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JDBCTM 4.3 Specification

JSR 221

Lance Andersen, Specification Lead July 2017

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Preface

This document supersedes and consolidates the content of these predecessor specifications:

- "JDBC: A Java SQL API"
- "JDBC 2.1 API"
- "JDBC 2.0 Standard Extension API"
- "JDBC 3.0 Specification"

This document introduces a range of new features for the JDBC API and is combined with various specification improvements that focus on features introduced in or before the JDBC 3.0 API. Where possible, any adjustment to the JDBC 3.0 API is marked for easy identification - look for the JDBC 4.3 API demarcation for specific features introduced in this revised and updated specification.

Readers can also download the API specification (JavadocTM API and comments) for a complete and precise definition of JDBC classes and interfaces. This documentation is available from the download page at

https://jcp.org/en/jsr/detail?id=221

Typographic Conventions

Typeface	Meaning	Examples
AaBbCc123	The names of commands, files, and directories; on-screen computer output	Edit your .login file. Use ls -a to list all files. % You have mail.
AaBbCc123	What you type, when contrasted with on-screen computer output	% su Password:
AaBbCc123	Book titles, new words or terms, words to be emphasized	Read Chapter 6 in the <i>User's Guide</i> . These are called <i>class</i> options. You <i>must</i> be superuser to do this.
	Command-line variable; replace with a real name or value	To delete a file, type rm <i>filename</i> .

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CHAPTER **1**

Introduction

1.1 The JDBC API

The JDBCTM API provides programmatic access to relational data from the JavaTM programming language. Using the JDBC API, applications written in the Java programming language can execute SQL statements, retrieve results, and propagate changes back to an underlying data source. The JDBC API can also be used to interact with multiple data sources in a distributed, heterogeneous environment.

The JDBC API is based on the X/Open SQL CLI, which is also the basis for ODBC. JDBC provides a natural and easy-to-use mapping from the Java programming language to the abstractions and concepts defined in the X/Open CLI and SQL standards.

Since its introduction in January 1997, the JDBC API has become widely accepted and implemented. The flexibility of the API allows for a broad range of implementations.

1.2 Platforms

The JDBC API is part of the Java platform, which includes the JavaTM Standard Edition (JavaTM SE) and the JavaTM Enterprise Edition (JavaTM EE). The JDBC API is divided into two packages: java.sql and javax.sql. Both packages are included in the Java SE and Java EE platforms.

1.3 Target Audience

This specification is targeted primarily towards the vendors of these types of products:

- drivers that implement the JDBC API
- application servers providing middle-tier services above the driver layer
- tools that use the JDBC API to provide services such as application generation

This specification is also intended to serve the following purposes:

- an introduction for end-users whose applications use the JDBC API
- a starting point for developers of other APIs layered on top of the JDBC API

1.4 Acknowledgements

The JDBC 4.3 specification work is being conducted as part of JSR-221 under the Java Community Process. This specification is the result of the collaborative efforts of the JDBC 4.3 Expert Group whose individual members contributed countess hours to ensure the success of this specification. We would like to thank the following members for their contributions:

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CHAPTER **2**

Goals

2.1 History

The JDBC API is a mature technology, having first been specified in January 1997. In its initial release, the JDBC API focused on providing a basic call-level interface to SQL databases. The JDBC 2.1 specification and the 2.0 Optional Package specification then broadened the scope of the API to include support for more advanced applications and for the features required by application servers to manage use of the JDBC API on behalf of their applications.

The JDBC 3.0 specification operated with the stated goal to round out the API by filling in smaller areas of missing functionality. With JDBC 4.3, our goals are two fold: Improve the Ease-of-Development experience for all developers working with SQL in the Java platform. Secondly, provide a range of enterprise level features to expose JDBC to a richer set of tools and APIs to manage JDBC resources.

2.2 Overview of Goals

The following list outlines the goals and design philosophy for the JDBC API in general and the JDBC 4.3 API in particular:

1. Fit into the Java EE and Java SE platforms

The JDBC API is a constituent technology of the Java platform. The JDBC 4.3 API should be aligned with the overall direction of the Java Enterprise Edition and Java Standard Edition platforms. In addition, recent developments with the Java SE platform have exposed a range of new features and language improvements that are extensively used in this specification.

2. Be consistent with SQL:2003

The JDBC API provides programmatic access from applications written in the Java programming language to standard SQL. JDBC 3.0 sought to ensure it's support for a subset of the SQL99 features that were likely to be widely supported by the industry. Similarly for JDBC 4.3, support for SQL:2003 is focused on the major components of this specification that we anticipate will be supported for the foreseeable future.

3. Offer vendor-neutral access to common features

The JDBC API strives to provide high-bandwidth access to features commonly supported across different vendor implementations. The goal is to provide a degree of feature access comparable to what can be achieved by native applications. However, the API must be general and flexible enough to allow for a wide range of implementations.

4. Maintain the focus on SQL

The focus of the JDBC API has always been on accessing relational data from the Java programming language. This goal, previously stated in the JDBC 3.0 API remains core to the principles on which this specification is built. The provision of ease of development themed improvements including APIs and utilities continue to focus on the needs for the SQL based software development from the Java platform. Similarly to previous specifications, this does not preclude interacting with additional technologies such as XML, CORBA and non-relational data.

5. Provide a foundation for tools and higher-level APIs

The JDBC API presents a standard API to access a wide range of underlying data sources or legacy systems. Implementation differences are made transparent through JDBC API abstractions, making it a valuable target platform for tools vendors who want to create portable tools and applications.

Because it is a "call-level" interface from the Java programming language to SQL, the JDBC API is also suitable as a base layer for higher-level facilities such as Enterprise JavaBeans (EJB) container-managed persistence, SQLJ and the JDBC RowSet implementation.

6. Keep it simple

The JDBC API is intended to be a simple-to-use, straight forward interface upon which more complex entities can be built. This goal is achieved by defining many compact, single-purpose methods instead of a smaller number of complex, multipurpose ones with control flag parameters.

7. Enhance reliability, availability, and scalability

Reliability, availability, and scalability are the themes of the Java EE and Java SE platforms, as well as the direction for future Java platforms. The JDBC API stays true to these themes by enhancing support in several areas, including resource management, the reuse of prepared statements across logical connections, and error handling.

8. Maintain backward compatibility with existing applications and drivers

Existing JDBC technology-enabled drivers (JDBC drivers) and the applications that use them must continue to work in an implementation of the Java virtual machine that supports the JDBC 4.3 API. Applications that use only features defined in earlier releases of the JDBC API will not require changes to continue running. It should be straightforward for existing applications to migrate to JDBC 4.3 technology.

9. Close Association with JDBC RowSet implementations

Java SE contains a standard JDBC RowSet implementation as specified in JDBC RowSet Implementations (JSR-114). This specification will provide a set of utilities described at both the utility class level and the Meta Data language level. This will allow developers to easily migrate JDBC-technology enabled applications towards the JDBC RowSet model that enables disconnected data source access in addition to the ability to manage relational data stores from an XML stand-point.

