

Best Practices for Developing High Performing Java Applications with Db2

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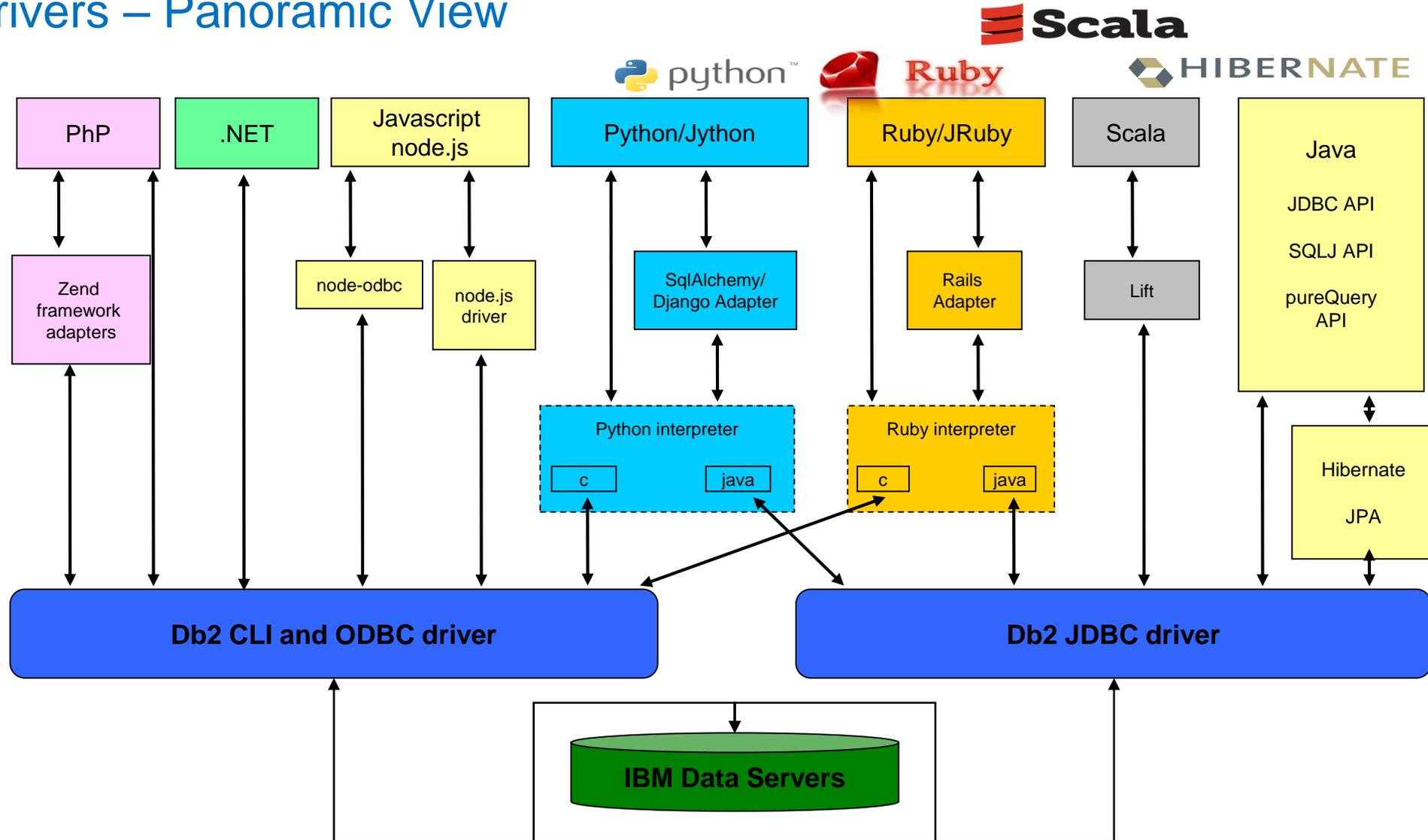
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Agenda

