



MySQL Enterprise Edition

Product Guide

A MySQL® White Paper



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1 Introduction

Whether you are building high volume websites, enterprise and departmental applications, or advanced communications networks, your organization needs the tools to build and manage these business-critical database applications. This paper explores how you can confidently deploy MySQL, on-premises and in the Cloud, as part of a cost-effective cross-platform solution for delivering high-performing, highly available, reliable and scalable applications. It examines some of the challenges associated with building and supporting scalable, data-driven applications using open source technologies and provides a detailed overview of how MySQL Enterprise Edition can address these challenges. MySQL Enterprise Edition, combines the most secure, scalable, “always on” version of the MySQL database with online backup, monitoring, management and visual database design and SQL development tools, all backed by Oracle Premier Support, 24x7 global enterprise-class support services. Further, MySQL Enterprise Edition supports your use of MySQL in conjunction with many of the Oracle products and tools you may already be familiar with or are currently using. MySQL Enterprise Edition is specifically designed to help you bring secure, high performing and scalable MySQL applications to market faster, mitigate risk, and ensure you meet customer and end-user Service Level Agreements (SLAs).

2 MySQL Enterprise Edition

MySQL is the world's most popular open source database. Whether you are a fast growing web property, software vendor, or large organization, MySQL can cost-effectively help you deliver high performance, scalable database applications. If you are currently using MySQL, you probably started with the MySQL Community Edition. In fact, in many instances MySQL enters an organization via an application development project and makes its way into the data center when the application is promoted for production use. Challenges arise when these applications become vital to business revenues or key business functions. The most common challenges around running MySQL and other open source technologies are revealed by a simple line of questioning:

- How will you ensure you are using the most reliable, secure, scalable, up-to-date version?
- How will you know:
 - If a server or applications is down?



- If there is a replication master/slave synchronization or latency issue?
- If something else is affecting the performance of a server?
- Will you know:
 - If MySQL is configured to scale-out as your application data and customer base grows?
 - How to configure MySQL variables to ensure your applications run at their peak performance?
- How will you:
 - Identify security loopholes in MySQL servers?
 - Know when there have been security alterations on a MySQL server?
 - Seamlessly add auditing compliance to your new and existing MySQL applications?
- How will you:
 - Optimize your database designs and queries before they are migrated into your production environments or included in your products?
 - Ensure replicated servers are configured correctly for performance and scalability?
 - Monitor and tune poorly performing user/application SQL code?
- How will you integrate MySQL with your existing security standards and infrastructure?
- If you or your customers also use the Oracle Database, how can you:
 - Manage MySQL high availability using existing Oracle solutions?

To help you answer these questions with confidence MySQL provides MySQL Enterprise Edition. MySQL Enterprise Edition is a commercial offering comprised of the MySQL database with security, encryption, auditing, high availability and scalability extensions, online backup, monitoring, management, and visual database design and SQL development tools. MySQL Enterprise Edition is backed by Oracle Premier support for organizations delivering highly available, business critical applications and services. MySQL Enterprise Edition includes the following components:

3 MySQL Database

The MySQL Database is a fully integrated transaction-safe, ACID compliant database with full commit, rollback, crash-recovery and row level locking capabilities. The MySQL Database is a cost-effective solution for:

- High-performance, scalable Web/Cloud/SaaS and E-commerce applications
- Corporate Departmental OLTP and Data Mart applications



- Operational data store integrated with Big Data repositories (Hadoop)
- Low administration, high performance, reliable embedded database applications
- And more

The MySQL Database provides the following features:

- **Self-healing Replication Clusters** to improve scalability, performance and availability of high-volume applications.
- **Performance/Scalability** to meet the demands of ever growing data loads and user concurrency.
- **Online DDL/Schema Changes** for dynamic applications that must remain available for updates at all times.
- **SQL and NoSQL Access** for applications that require complex queries and simple, fast Key Value operations against the same transactional dataset.
- **Native JSON Support** for efficient and flexible storage, search and manipulation of schema-less data.
- **Performance Schema** for monitoring user/application level performance and resource consumption.
- **Platform Interoperability** that allows MySQL to run across operating systems and to be used as the operational data store for Hadoop and other Big Data platform deployments.

You can learn more about what's new in MySQL 5.7 for DBAs and Developers here:

<http://www.mysql.com/why-mysql/white-papers/whats-new-mysql-5-7/>

MySQL Replication and High Availability

MySQL Replication has been widely deployed by MySQL users to deliver both scalability and high availability. It is simple for users to rapidly create multiple replicas of their database to scale-out beyond the capacity constraints of a single instance, enabling them to serve rapidly growing database workloads.

MySQL Replication works by simply having one server act as a master, while one or more servers act as slaves. The master server will log the changes to the database. Once these changes have been logged, they are then sent and applied to the slave(s).

Replication is often employed in a scale-out implementation so that requests that simply “read” data can be directed to slave servers. This allows transactions involving writes to be exclusively executed on the master



server and leads to not only a performance boost but a more efficient use of resources.

Replication is also the most common approach to delivering High Availability (HA) for MySQL databases. Updates are replicated from a master to slave server with the goal being to fail-over to the slave server in the event the master goes offline either due to an error, crash or for maintenance purposes. To this end MySQL provides an advanced set of automated, monitoring and fail-over utilities that enable DBAs to take a “set it and forget it” approach to ensuring the MySQL databases under their care remain up and available. Rendered in Python and provided as open source under the GPL, the MySQL Utilities provide advanced slave promotion and fail-over functionality and are fully extensible to meet custom needs. More information is available at <http://dev.mysql.com/doc/workbench/en/mysql-utilities.html>.

MySQL Enterprise Edition builds on the above feature set by providing a set of commercial extensions around the MySQL Database that meet the advanced security, performance, scale and availability requirements of the most demanding applications, web and online environments. These extended features are exclusive to MySQL Enterprise Edition and are described below.

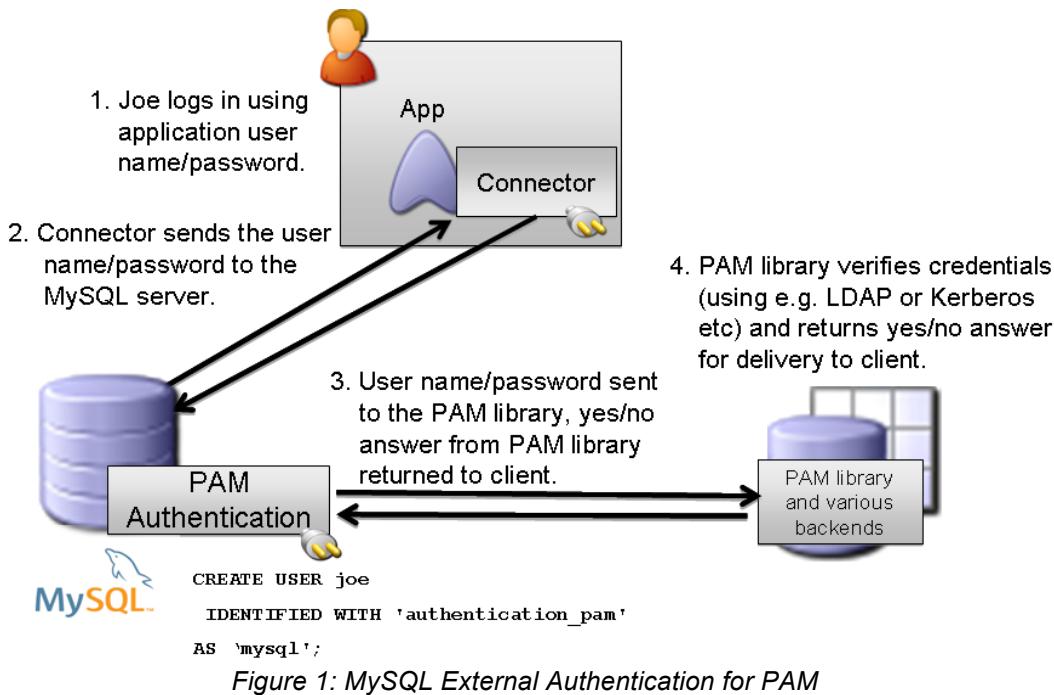
4 MySQL Enterprise Authentication

MySQL Database 5.5 and higher also supports an open, pluggable authentication interface that enables users to develop plug-ins to authenticate MySQL client connections against external resource such as LDAP, Windows Active Directory, PAM, etc. This enables MySQL to easily integrate with existing security standards and infrastructure.

