MySQL Database Administrator

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MySQL Server Usage

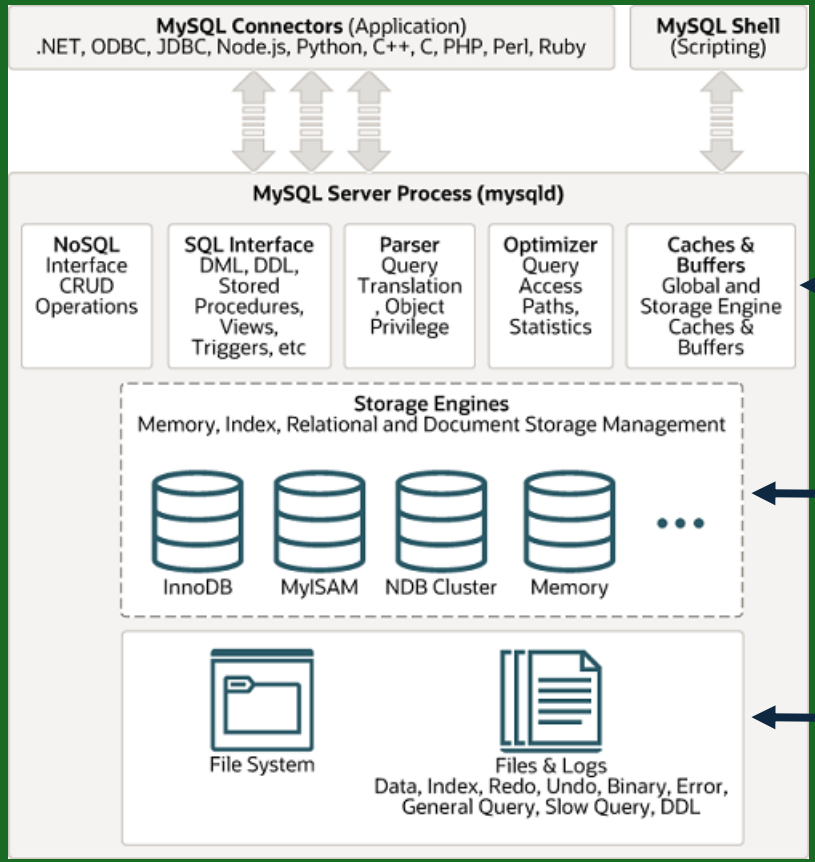
Course Introduction

- New Database Installations, Customization, Backup & Recovery
- Database Management -
- Database Upgrades - Both Major and Minor Upgrades
- InnoDB Storage Engine Tuning
- Database Replication, Troubleshooting, Performance Tuning

Course Objectives

- MySQL Server Installation
- Exploring MySQL Server
- MySQL Server Database Administration
- MySQL Storage Engines
- MySQL User Administration
- MySQL Server Configuration
- InnoDB Storage Engine
- MySQL Backup & Restore
- MySQL Replication
- Upgrading MySQL Server
- MySQL Performance and Monitoring