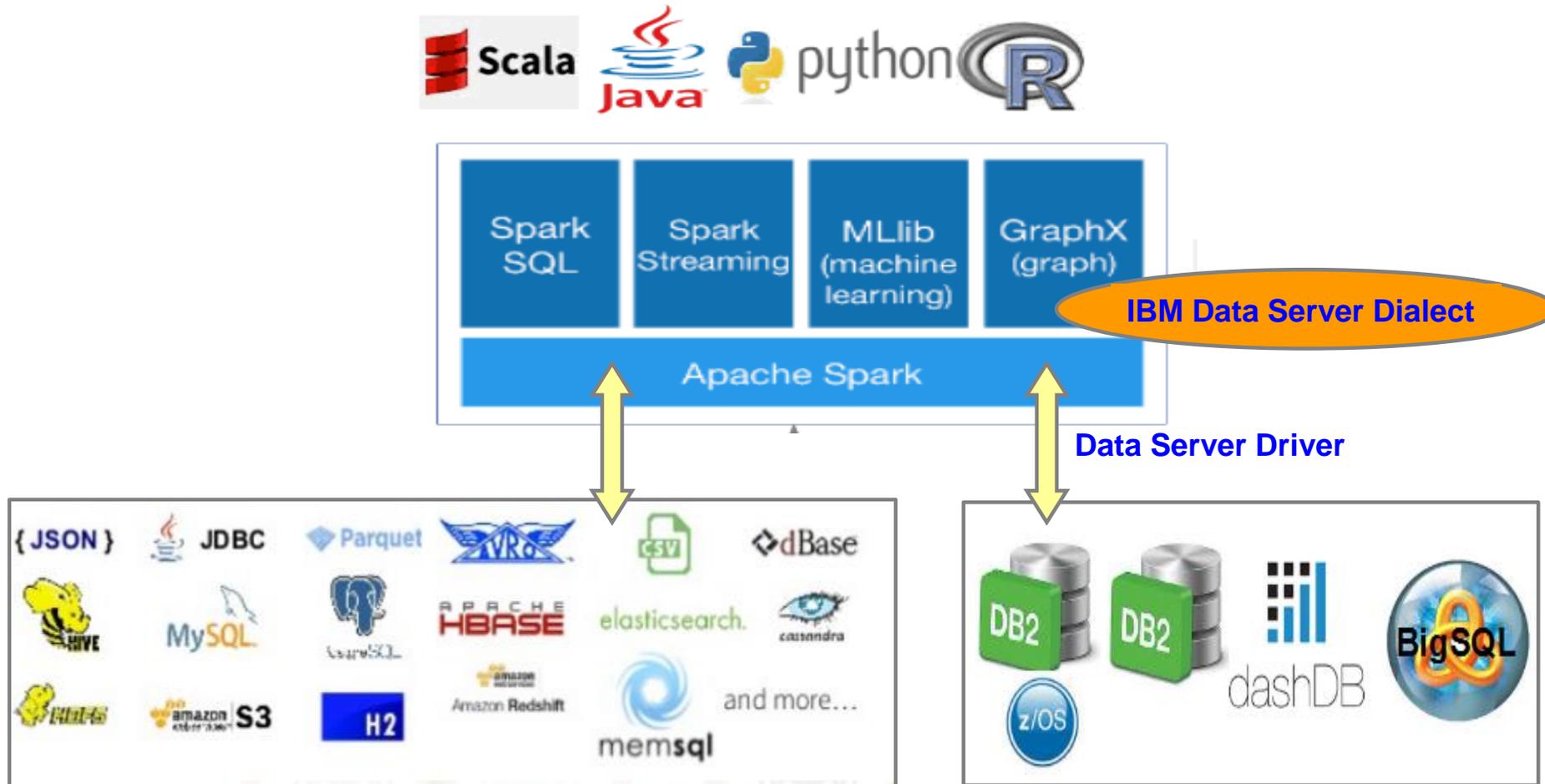
- Db2 JDBC driver architecture and API details
- Connection Management
- Db2 Dynamic Statement Cache
- Best practice for SQL Execution

