Chapter 3
DB-Gateways

Outline

- Coupling DBMS and programming languages
  - approaches
  - requirements
- Programming Model (JDBC)
  - overview
  - DB connection model
  - transactions
- Data Access in Distributed Information System Middleware
- DB-Gateways
  - architectures
    - ODBC
    - JDBC
- SQL/OLB – embedded SQL in Java
- Summary
Coupling Approaches – Overview

- **Embedded SQL**
  - (static) SQL queries are embedded in the programming language
  - cursors to bridge so-called impedance mismatch
  - preprocessor converts SQL into function calls of the programming language
  - potential performance advantages (early query compilation)
  - vendor-specific
- **Dynamic (embedded) SQL**
  - SQL queries can be created dynamically by the program
  - character strings interpreted as SQL statements by an SQL system
- **Call-Level Interface (CLI)**
  - standard library of functions that can be linked to the program
  - same capabilities as (static and dynamic) embedded
  - SQL queries are string parameters of function invocation
  - avoids vendor-specific precompiler

Coupling Approaches (Examples)

- **Embedded SQL**
  - static
    - Example:
      ```
      exec sql declare c cursor for
      SELECT empno FROM Employees WHERE dept = :deptno_var;
      exec sql open c;
      exec sql fetch c into :empno_var;
      ```
  - dynamic
    - Example:
      ```
      strcpy(stmt, "SELECT empno FROM Employees WHERE dept = ?");
      exec sql prepare s1 from stmt;
      exec sql declare c cursor for s1;
      exec sql open c using :deptno_var;
      exec sql fetch c into :empno_var;
      ```
- **Call-Level Interface (CLI)**
  - Example:
    ```
    strcpy(stmt, "SELECT empno FROM Employees WHERE dept = ?");
    SQLPrepare(st_handle, stmt, ...);
    SQLBindParam(st_handle, 1, ..., &deptno_var, ...);
    SQLBindCol(st_handle, 1, ..., &empno_var, ...);
    SQLExecute(st_handle);
    SQLFetch(st_handle);
    ```
Standard Call Level Interfaces - Requirements

- Uniform database access
  - query language (SQL)
  - meta data (both query results and DB-schema)
    - Alternative: SQL Information Schema
  - programming interface
- Portability
  - call level interface (CLI)
    - no vendor-specific pre-compiler
    - application binaries are portable
    - but: increased application complexity
  - dynamic binding of vendor-specific run-time libraries
- Dynamic, late binding to specific DB/DBS
  - late query compilation
  - flexibility vs. performance

Additional Requirements for DB-Gateways

- Remote data access
- Multiple simultaneously active DB-connections within the same application thread
  - to the same DB
  - to different DBs
  - within the same (distributed) transaction
- Simultaneous access to multiple DB/DBMS
  - architecture supports use of (multiple) DBMS-specific drivers
  - coordinated by a driver manager
- Support for vendor-specific extensions
**Historical Development**

- **ODBC: Open Database Connectivity**
  - introduced in 1992 by Microsoft
  - quickly became a de-facto standard
  - ODBC drivers available for almost any DBMS
  - "blueprint" for ISO SQL/CLI standard

- **JDBC**
  - introduced in 1997, initially defined by SUN, based on ODBC approach
  - leverages advantages of Java (compared to C) for the API
  - abstraction layer between Java programs and SQL
  - current version: JDBC 4.0 (Dec. 2006)

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**JDBC – Core Interfaces**

- **Connection**
- **Statement** (subclass of Connection)
  - `createStatement`
  - `prepareStatement`
  - `prepareCall`

- **PreparedStatement** (subclass of Statement)
  - `setXXX`
  - `getXXX`
  - `executeQuery`
  - `getResultSet`
  - `getMoreResults`

- **CallableStatement** (subclass of Statement)
  - `setXXX`
  - `executeQuery`
  - `getXXX`
  - `getMoreResults`

- **ResultSet**

**Data Types**

- `default: <source>.<method> -> <target>`

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Java application

**JDBC 4.0**

**SQL-92, SQL:1999, SQL:2003**

*(object-) relational DBS*
Example: JDBC

String url = "jdbc:db2:mydatabase";
...
Connection con = DriverManager.getConnection(url, "dessloch", "pass");

String sqlstr = "SELECT * FROM Employees WHERE dept = 1234";
Statement stmt = con.createStatement();

ResultSet rs = stmt.executeQuery(sqlstr);

while (rs.next()) {
    String a = rs.getString(1);
    String str = rs.getString(2);
    System.out.println(" empno= " + a);
    System.out.println(" firstname= " + str);
    System.out.println("\n");
}

JDBC – Processing Query Results

- ResultSet
  - getXXX-methods
  - scrollable ResultSets
  - updatable ResultSets

- Data types
  - conversion functions
  - streams to support large data values
  - with JDBC 2.0 support of SQL:1999 data types
    - LOBS (BLOBS, CLOBs)
    - arrays
    - user-defined data types
    - references
JDBC – Additional Functionality

- Metadata
  - methods for metadata lookup
  - important for generic applications
- Exception Handling
  - SQLException class (hierarchy) carries SQL error code, description
  - Integrated with Java (chained) exception handling
- Batch Updates
  - multiple statements can be submitted at once to improve performance
- RowSets
  - Can hold a (disconnected) copy of a result set
  - Modifications can be “buffered” and explicitly synchronized with the database later
- ...