MySQL Architecture



End-User/Client-Layer

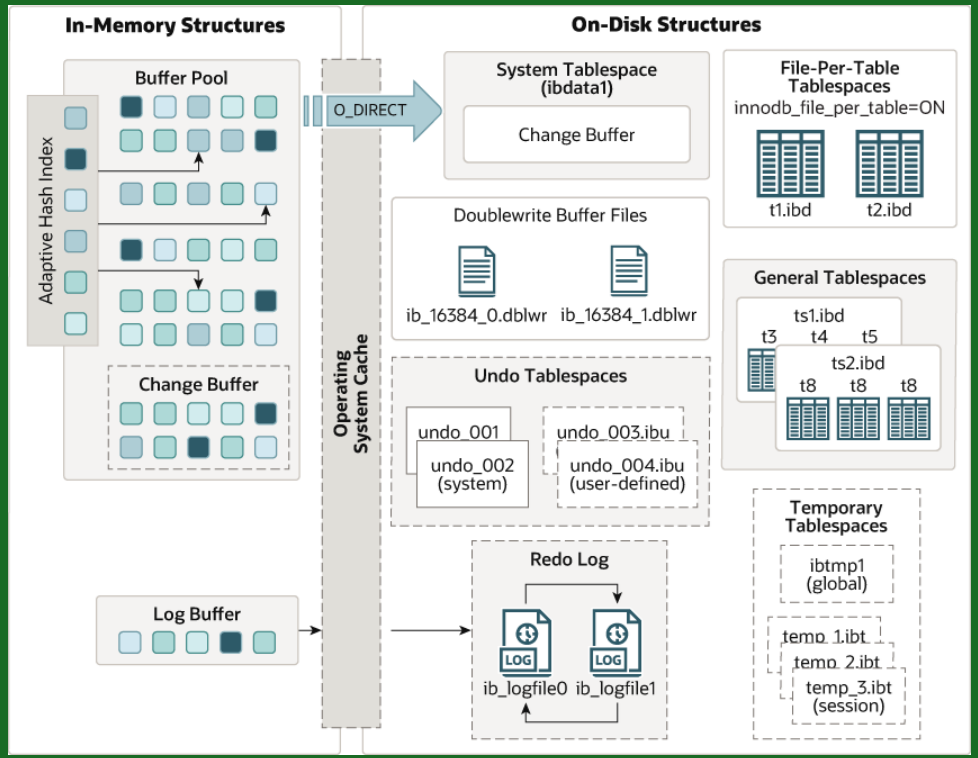
Daemon Process

MySQL Brain

Physical Storage

MySQL InnoDB Architecture

InnoDB Architecture:



In-Memory Structure:

- Buffer Pool - Area in main memory where InnoDB caches table & index data as it is accessd
- Change Buffer - caches changes to non-clustered indexes
- Adaptive Hash Index - acts like in-memory db
- Log Buffer - memory area that holds data to be written to the log files on disk

On-Disk Structure:

- System Tablespace
- Doublewrite Buffer Files
- Undo Tablespaces
- Redo Log Files
- File-Per-Table Tablespaces
- General Tablespaces
- Temporary Tablespaces

MySQL User Administration

- DBA Account
- MySQL Permissions
- WITH GRANT OPTION
- MySQL Workbench
- MySQL Roles
- Difference between Roles & Users
- Granting Permissions -> Roles, Roles -> Users
- Expired Account, Unlock Account
- Explore mysql.user table

MySQL Configuration

Option Files:

- Also called MySQL Configuration Files
- Most MySQL programs can read startup options from option files (configuration)
- Convenient way to specify commonly used options so need not to specify on command-line
- mysqld, mysqladmin, mysqlimport, mysqldump, mysql - examples of MySQL programs
- program –verbose –help - To get which default option file this programs uses
- Any program starts with –no-defaults option reads no option file other than .mylogin.cnf

MySQL Backup & Recovery

What do you want to protect?

- MySQL Instance - Physical Backup
- Option Files/Configuration Files - Source Control
- Database(s) - Logical Backup
- Table(s) - Logical Backup

MySQL Upgrades

Upgrade Types:

- Minor MySQL Version Upgrade
- Major MySQL Version Upgrade

Popular MySQL Servers

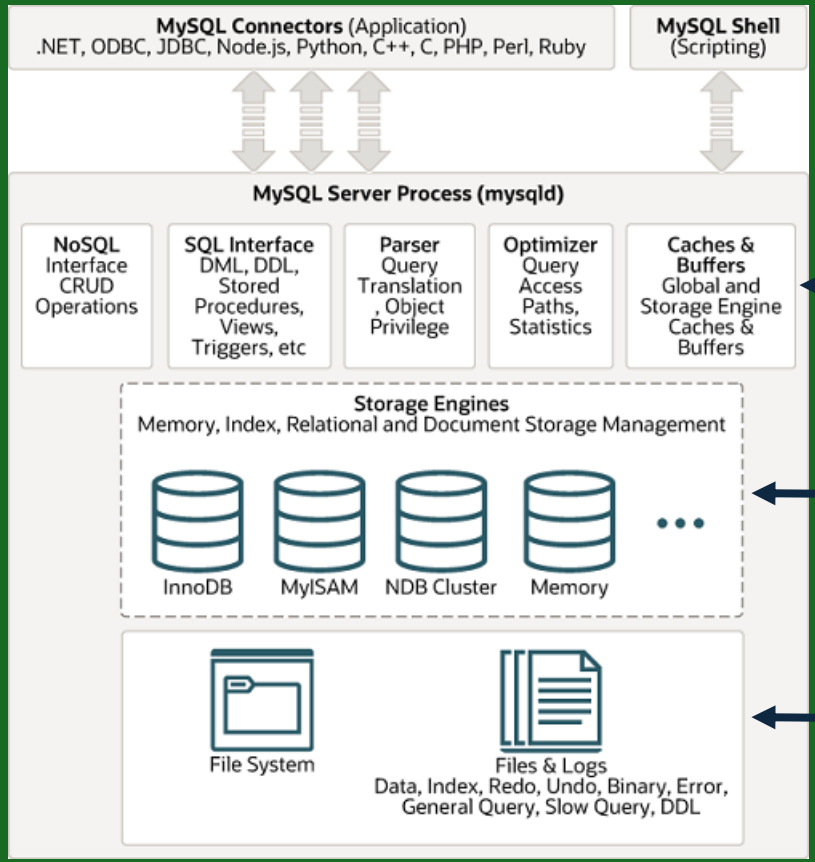
Oracle MySQL, MariaDB, Percona MySQL are **forks** of original MySQL

MariaDB Provides: Columnar Storage, Temporal Tables, Transaction replay, non-blocking backups, Oracle Compatible, Pluggable Storage Engines

Percona Provides: XtraDB Cluster, Percona-Toolkit, XtraBackup, TokuDB, MyRocks Storage Engine, InnoDB Full-Text Search, Compressed Columns

Oracle MySQL Provides: HeatWave, mysqlcheck, Scalability, Dual Passwords, High Performance

MySQL Architecture



End-User/Client-Layer

Daemon Process

MySQL Brain

Physical Storage

MYSQL File Types

Installed MySQL Files Location :

DATA DIRECTORY:

- Also known as datadir
- Default location: /var/lib/mysql
- Owned by mysql os user as it's home directory
- All the new databases that we create, reside there as folder

LOG FILES:

- Default location is /var/log/mysql/error.log
- Very critical file and single source of truth for all errors, warnings, info etc
- Also contains initial root password - newly installed MySQL

GLOBAL CONFIGURATION FILE:

- Default location is /etc/mysql/my.cnf
- Contains all the configuration settings that will be loaded when server starts

MYSQL Executable Programs

mysql	mysqladmin	mysqlbinlog	mysqlcheck	mysql_config_editor
mysqld_pre_systemd	mysqld_safe	mysql_ssl_rsa_setup	mysql_tzinfo_to_sql	mysql_upgrade
mysqlslap	mysql_secure_installation	mysqlshow	mysqld_safe	mysqldump

MYSQL Shell Commands

help:

- \h or \?
- Prints help about MySQL Shell and all available shell commands
- Display help for any of the shell commands

quit:

- Quits or Exits from MySQL Shell - \q

status:

- Shortcut is \s
- For how long MySQL Server has been up, what is my connection id, version of MySQL
- Is the current user logged in locally or from a remote location

system:

- Shortcut is \!
- Run operating system commands within MySQL Shell

MYSQL Shell Commands

use:

- \u for short
- Use another database
- Takes database name as argument

source:

- \. - Execute SQL file (.sql extension)
- Takes SQL file name as argument

edit:

- Edit the SQL statement that you recently executed

MYSQL Socket File

mysql.sock:

- MySQL special file that manages connections to the mysql server
- Used for local clients - if user is on the database host and want to connect to mysql
- Local clients/users can’t connect to MySQL without this file
- Owned by mysql user and default location is /var/run/mysqld
- Local connection = UNIX socket - Remote connection = TCP/IP
- This special file is empty but mysql creates another file mysqld.sock.lock and add pid

MYSQL Global Variables

Global Variables:

- MySQL server maintains many system variables that are used to configure how MySQL should operate.
- GLOBAL scope & SESSION scope
- Global variables affect the overall operation of MySQL server
- Each Global variable has default value which is initialized when server starts
- Default value can be changed in option file or on command line
- Identified by @@ sign
- SHOW GLOBAL <variable_name>; or SELECT @@<variable_nam>;
- Examples of system variables:
  - max_connections
  - server_id
  - sql_mode