Db2 Drivers – Panoramic View

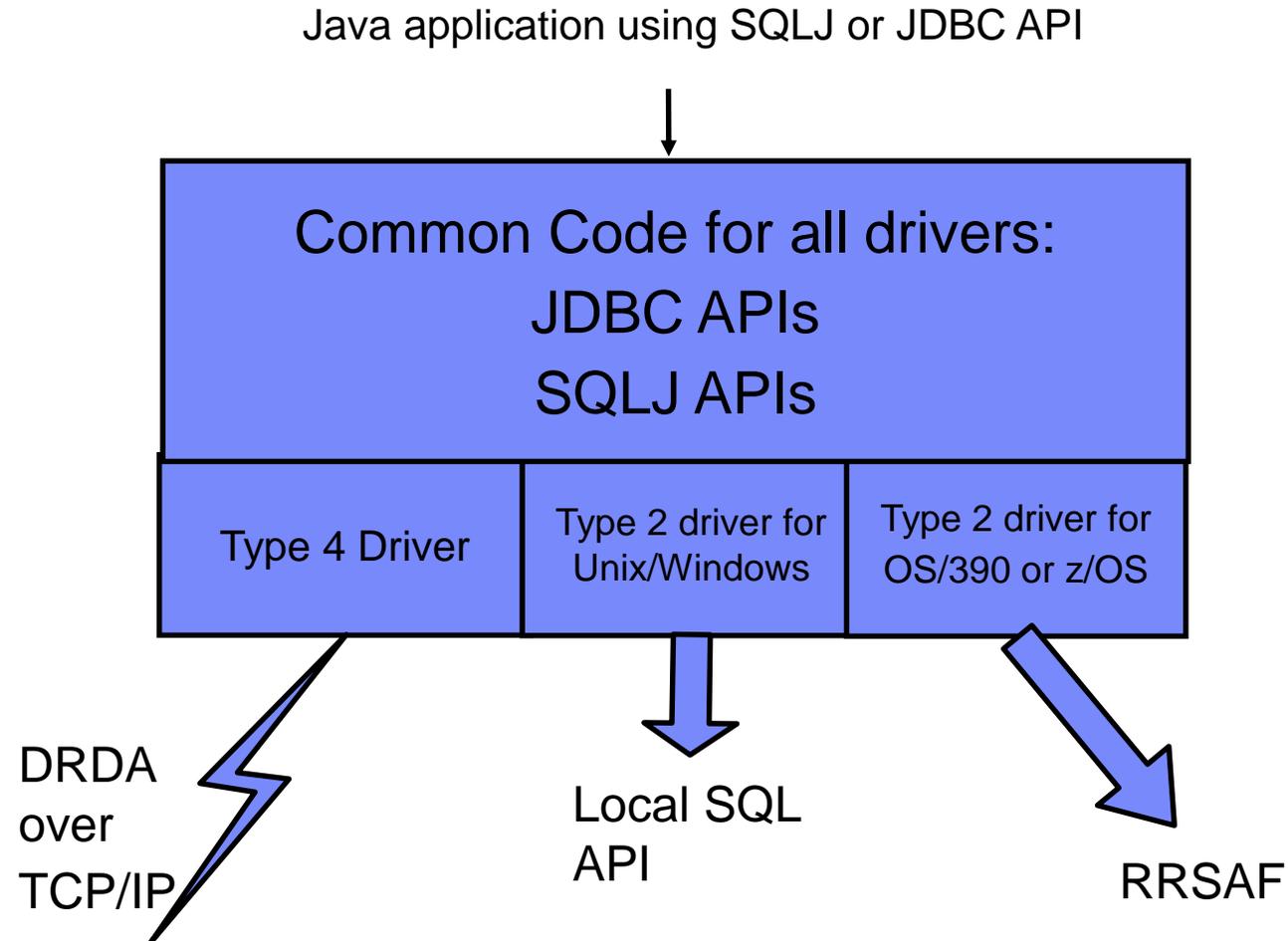


Integration with Spark

- Goal – Seamless read from IBM data servers into Spark & write from Spark DataFrames to IBM data servers



Data Server Driver for JDBC/SQLJ - Architecture



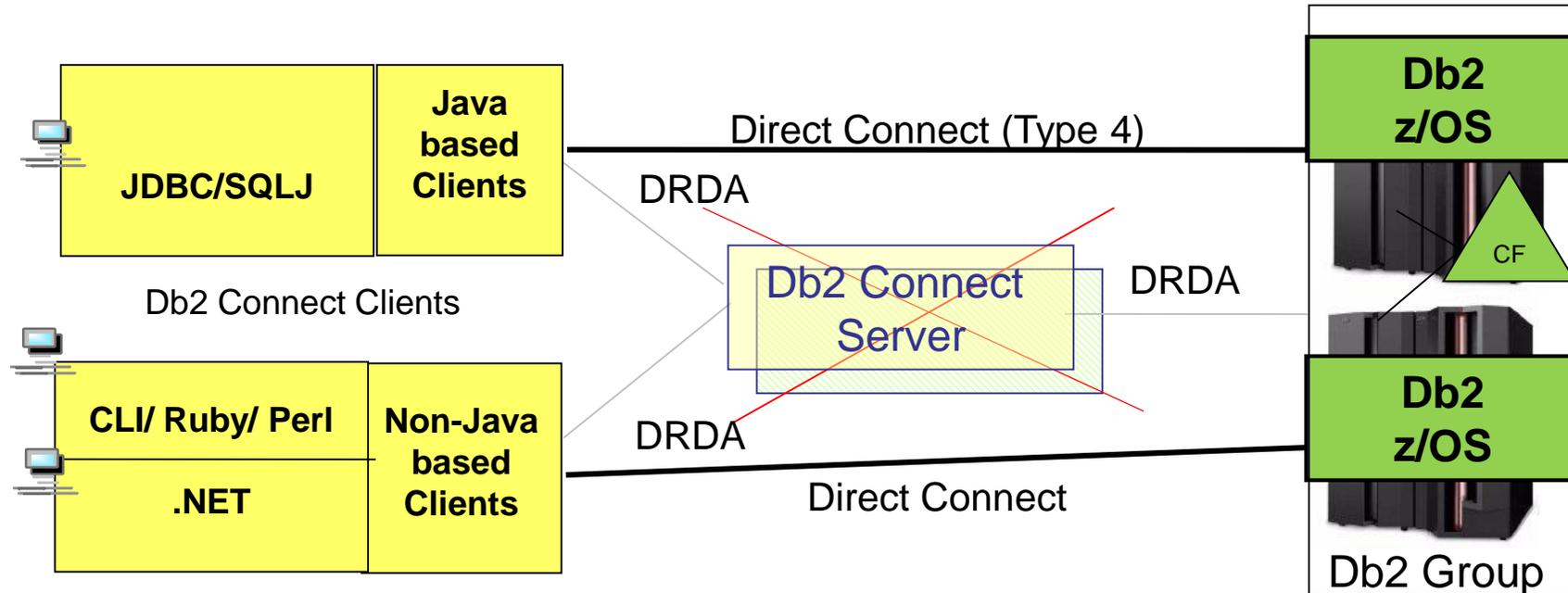
Features

- Full function JDBC driver, much more than a JDBC driver

| Feature | Details |
|----------------------------------|---|
| High Availability | Work load Balancing, Client re-route (Failover) |
| Scalability | Extensive Multi-threading; Better resource utilization |
| Performance | Connection Reuse/ efficient socket management; DRDA chaining / batching; Defer prepares ; Statement Caching |
| Security | Encryption / Authentication using SSL, Kerberos |
| Monitoring | Extended diagnostics for system monitoring |
| Robust Application functionality | Internationalization, Bi-di support, Distributed transactions, JSON, Oracle Compatibility |
| Data types | BIGINT, TIMESTAMP, XML/BLOB/CLOB |
| Standards | JDBC, ODBC, XA, DRDA |
| Programmer Productivity | Integration with Open Source ORM frameworks |

Client Configurations – Distributed Connectivity

- Based on DRDA - Distributed Relational Database Architecture



- Data Server Clients no longer require Db2 Connect Server
- Data Server Clients are Sysplex enabled with improved availability

Getting a Connection

▪ java.sql.DriverManager API

- The actual driver type determined during runtime from the connection URL format:
 - Type 2 - "jdbc:db2:database"
 - Type 4 - "jdbc:db2://host:port/database" (default port number 446)

```
Class.forName("com.ibm.db2.jcc.DB2Driver");  
Connection con = DriverManager.getConnection("jdbc:db2://localhost:50000/sample",  
"username", "password");
```

- Disadvantage – Reduces portability due to class name and URL.

