

JDBC – Java DB Connectivity

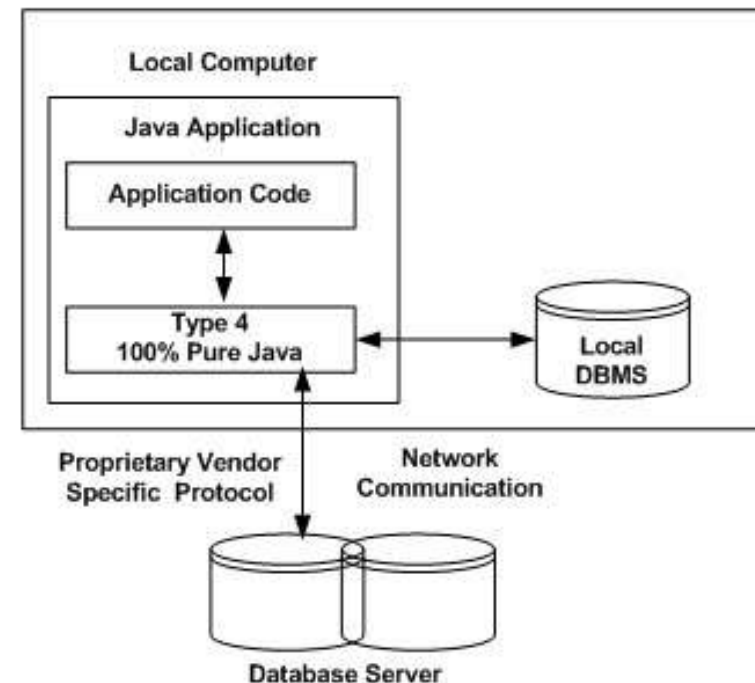
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DBMS Networking

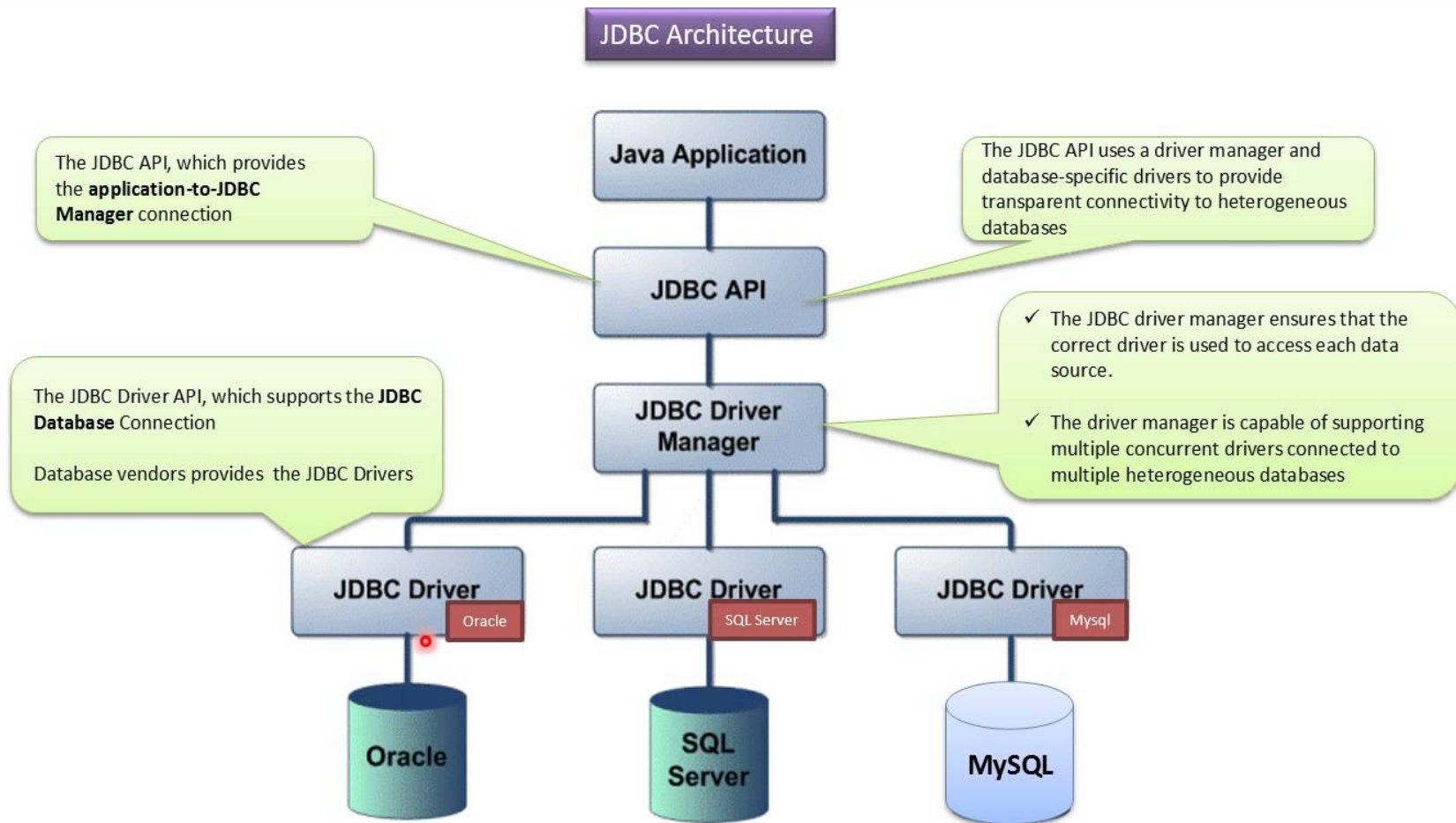
- The most of **DBMS** make use of the **TCP transport protocol** and accept incoming connections on a **specific port**. This allows both **local** and **remote connections**.
 - MS SQL Server (TCP:1433)
 - PostgreSQL (TCP:5432)
 - MySQL (TCP:3306)
 - Oracle (TCP:1521)
 - SQLite (*in-process*)



What is JDBC?