MYSQL Session Variables

Session Variables:

- MySQL server maintains many system variables that are used to configure how MySQL should operate.
- GLOBAL scope & SESSION scope
- SESSION variables affect only the current session
- Default value for session variables can only be changed on command line
- Identified by @@ sign
- SHOW SESSION VARIABLES LIKE <variable_name>; or SELECT @@<variable_nam>;
- Examples of session system variables:
  - sql_mode

MYSQL SHOW Command

SHOW Statements:

- SHOW DATABASES;
- SHOW TABLES LIKE ‘%view%’;
- SHOW BINARY LOGS;
- SHOW BINLOG EVENTS;
- SHOW ENGINES;
- SHOW CREATE TABLE | USER | DATABASE;
- SHOW ERRORS;
- SHOW WARNINGS;
- SHOW EVENTS;
- SHOW TRIGGERS;
- SHOW PROCESSLIST;

Note: SHOW Statements also accepts LIKE clause

MYSQL System Databases

System Databases:

- MySQL server comes with some default system databases
  - information_schema
  - mysql
  - performance_schema
  - sys
  - Test - Generally deleted by running mysql_secure_installation

MYSQL System Databases

information_shema:

- Each MySQL instance will have information_schema database
- Also called System Catalog or Data Dictionary
- Provides access to metadata, that is data about data
- The tables in this database are read-only - they are actually views
- So no INSERT, UPDATE, DELETE operations

mysql:

- Contains tables that store information required by MySQL server
- Grant information to user accounts, registry of event scheduler, plugins
- Replication System Tables
- System tables with timezone information

MYSQL System Databases

performance_schema:

- Inspect internal execution of the server.
- Primarily focuses on performance data
- Information about events waits, database locks, memory allocation

sys:

- Collection of views, functions, and stored procedures that help MySQL admins to get insight into MySQL database usage.
- Similar to performance_schema but is more user friendly
- How many total connections a user has established, memory consumption
- Database host summary about memory, storage, io

MYSQL Connections

localhost-connection:

- localhost
- root@localhost

specific-host-connection:

- Host or IP Address webserver01 or 192.168.10.10
- app_user@webserver01

any-host-connection:

- %
- dba@%

MYSQL Config Editor

mysql_config_editor:

- Configure Authentication information for connecting to MySQL server
- Stores authentication credentials in an obfuscated login path file called .mylogin.cnf - Encrypted
- Location: user's home directory - Syntax: mysql_config_editor set –login-path=client –host= –user= –password
- login-path is option group that specify which MySQL server to connect and which account to auth
- By default mysql client reads [client] and [mysql] groups

MySQL Config Editor

.mylogin.cnf:
[client]
user = root
password =
host = localhost

[prod]
user = user
password = password
host = proddb01

MYSQL Admin Program

mysqladmin:

- MySQL Server Administration program
- Client for performing administrative operations:
  - shutdown
  - create <database_name>
  - current status
  - ping if MySQL is alive
  - Start Replica
  - Stop Replica
- Syntax: mysqladmin options command

Example:

- mysqladmin status
- mysqladmin ping
- mysqladmin create database
- mysqladmin drop database

MYSQL Execute SQL Files

source:

- From within mysql shell - using \. or source
- mysql> source file.sql or mysql> \. file.sql

mysql:

- By running mysql client program and accepting .sql file as input
- mysql –host=host_name –user=user_name –password= database_name < file.sql

shell script:

- By creating an executable shell script and executing it
- mysql –host=host_name database_name < $1

pipe method:

- cat filename.sql | mysql

MYSQL Execute SQL Files

Execute employees.sql - Create staff table in employees db

Syntax:

- mysql>source employees.sql
- mysql –host=localhost employees < employees.sql
- bash employees.sh employees.sql
- cat employees.sql | mysql

MYSQL mysqlimport

mysqlimport:

- mysqlimport is a data import program
- Takes .txt with tab-delimited file as input

Syntax:

- mysqlimport [options] database file1.txt [file2.txt] ...