▪ javax.sql.DataSource API

- Logical name mapped to DataSource object via JNDI naming service
- logical name -> driver info, DB name, IP, port, user, password, etc.
- App servers used to manage & configure data sources
- Makes application portable

```
Context ctx=new InitialContext();  
DataSource ds=(DataSource)ctx.lookup("jdbc/sampled");  
Connection con=ds.getConnection();
```

Driver and Connection Properties

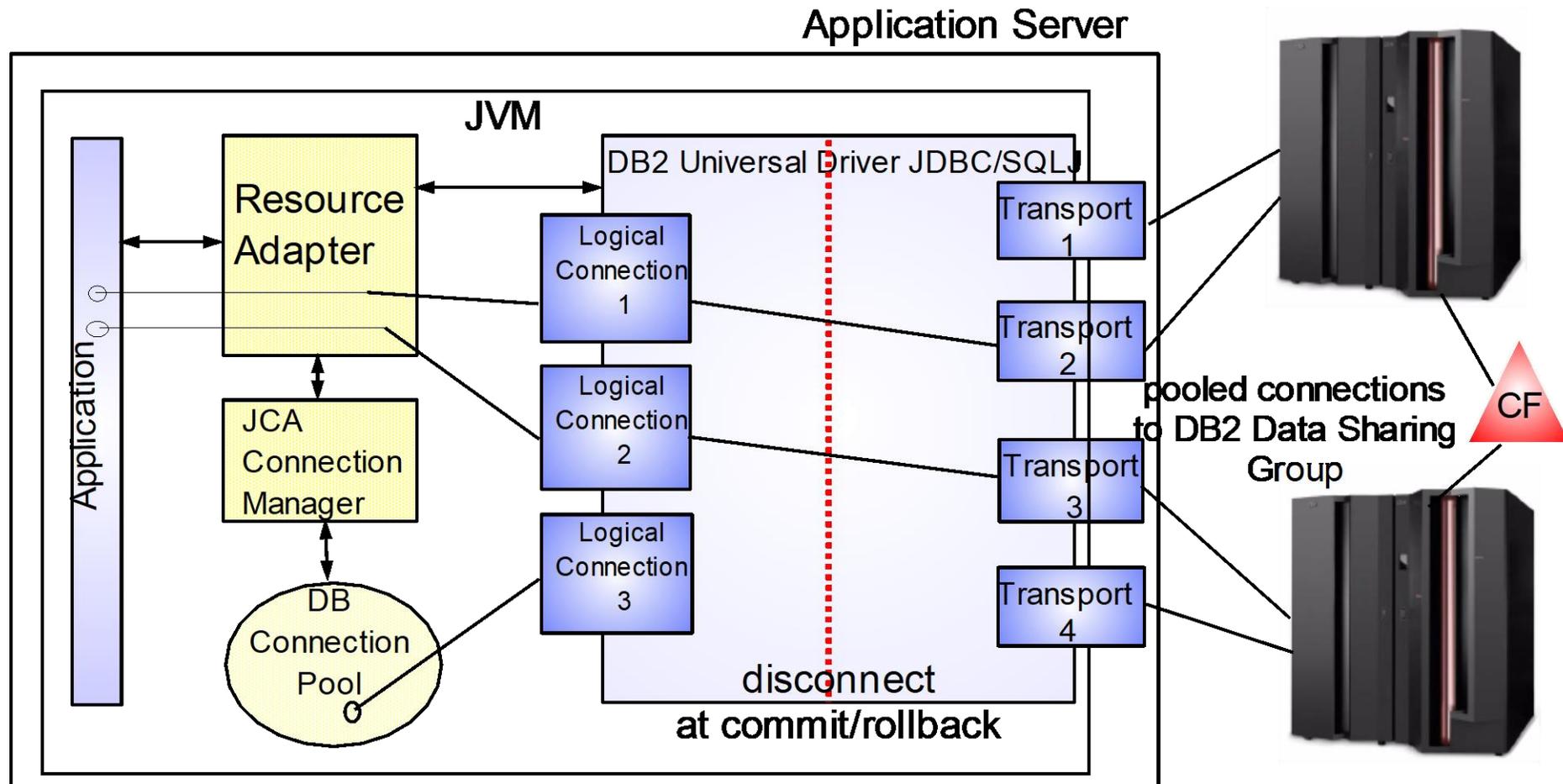
- Global driver properties can be provided through Java system properties or a properties file.
- JDBC API defines a set of properties to identify and describe a DataSource implementation.
- Properties may be specified in any of three ways
 - JDBC 1 connection properties passed as a `java.util.Properties` object (consisting of key/value pairs) as argument to `DB2Driver.connect()` or `java.sql.DriverManager.getConnection()`
 - As part of the database URL itself
 - `jdbc:db2://server[:port]/databaseName[:propertyKey=value;...]`
 - `jdbc:db2://localhost:50000/TESTDB:user=foo;password=bar;`
 - Using `setXXX` methods
 - most properties are defined in the abstract `com.ibm.db2.jcc.DB2BaseDataSource` class
- Examples of properties - `ProgressiveStreaming`, **`securityMechanism`**, `loginTimeout`, `keepdynamic`, `deferPrepares`, **`enableSysplexWLB`**, `currentExplainMode`, `cursorSensitivity`, `maxTransportObjects`, `traceFile`, `traceLevel`, **`currentSchema`**, `currentSQLID`, `dumpPool`