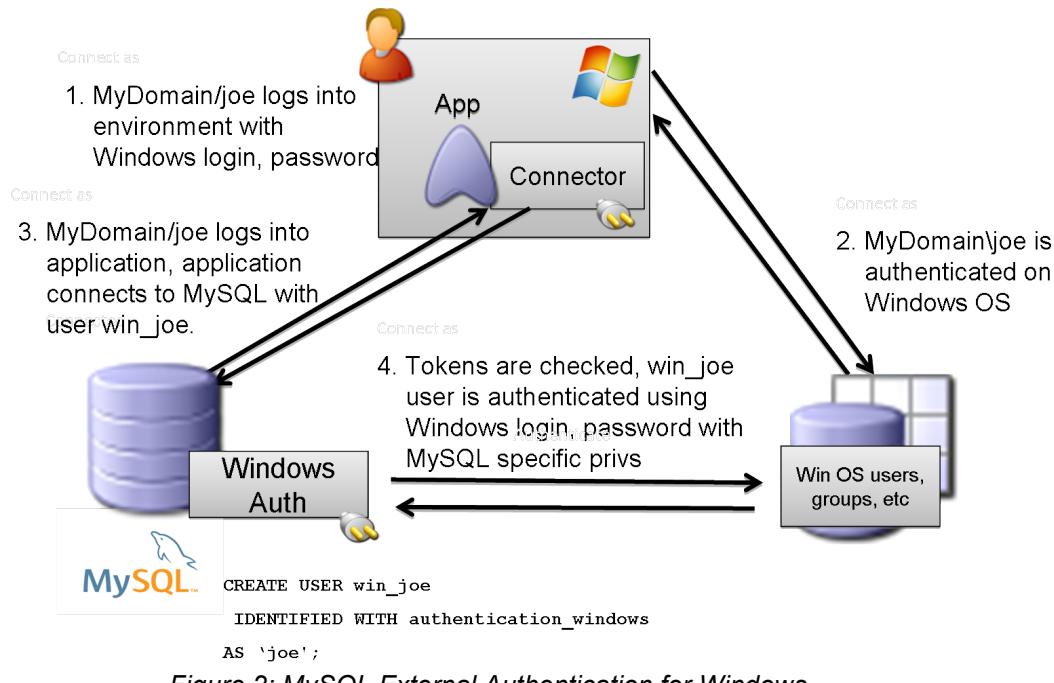
MySQL External Authentication

MySQL Enterprise Edition provides ready to use external authentication modules for users who authenticate users via Pluggable Authentication Modules (“PAM”) or native Windows OS services. Each is described below:

- MySQL External Authentication for PAM - Enables you to configure MySQL to use PAM to authenticate users on LDAP, Unix/Linux, and other systems.



- MySQL External Authentication for Windows – Enables you to configure MySQL to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the token information in their environment (via Active Directory) without specifying an additional password.





To learn more about MySQL Enterprise Authentication visit:
<http://www.mysql.com/products/enterprise/security.html>.

5 MySQL Enterprise Encryption

To protect sensitive data throughout its lifecycle, MySQL Enterprise Encryption provides industry standard functionality for asymmetric encryption (Public Key Cryptography). MySQL Enterprise Encryption provides encryption, key generation, digital signatures and other cryptographic features to help organizations protect confidential data and comply with regulatory requirements including HIPAA, Sarbanes-Oxley, and the PCI Data Security Standard.

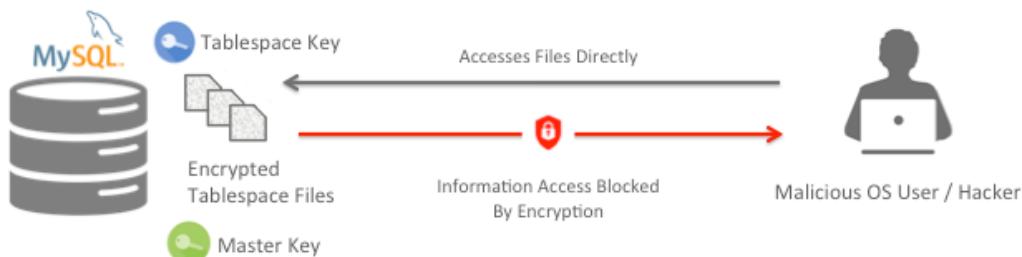
MySQL Enterprise Encryption gives DBAs and Developers the tools they need for:

- Asymmetric Public Key Encryption (RSA)
- Asymmetric Private Key Decryption (RSA)
- Generate Public/Private Key (RSA, DSA, DH)
- Derive Symmetric Keys from Public and Private Key pairs (DH)
- Digitally Sign Data (RSA, DSA)
- Verify Data Signature (RSA, DSA)
- Validation Data Authenticity (RSA, DSA)

This enables software developers to encrypt data by using RDS, DHS and DH encryption algorithms without changing existing applications.

6 MySQL Enterprise Transparent Data Encryption (TDE)

MySQL Enterprise Transparent Data Encryption (TDE) protects your critical data by enabling data-at-rest encryption in the database. It protects the privacy of your information, prevents data breaches and helps meet regulatory requirements including the Payment Card Industry Data Security Standard (PCI DSS), Health Insurance Portability and Accountability Act (HIPAA) and numerous others.

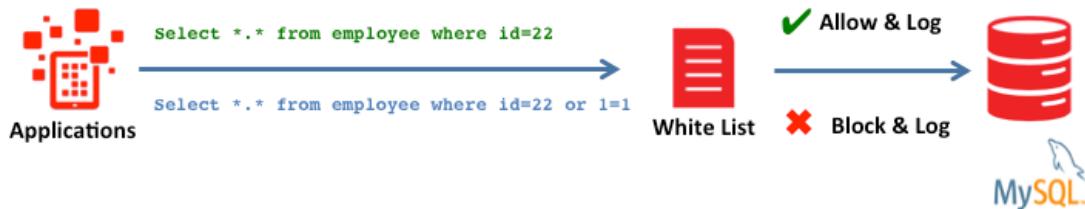


MySQL Enterprise TDE enables data-at-rest encryption by encrypting the physical files of the database. Data is encrypted automatically, in real time, prior to writing to storage and decrypted when read from storage. As a result, hackers and malicious users are unable to read sensitive data from tablespace files, database backups or disks.

MySQL Enterprise TDE uses a two-tier encryption key architecture, consisting of a master encryption key and tablespace keys which provides easy key management and rotation. Tablespace keys are managed automatically behind the scenes while the master encryption key is stored in a centralized key management solution such as Oracle Key Vault, which enforces clear separation of keys from encrypted data.

7 MySQL Enterprise Firewall

MySQL Enterprise Firewall guards against cyber security threats by providing real-time protection against database specific attacks, such as an SQL Injection. MySQL Enterprise Firewall monitors for database threats, automatically creates a whitelist of approved SQL statements and blocks unauthorized database activity.



- Real-time Threat Monitoring - All incoming queries pass through a SQL analysis engine and are matched against an approved Whitelist of expected SQL statements.
- Block Suspicious Traffic - Statements that do not match the approved whitelist are blocked, logged and can be analyzed to help block a potential SQL injection attack.
- Learn and Build Whitelists - Automatically create user specific whitelists of pre-approved SQL statements using a self-learning system.
- Transparent Protection - MySQL Enterprise Firewall requires no changes to your application regardless of development language, framework or 3rd party application.
- High Performance - MySQL Enterprise Firewall runs within each MySQL instance and provides scale-out performance.



- Logging - MySQL Enterprise Firewall tracks and provides metrics on both allowed and blocked SQL statements. Blocked statements are logged for inspection and alerting.

8 MySQL Enterprise Audit

Today's web-based applications have evolved from nice-to-have enablers to the mission-critical revenue generating mechanisms that characterize the modern business model. In this virtual marketplace, PCI compliance guidelines ensure credit card data is secure within e-commerce apps. From a corporate standpoint, Sarbanes-Oxley, HIPAA and other government imposed mandates guard the medical, financial, public sector and other personal data centric industries with required logging, archiving and "upon request" access to audit trails that reveal the eyes and hands that have viewed and acted upon the most sensitive of data. In all use cases, requirements for capturing application level user activity are most commonly implemented on the back-end database.

With this in mind, MySQL 5.5 and higher provides an open pluggable audit interface that enables all MySQL users to write their own auditing solutions based on application specific requirements. To help users quickly and seamlessly add auditing compliance to their existing applications MySQL Enterprise Edition includes MySQL Enterprise Audit, an easy to use policy-based auditing solution that enables users to:

- **Powerful Filtering to Protect Sensitive Data** - Define what you audit using templates or design highly custom filters using simple JSON filter definition. Filter on connections, users, table access, access type, statement status (success/failure), query content, and more.
- **Meet Regulatory Compliance Standards** - Provide the data your organization and auditors need to be in compliance with requirements including PCI, HIPAA, FERPA, SOX and more
- **Achieve Security Goals through Comprehensive Auditing** - Trust but verify DBA activity, prove your data's validity and perform forensic analysis to investigate or discover data breaches.
- **Easy Integration with Audit Vaults and Stores** - Externally archive and analyze XML-based audit logs with ease using Oracle Audit Vault and other third party solutions including Splunk.

- **Dynamic and Easy to Manage** - Dynamically enable/disable audit stream, change filtering, and more with no downtime. Automatically rotate audit log files based on size.
- **Low Overhead** - Collects critical audit data without minimal performance impact. Use fine grain filtering to minimize audit log size and IO impact.