Import Data Directory Configuration:

- secure_file_priv - denoted a directory from which data files can be loaded

MySQL mysqlimport

Load data from staff.txt - Populate staff table in employees db

Steps:

- We will use mysqlimport utility
- Fetch secure_file_priv value
- Copy file and change permissions
- Load Data mysqlimport [options] db_name ${secure_file_priv}/staff.txt

MYSQL mysqlcheck

mysqlcheck:

- mysqlcheck is a table maintenance program
- It checks, repairs, optimize, or analyze tables
- Table name as input

Note:

- Table will be locked while mysqlcheck is running - no db operations

Syntax:

- myqlcheck [options] db_name table_name

MySQL mysqlcheck

Check the integrity of staff table

Steps:

- We will use mysqlcheck utility
- mysqlcheck employees staff

MYSQL mysqlshow

mysqlshow:

- Display database, table, and column information
- Takes database name and table name as input

Syntax:

- mysqlshow [options] db_name table_name
- mysqlshow [options] db_name table_name [column_name]

MYSQL Timezone Data

mysql_tzinfo_to_sql:

- Loads the time zone data from zoneinfo database into system mysql database
- Zoneinfo database is actually zone files that describe time zones
- Typical location on Linux is /usr/share/zoneinfo

Timezone Tables:

- Time_zone
- Time_zone_name
- Time_zone_transition
- Time_zone_transition_type
- time_zone_leap_second

Syntax:

- mysql_tzinfo_to_sql zoneinfo_database | mysql [options] db_name

MySQL Timezone Data

Load Timezone Data into MySQL

Steps:

- We will use mysql_tzinfo_to_sql utility
- mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql mysql

MYSQL Example Databases

MySQL Example Databases:

- Free to download and use

Example Databases:

- employees
- world
- sakila

URL Information:

- https://dev.mysql.com/doc/index-other.html

MYSQL Storage Engines

FEDERATED	InnoDB	MyISAM	ARCHIVE
BLACKHOLE	CSV	MEMORY	PERFORMANCE_SCHEMA

- ➔ Pluggable storage engine architecture - load and unload on a running MySQL Server
- ➔ show engines - which storage engine your server support
- ➔ Shared library location for all the plugins - plugin_dir variable
- ➔ Can install & uninstall more storage engines

MYSQL Storage Engines

FEDERATED STORAGE ENGINE:

- Disabled by default
- Table created with FEDERATED Storage Engine, normally points to a table in another MySQL instance installed on a separate server.
- Linked Server - Microsoft SQL Server
- Database Link - Oracle
- Both tables should have the same name and definition
- The table in requester acts like a view
- Target table can have different storage engine but requester table should be created with FEDERATED

Syntax:

```
Create table employee_salaries (
Employee_id int,
Employee_salary int
) ENGINE = FEDERATED
CONNECTION = ‘mysql://db_user@target-server:3306/employees/employee_salaries’;
```

MYSQL Storage Engines

MEMORY STORAGE ENGINE:

- Called HEAP in older versions
- Very useful for temporary tables
- MEMORY will write table data in memory
- Not Persistent - Data lost on server crash
- Very fast data retrieval but memory is volatile so use only for read-only cache data or temp tables

USE CASE:

- Static Tables - lookup
- Temporary Tables

Caveats:

- No Transactions support
- No Referential Integrity support - No FK
- NO TEXT data type support - No BLOB column

MySQL Storage Engines

Create continents table in MEMORY - world database

Steps:

- Create table specifying ENGINE=MEMORY
- Insert data
- Verify data and also table definition from information_schema.tables
- Restart MySQL Service and observe table is there but data is gone

MYSQL Storage Engines

BLACKHOLE STORAGE ENGINE:

- Acts as a black hole, whatever goes into it, never comes back
- You can store as much data as you want, when you retrieve it, it returns empty result set
- Anything you write to it, disappears
- Does not support transactions

Syntax:

```
Create table employee_salaries (
Employee_id int,
Employee_salary int
) ENGINE = BLACKHOLE;
```

MySQL Storage Engines

Create continents table in BLACKHOLE - world database

Steps:

- Create table specifying ENGINE=BLACKHOLE
- Insert data
- Verify empty result set will return

MYSQL Storage Engines

CSV STORAGE ENGINE:

- Stores table in text files using comma-separated values format
- MySQL creates a .csv file in the $DATA_DIR - plain text file
- CSV format can be read, written by spreadsheet applications like Excel
- Does not support transactions
- CSV files are not indexed