- “An *API* that lets you access virtually *any tabular data source* from the Java programming language”
 - What’s an API? *Application Programming Interface*
 - What’s a tabular data source? *Relational databases, spreadsheets, flat files*
- We’ll focus on accessing relational databases. Nevertheless, **using the same principles** all the others can be accessed

General Architecture



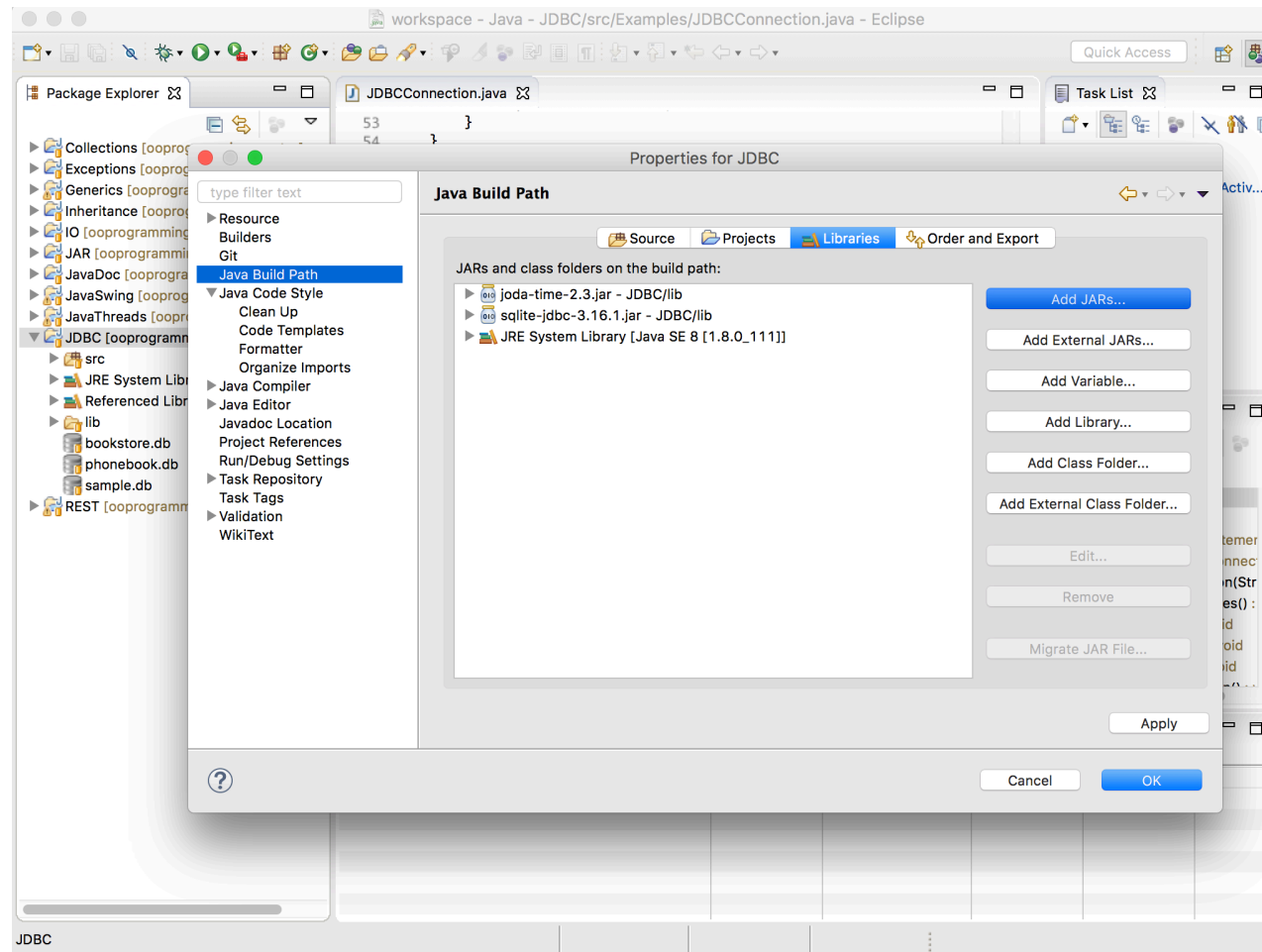
Basic steps

1. Load vendor specific **Driver**
2. Establish a **Connection**
3. Create a **JDBC Statement**
4. Execute **SQL** Statements
5. Get **ResultSet**
6. Close the Connection

Vendor specific drivers

- JDBC drivers provide the connection to the database and implement the protocol for transferring queries and results between the client and the database.
- There are 4 type of drivers. We refer to Type 4: Pure Java (see Appendix)
- Each database needs a specific driver. They need to be downloaded separately
 - [mySQL] <https://dev.mysql.com/downloads/connector/j/>
 - [SQLite] <https://github.com/xerial/sqlite-jdbc>
- Drivers are Java binary libraries and must be included into the CLASSPATH

Vendor specific drivers



1. Load vendor specific driver

```
import java.sql.*;

/* this is for MySQL*/
Class.forName("com.mysql.jdbc.Driver");

/* this is for SQLite */
Class.forName("org.sqlite.jdbc");
```

JDBC is an abstract API mostly composed of Java Interfaces. Concrete classes are provided with drivers.