10. Allow forward compatibility with Connectors

The Connector architecture defines a standard way to package and deploy a resource adapter that allows a Java EE container to integrate its connection, transaction, and security management with those of an external resource. The JDBC API provides the migration path for JDBC drivers to the Connector architecture. It should be possible for vendors whose products use JDBC technology to move incrementally towards implementing the Connector API. The expectation is that JDBC driver vendors will write resource manager wrappers around their existing data source implementations so that they can be reused in a Connector framework.

11. Specify requirements unambiguously

The requirements for JDBC compliance need to be unambiguous and easy to identify. The JDBC specification and the API documentation (Javadoc) will clarify which features are required and which are optional.

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CHAPTER **3**

Summary of New Features

3.1 Overview of changes

The JDBC 4.3 API introduces new material and changes in the following areas:

Added support for Sharding.

Sharding is a scaling technique in which data is horizontally partitioned across independent databases.

Addition of the *java.sql.ConnectionBuilder* interface

A builder created from a *DataSource* object, used to establish a connection to the database that the data source object represents.

Addition of the *java.sql.ShardigKey* interface

This interface is used to indicate that this object represents a Sharding Key. A *ShardingKey* instance is only guaranteed to be compatible with the data source instance that it was derived from.

Addition of the *java.sql.ShardingKeyBuilder* interface

A builder created from a *DataSource* or XADataSource object, used to create a *ShardingKey* with sub-keys of supported data types.

Addition of the *javax.sql.XAConnectionBuilder* interface

A builder created from a *XADataSource* object, used to establish a connection to the database that the data source object represents.

Addition of the *javax.sql.PooledConnectionBuilder* interface

A builder created from a *PooledConnectionDataSource* object, used to establish a connection to the database that the data source object represents.

JDBC API changes

The following changes were made to existing JDBC interfaces..

java.sql.Connection

Added the methods beginRequest, endRequest, setShardingKey, setShardingKeyIfValid.

java.sql.CallableStatement

Clarified the getBigDecimal method.

java.sql.Date

```
Clarified the Date, getHours, getMinutes, getSeconds, setHours, setMinutes, setSeconds, toInstant, toLocalDate methods.
```

java.sql.DatabaseMetaData

Added the method supportsSharding.

Clarified the getTables method.

java.sql.DriverManager

Added the drivers method.

Clarified the deregisterDriver, getLogStream, setLogStream, and setLogWriter, methods.

java.sql.PreparedStatement

Clarified the method setUnicodeStream.

java.sql.ResultSet

Clarified the getBigDecimal, and getUnicodeStream, methods.

java.sql.Statement

Added the methods enquoteIdentifer, *enquoteLiteral*. enquoteNCharLiteral, and isSimpleIdentifier.

java.sql.Time

Clarified the Time, getDate, getDay, getMonth, getYear, setDate, setDay, setMonth, setYear, toInstant, toLocalTime, valueOf methods.

- java.sql.Timestamp
 - Clarified the Timestamp, hashCode, toString methods.
- javax.sql.CommonDataSource
 - Added the createShardingKeyBuilder method.
- javax.sql.ConnectionPoolDataSource
- Added the *createPooledConnectionBuilder* method.
- javax.sql.DataSource
- Added the *createConnectionBuilder* method.
- javax.sql.XADataSource

Added the createXAConnectionBuilder method.

See Chapter 5 "Classes and Interfaces" for a list of the classes and interfaces affected by these changes.

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CHAPTER 4

Overview

The JDBC API provides a way for Java programs to access one or more sources of data. In the majority of cases, the data source is a relational DBMS, and its data is accessed using SQL. However, it is also possible for JDBC technology-enabled drivers to be implemented on top of other data sources, including legacy file systems and object-oriented systems. A primary motivation for the JDBC API is to provide a standard API for applications to access a wide variety of data sources.

This chapter introduces some of the key concepts of the JDBC API. In addition, it describes two common environments for JDBC applications, with a discussion of how different functional roles are implemented in each one. The two-tier and three-tier models are logical configurations that can be implemented on a variety of physical configurations.

4.1 Establishing a Connection

The JDBC API defines the Connection interface to represent a connection to an underlying data source.

In a typical scenario, a JDBC application will connect to a target data source using one of two mechanisms:

- DriverManager this fully implemented class was introduced in the original JDBC 1.0 API. When an application first attempts to connect to a data source by specifying a URL, DriverManager will automatically load any JDBC drivers found within the CLASSPATH (any drivers that are pre-JDBC 4.0 must be explicitly loaded by the application).
- DataSource this interface was introduced in the JDBC 2.0 Optional Package API. It is preferred over DriverManager because it allows details about the underlying data source to be transparent to the application. A DataSource object's properties are set so that it represents a particular data source. When its getConnection method is invoked, the DataSource instance will return a

connection to that data source. An application can be directed to a different data source by simply changing the DataSource object's properties; no change in application code is needed. Likewise, a DataSource implementation can be changed without changing the application code that uses it.

The JDBC API also defines two important extensions of the DataSource interface to support enterprise applications. These extensions are the following two interfaces:

- ConnectionPoolDataSource supports caching and reusing of physical connections, which improves application performance and scalability
- XADataSource provides connections that can participate in a distributed transaction

4.2 Executing SQL Statements and Manipulating Results

Once a connection has been established, an application using the JDBC API can execute queries and updates against the target data source. The JDBC API provides access to the most commonly implemented features of SQL:2003. Because different vendors vary in their level of support for these features, the JDBC API includes the DatabaseMetadata interface. Applications can use this interface to determine whether a particular feature is supported by the data source they are using. The JDBC API also defines escape syntax to allow an application to access non-standard vendor-specific features. The use of escape syntax has the advantage of giving JDBC applications access to the same feature set as native applications and at the same time maintaining the portability of the application.

Applications use methods in the Connection interface to specify transaction attributes and create Statement, PreparedStatement, or CallableStatement objects. These statements are used to execute SQL statements and retrieve results. The ResultSet interface encapsulates the results of an SQL query. Statements may also be batched, allowing an application to submit multiple updates to a data source as a single unit of execution.

The JDBC API extends the ResultSet interface with the RowSet interface, thereby providing a container for tabular data that is much more versatile than a standard result set. A RowSet object is a JavaBeansTM component, and it may operate without being connected to its data source. For example, a RowSet implementation can be serializable and therefore sent across a network, which is particularly useful for small-footprint clients that want to operate on tabular data without incurring the overhead of a JDBC driver and data source connection. Another feature of a RowSet implementation is that it can include a custom reader for accessing any data in tabular format, not just data in a relational database. Further, a RowSet object can

update its rows while it is disconnected from its data source, and its implementation can include a custom writer that writes those updates back to the underlying data source.

4.2.1 Support for SQL Advanced Data Types

The JDBC API defines standard mappings to convert SQL data types to JDBC data types and back. This includes support for SQL:2003 advanced data types such as BLOB, CLOB, ARRAY, REF, STRUCT, XML, and DISTINCT. JDBC drivers may also implement one or more customized type mappings for user-defined types (UDTs), in which the UDT is mapped to a class in the Java programming language. The JDBC API also provides support for externally managed data, for example, data in a file outside the data source.

4.3 Two-tier Model

A two-tier model divides functionality into a client layer and a server layer, as shown in FIGURE 4-1.