A common set up and use case scenario is depicted here:

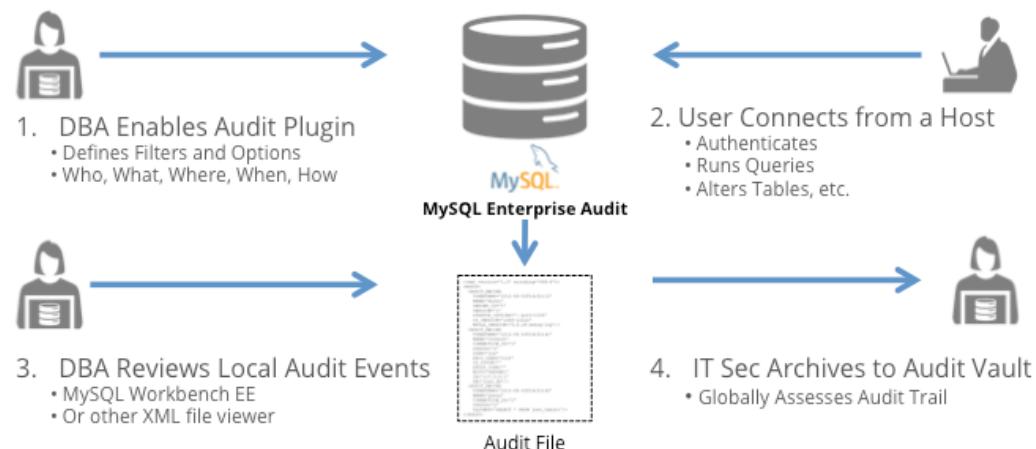


Figure 3: MySQL Enterprise Audit Set Up and Use Case

To learn more about MySQL Enterprise Audit visit:
<http://www.mysql.com/products/enterprise/audit.html>.

9 MySQL Enterprise Scalability

By default the MySQL Database provides a complex thread-handling model that provides excellent throughput and performance for online and web-based applications. User connections are mapped to execution threads on a one-to-one basis with each connection/thread assignment remaining intact until the connection is terminated by the client. Under this model the MySQL Database provides scalable concurrency of both user connections and query executions.

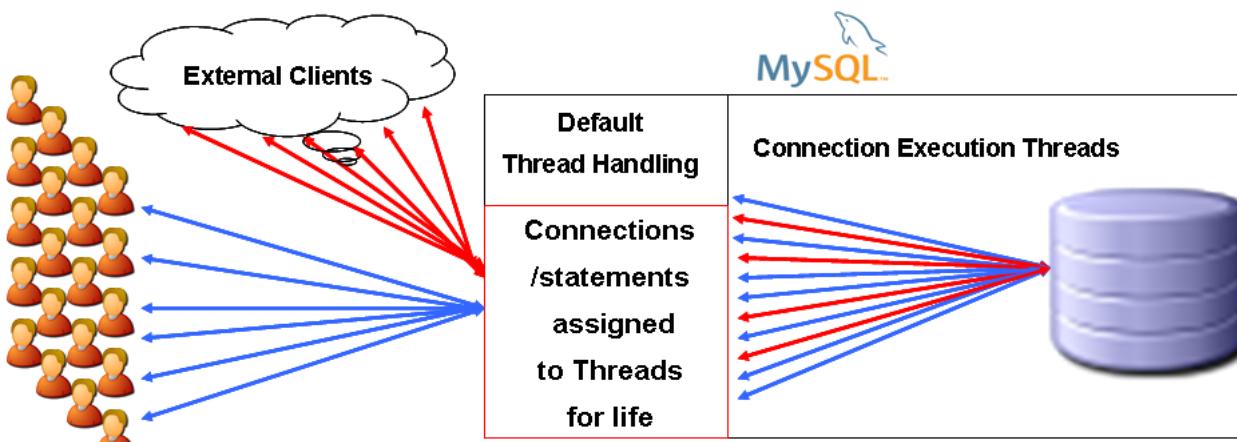


Figure 4: Default Thread Handling Model

While this model serves and scales most web deployment use cases very well it does have the potential to limit scalability as connection and query loads increase at an increasing rate. This use case is becoming more common as application clients now extend far beyond the keyboard to mobile and other web-enabled devices. For the most highly-trafficked applications when concurrent connections grow from hundreds to thousands and associated query executions grow proportionally scalability challenges and limitations with the default model are potentially exposed:

- Current model does not prioritize connection queries for execution, regardless of the number that have been submitted or that are in a “wait” status. No prioritization of queries means that all attempt to execute in parallel with no regard for server resource limitations.
- More concurrency of query executions requires significantly more server memory. In an extreme case if the amount of memory needed by all active connections exceeds server memory, the MySQL server may revert to memory/disk swapping, which will greatly impact user response times.
- More query executions also leads to more cache flushing, which leads to more cache misses and disk I/O requests. More disk I/O leads to longer query execution and user response times.
- Write intensive applications are impacted significantly as concurrent DML statement execution times can degrade exponentially as disk I/O increases.

The MySQL Thread Pool

To meet these challenges around the most demanding “mobilized” application user and workloads MySQL Enterprise Edition provides the MySQL Thread Pool. The Thread Pool is a user configurable option that provides an efficient, alternate thread-handling model designed to sustain

performance and scalability as concurrent user loads continue to grow. In these use cases the Thread Pool addresses the limitations to scalability by:

- Managing/controlling query execution until the MySQL server has the resources to execute it.
- Splitting threads into managed Thread Groups. Inbound connections are assigned to a group via a round-robin algorithm and the number of concurrent connections/threads per group is limited based on queue prioritization and nature of queries awaiting execution. Transactional queries are given a higher priority in queue than non-transactional, but queue prioritization can be overridden at the user level as needed.
- Avoiding deadlocks when queries are stalled or executing for long period of time.

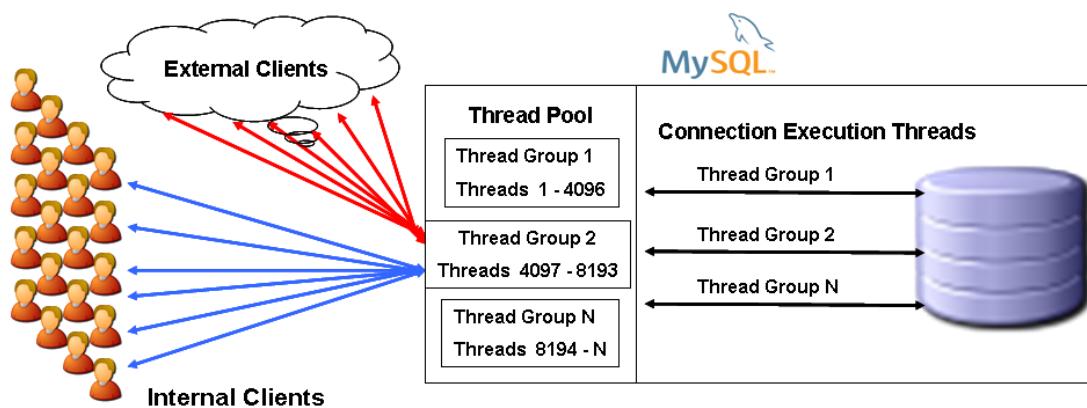


Figure 5: MySQL Thread Pool

The result is sustained performance and scalability as concurrent user connections and work loads grow as shown here in a benchmark conducted using MySQL 5.6:

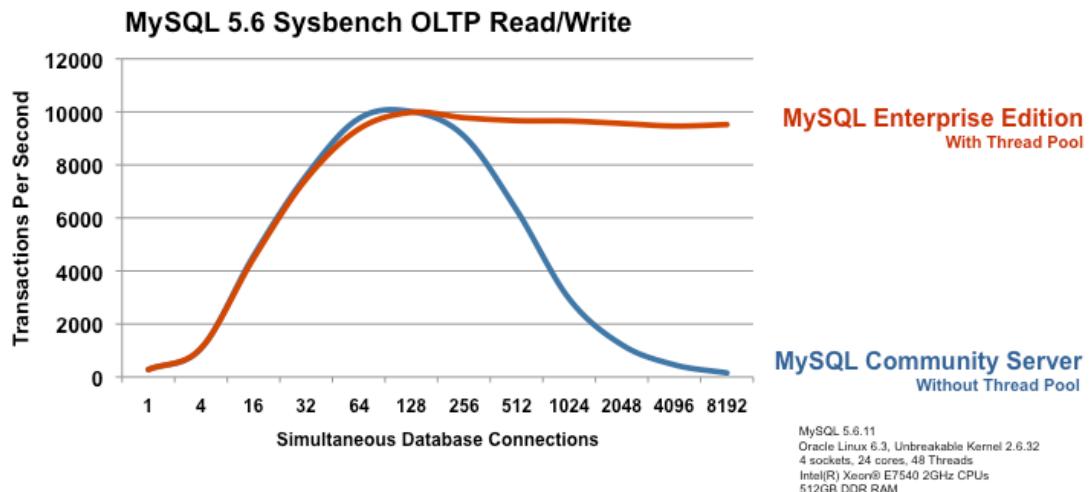


Figure 6: MySQL Enterprise Edition provides 60x better scalability for OLTP Read/Write activity with Thread Pool