Class.forName() dynamically loads the driver's classes.

**throws ClassNotFoundException!*



2. Establish a Connection (with URL)

- `DriverManager.getConnection(String url);`
- `DriverManager.getConnection(String url,
Properties prop);`
- `DriverManager.getConnection(String url,
String user,
String password);`

2. Establish a Connection (with URL)

```
/* this is for MySQL*/  
Connection c = DriverManager.getConnection(  
    "jdbc:mysql://localhost/dbname?user=user&password=pass");
```

```
/* this is for SQLite */  
Connection c = DriverManager.getConnection(  
    "jdbc:sqlite:filename.db");
```

Establishes a connection to a database mediated by the **Connection interface**. The driver implements the **Connection interface** provided by JDBC



3. Create JDBC Statement(s)

```
Statement statement = c.createStatement() ;
```

The JDBC **Statement**, **CallableStatement**, and **PreparedStatement** interfaces define the methods and properties that enable you to **send SQL or PL/SQL commands and receive data** from your database.

They also define methods that help **bridge data type differences between Java and SQL data types** used in a database.



3. Create JDBC Statement(s)

Interfaces	Recommended Use
Statement	Use the for general-purpose access to your database. Useful when you are using static SQL statements at runtime. The Statement interface cannot accept parameters.
PreparedStatement	Use the when you plan to use the SQL statements many times. The PreparedStatement interface accepts input parameters at runtime.
CallableStatement	Use the when you want to access the database stored procedures. The CallableStatement interface can also accept runtime input parameters.

4. Execute SQL Statements

Once you've created a Statement object, you can then use it to execute an SQL statement with one of its methods.

- **int executeUpdate (String SQL):** Returns the **number of rows** affected by the execution of the SQL statement. Use this method to execute SQL statements for which you expect to get a number of rows affected - for example, an **INSERT, UPDATE, or DELETE** statement.
- **ResultSet executeQuery (String SQL):** Returns a **ResultSet** object. Use this method when you expect to get a result set, as you would with a **SELECT** statement.



4. Execute SQL Statements

```
statement.executeUpdate("CREATE TABLE person (" +  
    "_id INTEGER PRIMARY KEY AUTOINCREMENT, " +  
    "cf VARCHAR(30) UNIQUE, " +  
    "name VARCHAR(30), " +  
    "surname VARCHAR(30))");
```

```
statement.executeUpdate("INSERT INTO item (year, title,  
type, lenght) VALUES(2002, 'Soffocare', 'Book', 170)");
```

```
statement.executeQuery("SELECT * FROM person");
```

The String passed to the Statement methods depends on the specific **SQL dialect** used by the database. **It is not Java!**



5. Get ResultSet

- The `java.sql.ResultSet` interface represents the **result set of a database query**. A `ResultSet` object maintains a **cursor that points to the current row** in the result set.
 - **Navigational methods**: Used to move the cursor around the `ResultSet`
 - **Get methods**: Used to view the data in the columns of the current row being pointed by the cursor.
 - **Update methods**: Used to update the data in the columns of the current row. The updates can then be updated in the underlying database as well.

Navigational methods

Method	Description
<code>absolute()</code>	Moves the <code>ResultSet</code> to point at an absolute position. The position is a row number passed as parameter to the <code>absolute()</code> method.
<code>afterLast()</code>	Moves the <code>ResultSet</code> to point after the last row in the <code>ResultSet</code> .
<code>beforeFirst()</code>	Moves the <code>ResultSet</code> to point before the first row in the <code>ResultSet</code> .
<code>first()</code>	Moves the <code>ResultSet</code> to point at the first row in the <code>ResultSet</code> .
<code>last()</code>	Moves the <code>ResultSet</code> to point at the last row in the <code>ResultSet</code> .
<code>next()</code>	Moves the <code>ResultSet</code> to point at the next row in the <code>ResultSet</code> .
<code>previous()</code>	Moves the <code>ResultSet</code> to point at the previous row in the <code>ResultSet</code> .
<code>relative()</code>	Moves the <code>ResultSet</code> to point to a position relative to its current position. The relative position is passed as a parameter to the <code>relative</code> method, and can be both positive and negative. Moves the <code>ResultSet</code>

Method	Description
<code>getRow()</code>	Returns the row number of the current row - the row currently pointed to by the <code>ResultSet</code> .
<code>getType()</code>	Returns the <code>ResultSet</code> type.
<code>isAfterLast()</code>	Returns true if the <code>ResultSet</code> points after the last row. False if not.
<code>isBeforeFirst()</code>	Returns true if the <code>ResultSet</code> points before the first row. False if not.
<code>isFirst()</code>	Returns true if the <code>ResultSet</code> points at the first row. False if not.