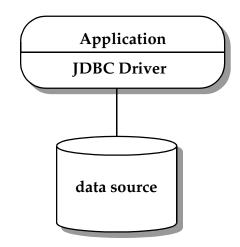


FIGURE 4-1 Two-tier Model

The client layer includes the application(s) and one or more JDBC drivers, with the application handling these areas of responsibility:

- presentation logic
- business logic
- transaction management for multiple-statement transactions or distributed transactions
- resource management

In this model, the application interacts directly with the JDBC driver(s), including establishing and managing the physical connection(s) and dealing with the details of specific underlying data source implementations. The application may use its knowledge of a specific implementation to take advantage of nonstandard features or do performance tuning.

Some drawbacks of this model include:

- mingling presentation and business logic with infrastructure and system-level functions. This presents an obstacle to producing maintainable code with a welldefined architecture.
- making applications less portable because they are tuned to a particular database implementation. Applications that require connections to multiple databases must be aware of the differences between the different vendors' implementations.
- limiting scalability. Typically, the application will hold onto one or more physical database connections until it terminates, limiting the number of concurrent applications that can be supported. In this model, issues of performance, scalability and availability are handled by the JDBC driver and the corresponding underlying data source. If an application deals with multiple drivers, it may also need to be aware of the different ways in which each driver/data source pair resolves these issues.

4.4 Three-tier Model

The three-tier model introduces a middle-tier server to house business logic and infrastructure, as shown in FIGURE 4-2.

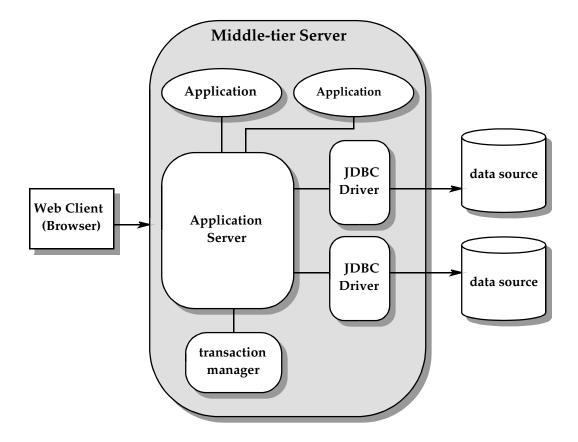


FIGURE 4-2 Three-tier Model

This architecture is designed to provide improved performance, scalability and availability for enterprise applications. Functionality is divided among the tiers as follows:

- 1. Client tier a thin layer implementing presentation logic for human interaction. Java programs, web browsers and PDAs are typical client-tier implementations. The client interacts with the middle-tier application and does not need to include any knowledge of infrastructure or underlying data source functions.
- 2. Middle-tier server a middle tier that includes:
 - *Applications* to interact with the client and implement business logic. If the application includes interaction with a data source, it will deal with higher-level abstractions, such as DataSource objects and logical connections rather than lower-level driver API.

- An application server to provide supporting infrastructure for a wide range of applications. This can include management and pooling of physical connections, transaction management, and the masking of differences between different JDBC drivers. This last point makes it easier to write portable applications. The application server role can be implemented by a Java EE server. Application servers implement the higher-level abstractions used by applications and interact directly with JDBC drivers.
- *JDBC driver(s)* to provide connectivity to the underlying data sources. Each driver implements the standard JDBC API on top of whatever features are supported by its underlying data source. The driver layer may mask differences between standard SQL:2003 syntax and the native dialect supported by the data source. If the data source is not a relational DBMS, the driver implements the relational layer used by the application server.
- 3. Underlying data source the tier where the data resides. It can include relational DBMSs, legacy file systems, object-oriented DBMSs, data warehouses, spreadsheets, or other means of packaging and presenting data. The only requirement is a corresponding driver that supports the JDBC API.

4.5 JDBC in the Java EE Platform

Java EE components, such as JavaServerTM Pages, Servlets, and Enterprise Java BeansTM (EJBTM) components, often require access to relational data and use the JDBC API for this access. When Java EE components use the JDBC API, the container manages their transactions and data sources. This means that Java EE component developers do not directly use the JDBC API's transaction and datasource management facilities. See the Java EE Platform Specification for further details.

CHAPTER 5

Classes and Interfaces

The following classes and interfaces make up the JDBC API.

5.1 The java.sql Package

The core JDBC API is contained in the package java.sql. The enums, classes and interfaces in java.sql are listed below. Enums and classes are bold type; interfaces are in standard type.

java.sql.Array java.sql.BatchUpdateException java.sql.Blob java.sql.CallableStatement java.sql.Clob java.sql.ClientinfoStatus java.sql.Connection java.sql.ConnectionBuilder java.sql.DataTruncation java.sql.DatabaseMetaData java.sql.Date java.sql.Driver java.sql.DriverAction java.sql.DriverManager java.sql.DriverPropertyInfo java.sql.JDBCType

```
java.sql.NClob
```

- java.sql.ParameterMetaData
- java.sql.PreparedStatement
- java.sql.PseudoColumnUsage
- java.sql.Ref
- java.sql.ResultSet
- java.sql.ResultSetMetaData
- java.sql.RowId

java.sql.RowIdLifeTime

- java.sql.Savepoint
- java.sql.ShardingKey
- java.sql.ShardingKeyBuilder
- java.sql.SQLClientInfoException
- java.sql.SQLData
- java.sql.SQLDataException
- java.sql.SQLException
- java.sql.SQLFeatureNotSupportedException
- java.sql.SQLInput
- java.sql.SQLIntegrityConstraintViolationException
- ${\tt java.sql.SQLInvalidAuthorizationSpecException}$
- ${\tt java.sql.SQLNonTransientConnectionException}$
- java.sql.SQLNonTransientException
- java.sql.SQLOutput
- java.sql.SQLPermission
- java.sql.SQLSyntaxErrorException
- java.sql.SQLTimeoutException
- java.sql.SQLTransactionRollbackException
- java.sql.SQLTransientConnectionException
- java.sql.SQLTransientException
- java.sql.SQLType
- java.sql.SQLXML
- java.sql.SQLWarning
- java.sql.Statement
- java.sql.Struct
- java.sql.Time
- java.sql.Timestamp

java.sql.Types

java.sql.Wrapper

The following classes and interfaces are either new or updated in the JDBC 4.3 API. New classes and interfaces are highlighted in bold.

java.sql.CallableStatement java.sql.Connection java.sql.ConnectionBuilder java.sql.DatabaseMetaData java.sql.Date java.sql.DriverManager java.sql.PreparedStatement java.sql.ResultSet java.sql.ShardingKey java.sql.ShardkingKeyBuilder java.sql.Statement java.sql.Timestamp javax.sql.CommonDataSource javax.sql.ConnectionPoolDataSource javax.sql.DataSource javax.sql.PooledConnection javax.sql.PooledConnectionBuilder javax.sql.XAConnectionBuilder javax.sql.XADataSource

FIGURE 5-1 shows the interactions and relationships between the key classes and interfaces in the java.sql package. The methods involved in creating statements, setting parameters and retrieving results are also shown.