USE CASE:

- When data need to be shared with other applications that also use CSV format

Syntax:

```
Create table continents (
cid int NOT NULL,
cname VARCHAR(25) NOT NULL
) ENGINE = CSV;
```

MySQL Storage Engines

Create continents table in CSV - world database

Steps:

- Create table specifying ENGINE=CSV
- Insert data
- Search for continents.CSV file under $DATA_DIR/world

MYSQL Storage Engines

MyISAM STORAGE ENGINE:

- MyISAM = My + ISAM = Indexed Sequential Access Method
- Indexing algorithm developed by IBM that allows retrieving information from large sets of data in a fast way
- MyISAM was default storage engine up until MySQL 5.5 - around 2009-2010
- Good speed advantages especially useful in Data warehouse scenario
- Replaced by InnoDB
- Does not support transactions - ACID Model

USE CASE:

- Data Warehouse - a lot of reads

MySQL Storage Engines

Create continents table in MyISAM - world database

Steps:

- Create table specifying ENGINE=MyISAM
- Insert data
- Start Transaction, Commit, Rollback

MYSQL Storage Engines

ARCHIVE STORAGE ENGINE:

- Produces special-purpose tables that store large amounts of un-indexed data in very small footprint
- Creates .ARZ files with same name as table name
- ARZ files are binary data files and are called MySQL Archive Storage Engine Data File
- Uses gzip to compress rows

CAVEAT:

- No DELETE or UPDATE operation
- No Partitioning

Syntax:

```
Create table continents (
cid int NOT NULL,
cname VARCHAR(25) NOT NULL
) ENGINE = ARCHIVE;
```

MySQL Storage Engines

Create continents table in ARCHIVE - world database

Steps:

- Create table specifying ENGINE=ARCHIVE
- Insert data
- Look for .ARZ file

MYSQL Storage Engines

InnoDB STORAGE ENGINE:

- ACID compliant storage engine that support all types of transactions
- A - Atomicity, involves transactions COMMIT & ROLLBACK
- C - Consistency, mechanism for crash recovery
- I - Isolation, different isolation levels that applies at each transaction level
- D - Durability, storage engine interacts with underlying hardware to provide best performance
- Default storage engine, robust, fast, heart of MySQL
- Best for OLTP - Online Transaction Processing
- Row-level locking, indexing
- InnoDB maintains its own buffer pool (memory area where InnoDB cache table and indexed data)

MySQL Storage Engines

Create continents table in InnoDB - world database

Steps:

- Create table specifying ENGINE=InnoDB or skip
- Insert data
- Test all operations

REVIEW CONTENT

- Storage Engines
- InnoDB - Default Storage Engine
- Storage Engine Status
- Migrate table from one storage engine to other
- Disable storage engine

MySQL User Administration

- DBA Account
- MySQL Permissions
- WITH GRANT OPTION
- MySQL Workbench
- MySQL Roles
- Difference between Roles & Users
- Granting Permissions -> Roles, Roles -> Users
- Expired Account, Unlock Account
- Explore mysql.user table

MySQL User Administration

MySQL Permissions:

- Permissions are Privileges Granted to MySQL Account to perform actions
- ALL - All Permissions
- ALTER, DROP, CREATE - Database, table, index, etc
- DROP - Database, table, index, etc
- EXECUTE - Stored Procedure
- INSERT, DELETE, UPDATE, RENAME - On tables
- * - On all objects
- SELECT, SHOW - Read-Only Permissions
- Replication Client, Replication Slave
- Grant Permission(s)

MySQL User Administration

WITH GRANT OPTION:

- Clause used when creating new user
- Ability to grant others permissions
- DBA user statement should add this clause
- Create user with all privileges and with grant option

MySQL Auth Plugins

Authentication Plugins: mysql_native_password & caching_sha2_password

mysql_native_password:

- Implements Native Pluggable Authentication
- NPA is based on the password hashing method in use before the intro of pluggable authentication
- mysql_native_password is not pluggable so there is no library file and this plugin is built-in
- MySQL 5.7 and older version - mysql_native_password was default
- mysql –default-auth=mysql_native_password

MySQL Auth Plugins

Authentication Plugins: mysql_native_password & caching_sha2_password

caching_sha2_password:

- Default password authentication plugin starting MySQL 8
- MySQL recommends using caching_sha2_password as preferred plugin
- The server assigns this plugin to the account and uses it to encrypt the password using SHA-256, storing those values in the plugin and authentication_string column of mysql.user system table
- Built into the server, need not be loaded explicitly and can’t be disabled by unloading it

MySQL Auth Plugins

Authentication Plugins: mysql_native_password & caching_sha2_password

which one?