Connection Optimization

- All DB resources hang off Connection objects, must be managed carefully
- Creating and terminating a connection is resource consuming, both in the driver and Db2
- Client obtaining a physical database connection requires multiple network requests to
 - Handshake on DRDA protocol
 - Validate client user credentials
 - Establish code page, packet sizes etc
- Get a connection object when needed
- Reuse a connection object for multiple Statement objects when possible, use connection pooling
- Close connections promptly, don't leave connection cleanup up to garbage collection

Sysplex Workload Balancing

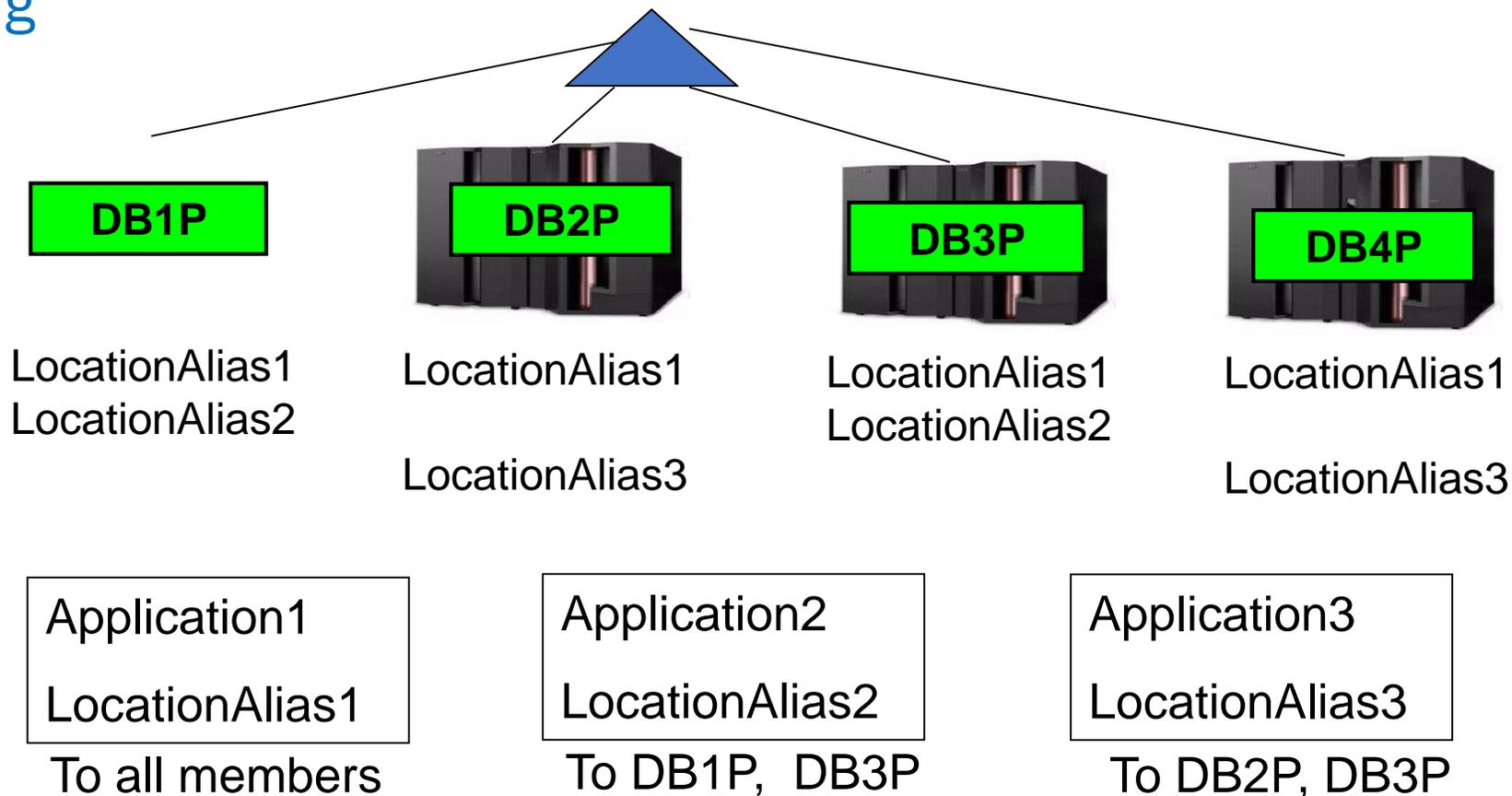
- Data Server Driver Type 4 supports sysplex distribution and transparent failover at transaction boundary



Use ClientInfo fields

- Can be used in WLM, RLF and profile definition and performance monitoring
- WebSphere Application Server supports explicit and implicit setting of client information
 - Example how to call explicitly
 - ...
 - ```
WSConnection conn = (WSConnection) ds.getConnection();
props.setProperty(WSConnection.CLIENT_ID, "user123");
conn.setClientInformation(props);
```
  - Example how to call implicitly by turning on WebSphere Trace Group
    - WAS.clientinfo=all=enabled or
    - WAS.clientinfopluslogging=all=enabled

## Db2 Location Alias for Subgrouping



**–MODIFY DDF** command with the **ALIAS** keyword to configure and manage aliases dynamically without taking a Db2 or DDF outage.