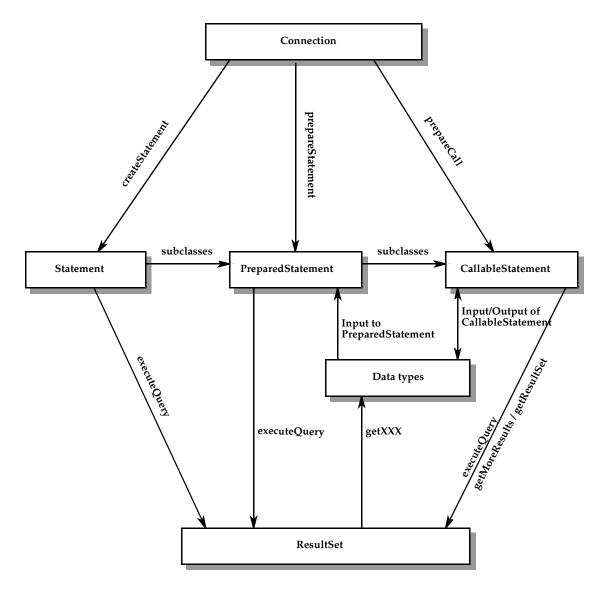


FIGURE 5-1 Relationships between major classes and interface in the java.sql package

5.2 The javax.sql Package

The following list contains the classes and interfaces that are contained in the javax.sql package. Classes are highlighted in bold; interfaces are in normal type.

```
javax.sql.CommonDataSource
javax.sql.ConnectionEvent
javax.sql.ConnectionEventListener
javax.sql.ConnectionPoolDataSource
javax.sql.DataSource
javax.sql.PooledConnection
javax.sql.PooledConnectionBuilder
javax.sql.RowSet
javax.sql.RowSetEvent
javax.sql.RowSetInternal
javax.sql.RowSetListener
javax.sql.RowSetMetaData
javax.sql.RowSetReader
javax.sql.RowSetWriter
javax.sql.StatementEvent
javax.sql.StatementEventListener
javax.sql.XAConnection
javax.sql.XAConnectionBuilder
javax.sql.XADataSource
```

Note – The classes and interfaces in the javax.sql package were first made available as the JDBC 2.0 Optional Package. This optional package was previously separate from the java.sql package, which was part of J2SE 1.2. Both packages (java.sql and javax.sql) are now part of Java SE as of J2SE 1.4.

FIGURE 5-2, FIGURE 5-3, FIGURE 5-4, and FIGURE 5-5 show the relationships between key classes and interfaces in these areas of functionality: DataSource objects, connection pooling, distributed transactions, and rowsets.

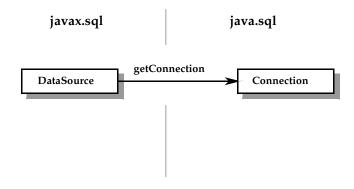


FIGURE 5-2 Relationship between javax.sql.DataSource and java.sql.Connection

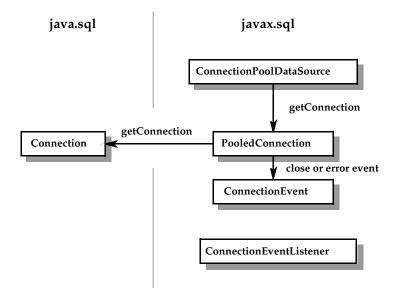


FIGURE 5-3 Relationships involved in connection pooling

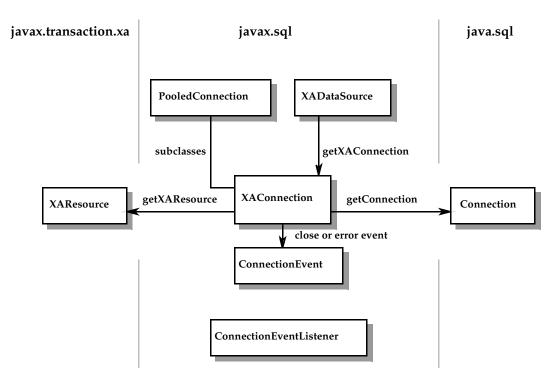


FIGURE 5-4 Relationships involved in distributed transaction support

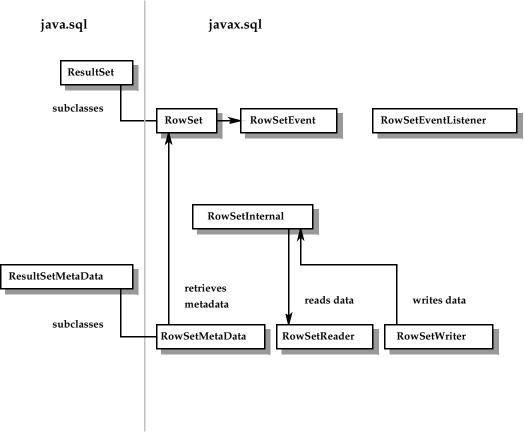


FIGURE 5-5 RowSet relationships

CHAPTER 6

Compliance

This chapter identifies the features that a JDBC driver implementation is required to support to claim compliance. Any features not identified are considered optional for compliance.

6.1 Definitions

To avoid ambiguity, we will use these terms in our discussion of compliance:

- JDBC driver implementation a JDBC technology-enabled driver and its underlying data source. The driver may provide support for features that are not implemented by the underlying data source. It may also provide the mapping between standard syntax/semantics and the native API implemented by the data source.
- Relevant specifications this document, the API specification, and the relevant SQL specification. This is also the order of precedence if a feature is described in more than one of these documents. For the JDBC API, it is SQL92 plus the relevant sections of SQL:2003 and X/Open SQL CLI.
- Supported feature a feature for which the JDBC API implementation supports standard syntax and semantics for that feature as defined in the relevant specifications.
- Partially Supported Feature—A feature for which some methods are implemented via standard syntax and semantics and some required methods throw SQLFeatureNotSupportedException to indicate that it is not supported.
- Extension a feature that is not covered by any of the relevant specifications or a non-standard implementation of a feature that is covered.
- Fully implemented a term applied to an interface that has all of its methods implemented to support the semantics defined in the relevant specifications. None of the methods may throw an exception because they are not implemented.

 Must implement — an interface that must be implemented although some methods on the interface are considered optional. Methods that are not implemented must throw an SQLFeatureNotSupportedException to indicate that the corresponding feature is not supported.

6.2 Guidelines and Requirements

The following guidelines apply to JDBC compliance:

 A JDBC API implementation must support Entry Level SQL92 plus the SQL command Drop Table (see note.)

Entry Level SQL92 represents a "floor" for the level of SQL that a JDBC API implementation must support. Access to features based on SQL99 or SQL:2003 should be provided in a way that is compatible with the relevant part of the SQL99 or SQL:2003 specification.

- Drivers must support escape syntax. Escape syntax is described in Chapter 13 "Statements".
- Drivers must support transactions. See Chapter 10 "Transactions" for details.
- If a DatabaseMetaData method indicates that a given feature is supported, it must be supported via standard syntax and semantics as described in the relevant specifications and meet the requirements outlined in "JDBC 4.3 API Compliance" on page 31. This may require the driver to provide the mapping to the data source's native API or SQL dialect if it differs from the standard.

If a feature is supported, all of the relevant metadata methods must be implemented. For example, if a JDBC API implementation supports the RowSet interface, it must also implement the RowSetMetaData interface.