Get methods

- resultSet.getXXX(), where XXX is a primitive data type
 - rs.getString("columnName")
 - rs.getLong("columnName")
 - rs.getInt("columnName")
 - rs.getDouble("columnName")
- rs.getString(1)
- rs.getLong(2)
- rs.getInt(3)
- rs.getDouble(4)

5. Get ResultSet

```
ResultSet rs = statement.executeQuery(  
    "SELECT * FROM person");
```

```
while(rs.next()) {  
    rs.getInt("_id");  
    rs.getString("cf");  
    rs.getString("name");  
    rs.getString("surname");  
}
```

5. Get ResultSet

```
ResultSet rs = statement.executeQuery(  
    "SELECT * FROM person");
```

```
while(rs.next()) {  
    rs.getInt(1);  
    rs.getString(2);  
    rs.getString(3);  
    rs.getString(4);  
}
```



Finding Columns

```
int idIndex = rs.findColumn("_id");
int cfIndex = rs.findColumn("cf");
int nameIndex = rs.findColumn("name");
int surnameIndex = rs.findColumn("surname");

while(result.next()) {
    int id = rs.getInt(idIndex);
    String cf = rs.getString(cfIndex);
    String name = rs.getString(nameIndex);
    String surname = rs.getString(surnameIndex);
}
```

** If you need to access by ID but know only the column names*



6. Close Connection

```
statement.close();  
connection.close();
```

However...

6. Close Connection

- Programs should recover from errors and leave the database in a consistent state. **Runtime errors must be minimized in industrial applications!**
- If a statement in the try block throws an exception or warning, it must be caught in one of the corresponding catch statements.
- The **finally {...}** clause can be used to leave the database in a consistent state.

6. Close Connection

```
connection = null;
statement = null;

try {
    . . .
} catch(SQLException e) {
    // do something
} finally {
    if (connection != null) {
        statement.close();
        connection.close();
    }
}
```



Types

- There are significant variations between the SQL types supported by different database products. For example, most of the major databases support an SQL data type for large binary values, but Oracle calls this type LONG RAW, Sybase calls it IMAGE and Informix calls it BYTE.
- JDBC programmers mostly program with existing database tables, and they need not concern themselves with the exact SQL type names that were used.
- The one major place where programmers may need to use SQL type names is in the SQL CREATE TABLE statement when they are creating a new database table. In this case programmers must take care to use SQL type names that are supported by their target database.

Mapping JDBC to Java types

Java Type	JDBC type
String	VARCHAR or LONGVARCHAR
java.math.BigDecimal	NUMERIC
boolean	BIT
byte	TINYINT
short	SMALLINT
int	INTEGER
long	BIGINT
float	REAL
double	DOUBLE
byte[]	VARBINARY or LONGVARBINARY
java.sql.Date	DATE
java.sql.Time	TIME
java.sql.Timestamp	TIMESTAMP

JDBC type	Java type
CHAR	String
VARCHAR	String
LONGVARCHAR	String
NUMERIC	java.math.BigDecimal
DECIMAL	java.math.BigDecimal
BIT	boolean
TINYINT	byte
SMALLINT	short
INTEGER	int
BIGINT	long
REAL	float
FLOAT	double
DOUBLE	double
BINARY	byte[]
VARBINARY	byte[]
LONGVARBINARY	byte[]
DATE	java.sql.Date
TIME	java.sql.Time
TIMESTAMP	java.sql.Timestamp

Mapping JDBC to Java objects

Java Object Type	JDBC Type
String	VARCHAR or LONGVARCHAR
java.math.BigDecimal	NUMERIC
Boolean	BIT
Integer	INTEGER
Long	BIGINT
Float	REAL
Double	DOUBLE
byte[]	VARBINARY or LONGVARBINARY
java.sql.Date	DATE
java.sql.Time	TIME
java.sql.Timestamp	TIMESTAMP

JDBC Type	Java Object Type
CHAR	String
VARCHAR	String
LONGVARCHAR	String
NUMERIC	java.math.BigDecimal
DECIMAL	java.math.BigDecimal
BIT	Boolean
TINYINT	Integer
SMALLINT	Integer
INTEGER	Integer
BIGINT	Long
REAL	Float
FLOAT	Double
DOUBLE	Double
BINARY	byte[]
VARBINARY	byte[]
LONGVARBINARY	byte[]
DATE	java.sql.Date
TIME	java.sql.Time
TIMESTAMP	java.sql.Timestamp



ADVANCED RESULTSET



Advanced ResultSet

- ResultSet is an Iterable class.
- It is **not possible to move back and forth** within a default (TYPE_FORWARD_ONLY) ResultSet
 - Only **next()** can be called
- It is **not possible to modify the data** and, transparently, the database
 - Data have to be manipulated in memory and stored back with another operation (**statement.executeUpdate()**)

5. Get ResultSet

createStatement

```
Statement createStatement(int resultSetType,  
                          int resultSetConcurrency)  
    throws SQLException
```

Creates a Statement object that will generate ResultSet objects with the given type and concurrency. This method is the same as the createStatement method above, but it allows the default result set type and concurrency to be overridden. The holdability of the created result sets can be determined by calling `getHoldability()`.