## Db2 High Performance DBAT

- **High Performance DBATs reduce CPU consumption by**
  - Supporting RELEASE(DEALLOCATE) to avoid repeated package allocation/deallocation
  - Avoiding connection going inactive and then back to active
  - Avoid DBAT being pooled at commit and probably reused by a different connection
- **Enable High Performance DBAT**
  - BIND client packages into different collection coll2 with RELEASE(DEALLOCATE)
  - BIND other frequently executed packages with RELEASE(DEALLOCATE)
    - E.g.trigger packages
  - Set -MODIFY DDF PKGREL(BNDOPT) to enable High Performance DBAT
  - Monitor MAXDBAT as more DBAT could stay active at any point in time and review size of application server connection pools for reasonable size
- **In WAS datasource property definition point to new collection**
  - E.g. jdbcCollection=coll2
- **JDBC Type 2 connection use RRSAF and would similarly benefit from client packages bound with RELEASE(DEALLOCATE)**

## Db2 Connection Profile

- **Problem:** For distributed workloads, low priority or poorly behaving client applications may monopolize Db2 resources and prevent high-priority applications from executing.
- **Solution:** Increased granularity of monitoring for system level activities
  - Number of connections
  - Number of threads
  - Idle thread timeout
- Profiles specified in **SYSIBM.DSN\_PROFILE\_TABLE**
- Db2 supports filtering and threshold monitoring of system related activities via keywords
  - Number of threads - Db2 11 special register
  - Number of connections - Db2 12 Db2-provided global var
  - Idle thread timeout
- Scope filters
  - ROLE (available through Trusted Context support)
  - Product-specific identifier

## Prepared Statement Objects - Benefits

- PreparedStatement objects vs. Statement objects
  - 2 DB calls needed for fetch (describe, data)
  - PreparedStatement makes description calls at construction time, Statement makes them on every execution.
  - PreparedStatement enables Statement Pooling
  - Use Statement when SQL is not executed often
  
- PreparedStatement object pool
  - Client side optimization
  - Pool of PreparedStatement and CallableStatement objects, not active in a Connection
  - Reduced overhead of Java object creation and garbage collection
  - Pool exists for the life of an open connection, effectiveness depends on connection pooling.
  - No impact to application
  
- **No concern for SQLJ**

# Statement or PreparedStatement

- Statement example

```
Statement stmt = con.createStatement();
stmt.executeUpdate("INSERT INTO EMPLOYEE VALUES('John', 123)");
stmt.executeUpdate("INSERT INTO EMPLOYEE VALUES('Mary', 425)");
```

- PreparedStatement example

```
PreparedStatement ps = con.prepareStatement("INSERT INTO EMPLOYEE VALUES(?, ?)");
ps.setString(1,"John");
ps.setInt(2, 123);
ps.executeUpdate();
ps.setString(1,"Mary");
ps.setInt(2, 425);
ps.executeUpdate();
```

## Db2 Dynamic Statement Cache

- Dynamic statement prepared at run time
- Dynamic statement cache
  - To improve performance of dynamic SQL
  - Enabled by DSNZPARM CACHEDYN = YES
  - Allows applications (multiple threads) to reuse and share prepared statements
- Prepared stmt is saved in an in-memory cache
- Subsequent prepares of same stmt loads from cache if cache match criteria met (sql, authid, special regs, bind options etc.)
- Cache pool shared by different threads, plans and packages (“global cache”)
- Good cache hit rate produces significant performance benefits
- A Full Prepare can consume 10-100X more CPU than a Short Prepare!

## Dynamic Statement Cache

- SQL can be EXPLAINED using the 'EXPLAIN STMTCACHE' feature.
  - Populates various explain tables with details on statements in the dynamic statement cache including access path information
- Use Dynamic SQL Stmt section of statistics to monitor the Global Cache Hit Ratio % to determine if the cache size needs to be increased.

| DYNAMIC SQL STMT           | QUANTITY | /SECOND | /THREAD | /COMMIT |
|----------------------------|----------|---------|---------|---------|
| PREPARE REQUESTS           | 5099.0K  | 16.2K   | N/C     | 7.83    |
| FULL PREPARES              | 0.00     | 0.00    | N/C     | 0.00    |
| SHORT PREPARES             | 5098.5K  | 16.2K   | N/C     | 7.83    |
| GLOBAL CACHE HIT RATIO (%) | 100.00   | N/A     | N/A     | N/A     |
| IMPLICIT PREPARES          | 0.00     | 0.00    | N/C     | 0.00    |
| PREPARES AVOIDED           | 0.00     | 0.00    | N/C     | 0.00    |
| CACHE LIMIT EXCEEDED       | 0.00     | 0.00    | N/C     | 0.00    |
| PREP STMT PURGED           | 0.00     | 0.00    | N/C     | 0.00    |
| LOCAL CACHE HIT RATIO (%)  | N/C      | N/A     | N/A     | N/A     |
| CSWL - STMTS PARSED        | 0.00     | 0.00    | 0.00    | 0.00    |
| CSWL - LITS REPLACED       | 0.00     | 0.00    | 0.00    | 0.00    |
| CSWL - MATCHES FOUND       | 0.00     | 0.00    | 0.00    | 0.00    |
| CSWL - DUPLS CREATED       | 0.00     | 0.00    | 0.00    | 0.00    |