- Drivers should provide access to every feature implemented by the underlying data source, including features that extend the JDBC API. The intent is for applications using the JDBC API to have access to the same feature set as native applications.
- If a JDBC driver does not support or only provides partial support for an optional feature, the corresponding DatabaseMetaData method must indicate the feature is not supported. Any methods for a feature that is not implemented are required to throw a SQLFeatureNotSupportedException.

Note – A JDBC API implementation is required to support the DROP TABLE command as specified by SQL92, Transitional Level. However, support for the CASCADE and RESTRICT options of DROP TABLE is optional. In addition, the behavior of DROP TABLE is implementation-defined when there are views or integrity constraints defined that reference the table being dropped.

6.3 JDBC 4.3 API Compliance

A driver that is compliant with the JDBC specification must do the following:

- Adhere to the preceding guidelines and requirements
- Support auto loading of the drivers java.sql.Driver implementation
- Support a ResultSet type of TYPE_FORWARD_ONLY
- Support a ResultSet concurrency of CONCUR_READ_ONLY
- Support batch updates
- Fully implement the following interfaces:
 - java.sql.DatabaseMetaData
 - java.sql.ParameterMetaData
 - java.sql.ResultSetMetaData
 - java.sql.Wrapper
- It must implement the DataSource interface with the exception of the following optional methods:
 - getParentLogger
- It must implement the Driver interface with the exception of the following optional methods:
 - getParentLogger
- It must implement the Connection interface with the exception of the following optional methods:
 - createArrayOf unless the driver supports the associated data type
 - createBlob unless the driver supports the associated data type
 - createClob unless the driver supports the associated data type
 - createNClob unless the driver supports the associated data type
 - createSQLXML unless the driver supports the associated data type
 - createStruct unless the driver supports the associated data type
 - getNetworkTimeout

- getTypeMap unless the driver supports the associated data type
- setTypeMap unless the driver supports the associated data type
- prepareStatement(String sql, Statement.RETURN_GENERATED_KEYS)
- prepareStatement(String sql, int[] columnIndexes)
- prepareStatement(String sql, String[] columnNames)
- setSavePoint
- rollback(java.sql.SavePoint savepoint)
- releaseSavePoint
- setNetworkTimeout
- It must implement the Statement interface with the exception of the following optional methods:
 - cancel
 - execute(String sql, Statement.RETURN_GENERATED_KEYS)
 - execute(String sql, int[] columnIndexes)
 - execute(String sql, String[] columnNames)
 - executeUpdate(String sql, Statement.RETURN_GENERATED_KEYS)
 - executeUpdate(String sql, int[] columnIndexes)
 - executeUpdate(String sql, String[] columnNames)
 - getGeneratedKeys
 - getMoreResults(Statement.KEEP_CURRENT_RESULT) unless
 DatabasemetaData.supportsMultipleOpenResults() returns true.
 - getMoreResults(Statement.CLOSE_ALL_RESULTS) unless
 DatabasemetaData.supportsMultipleOpenResults() returns true.
 - setCursorName
- It must implement the PreparedStatement interface with the exception of the following optional methods:
 - getMetaData
 - setArray, setBlob, setClob, setNClob, setNCharacterStream, setNString, setRef, setRowId, setSQLXML and setURL unless the driver supports the associated data type
 - setNull(int parameterIndex, int sqlType, String typeName) unless the driver supports the associated data type
 - setUnicodeStream
 - setAsciiStream, setBinaryStream, setCharacterStream, setNCharacterStream which do not take a length parameter

- It must implement the CallableStatement interface if the method DatabaseMetaData.supportsStoredProcedures() returns true with the exception of the following optional methods:
 - All setXXX, getXXX and registerOutputParameter methods which support named parameters
 - getArray, getBlob, getClob, getNClob, getNCharacterStream, getNString, getRef, getRowId, getSQLXML and getURL unless the driver supports the associated data type
 - getBigDecimal(int parameterIndex, int scale)
 - getObject(int i, Class<T> type)
 - getObject(String colName, Class<T> type)
 - getObject(int parameterIndex, java.util.Map<java.lang.String,java.lang.Class<?>> map) unless the driver supports the associated data type
 - registerOutputParam(String parameterName, int sqlType, String typeName) unless the driver supports the associated data type
 - setNull(String parameterName, int sqlType, String typeName) unless the driver supports the associated data type
 - setAsciiStream, setBinaryStream, setCharacterStream, setNCharacterStream which do not take a length parameter
- It must implement the ResultSet interface with the exception of the following optional methods:
 - All updateXXX methods
 - absolute
 - afterLast
 - beforeFirst
 - cancelRowUpdates
 - deleteRow
 - first
 - getArray, getBlob, getClob, getNClob, getNCharacterStream, getNString, getRef, getRowId, getSQLXML and getURL unless the driver supports the associated data type
 - getBigDecimal(int i, int scale)
 - getBigDecimal(String colName, int scale)
 - getCursorName
 - getObject(int i, Class<T> type)
 - getObject(String colName, Class<T> type)
 - getObject(int i, Map<String,Class<?>> map) unless the driver supports the associated data type

- getObject(String colName, Map<String,Class<?>> map) unless the driver supports the associated data type
- getRow
- getUnicodeStream
- insertRow
- isAfterLast
- isBeforeFirst
- isFirst
- isLast
- last
- moveToCurrentRow
- moveToInsertRow
- previous
- refreshRow
- relative
- rowDeleted
- rowInserted
- rowUpdated
- updateRow
- if a JDBC driver supports a ResultSet concurrency of CONCUR_UPDATABLE, the following ResultSet interface methods must be implemented:
 - All updateXXX methods except for updateArray, updateBlob, updateClob, updateNClob, updateNCharacterstream, updateNString, updateRef, updateRowId, updateSQLXML and updateURL unless the driver supports the associated data type and the updateBlob, updateClob, updateNClob, updateAsciiStream, updateBinaryStream, updateCharacterStream and updateNCharacterstream methods which take a length parameter
 - cancelRowUpdates
 - deleteRow
 - rowDeleted
 - rowUpdated
 - updateRow
- if a JDBC driver supports a ResultSet type of TYPE_SCROLL_SENSITIVE or TYPE_SCROLL_INSENSITIVE, the following ResultSet interface methods must be implemented:
 - absolute
 - afterLast

- beforeFirst
- first
- isAfterLast
- isBeforeFirst
- isFirst
- ∎ isLast
- last
- previous
- relative
- If an optional interface is implemented, then all methods on the interface must also be fully implemented with the following exception:
 - java.sql.SQLInput and java.sql.SQLOutput are not required to implement the methods for the Array, Blob, Clob, NClob, NString, Ref, RowId, SQLXML and URL data types unless the driver supports the associated data type.

6.4 Java EE JDBC Compliance

Drivers supporting the JDBC API in a Java EE environment must meet the JDBC 4.3 API Compliance requirements and must meet the following additional requirements in their implementation of JDBC APIs, as described below:

- Drivers must support stored procedures. The DatabaseMetaData method supportsStoredProcedures must return true. The driver must also support the full JDBC API escape syntax for calling stored procedures with the following methods on the Statement, PreparedStatement, and CallableStatement classes:
 - executeUpdate
 - executeQuery
 - execute

Support for calling stored procedures using the execute method on the Statement, PreparedStatement, and CallableStatement interfaces only requires that a SQL statement being executed returns either an update count or a single ResultSet object. This is due to the fact that some databases don't support returning more than a single ResultSet from a stored procedure.