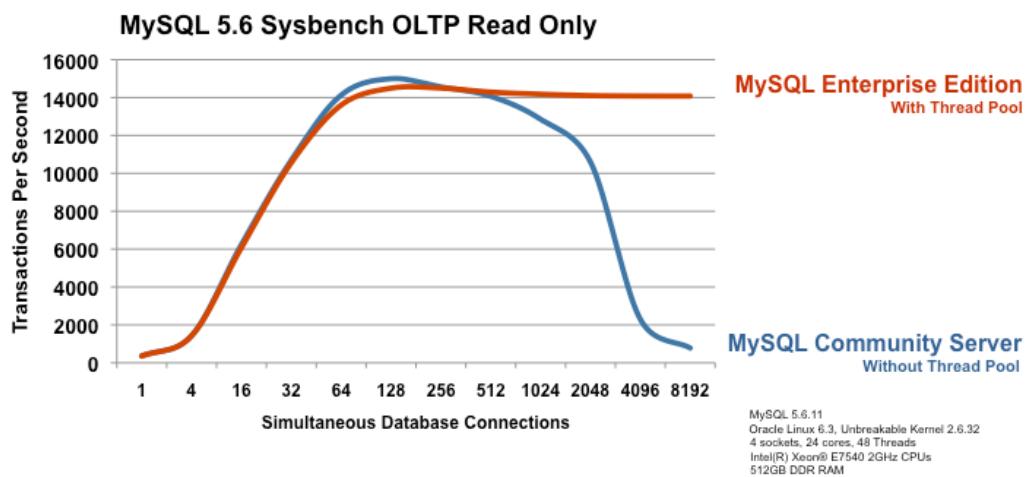


Figure 7: MySQL Enterprise Edition provides 18x better scalability for OLTP Read activity with Thread Pool

SysBench OLTP benchmarks show that the MySQL Thread Pool provides a significant improvement in sustained performance and scalability for applications that service a growing number of concurrent user connections and query executions. The graphs above show read/write activity improves by a factor of 60 while read only activity improves by a factor of 18, both at 8,192 concurrent connections, with the Thread Pool enabled.

To learn more about MySQL Enterprise Scalability visit:



<http://www.mysql.com/products/enterprise/scalability.html>.

10 MySQL Enterprise High Availability

Databases are the center of today's applications – whether SMB, enterprise, web or cloud, as they store and protect an organization's most valuable assets, and run business-critical applications. Just minutes of downtime can often result in significant amounts of lost revenue and unsatisfied customers. Making database applications highly available is therefore a top priority for DevOps and Architect teams.

As demonstrated below, MySQL Enterprise Edition offers a range of solutions to meet different application and operations environments that automatically detect and recover from failures – whether these occur at the network, host, OS or database layer – as well as eliminate downtime resulting from scheduled maintenance activities.

Oracle Clusterware Agent for MySQL

Oracle Clusterware delivers high availability by unifying servers to form a cluster. The Oracle Clusterware XAG Agent for MySQL enables Oracle Clusterware to provide a Highly Available MySQL Service using MySQL Enterprise Edition. It ensures that the MySQL Server process can be moved between different machines - either manually or as part of an automated failover.

Oracle Solaris Clustering

Oracle Solaris Cluster provides high availability and load balancing to mission-critical applications and services in physical or virtualized environments. With Oracle Solaris Cluster, organizations have a scalable and flexible solution that is suited equally to small clusters in local datacenters or larger multi-site, multi-cluster deployments that are part of enterprise disaster recovery implementations.

The Oracle Solaris Cluster MySQL agent integrates seamlessly with MySQL offering a selection of configuration options in the various Oracle Solaris Cluster topologies

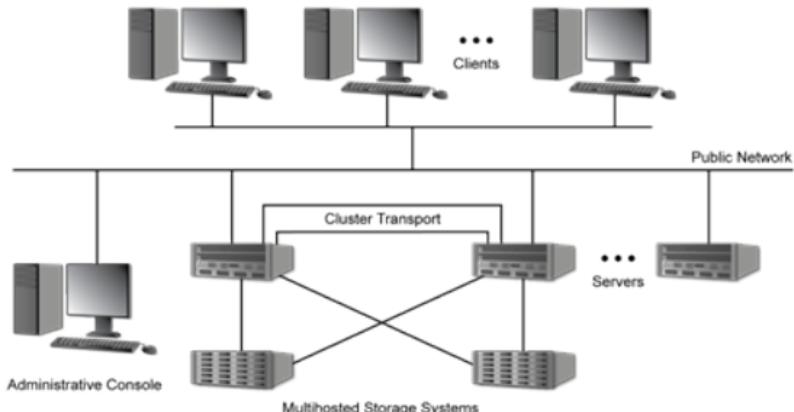


Figure 9: Oracle Solaris Clustering

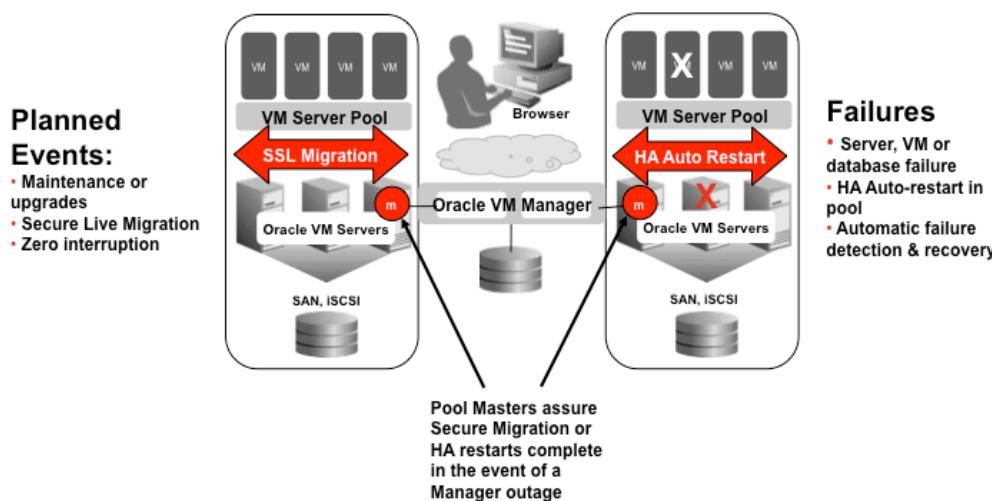
You can learn more about Oracle Solaris Cluster and the MySQL agents here: <http://www.oracle.com/technetwork/server-storage/solaris-cluster/overview/index.html>

To learn more about MySQL Enterprise High Availability visit: http://www.mysql.com/products/enterprise/high_availability.html.

Oracle VM

In addition to the proven benefits of virtualization, Oracle VM enhances MySQL high availability through:

- **Secure Live VM Migration** – Eliminates service outages associated with planned maintenance by migrating running VMs to other servers over secure SSL links, without interruption. Oracle VM is the first major virtualization solution to SSL-encrypt migration traffic by default to protect sensitive data from exploitation.
- **Automatic VM Restart** – Detects and automatically restarts instances within the server pool after failures of physical server hardware, VM instances, or MySQL.



- **Automatic or Manual Server Pool Load Balancing** – Guest VMs are automatically placed on the server with the most resources available in the pool at start-up, or can be started within a user-designated subset of servers.
- **Automated Network Management** – Oracle VM configures a common, virtualized system IP that is automatically bound and re-bound to physical network layers, regardless of the platform it is initially started on, thereby eliminating the manual administration effort involved with updating routing tables or network configurations.

Underpinning the HA mechanisms, Oracle VM provides:

- Powerful cluster-based network and storage heartbeat algorithms to quickly and deterministically identify failed and/or isolated servers in the server pool to ensure rapid recovery;
- Sophisticated distributed lock management functionality for SAN and iSCSI storage that ensures VMs or entire servers can be rapidly restarted with no risk of data corruption.

11 MySQL Enterprise Backup

Backup

MySQL Enterprise Backup performs online "Hot", non-blocking backups of MySQL databases. Full backups can be performed on all InnoDB data while MySQL is online, without interrupting queries or updates. In addition, incremental backups are supported so that only data that has changed from a previous backup are backed up. Also partial backups are supported when only certain tables or tablespaces need to be backed up.

Restore

MySQL Enterprise Backup restores data from a full backup with full backward compatibility. Consistent Point-in-Time Recovery (PITR) enables restoration to a specific point in time. Using MySQL backups and binlog, you can also perform fine-grained roll forward recovery to a specific transaction. A partial restore allows recovery of targeted tables or tablespaces. In addition, you can restore backups to a separate location, or create clones for fast replication setup or administration.

Compression



MySQL Enterprise Backup supports creating compressed backup files, typically reducing backup size from 70% to over 90% when compared to the size of actual database files, reducing storage and other costs.