## Literal Replacement for Global Dynamic Statement Cache

- Dynamic SQL with literals can be re-used in the cache
  - Literals replaced with &  
(similar to parameter markers but not the same)
- To enable set the property enableLiteralReplacement='YES' in the JCC Driver
- Lookup Sequence
  - Original SQL with literals is looked up in the cache
  - If not found, literals are replaced and new SQL is looked up in the cache
    - Additional match on literal usability
    - Can only match with SQL stored with same attribute, not parameter marker
  - If not found, new SQL is prepared and stored in the cache
- **Db2 12 support as BIND option CONCENTRATESTMT on package**

## Why SQLJ?

- Static SQL performance for Java applications
- Static SQL authorization model
- Monitoring/Manageability
  - Static SQL packages for accounting/monitoring
  - Static SQL locks in access path, so that access path changes do not occur without a conscious choice
- Measurements with the IRWW workload comparing JDBC vs SQLJ with the T2 driver

|                | Throughput (ETR) | Normalized Throughput (ITR) | z/OS CPU Utilization | CL.1 CPU time      |
|----------------|------------------|-----------------------------|----------------------|--------------------|
| <b>JDBC T2</b> | 2636.83          | 3773.37                     | 69.88                | 0.000672           |
| <b>SQLJ T2</b> | 2694.80 (+2.20%) | 5174.35 (+37.13%)           | 52.08 (-25.47%)      | 0.000457 (-32.00%) |

## Batching INSERT and SELECT

- INSERT – JDBC API

```
ps = conn.prepareStatement("INSERT INTO EMPLOYEE VALUES (?)")
ps.setInt(1)
ps.addBatch()
ps.setInt(2)
ps.addBatch()
Int[] returncodes = ps.executeBatch()
```

- SELECT - Db2 driver extension (executeDB2QueryBatch)

```
PreparedStatement ps = conn.prepareStatement("SELECT * from T1 where C1 = ?")
ps.setInt(1,1)
ps.addBatch()
ps.setInt(1,2)
ps.addBatch()
((com.ibm.db2.jcc.DB2PreparedStatement)pstmt).executeDB2QueryBatch();
While (ps.getMoreResults()) {
 Rs = ps.getResultSet()
 While (rs.next()){
 }
}
rs.close
```

## Load Data from Distributed Client

### ■ Current solutions

- First, file transfer from client to z/OS and then use Db2 LOAD utility
  - Invoke DSNUTILU stored procedure to call LOAD utility
- Other DRDA connection-based approaches
  - Client application can issue SQL INSERTs
  - Db2 Connect IMPORT utility with SQL INSERT option and IXF input
  - Db2 z/OS cross-loader from Db2 LUW tables

### ■ New: DRDA fast load

- Easy and fast loading of data from file that resides on client
- **Available** with **Db2 Client V11.1 FP1** and **Db2 V12R1M100**
  - **Java T4** application can use ZLOAD method in a Db2 connection class
  - Supported client file formats:  
Internal format, as well as delimited and spanned (LOB/XML data)
- Performance results showed DRDA fast load as fast as LOAD utility
  - Significant elapsed time reduction and up to 100% zIIP exploitation



# DRDA Fast Load Implementation

Data Server Client for JDBC/SQLJ

```

...
DB2Connection db2conn = (DB2Connection)con;

// LOAD statement text is in a string or input file
String loadstmt = "TEMPLATE SORTIN" +
"TEMPLATE SORTOUT" +
"SYSLIEN WORKDDN(SORTIN) REPLACE PREFORMAT
LOG(NO) REUSE NOCOPYPEND FORMAT DELIMITED
UNICODE INTO TABLE MYID.CUSTOMER_DATA NUMRECS
30000";

// Name of the file that contains the input data
String dataFilename = "C:\\customer.data";

// Identifier for this run of the LOAD utility
String utilid = "ZLOADTEST1";
LoadResult lr = db2conn.zLoad(loadstmt, dataFilename, utilid);

int returnCode = lr.getReturnCode();
String loadMessage = lr.getMessage();

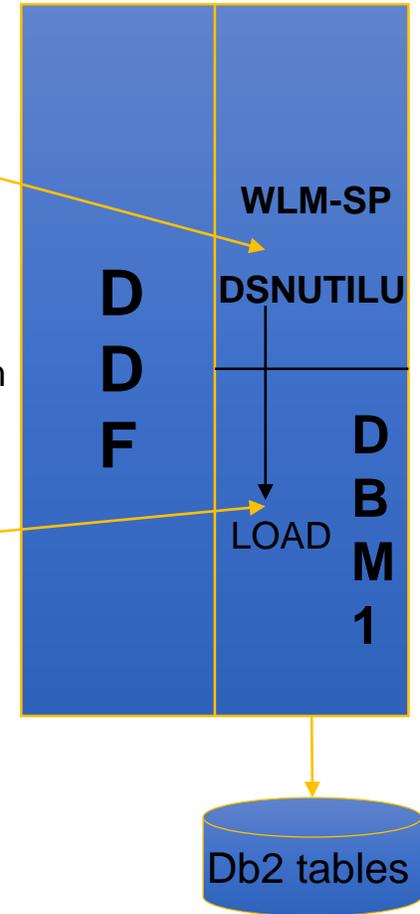
```