All parameter types (IN, OUT, and INOUT) must be supported.

A driver must support the Statement escape syntax for the following functions:

- ABS
- CONCAT
- LCASE
- LENGTH
- LOCATE (two argument version only)
- LTRIM
- MOD
- RTRIM
- ∎ SQRT
- SUBSTRING
- UCASE

CHAPTER **7**

Database Metadata

The DatabaseMetaData interface is implemented by JDBC drivers to provide information about their underlying data sources. It is used primarily by application servers and tools to determine how to interact with a given data source. Applications may also use DatabaseMetaData methods to get information about a data source, but this is less typical.

The DatabaseMetaData interface includes over 150 methods, which can be categorized according to the types of information they provide:

- general information about the data source
- whether or not the data source supports a given feature or capability
- data source limits
- what SQL objects the data source contains and attributes of those objects
- transaction support offered by the data source

The DatabaseMetaData interface also contains over 40 fields, which are constants used as return values for various DatabaseMetaData methods.

This chapter presents an overview of the DatabaseMetaData interface, gives examples to illustrate the categories of metadata methods, and introduces some new methods. For a comprehensive listing, however, the reader should consult the JDBC API specification.

Note – JDBC also defines the ResultSetMetaData interface, which is discussed in Chapter 15 "Result Sets".

7.1 Creating a DatabaseMetadata Object

A DatabaseMetaData object is created with the Connection method getMetaData. Once created, it can be used to dynamically discover information about the underlying data source. CODE EXAMPLE 7-1 creates a DatabaseMetadata object and uses it to determine the maximum number of characters allowed for a table name.

// con is a Connection object
DatabaseMetaData dbmd = con.getMetadata();
int maxLen = dbmd.getMaxTableNameLength();
CODE EXAMPLE 7-1 Creating and using a DatabaseMetadata object

7.2 Retrieving General Information

Some DatabaseMetaData methods are used to dynamically discover general information about a data source as well as some details about its implementation. Some of the methods in this category are:

- getURL
- getUserName
- getDatabaseProductVersion, getDriverMajorVersion and getDriverMinorVersion
- getSchemaTerm, getCatalogTerm and getProcedureTerm
- nullsAreSortedHigh and nullsAreSortedLow
- usesLocalFiles and usesLocalFilePerTable
- getSQLKeywords

7.3 Determining Feature Support

A large group of DatabaseMetaData methods can be used to determine whether a given feature or set of features is supported by the driver or underlying data source. Beyond this, some of the methods describe what *level* of support is provided. Some of the methods that describe support for individual features are:

- supportsAlterTableWithDropColumn
- supportsBatchUpdates
- supportsTableCorrelationNames
- supportsPositionedDelete
- supportsFullOuterJoins
- supportsStoredProcedures
- supportsMixedCaseQuotedIdentifiers

Methods to describe a level of feature support include:

- supportsANSI92EntryLevelSQL
- supportsCoreSQLGrammar

7.4 Data Source Limits

Another group of methods provides the limits imposed by a given data source. Some of the methods in this category are:

- getMaxRowSize
- getMaxStatementLength
- getMaxTablesInSelect
- getMaxConnections
- getMaxCharLiteralLength
- getMaxColumnsInTable

Methods in this group return the limit as an int. A return value of zero means that there is no limit or the limit is unknown.

7.5 SQL Objects and Their Attributes

Some DatabaseMetaData methods provide information about the SQL objects that populate a given data source. This group also includes methods to determine the attributes of those objects. Methods in this group return ResultSet objects in which each row describes a particular object. For example, the method getUDTs returns a ResultSet object in which there is a row for each UDT that has been defined in the data source. Examples of this category are:

- getSchemas
- getCatalogs
- getTables
- getPrimaryKeys
- getProcedures
- getProcedureColumns
- ∎ getUDTs
- getFunctions
- getFunctionColumns

The ResultSet objects that are returned from a DatabaseMetaData method have a sensitivity of TYPE_FORWARD_ONLY and a concurrency of CONCUR_READ_ONLY. ResultSet.getHoldability can be called to determine the holdability of the returned ResultSet object as the default holdability is implementation defined.

Additional columns beyond the columns defined to be returned by the ResultSet object for a given method can be defined by the JDBC driver vendor and must be accessed by their column label. This allows for future JDBC specifications to be able to add additional columns if needed to existing DatabaseMetaData methods without an significant impact to existing applications

7.6 Transaction Support

A small group of methods provides information about the transaction semantics supported by the data source. Examples of this category include:

- supportsMultipleTransactions
- getDefaultTransactionIsolation

7.7 New Methods

The JDBC 4.3 API introduces the following new DatabaseMetaData methods:

 supportsSharding — Method used to indicate whether the JDBC Driver and database support Sharding.

A complete definition of these methods may be found in the JDBC API specification (javadoc).

7.8 Modified Methods

The JDBC 4.3 API modifies the definitions of these existing ${\tt DatabaseMetaData}$ methods:

getTables — Clarify that the REMARKS column may return null.

The JDBC 4.3 API specification includes updated definitions of these methods.

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CHAPTER 8

Exceptions

The SQLException class and its subtypes provide information about errors and warnings that occur while a data source is being accessed.

8.1 SQLException

An instance of SQLException is thrown when an error occurs during an interaction with a data source. The exception contains the following information:

- a textual description of the error. The String containing the description can be retrieved by calling the method SQLException.getMessage.
- a SQLState. The String containing the SQLState can be retrieved by calling the method SQLException.getSQLState.

The value of the SQLState string will depend on the underlying data source setting the value. Both X/Open and SQL:2003 define SQLState values and the conditions in which they should be set. Although the sets of values overlap, the values defined by SQL:2003 are not a superset of X/Open.

The DatabaseMetaData method getSQLStateType allows an application to determine if the SQLStates being returned by a data source are X/Open or SQL:2003.

- an error code. This is an integer value identifying the error that caused the SQLException to be thrown. Its value and meaning are implementation specific and may be the actual error code returned by the underlying data source. The error code can be retrieved using the SQLException.getErrorCode method.
- a cause. This is another Throwable which caused this SQLException to occur.

 a reference to any "chained" exceptions. If more than one error occurs the exceptions are referenced via this chain. All chained exception can be recursively retrieved by calling the SQLException.getNextException method on the exception that was thrown. If no more exceptions are chained, the getNextException method returns null.

There are multiple subclasses that extend SQLException which are described in Section 8.5 "Categorized SQLExceptions" on page 8-48.

8.1.1 Support for the Java SE Chained Execeptions

The SQLException class and its subclasses have been enhanced to provide support for the Java SE chained exception facility, also known as the cause facility. The changes to support this functionality are:

- The addition of four Constructors in order to provide support for the cause parameter.
- Added support to the SQLException class to support the enchanced For-Each Loop, introduced in J2SE 5.0, allowing the navigation of SQLExceptions and their cause relationship without having to call getCause after each invocation of getNextException.
- The getCause method may return Non-SQLExceptions in addition to SQLExceptions

Please refer to the JDBC API specification for additional information.