Parameters:

`resultSetType` - a result set type; one of `ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_INSENSITIVE`, or `ResultSet.TYPE_SCROLL_SENSITIVE`

`resultSetConcurrency` - a concurrency type; one of `ResultSet.CONCUR_READ_ONLY` or `ResultSet.CONCUR_UPDATABLE`

Returns:

a new Statement object that will generate ResultSet objects with the given type and concurrency



JDBC – Scrollable ResultSet

```
Statement s = c.createStatement(  
    ResultSet.TYPE_SCROLL_INSENSITIVE|ResultSet.TYPE_SCROLL_SENSITIVE,  
    ResultSet.CONCUR_READ_ONLY);
```

```
ResultSet rs = s.executeQuery("SELECT * FROM person");
```

```
rs.previous();      // go 1 record back  
rs.relative(-5);    // go 5 records back  
rs.relative(7);     // go 7 records forward  
rs.absolute(100);   // go to 100th record
```

JDBC – Updateable ResultSet

```
Statement s = c.createStatement(  
    ResultSet.TYPE_FORWARD_ONLY,  
    ResultSet.CONCUR_UPDATABLE);
```

```
ResultSet rs = s.executeQuery("SELECT * FROM students  
    WHERE type='listening'");
```

```
while (rs.next()) {  
    int grade = rs.getInt("grade");  
    rs.updateInt("grade", grade + 1);  
    rs.updateRow();  
}
```

DatabaseMetaData object

- A **Connection** object provides a **DatabaseMetaData** object which is able to provide **schema** information describing:
 - tables
 - supported SQL grammar
 - *supported capabilities of the connection*
 - stored procedures

** What is a stored procedure? A group of SQL statements forming a logical unit aimed at performing a specific task*

DatabaseMetaData object

```
// Establish Connection
Class.forName("org.sqlite.JDBC");
Connection connection = DriverManager.getConnection("jdbc:sqlite:sample.db");

// Get metadata
DatabaseMetaData md = connection.getMetaData();

// Verify ResultSet supported types
System.out.println("-- ResultSet Type --");
System.out.println("Supports TYPE_FORWARD_ONLY: "
    + md.supportsResultSetType(ResultSet.TYPE_FORWARD_ONLY));
System.out.println("Supports TYPE_SCROLL_INSENSITIVE: "
    + md.supportsResultSetType(ResultSet.TYPE_SCROLL_INSENSITIVE));
System.out.println("Supports TYPE_SCROLL_SENSITIVE: "
    + md.supportsResultSetType(ResultSet.TYPE_SCROLL_SENSITIVE));
```



ResultSetMetaData

- A **ResultSet** object is able to provide **schema** information describing its columns.
 - Useful for writing code running on different tables. For example, converting in JSON or XML the output of different queries.

```
public static void printRS(ResultSet rs) throws SQLException {  
    ResultSetMetaData md = rs.getMetaData();  
    // get number of columns  
    int nCols = md.getColumnCount();  
    // print column names  
    for(int i=1; i < nCols; ++i)  
        System.out.print(md.getColumnName(i)+",");  
}
```

TRANSACTIONS



Definition

- A transaction is a set of actions to be carried out as a single, atomic action. Either all of the actions are carried out, or none of them are.
- The classic example of when transactions are necessary is the example of bank accounts. You need to transfer \$100 from one account to the other. You do so by subtracting \$100 from the first account, and adding \$100 to the second account. If this process fails after you have subtracted the \$100 from the first bank account, the \$100 are never added to the second bank account. The money is lost in cyber space.

JDBC Transactions

- JDBC allows SQL statements to be grouped together into a single transaction
- Transaction control is performed by the `Connection` object, default mode is auto-commit, i.e., each sql statement is treated as a transaction
- We can turn off the auto-commit mode with `connection.setAutoCommit(false);`
- And turn it back on with `connection.setAutoCommit(true);`
- Once auto-commit is off, no SQL statement will be committed until an explicit is invoked `connection.commit()`. At this point all changes done by the SQL statements will be made permanent in the database.

JDBC Transactions

```
Connection connection = ...
try{
    connection.setAutoCommit(false);

    // create and execute statements etc.

    connection.commit();
} catch(Exception e) {
    connection.rollback();
} finally {
    if(connection != null) {
        connection.close();
    }
}
```