Direct to Cloud Storage

Support for Oracle Storage Cloud, AWS S3 (Simple Storage Service) API to backup and restore direct to inexpensive Cloud Storage (S3, Swift, and more)

12 MySQL Enterprise Monitor

MySQL developers, DBAs and SysAdmins often find themselves having to manage dynamic, high growth applications that require continuous uptime. The MySQL Enterprise Monitor helps them automate the management of their MySQL infrastructure and improve the performance and availability of their applications.

The MySQL Enterprise Monitor is a web-based application that can manage MySQL within the safety of a corporate firewall or remotely in a public cloud. MySQL Enterprise Monitor provides:

- **Performance & Availability Monitoring** - Continuously monitor MySQL queries and performance related server metrics
- **Visual Query Analysis** – Monitor query performance and pinpoint SQL code that is causing a slow-down
- **InnoDB Monitoring** - Monitor key InnoDB metrics that impact MySQL performance
- **MySQL Cluster Monitoring** - Monitor key MySQL Cluster metrics that impact performance and availability
- **Replication Monitoring** – Gain visibility into the performance, and health of all MySQL Masters and Slaves
- **Backup Monitoring** – Ensure your online, hot backups are running as expected
- **Firewall Monitoring** - monitor MySQL Enterprise Firewall activity and protect your MySQL servers against database attacks
- **Audit Monitoring** – enforce MySQL Enterprise Audit usage across all of your MySQL servers
- **Disk Monitoring** – Forecast future capacity requirements using trend analysis and projections.
- **Security Monitoring** - Identify and resolve security vulnerabilities across all MySQL servers
- **Operating System Monitoring** - Monitor operating system level performance metrics such as load average, CPU usage, RAM usage and swap usage

- **Access Control Lists (ACLs)** - Role and group based access controls provide an easy way for MySQL DBAs to define fine-grained security policies for their MySQL servers

Enterprise Dashboard for Monitoring all MySQL Servers

The Enterprise Dashboard, provides real-time visibility into the performance and availability of all your MySQL databases. You can monitor MySQL metrics for a single server or groups of servers, and manage all of their replication topologies. The Enterprise Dashboard is designed to give you an overall view of the health of your MySQL Servers and point you to potentially critical issues that may impact the performance and availability of your applications. A rich set of real time and historical graphs allow you to drill down into server statistic details.

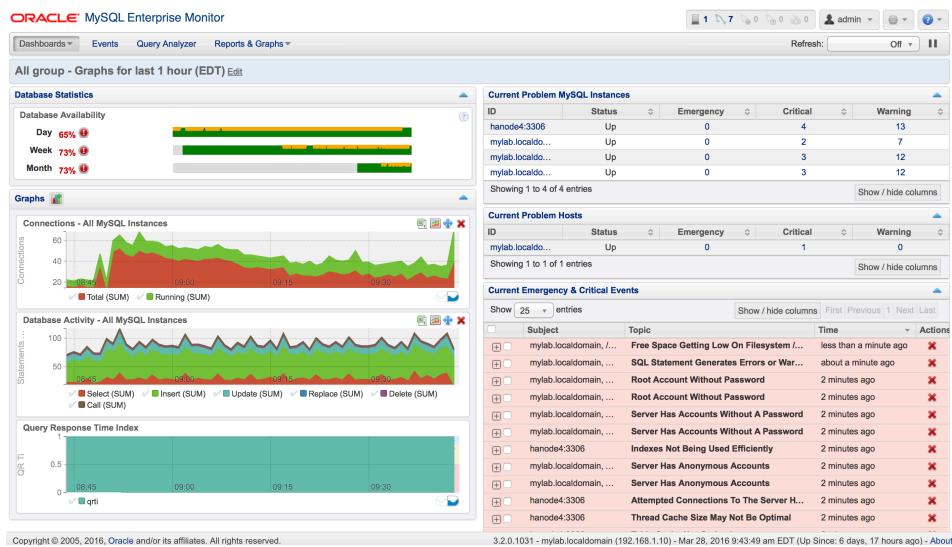


Figure 10: MySQL Enterprise Dashboard

Monitoring of Replication/Scale-Out Topologies

The Replication Dashboard makes it easier to scale out using MySQL Replication by providing industry-leading auto detection, grouping, documenting and monitoring of all MySQL Replication master/slave hierarchical relationships. Changes and additions to existing replication topologies are also auto detected and maintained providing you instant visibility into newly implemented updates. This helps reduce the learning curve for anyone new to MySQL Replication or to specific scale-out environments.



To fully support Multi-Source Replication and display replication instrumentation available within MySQL, a new [Replication Dashboard](#) has replaced the original dashboard.

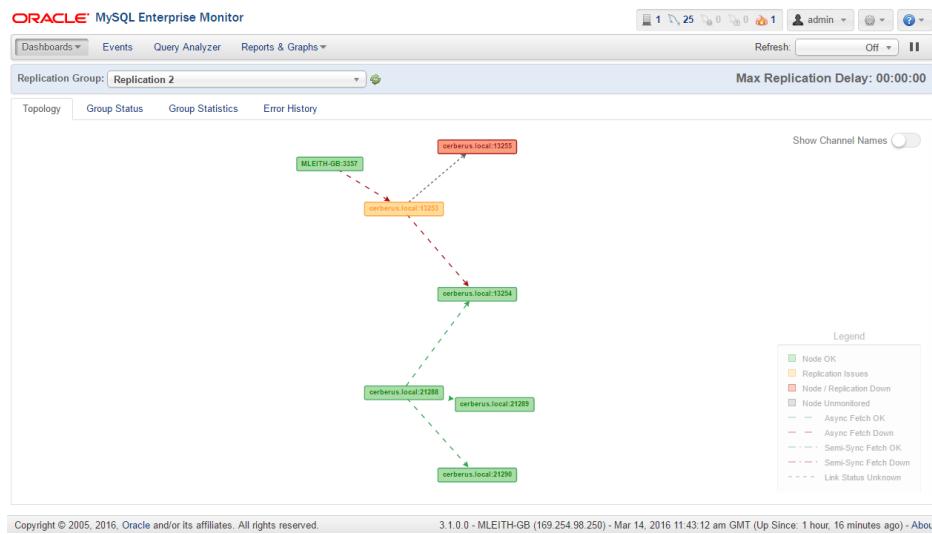


Figure 11: MySQL Enterprise Replication Dashboard topology view

Whether you use a single-source tree hierarchy, circular replication, or a complex, multi-level, multi-source hierarchy, the Topology view shows how your Replication Group is currently replicating.

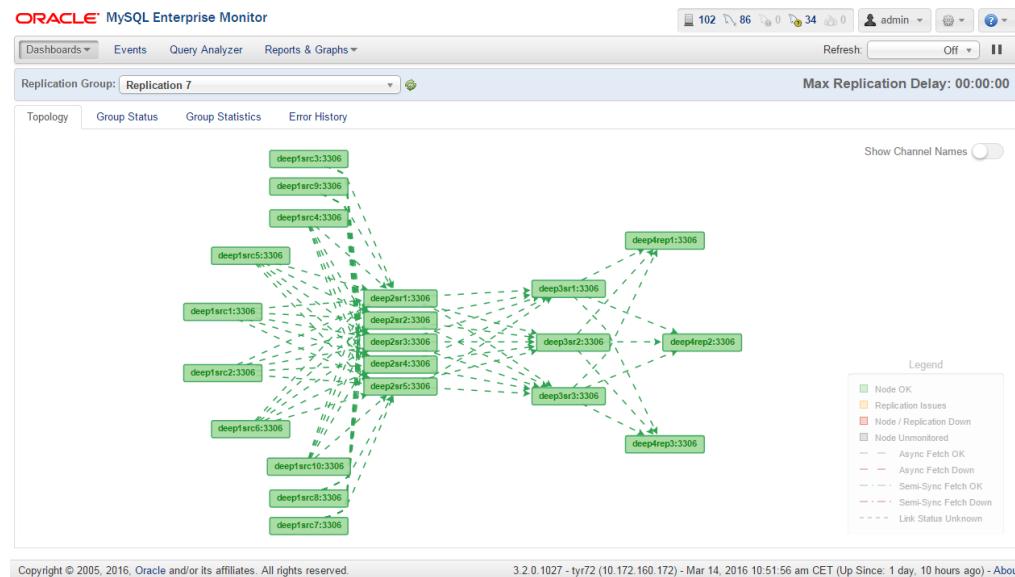


Figure 12: Multi-source Replication topology view

The [Replication](#) Dashboard shows context-sensitive information for each node and node type. High-level identity and throughput metrics are always displayed. For each Replication Source, you'll see Binary Logging and GTID status, or, if enabled, statistics on Semi-Sync Replication performance. For each Replica, you'll see the status of each Replication Channel, statistics on



Relay Logging, Multi-Threaded Replication and other source configuration details.