Transactions in JDBC

- Connection interface – transaction-oriented methods for local TAs
  - begin is implicit
  - commit()
  - rollback()
  - get/setTransactionIsolation()
    - NONE, READ_UNCOMMITTED, READ_COMMITTED, REPEATABLE_READ, SERIALIZABLE
  - get/setAutoCommit()
- Here, the scope of the transaction is a single connection!
  - support for distributed transactions requires additional extensions, interactions with a transaction manager (see subsequent chapters)
**JDBC DataSource**

- **DataSource Interface**
  - motivation: increase portability by abstracting from driver-specific connection details
  - application uses logical name to obtain connection, interacting with Java Naming and Directory Service (JNDI)
  - connections can be created, registered, reconfigured, directed to another physical DB without impacting the application
    - example: connections are set up and managed by an application server administrator

- **Steps**
  - DataSource object is created, configured, registered with JNDI
    - using administration capability of application server
    - outside the application component
  - application component obtains a DataSource object
    - JNDI lookup
    - no driver-specific details required
  - application obtains a Connection object using DataSource
    - DataSource.getConnection()

**Architecture**

- **Applications**
  - programs using DB-CLI functionality
  - usage
    - connect to data sources
    - execute SQL statements (e.g., queries) over data sources
    - receive (and process) results

- **Driver**
  - processes CLI calls
  - communicates SQL requests to DBMS
    - Alternative: does the entire processing of the SQL requests
    - hides heterogeneity of data sources

- **Driver Manager**
  - manages interactions between applications and drivers
  - realizes (n:m)-relationship between applications and drivers
  - tasks
    - load/unload driver
    - mapping data sources to drivers
    - communication/logging of function/method calls
    - simple error handling

**O/JDBC API**

- application
- driver manager
- Oracle driver
- DB2 driver
Driver Manager Tasks

Driver – Tasks and Responsibilities

- Connection Management
- Error handling
  - standard error functions/codes/messages, ...
- Translation of SQL requests
  - if syntax of DBMS deviates from standard SQL
- Data type mapping
- Meta data functions
  - access (proprietary) system catalogs
- Information functions
  - provide information about driver (self), data sources, supported data types and DBMS capabilities
- Option functions
  - Parameter for connections and statements (e.g., statement execution timeout)
Realization Alternatives

- ODBC driver types
  - one-tier
  - two-tier
  - three-tier
- JDBC driver types
  - Type 1: JDBC-ODBC bridge
  - Type 2: Part Java, Part Native
  - Type 3: Intermediate DB Access Server
  - Type 4: Pure Java
- Application does not "see" realization alternatives!

Single-Tier Driver

- Used to access flat files, ISAM files, desktop databases
- Data resides on the same machine as the driver
- Functionality:
  - complete SQL processing (parse, optimize, execute)
  - often lacks multi-user and transaction support

<table>
<thead>
<tr>
<th>accessing flat files</th>
<th>accessing ISAM files or desktop DBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>application</td>
<td>application</td>
</tr>
<tr>
<td>driver manager</td>
<td>driver manager</td>
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<tr>
<td>driver</td>
<td>driver</td>
</tr>
<tr>
<td>file I/O calls</td>
<td>engine calls</td>
</tr>
<tr>
<td>ISAM/DTDB engine</td>
<td>file I/O calls</td>
</tr>
<tr>
<td>file system</td>
<td>file system</td>
</tr>
</tbody>
</table>
Two-Tier Driver

- Classical client/server support
  - driver acts as a client interacting with DBMS (server) through data protocol
- Implementation alternatives
  1. direct data protocol support
  2. mapping ODBC to DBMS-client API
  3. middleware solution
- Direct data protocol support
  - message-based or RPC-based
  - utilizes DBMS-specific network libraries or RPC runtime

Direct data protocol support

- Mapping to DBMS-client API
- Middleware solution
Three-Tier Driver

- Middleware Server
  - connects and relays requests to one or more DBMS servers
  - Moves the complexity from the client to the middleware server
    - client requires only a single driver (for the middleware server)
  - Arbitrary number of tiers possible

JDBC Driver Types

**Partial Java**

- Type 1: JDBC-ODBC bridge
  - 2-tier
  - mapping to ODBC API
    - uses Java Native Interface (JNI)
    - requires native binaries at the client
  - Type 2: Native-API Partial-Java driver
  - 2-tier
  - uses a native DBMS client library
    - requires binaries at the client