JDBC-ODBC

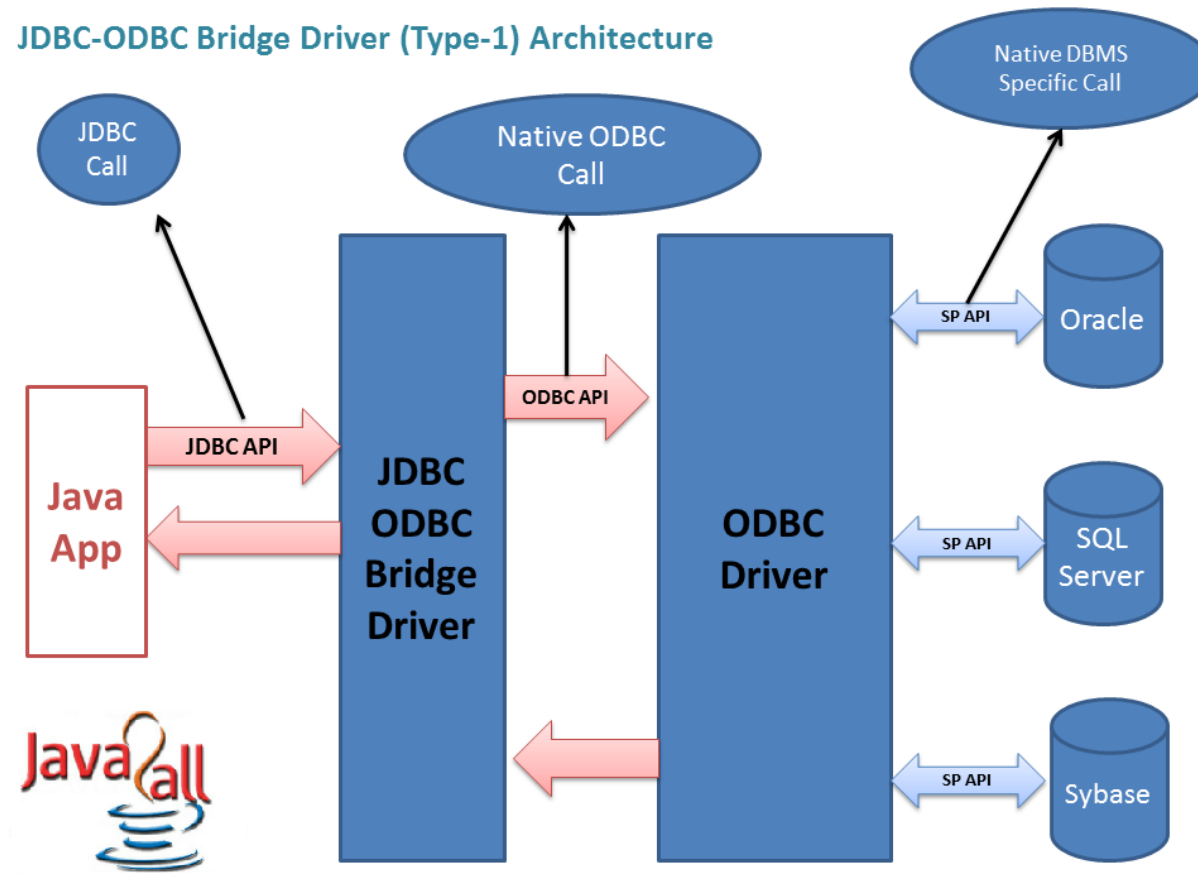


General Architecture

- What happens if I need to use a *rare* DBMS which is not supported by JDBC? (e.g., no driver released) ? Use **ODBC**!
- Open Database Connectivity (**ODBC**) is a standard application programming interface (**API**) for accessing database management systems (**DBMS**).
- Released in 1992, it allows applications to be independent from database-specific details. Same goal as JDBC, released in 1997.

JDBC-ODBC

JDBC-ODBC Bridge Driver (Type-1) Architecture



JDBC-ODBC

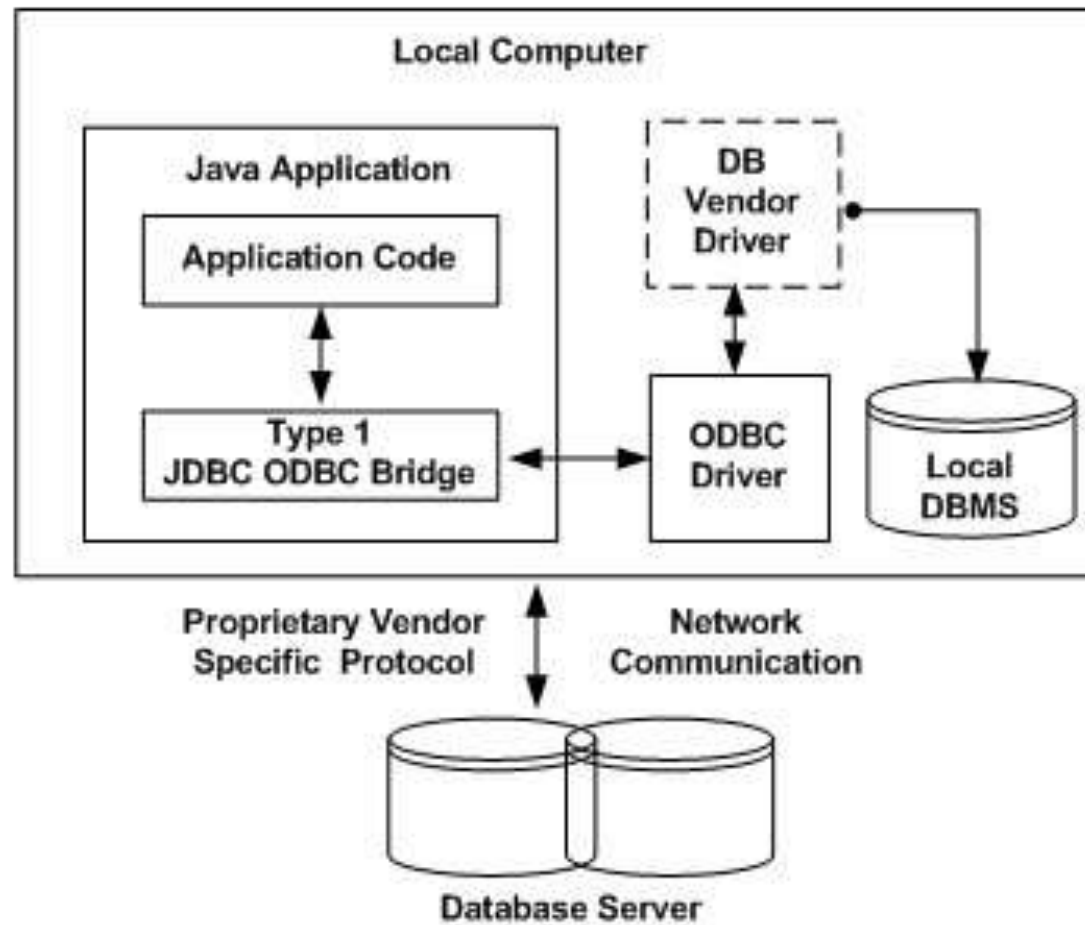
A JDBC-ODBC bridge consists of a JDBC driver which employs an ODBC driver to connect to a target database. This driver translates JDBC method calls into ODBC function calls. Programmers usually use such a bridge when a given database lacks a JDBC driver, but is accessible through an ODBC driver.