Instance	Fetch State	Apply State	Time Behind	Read Only	GTID Enabled	Has Errant Trxs	Binary Log Format	Node Type	Replication Type	Version
cerberus local:21288	N/A	N/A	N/A	N/A	ON	N/A	STATEMENT	Source	async	5.6.23-log
MLEITH-GB:3357	N/A	N/A	N/A	N/A	ON	N/A	ROW	Source	async	5.7.9-log
cerberus local:13253	●	●	Unknown	N/A	ON	YES	ROW	Replica/Source	async	5.7.8-rc-log
cerberus local:1289	●	●	00:00:00	OFF	ON	NO	STATEMENT	Replica	async	5.6.23-log
cerberus local:13254	●	●	Unknown	OFF	ON	YES	ROW	Replica	async	5.7.8-rc-log
cerberus local:21290	●	●	00:00:00	OFF	ON	NO	STATEMENT	Replica	async	5.6.23-log
cerberus.local:13255	●	●	Unknown	OFF	ON	YES	ROW	Replica	async	5.7.8-rc-log

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Figure 13: MySQL Replication Group Status View

MySQL Query Analyzer

The MySQL Query Analyzer helps developers and DBAs improve application performance by monitoring queries and accurately pinpointing SQL code that is causing a slowdown. Using the Performance Schema with MySQL Server 5.6, data is gathered directly from the MySQL server without the need for any additional software or configuration.

Queries are presented in an aggregated view across all MySQL servers so DBAs and developers can filter for specific query problems and identify the code that consumes the most resources. With the MySQL Query Analyzer, DBAs can improve the SQL code during active development and continuously monitor and tune the queries in production.

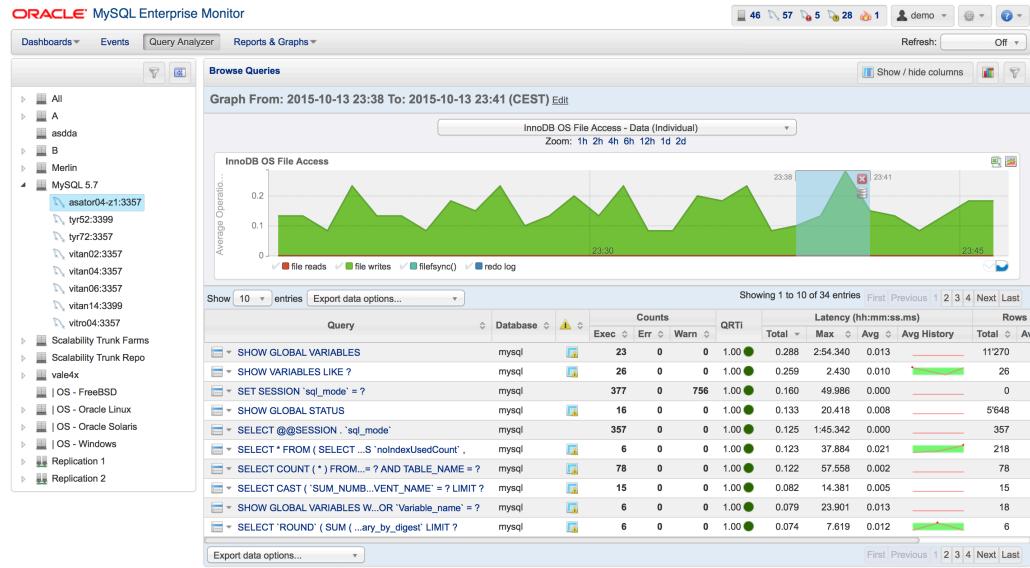


Figure 14: MySQL Query Analyzer

The MySQL Query Analyzer saves you time and effort in monitoring MySQL servers for problem queries by providing:

- An integrated monitoring solution for all supported versions of MySQL (5.1 and higher).
- Aggregated query content and performance stats in real time with no reliance on MySQL logs or SHOW PROCESSLIST.
- Visual “grab and go” correlation of query activity with Monitor graphs.
- A consolidated view into query activity across all MySQL servers, no user parsing required.
- Historical browsing/analysis of queries across all MySQL servers.
- Aggregated, searchable roll ups of all queries in canonical form (no variables) with total number of executions, total execution time, total data size and date/time of when query was “first seen”:
 - **Total Executions** helps you see when queries are running too often or in error. Even properly tuned queries cause performance problems when they run excessively.
 - **SQL Warning and Error counts** help you see queries that did not finish or that returned incorrect result sets. These executions may never be found using other query monitoring options.
 - **Total Execution Time** helps you see the most “expensive” queries across all of the servers. This value helps you see where systems are spending the most time and resources and where you should focus your tuning efforts.
 - **Total Data Size (Rows and Bytes)** helps you analyze if queries are returning more data than your application is using. Sorting on this value, examining the underlying queries and comparing the returned rows and columns with your



application requirements will help you tune your applications and schema for better performance.

- “**First Seen**” allows you to easily monitor when queries attributed to new application deployments are affecting the performance of your production systems.
- Drill downs into query details, number of executions, execution stats, visual EXPLAIN plan, and query specific execution graphs.
- Drill downs that allow developers to trace query execution back to the originating source code.

To learn more, visit: <http://www.mysql.com/products/enterprise/query.html>

MySQL Reports

The MySQL Enterprise Monitor also helps developers and DBAs understand the real-time behavior and performance of a MySQL instance, offering unprecedented insights into the current state of the system.

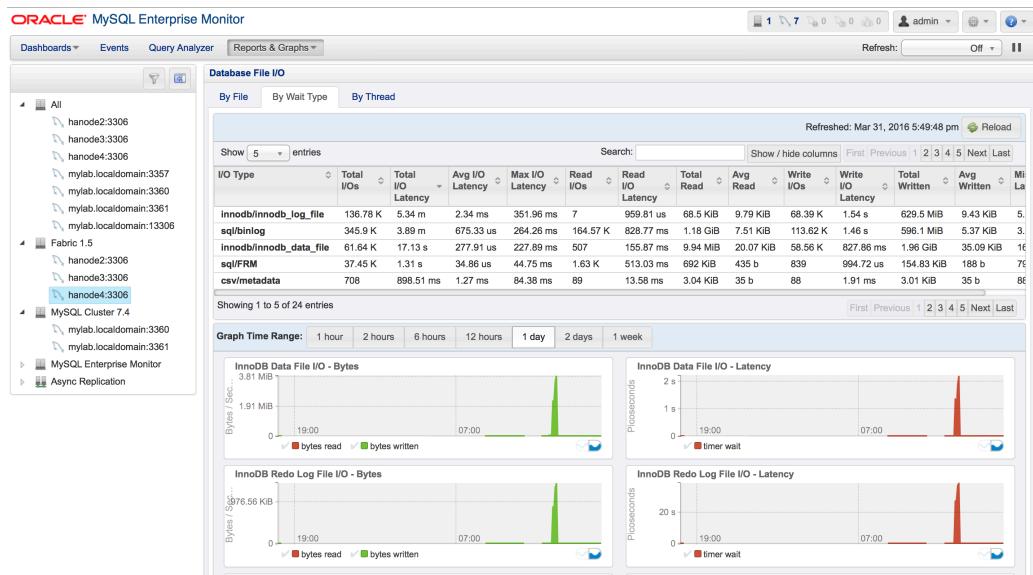


Figure 15: MySQL Database File I/O – By Wait Type

These reports include:

- **Database File I/O** report allows you to easily see exactly where your disk I/O hotspots are.
- **Lock Waits** report provides an incredibly powerful and easy to understand breakdown of the lock waits (row and metadata locks) within the system.
- **Process** report provides invaluable insights into exactly what the threads/connections are doing within the system.
- **InnoDB Buffer Pool Usage** report allows you to quickly and easily determine the breakdown of your primary caching layer by database object.

The total of these reports gives MySQL developers and DBAs insights into MySQL that were simply impossible in the past. This makes MySQL Enterprise Monitor the best in class solution for real-time debugging of MySQL.

To learn more, visit:

<https://dev.mysql.com/doc/mysql-monitor/en/mem-reports-and-graphs.html>

13 Oracle Enterprise Manager for MySQL

Oracle Enterprise Manager for MySQL provides Oracle developers and DBAs with real-time monitoring and delivers comprehensive performance, availability and configuration information for your MySQL databases. Enterprise Manager collects more than 500 metrics covering various



MySQL components. Custom critical and warning thresholds can then be set for each of the collected metrics. Plus, DBAs can track configuration details over time to easily keep track of configuration changes.