8.1.2 Navigating SQLExceptions

It is possible that during the execution of a SQL statement that one or more Exceptions could occur, each with their own potential causal relationship. This means that when a JDBC application catches a SQLException, there is a possibility that there may be additional SQLExceptions chained to the original thrown SQLException. To access the additional chained SQLExceptions, an application would recursively invoke getNextException until a null value is returned.

A SQLException may have a causal relationship, which consists of one or more Throwables which caused the SQLException to be thrown. You may recursively call the method SQLException.getCause, until a null value is returned, to navigate the chain of causes.

The following code demonstrates how an application could navigate SQLExceptions and their causes.

```
catch(SQLException ex) {
  while(ex != null) {
    System.out.println("SQLState:" + ex.getSQLState());
    System.out.println("Error Code:" + ex.getErrorCode());
    System.out.println("Message:" + ex.getMessage());
    Throwable t = ex.getCause();
    while(t != null) {
        System.out.println("Cause:" + t);
        t = t.getCause();
    }
    ex = ex.getNextException();
    }
}
CODE EXAMPLE 8-1 Navigating SQLException and causes
```

8.1.2.1 Using a For-Each Loop with SQLExceptions

JDBC applications may use the Java SE For-Each Loop enhancement to navigate the SQLExceptions and their causal relationship.

The following code demonstrates how to use the For-Each Loop with SQLExceptions.

```
catch(SQLException ex) {
  for(Throwable e : ex ) {
    System.out.println("Error encountered: " + e);
  }
}
```

CODE EXAMPLE 8-2 Using SQLExceptions with a For-Each Loop

8.2 SQLWarning

SQLWarning is a subclass of SQLException. The methods in the following interfaces will generate an SQLWarning object if they encounter a database access warning:

- Connection
- DataSet
- Statement
- ResultSet

When a method generates an SQLWarning object, the caller is not informed that a data access warning has occurred. The method getWarnings must be called on the appropriate object to retrieve the SQLWarning object. However, the DataTruncation sub-class of SQLWarning may be thrown in some circumstances, see Section 8.3 "DataTruncation" on page 8-46 for more details.

If multiple data access warnings occur, they are chained to the first one and can be retrieved by recursively calling the SQLWarning.getNextWarning method. If there are no more warnings in the chain, getNextWarning returns null.

Subsequent SQLWarning objects continue to be added to the chain until the next statement is executed or, in the case of a ResultSet object, when the cursor is repositioned, at which point all SQLWarning objects in the chain are removed.

8.3 DataTruncation

The DataTruncation class, a sub-class of SQLWarning, provides information when data is truncated. When data truncation occurs on a write to the data source, a DataTruncation object is thrown. The data value that has been truncated may have been written to the data source even if a warning has been generated. When data truncation occurs on a read from the data source, a SQLWarning is reported.

A DataTruncation object contains the following information:

- the descriptive String "Data truncation"
- the SQLState "01004" when data truncation occurs on a read from the data source
- the SQLState "22001" when data truncation occurs on a write to the data source
- a boolean to indicate whether a column value or a parameter was truncated. The method DataTruncation.getParameter returns true if a parameter was truncated and false if a column value was truncated.

- an int giving the index of the column or parameter that was truncated. If the index of the column or parameter is unknown, the method
 DataTruncation.getIndex returns -1. If the index is unknown, the values returned by the methods DataTruncation.getParameter and
 DataTruncation.getRead are undefined.
- a boolean to indicate whether the truncation occurred on a read or a write operation. The method DataTruncation.getRead returns true if the truncation occurred on a read and false if the truncation occurred on a write.
- The method DataTruncation.getDataSize returns an int, representing the number of bytes of data that should have been transferred. This number may be approximate if data conversions were being performed. The value may be -1 if the size is unknown.
- an int indicating the actual number of bytes that were transferred. The method DataTruncation.getTransferSize returns the number of bytes actually transferred or -1 if the number of bytes is unknown.

8.3.1 Silent Truncation

The Statement.setMaxFieldSize method allows a maximum size (in bytes) to be set. This limit applies only to the BINARY, VARBINARY, LONGVARBINARY, CHAR, VARCHAR, LONGVARCHAR, NCHAR, NVARCHAR, and LONGNVARCHAR data types.

If a limit has been set using setMaxFieldSize and there is an attempt to read data that exceeds the limit, any truncation that occurs as a result of exceeding the set limit will *not* be reported.

8.4 BatchUpdateException

A BatchUpdateException object provides information about errors that occur while a batch of statements is being executed. This exception's behavior is described in Chapter 14 "Batch Updates".

8.5 Categorized SQLExceptions

Categorized SQLExceptions provide a standard mapping to common SQLStates class values and to common error states which are not associated with a specific SQLState class value. The SQLState class values are defined in the SQL:2003 specification. A JDBC driver may also throw a Categorized SQLException for JDBC driver detected errors. The new SQLException subclasses will provide a means for JDBC programmers to write more portable error-handling code.

The new SQLExceptions will be broken into three exception categories:

- SQLNonTransientException
- SQLTransientException
- SQLRecoverableException

8.5.1 NonTransient SQLExceptions

A NonTransient SQLException must extend the class SQLNonTransientException. A NonTransient SQLException would be thrown in instances where a retry of the same operation would fail unless the cause of the SQLException is corrected. After a NonTransient SQLException other than SQLNonTransientConnectionException occurs, the application can assume that the connection is still valid. For SQLState class values that indicate non-transient errors but which are not specified in the following table, an implementation may throw an instance of the class SQLNonTransientException.

TABLE 8-1 specifies which NonTransientSQLException subclass must be thrown for a a given SQLState class value:

SQL State Class	SQLNonTransientException Subclass
0A	SQLFeatureNotSupportedException
08	SQLNonTransientConnectionException
22	SQLDataException
23	SQLIntegrityConstraintViolationException
28	SQLInvalidAuthorizationException

TABLE 8-1	NonTransientSQLExeceptions Subclasses
-----------	---------------------------------------

 TABLE 8-1
 NonTransientSQLExeceptions Subclasses

SQL State Class	SQLNonTransientException Subclass
42	SQLSyntaxErrorException

A JDBC driver implementation may also throw a NonTransientSQLException for vendor specific non-transient coditions that are not specified in TABLE 8-1.

Note – A SQLSyntaxException will also occur when the accessibility of schema objects is violated, for example, based on the rules given in the SQL:2003 specification.

8.5.2 Transient SQLExceptions

A Transient SQLException must extend the class SQLTransientException. A Transient SQLException will be thrown in situations where a previously failed operation might be able to succeed when the operation is retried without any intervention by application-level functionality. After a Transient SQLException other than SQLTransientConnectionException occurs, the application can assume that the connection is still valid. For SQLState class values that indicate a transient error but which are not specified in the following table, an implementation may throw an instance of the class SQLTransientException.

TABLE 8-2 specifies which SQLTransientException subclass must be thrown for a a given SQLState code:

SQL State Class	SQLTransientException Subclass
08	SQLTransientConnectionException
40	SQLTransactionRollbackException
N/A	SQLTimeoutException

 TABLE 8-2
 TransientSQLExeceptions Subclasses

A JDBC driver implementation may also throw a TransientSQLException for vendor specific transient coditions that are not specified in TABLE 8-2.