Authentication plugin ‘caching_sha2_password’ cannot be loaded

ALTER USER john IDENTIFIED WITH ‘mysql_native_password’ by ‘password’;

[mysqld]

default_authentication_plugin=caching_sha2_password

CREATE USER john WITH ‘caching_sha2_password’ by ‘password’;

CREATE USER john by ‘password’;

MySQL User Administration

MySQL Roles:

- Named collections of privileges
- GLOBAL CREATE ROLE or CREATE USER privilege
- Written in binary log when succeeded
- A Role when created is locked, assigned default auth plugin
- No password i.e authentication_string is empty
- Roles are considered Users in the mysql.user system table

Syntax:

- CREATE ROLE IF NOT EXISTS ‘reader’, ‘writer’, ‘admin’;

MySQL User Administration

- Create Roles reader, writer, admin
- Create User db_reader, db_writer, db_admin
- Permissions:
  - reader=SELECT on continents table
  - writer=INSERT, UPDATE, DELETE on continents table
  - admin=ALL Permissions on world database
- Grant: reader to db_reader, writer to db_writer, admin to db_admin

MySQL Configuration

Option Files:

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Option Files Format:

MySQL Configuration

Option Files Syntax:

- Comments - # sign
- option group - stanza
- option = value
- Space is allowed either side
- Value can be without quote, single-quote, double-quote
- Any option that may be given at command-line, can be given in option file as well
- –server-id at command-line can be given in option file as server-id
- option IS NOT variable

Groups:

- mysqld, mysqladmin, client, mysql, server

Note: [client] option group is read by all client-programs except mysqld

MySQL Configuration

Option File Inclusions:

- !include = for file
- !includedir = for multiple option files

Examples:

- !include /home/john/my-options.cnf
- !includedir /home/john

Note:

- All option files must end with .cnf

MySQL Configuration

MySQL Data Directory:

- Default path is /var/lib/mysql
- mysql user is created and /var/lib/mysql set as home directory
- Owned by mysql user
- Should be on its own Filesystem - SSSD is preferred
- Controlled by datadir option in my.cnf

MySQL Configuration

- Move Data Directory to /var/lib/mysql/prod

Steps:

- Shutdown mysql service
- Create directory and change owner to mysql
- Move all data files
- Set option in my.cnf
- Restart mysql service

MySQL Configuration

MySQL Binary Log Files:

- Record database changes as events
- Binary format - Encrypted
- mysqlbinlog utility to read binary log files and output in clear text
- Contains information on how long each statement took that updated data
- Very import for Replication - provides a records of data changes on source
- Point-in-Time Recovery - Bring database up to date from the point of backup
- After a backup has been restored, the events in the binary log that were recorded after the backup was made are re-executed
- Default size is 1GB - controlled by max_binlog_size
- Retention - How many days worth of binary logs should we keep - binlog_expire_logs_seconds

MySQL Configuration

Enable Binary Logging:

- Enabled by default - system variable log_bin ON
- log_bin - binlog | mysqld-bin | prod-bin
- log_bin_index - binlog.index | mysqld-bin.index | prod-bin.index

Disable Binary Logging:

- disable-log-bin

MySQL Configuration

TASK:

- Disable Binary Logging
- Enable Binary Logging - Move to a new location

MySQL Configuration

MySQL Error Log File:

- Contains a record of mysqld startup and shutdown times
- Also contains diagnostic messages like errors, warnings that occurs during startup or shutdown, and while the server is running
- Different MySQL components writes log events in the error log i.e system, innodb, etc
- log-error is the system variable
- Default error log is /var/log/error.log

MySQL Configuration

- Configure Error Logging to /var/log/mysql/errorlog location