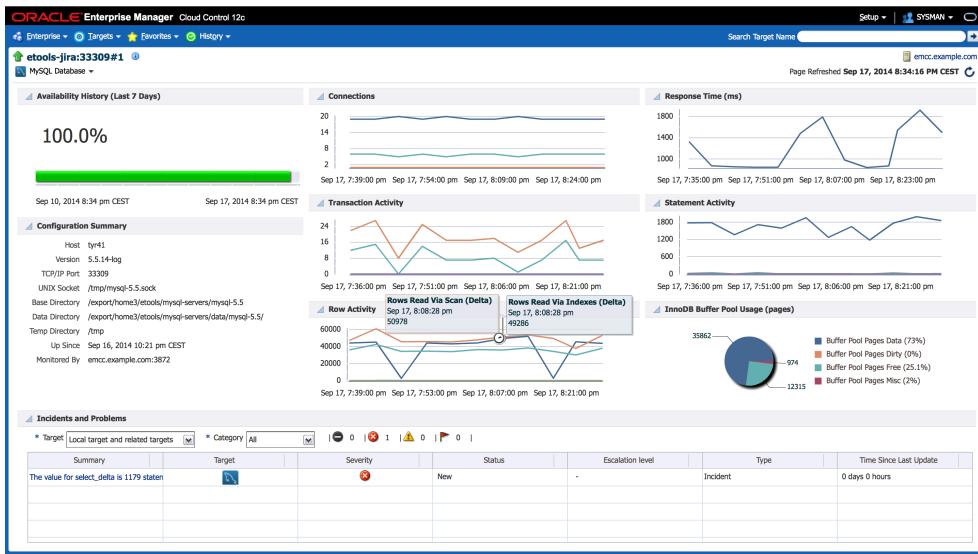


Figure 16: Oracle Enterprise Manager for MySQL allows Oracle developers and DBAs manage MySQL databases.

More information about Oracle Enterprise Manager for MySQL is available at: <http://www.mysql.com/products/enterprise/em.html>

14 MySQL Workbench Enterprise Edition

MySQL Workbench is a unified visual development tool that includes advanced data modeling capabilities, a visual SQL editor and comprehensive administration tools for database design, query development, server configuration, user administration, and wizard-driven database migrations.

Design

MySQL Workbench enables a DBA, developer, or data architect to visually design, model, generate, and manage databases. It includes everything a data modeler needs for creating complex ER models, forward and reverse engineering, and also delivers key features for performing difficult change management and documentation tasks that normally require much time and effort.

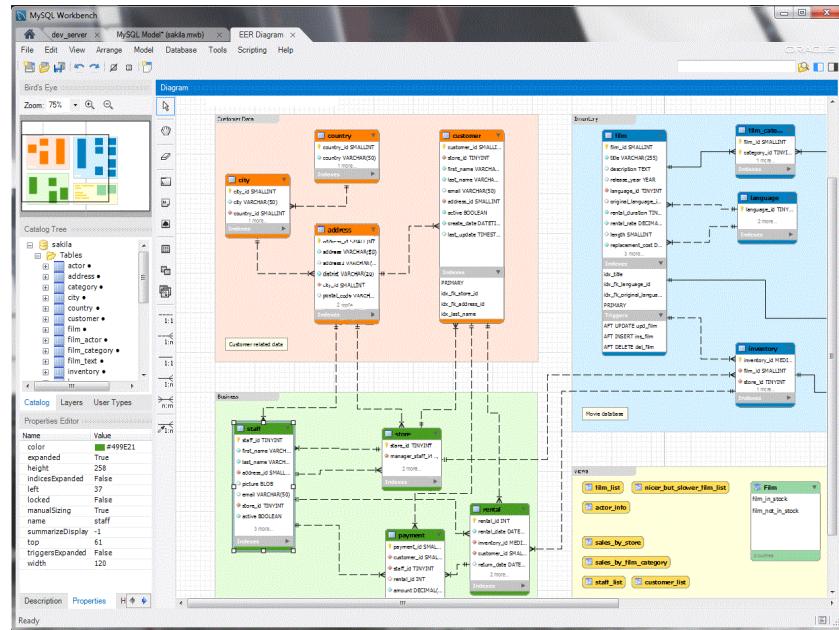
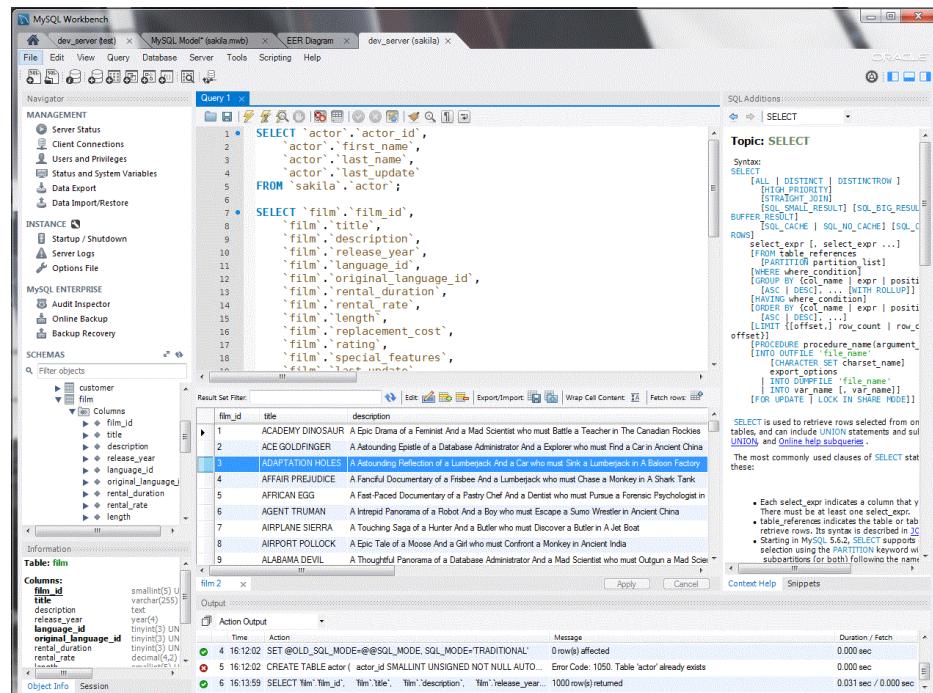


Figure 17: MySQL Workbench – Visual Database Design

Develop

MySQL Workbench delivers visual tools for creating, executing, and optimizing SQL queries. The SQL Editor provides color syntax highlighting, reuse of SQL snippets, and execution history of SQL. The Database Connections Panel enables developers to easily manage database connections. The Object Browser provides instant access to database schema and objects.



```

SELECT `actor`.`actor_id`,
       `actor`.`first_name`,
       `actor`.`last_name`,
       `actor`.`last_update`
  FROM `sakila`.`actor`;

SELECT `film`.`film_id`,
       `film`.`title`,
       `film`.`description`,
       `film`.`release_year`,
       `film`.`language_id`,
       `film`.`original_language_id`,
       `film`.`rental_duration`,
       `film`.`rental_rate`,
       `film`.`length`,
       `film`.`replacement_cost`,
       `film`.`rating`,
       `film`.`special_features`,
       `film`.`last_update`;
    
```

The SQL Syntax tree on the right shows the structure of the SELECT statement, including clauses like DISTINCT, ORDER BY, and GROUP BY, along with their respective parameters and conditions.



Figure 18: MySQL Workbench – SQL Development, Execution, Tuning

Administer

MySQL Workbench provides a visual console to easily administer MySQL environments and gain better visibility into databases. Developers and DBAs can use the visual tools for configuring servers, administering users, and viewing database health.

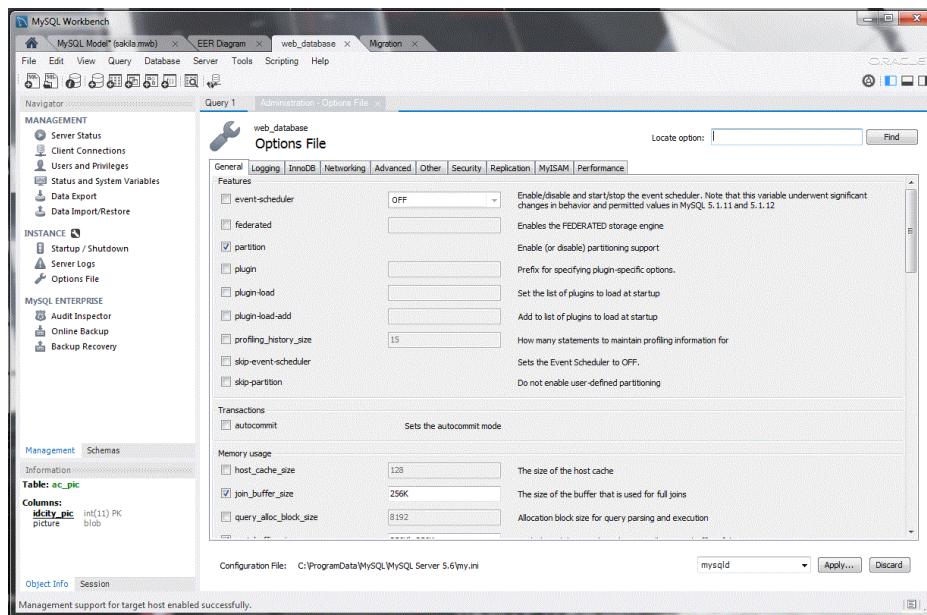


Figure 19: MySQL Workbench – Server Administration, Monitoring

Migrate

MySQL Workbench provides a visual console to easily administer MySQL environments and gain better visibility into databases. Developers and DBAs can use the visual tools for configuring servers, administering users, and viewing database health.