Vendors deliver JDBC-ODBC bridges which far outperform the JVM built-in (Removed from JVM since Java8).

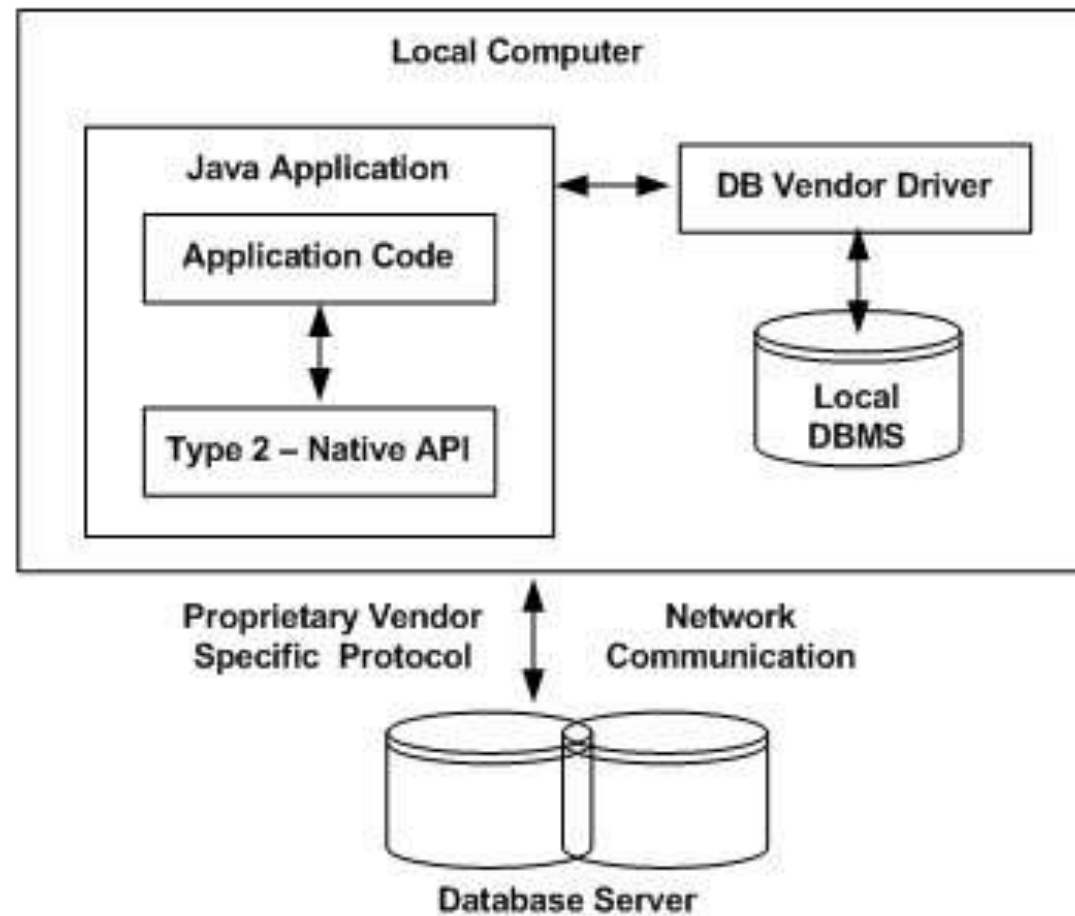
APPENDIX



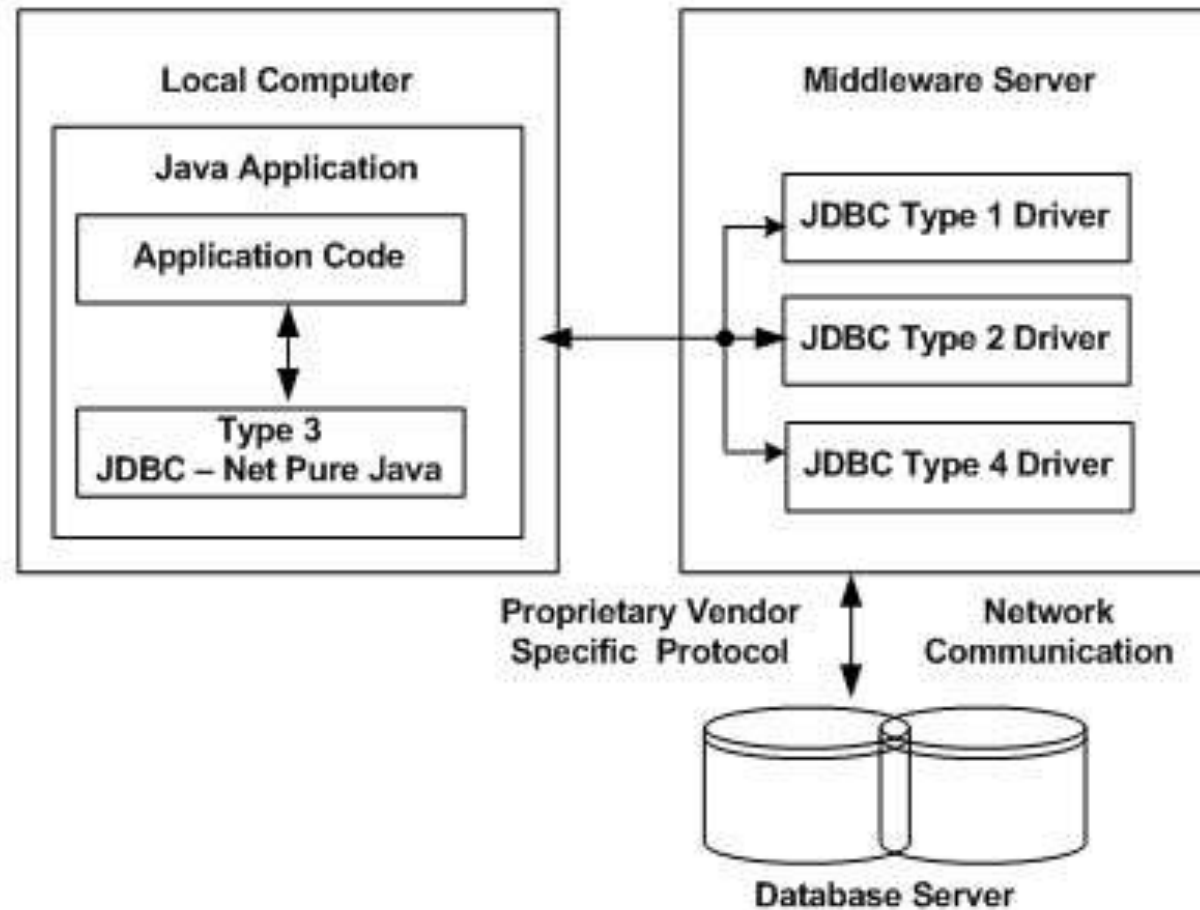
Type 1 JDBC Driver



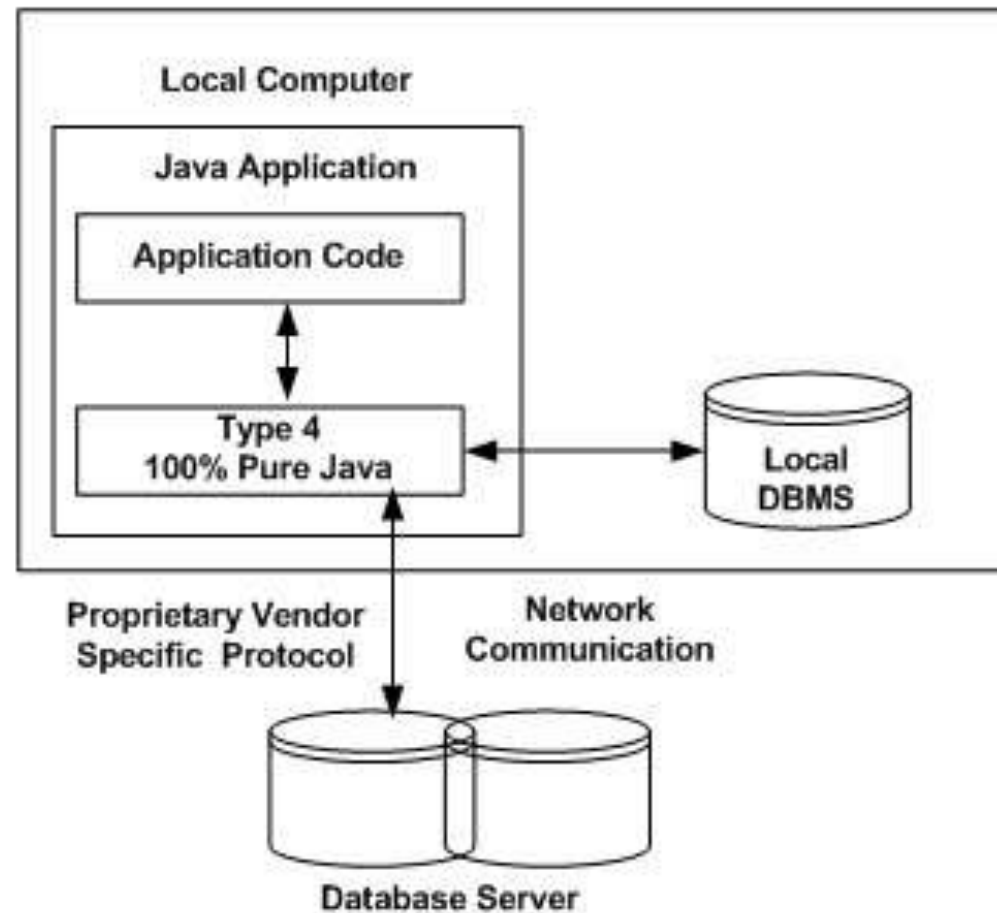
Type 2 JDBC Driver



Type 3 JDBC Driver



Type 4 JDBC Driver



References

- JDBC Data Access API – JDBC Technology Homepage
 - <http://java.sun.com/products/jdbc/index.html>
- JDBC Database Access – The Java Tutorial
 - <http://java.sun.com/docs/books/tutorial/jdbc/index.html>
- JDBC Documentation
 - <http://java.sun.com/j2se/1.4.2/docs/guide/jdbc/index.html>
- java.sql package
 - <http://java.sun.com/j2se/1.4.2/docs/api/java/sql/package-summary.html>
- JDBC Technology Guide: Getting Started
 - <http://java.sun.com/j2se/1.4.2/docs/guide/jdbc/getstart/GettingStartedTOC.fm.html>
- JDBC API Tutorial and Reference (book)
 - <http://java.sun.com/docs/books/jdbc/>