**File formats  
ftp block mode**

1. **INTERNAL**, used by SAP
2. **DELIMITED**
3. **SPANNED** for LOB/XML columns

Db2 z/OS server

1. Connect
2. Establish LOAD environment
3. Start data stream and provide continuous blocks for LOAD



- Cancel of LOAD with RESUME YES  
 → RECP / RBDP, despite BACKOUT YES



# Java Performance Problem Areas

## ➤ Java Application

- Autocommit(on) - default
- Mismatch of Java and Db2 data types
- Usage of String for numbers
- Retrieval of unused columns (select \* )
- Transaction isolation REPEATABLE READ (default in WAS) or SERIALIZABLE
- Open cursor SELECT ... FOR UPDATE for locking semantics
  - Consider using WITH RS USE AND KEEP UPDATE LOCKS

## ➤ JDBC

- JDBC resources not closed (cursor, statements, connections)
- No usage of Parameter Markers
  - E.g. select c1, c2 FROM t1 WHERE c3=?  
-> use literal replacement option
- Cursor are defined as hold by default
- Usage of Statement() instead of preparedStatement() objects
  - No object caching in WAS

## Locking and Concurrency

- If deadlocks and timeouts, turn on Db2 Performance Trace class(6)
  - Use LOCKSIZE ROW selectively for top reported tables
  - Combine with MEMBER CLUSTER if data sharing to reduce page P-lock and page latch contention on data pages
    - Can be defined via deferred ALTER/REORG
- Review indexes
  - Missing index causing table scan and deadlocks
  - Drop unused indexes and Ris
- Zparm SKIPUNCI – skip uncommitted inserts for ISOLATION(CS|RS)

## Let's Practice

- Type 2 vs. Type 4 connectivity
  - SE utilization
  - Failover configuration considerations

| AVERAGE      | APPL (CL.1) | DB2 (CL.2) |
|--------------|-------------|------------|
| -----        | -----       | -----      |
| ELAPSED TIME | 0.278042    | 0.000280   |
| NONNESTED    | 0.278042    | 0.000280   |
| STORED PROC  | 0.000000    | 0.000000   |
| UDF          | 0.000000    | 0.000000   |
| TRIGGER      | 0.000000    | 0.000000   |
| CP CPU TIME  | 0.000111    | 0.000080   |
| AGENT        | 0.000111    | 0.000080   |
| NONNESTED    | 0.000111    | 0.000080   |
| STORED PRC   | 0.000000    | 0.000000   |
| UDF          | 0.000000    | 0.000000   |
| TRIGGER      | 0.000000    | 0.000000   |
| PAR.TASKS    | 0.000000    | 0.000000   |
| SE CPU TIME  | 0.000097    | 0.000071   |
| NONNESTED    | 0.000097    | 0.000071   |
| STORED PROC  | 0.000000    | 0.000000   |
| UDF          | 0.000000    | 0.000000   |
| TRIGGER      | 0.000000    | 0.000000   |

# Let's Practice ....

- SQL activity per commit
- Thread management per commit

| NORMAL TERM.    | AVERAGE | TOTAL |
|-----------------|---------|-------|
| -----           | -----   | ----- |
| NEW USER        | 0.00    | 0     |
| DEALLOCATION    | 0.00    | 7     |
| APPL.PROGR. END | 0.00    | 0     |
| RESIGNON        | 1.00    | 53571 |
| DBAT INACTIVE   | 0.00    | 0     |
| TYPE2 INACTIVE  | 0.00    | 0     |
| RRS COMMIT      | 0.00    | 0     |

| SQL DML  | AVERAGE | TOTAL  |
|----------|---------|--------|
| -----    | -----   | -----  |
| SELECT   | 0.00    | 0      |
| INSERT   | 0.00    | 0      |
| ROWS     | 0.00    | 0      |
| UPDATE   | 0.00    | 0      |
| ROWS     | 0.00    | 0      |
| MERGE    | 0.00    | 0      |
| DELETE   | 0.00    | 0      |
| ROWS     | 0.00    | 0      |
| DESCRIBE | 0.94    | 50413  |
| DESC.TBL | 0.00    | 0      |
| PREPARE  | 1.00    | 53571  |
| OPEN     | 1.00    | 53571  |
| FETCH    | 1.00    | 53571  |
| ROWS     | 1.22    | 65594  |
| CLOSE    | 0.00    | 0      |
| DML-ALL  | 3.94    | 211126 |

## Useful links

- IBM Redbook - Db2 for z/OS and WebSphere Integration for Enterprise Java Applications – <http://www.redbooks.ibm.com/abstracts/sg248074.html?Open>

## Summary

- Business critical Java applications with Db2 for z/OS as enterprise database server have been implemented commonly and successfully for many years now
- Going through installation checklist is highly recommended prior to each implementation to ensure success
  - Communication among WAS Administrator, Db2 System Programmer, and Application Architect
- No shortcuts in respect to setup for availability
  - User sees application availability and not Db2 system availability
- Monitor and react proactively and do not wait until user complains
  - Workload behavior changes over time