MySQL Workbench provides a visual Migration Wizard that enables quick migration of tables, objects and data from Microsoft SQL Server, Microsoft Access, Sybase and other RDBMS platforms to MySQL. The MySQL Workbench Migration Wizard is designed to save DBA and developer time by providing visual, point and click ease of use around all phases of configuring and managing a complex migration process:

- **Migration project management** - allows migrations to be configured, copied, edited, executed and scheduled.
- **Source and Target selection** - allows users to define specific data sources and to analyze source data in advance of the migration.



- **Object migration** - allows users to select objects to migrate, assign source to target mappings where needed, edit migration scripts and create the target schema.
- **Data migration** - allows users to map source and target data and data types, set up data transfer and assign post data transfer events where needed.

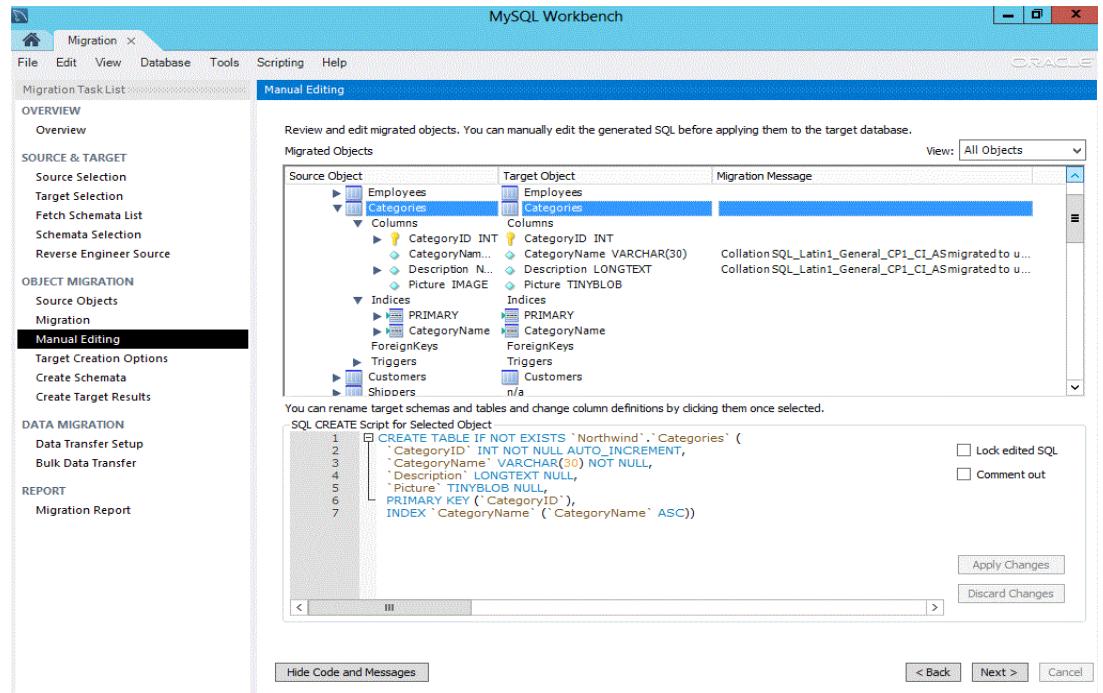


Figure 20: MySQL Workbench – Database Migration Wizard

To learn more, download the whitepaper:

<http://mysql.com/why-mysql/white-papers/mysql-wp-workbench.php>

15 Oracle Product Certifications/Integrations

An estimated 70% of Oracle's customers also use MySQL. MySQL Enterprise Edition makes managing MySQL easier in these environments by certifying and supporting the use of the MySQL Database in conjunction with many Oracle products. These include:

- Oracle Linux
- Oracle VM
- Oracle Fusion Middleware
- Oracle Secure Backup
- Oracle Golden Gate



- Oracle Audit Vault and Database Firewall
- Oracle Enterprise Manager
- Oracle OpenStack for Oracle Linux
- Oracle Clusterware

Learn more about Oracle products certified with MySQL Enterprise Edition:
<http://www.mysql.com/why-mysql/white-papers/spotlight-on-mysql-enterprise-oracle-certifications/>

16 Oracle Premier Support

Oracle offers 24x7, global support for MySQL. The MySQL Support team is composed of seasoned MySQL developers, who are database experts and understand the issues and challenges you face. With Oracle Premier Support, you can lower the total cost and risk of owning your MySQL databases, improve the return from your IT investment, and optimize the business value of your IT solutions. MySQL support is included in the subscription for end users, and available separately from commercial licenses for ISVs and OEMs. Oracle Premier Support for MySQL includes the following features:

- 24 X 7 production support
- Unlimited support incidents
- Knowledge Base
- Maintenance releases, bug fixes, patches and updates
- MySQL Consultative support
- Staffed by the most experienced MySQL Engineers in the industry
- The ability to get MySQL support in 29 languages

MySQL Consultative Support service is included in Premier Support. MySQL Consultative Support is a proactive approach that is designed to help you avoid critical outages. MySQL Support Engineers advise you on how to properly setup and tune your MySQL servers, schema, queries, and replication set-up to maximize performance and availability. Also, by taking the initiative to properly design and tune your MySQL database applications you can avoid having to purchase expensive hardware for your IT infrastructure.

Learn more about Oracle Premier Support:
<http://mysql.com/support/>



17 Conclusion

In this paper we explored the components that are included in MySQL Enterprise Edition. These components are designed to help you mitigate risk and meet Service Level Agreements (SLAs) as you implement applications built on the lower costs and licensing freedom that comes with standardizing on MySQL and other open source technologies. MySQL Enterprise Edition extends the MySQL Database to include advanced Auditing, Security, Encryption, Performance/Scale and High Availability features. The MySQL Enterprise Backup performs online "Hot", non-blocking backups of your MySQL databases. The Enterprise Monitor, Advisors and Query Analyzer proactively notify you of problems and tuning opportunities before they turn into customer facing issues. MySQL Workbench enables developers, DBAs, and data architects to design, develop, migrate, and administer database applications. For managing Oracle and MySQL databases, there are supported integrations and certifications that allow you to manage MySQL using many Oracle products. Finally, the Oracle Premier Support provides you with quick answers and resolutions when you need help, so your systems provide uninterrupted availability to your customers.

18 About MySQL Enterprise Edition

MySQL Enterprise Edition includes the most comprehensive set of advanced features, management tools and technical support to help you achieve the highest levels of MySQL scalability, security, reliability, and uptime. It reduces the risk, cost, and complexity in developing, deploying, and managing business-critical MySQL applications.

- **MySQL Database** to power the most demanding Web, E-commerce and Online Transaction Processing (OLTP) applications.
- **MySQL Query Analyzer** to optimize performance by visualizing query activity, pinpointing expensive queries, and fixing problematic SQL code
- **Oracle Enterprise Manager** for MySQL for real-time performance and availability monitoring
- **MySQL Enterprise Monitor** to monitor MySQL performance, sessions, connections, and more
- **MySQL Enterprise Backup** to perform online "Hot" backups of your databases
- **MySQL Enterprise High Availability** to automatically detect and recover from failures
- **MySQL Enterprise Scalability** to improve read/write scalability by 20x
- **MySQL Enterprise Authentication** to easily integrate existing security infrastructures (PAM & Windows Active Directory)



- **MySQL Enterprise Encryption** to protect sensitive data throughout its lifecycle
- **MySQL Enterprise Transparent Data Encryption (TDE)** for encrypting data-at-rest
- **MySQL Enterprise Firewall** to block database threats in real-time and protect against specific attacks, such as an SQL Injection
- **MySQL Enterprise Audit** to add policy-based auditing compliance to new and existing applications
- **MySQL Replication Monitor** that provides real-time information on master/slave performance and latency issues
- **MySQL Advisors** to implement security, performance, replication and administration best practices
- **MySQL Workbench Enterprise Edition** for visual database design, SQL development, administration and database migration

19 Additional Resources

MySQL Whitepapers

<http://www.mysql.com/why-mysql/white-papers/>

MySQL Webinars:

- Live: <http://www.mysql.com/news-and-events/web-seminars/index.html>
- On Demand: <http://www.mysql.com/news-and-events/on-demand-webinars/>

MySQL Enterprise Edition Demo:

<https://www.youtube.com/watch?v=ypQh9H9Rf9w&feature=youtu.be>

MySQL Cluster Demo:

https://www.youtube.com/watch?v=A7dBB8_yNJI

MySQL Enterprise Edition Trial:

<http://www.mysql.com/trials/>

MySQL Case Studies:

<http://www.mysql.com/why-mysql/case-studies/>

MySQL TCO Savings Calculator:

<http://mysql.com/tco>

To contact an Oracle MySQL Representative:

<http://www.mysql.com/about/contact/>