**All-Java**

- Type 3: Net-Protocol All-Java driver
  - 3-tier
  - driver on client is pure Java
  - communicates with JDBC server/gateway
    - no native binaries on client required
      - applet-based DB access is possible
  - Type 4: Native-Protocol All-Java driver
  - 2-tier
  - pure Java
  - implements the network data protocol of the DBMS
  - directly connects to the data source
    - no native binaries on client required
      - applet-based DB access is possible
SQL Object Language Bindings (OLB)

- aka SQLJ Part 0
- Static, embedded SQL in Java
  - Development advantages over JDBC
    - more concise, easier to code
    - static type checking, error checking at precompilation time
  - Permits static authorization
- Can be used in client code and stored procedures
- SQLJ translator/customizer framework supports binary compatibility
  - SQLJ translator implemented using JDBC
    - produces statement profiles
  - vendor-specific customizers
    - can add different implementation, to be used instead of default produced by translator
    - potential performance benefits
    - resulting binary contains default and possibly multiple customized implementations
- Interoperability with JDBC
  - combined use of SQL with JDBC for flexibility

SQL/OLB

- Static SQL authorization option
  - Static SQL is associated with "program"
    - Plans/packages identify "programs" to DB
    - Program author's table privileges are used
    - Users are granted EXECUTE on program
  - Dynamic SQL is associated with "user"
    - No notion of "program"
    - End users must have table privileges
    - BIG PROBLEM FOR A LARGE ENTERPRISE !!!
- Static SQL syntax for Java
  - INSERT, UPDATE, DELETE, CREATE, GRANT, etc.
  - Singleton SELECT and cursor-based SELECT
  - Calls to stored procedures (including result sets)
  - COMMIT, ROLLBACK
  - Methods for CONNECT, DISCONNECT
### SQL/OLB vs. JDBC: Retrieve Single Row

**SQL OLB**

```sql
#sql [con] { SELECT ADDRESS INTO :addr FROM EMP
  WHERE NAME=:name ; }
```

**JDBC**

```java
java.sql.PreparedStatement ps = con.prepareStatement(
  "SELECT ADDRESS FROM EMP WHERE NAME=?");
ps.setString(1, name);
java.sql.ResultSet names = ps.executeQuery();
names.next();
name = names.getString(1);
names.close();
```

### Result Set Iterators

- Mechanism for accessing the rows returned by a query
- Comparable to an SQL cursor
- Iterator declaration clause results in generated iterator class
  - Iterator is a Java object
  - Iterators are strongly typed
  - Generic methods for advancing to next row
- Assignment clause assigns query result to iterator
- Two types of iterators
  - Named iterator
  - Positioned iterator
**Named Iterators - Example**

- Generated iterator class has accessor methods for each result column

```java
#sql iterator Honors ( String name, float grade );
Honors honor;

#sql [recs] honor =
{ SELECT SCORE AS "grade", STUDENT AS "name"
  FROM GRADE_REPORTS
  WHERE SCORE >= :limit AND ATTENDED >= :days
  ORDER BY SCORE DESCENDING };
while (honor.next())
{
  System.out.println( honor.name() + " has grade "
    + honor.grade() );
}
```

**Positioned Iterator**

- Use FETCH statement to retrieve result columns into host variables based on position

```java
#sql iterator Honors ( String, float );
Honors honor;
String name;
float grade;

#sql [recs] honor =
{ SELECT STUDENT, SCORE FROM GRADE_REPORTS
  WHERE SCORE >= :limit AND ATTENDED >= :days
  ORDER BY SCORE DESCENDING };
while (true) {
  #sql {FETCH :honor INTO :name, :grade };
  if (honor.endFetch()) break;
  System.out.println( name + " has grade " + grade );
}
```
**SQLJ - Binary Portability**

- Java as a platform-independent language
- Use of generic SQLJ-precompiler/translator (avoids DBMS-specific precompiler technology)
- Generated code uses "standard" JDBC by default
- Compiled SQLJ application (Java byte code) is portable
- Customizer technology allows DBMS-specific optimizations after the compilation

```java
SQLJ source
class ABC {
  #sql
  SELECT ...
}
```

Most vendors use default JDBC "stub"

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**Summary**

- Gateways
  - ODBC / JDBC
  - support uniform, standardized access to heterogeneous data sources
  - encapsulate/hide vendor-specific aspects
  - multiple, simultaneously active connections to different databases and DBMSs
  - driver/driver manager architecture
  - enabled for distributed transaction processing
  - high acceptance
  - important infrastructure for realizing IS distribution at DB-operation level
  - no support for data source integration

- JDBC
  - ‘for Java’, ‘in Java’
  - important basis for data access in Java-based middleware (e.g., J2EE)

- SQLJ
  - combines advantages of embedded SQL with portability, vendor-independence