Binary protocol
- Use and cache prepared statements
  - Client or server side
- Solaris => useConfigs=solarisMaxPerformance

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More on C/J

- Browse the codebase
  - There's a lot to learned from getting familiar with the nitty gritty code
- Discuss C/J on the forums
  - http://forums.mysql.com
- MySQL Connector/J Developer Guide
  - Main source of documentation

C/J Blogs

- Todd Farmer – http://mysqlblog.fivefarmers.com
  - Typically focused on load-balance and replication connections
- Mark Matthews – http://www.jroller.com/mmatthews/
  - Description of many C/J features and tips on using them
- Jess Balint – http://blogs.oracle.com/jbalint
  - Connector/J announcements, tips, tutorials
- Connectors Team Java – http://blogs.oracle.com/mysqlconnectors-java
  - New!

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