8.5.3 SQLRecoverableException

A SQLRecoverableException would be thrown in situations where the failed operation might succeed if the application performs some recovery steps and retries the entire transaction or in the case of a distributed transaction, the transaction branch. At a minimum, recovery includes closing the current connection and getting a new one. After a SQLRecoverableException the application must assume that the connection is no longer valid.

8.6 SQLClientinfoException

A SQLClientInfoException is thrown by the Connection.setClientInfo method when a failure occurs setting one or more of the specified client properties. The SQLClientInfoException contains information indicating which client info properties were not set.

CHAPTER 9

Connections

A Connection object represents a connection to a data source via a JDBC technology-enabled driver. The data source can be a DBMS, a legacy file system, or some other source of data with a corresponding JDBC driver. A single application using the JDBC API may maintain multiple connections. These connections may access multiple data sources, or they may all access a single data source.

From the JDBC driver perspective, a Connection object represents a client session. It has associated state information such as user ID, a set of SQL statements and result sets being used in that session, and what transaction semantics are in effect.

To obtain a connection, the application may interact with either:

the DriverManager class working with one or more Driver implementations

OR

a DataSource implementation

Using a DataSource object is the preferred method because it enhances application portability, it makes code maintenance easier, and it makes it possible for an application to transparently make use of connection pooling and distributed transactions. All Java EE components that establish a connection to a data source use a DataSource object to get a connection.

This chapter describes the various types of JDBC drivers and the use of the Driver interface, the DriverManager class, and the basic DataSource interface. DataSource implementations that support connection pooling and distributed transactions are discussed in Chapter 11 "Connection Pooling" and Chapter 12 "Distributed Transactions".

9.1 Types of Drivers

There are many possible implementations of JDBC drivers. These implementations are categorized as follows:

- Type 1 drivers that implement the JDBC API as a mapping to another data access API, such as ODBC. Drivers of this type are generally dependent on a native library, which limits their portability. The JDBC-ODBC Bridge driver is an example of a Type 1 driver.
- Type 2 drivers that are written partly in the Java programming language and partly in native code. These drivers use a native client library specific to the data source to which they connect. Again, because of the native code, their portability is limited.
- Type 3 drivers that use a pure Java client and communicate with a middleware server using a database-independent protocol. The middleware server then communicates the client's requests to the data source.
- Type 4 drivers that are pure Java often using a network protocol or File I/O to communicate with a specific data source. The client connects directly to the data source.

9.2 The Driver Interface

JDBC drivers must implement the Driver interface, and the implementation must contain a static initializer that will be called when the driver is loaded. This initializer registers a new instance of itself with the DriverManager, as shown in CODE EXAMPLE 9-1.

When a Driver implementation is loaded, the static initializer will automatically register an instance of the driver.

To insure that drivers can be loaded using this mechanism, drivers are required to provide a no-argument constructor.

The DriverManager class invokes Driver methods when it wishes to interact with a registered driver. The Driver interface also includes the method acceptsURL. The DriverManager can use this method to determine which of its registered drivers it should use for a given URL.

When the DriverManager is trying to establish a connection, it calls that driver's connect method and passes the driver the URL. If the Driver implementation understands the URL, it will return a Connection object or throw a SQLException if a connection cannot be maded to the database. If the Driver implementation does not understand the URL, it will return null.

9.2.1 Loading a driver that implements java.sql.Driver

As part of its initialization, the DriverManager class will attempt to load available JDBC drivers by using:

- The "*jdbc.drivers*" system property which contains a fully qualified list of class names of JDBC Drivers. Each driver is loaded using the system class loader
- Service providers of the *java.sql.Driver* class, that are loaded via the serviceprovider loading mechanism.

JDBC 4.0 drivers must provide support for service providers of the *java.sql.Driver* class.

java -Djdbc.drivers=com.acme.jdbc.AcmeJdbcDriver Test

CODE EXAMPLE 9-2 Loading a driver using the jdbc.drivers system property

Note – *DriverManager* initialization is done lazily and looks up service providers using the thread context class loader. The drivers loaded and available to an application will depend on the thread context class loader of the thread that triggers driver initialization by *DriverManager*.

When *DriverManager.getConnection* is called, The *DriverManager* will attempt to locate a suitable driver from amongst those loaded at initialization and those loaded explicitly using the same class loader as the current application.

Note – Existing applications that currently load JDBC drivers using Class.forName() will continue to work without modification.

9.3 The DriverAction Interface

A JDBC driver may implement the *DriverAction* interface when the driver wants to be notified by the *DriverManager* method *deregisterDriver*.

A *DriverAction* implementation is not intended to be used directly by applications. A JDBC Driver may choose to create its *DriverAction* implementation in a private class to avoid it being called directly.

The JDBC driver's static initialization block must call *DriverManager.registerDriver(java.sql.Driver, java.sql.DriverAction)* in order to inform *DriverManager* which *DriverAction* implementation to call when the JDBC driver is de-registered.

```
public class AcmeJdbcDriver implements java.sql.Driver {
        static DriverAction da;
        static {
            java.sql.DriverManager.registerDriver(new
AcmeJdbcDriver(), da);
        }
....
}
CODE EXAMPLE 9-3 Example static initializer for a driver implementing java.sql.Driver
```

and java.sql.DriverAction

9.4 The DriverManager Class

The DriverManager class works with the Driver interface to manage the set of drivers available to a JDBC client. When the client requests a connection and provides a URL, the DriverManager is responsible for finding a driver that recognizes the URL and using it to connect to the corresponding data source.

Key DriverManager methods include:

 registerDriver — this method adds a driver to the set of available drivers and is invoked implicitly when the driver is loaded. The registerDriver method is typically called by the static initializer provided by each driver. getConnection — the method the JDBC client invokes to establish a connection. The invocation includes a JDBC URL, which the DriverManager passes to each driver in its list until it finds one whose Driver.connect method recognizes the URL. That driver returns a Connection object to the DriverManager, which in turn passes it to the application.

The format of a JDBC URL is :

jdbc:<subprotocol>:<subname>

where *subprotocol* defines the kind of database connectivity mechanism that may be supported by one or more drivers. The contents and syntax of the *subname* will depend on the *subprotocol*.

Note – A JDBC URL is not required to fully adhere to the URI syntax as defined in RFC 3986, Uniform Resource Identifier (URI): Generic Syntax.

CODE EXAMPLE 9-4 illustrates how a JDBC client obtains a connection from the DriverManager.

```
// Set up arguments for the call to the getConnection method.
// The sub-protocol "derby" in the driver URL indicates the
// use of the derby JDBC driver.
String url = "jdbc:derby:sample";
String user = "SomeUser";
String passwd = "SomePwd";
```

// Get a connection from the first driver in the DriverManager
// list that recognizes the URL "jdbc:derby:sample".

```
// The call to geConnection will also load the driver if needed.
// When the driver is loaded, an instance of the driver is created
// and the registerDriver method is also called to make the driver
// available to clients.
```

Connection con = DriverManager.getConnection(url, user, passwd); CODE EXAMPLE 9-4 Loading a driver and getting a connection using the DriverManager The DriverManager class also provides two other getConnection methods:

getConnection(String url) for connecting to data sources that do not use username and passwords. getConnection(String url, java.util.Properties prop), which allows the client to connect using a set of properties describing the user name and password along with any addition information that may be required.

The DriverPropertyInfo class provides information on the properties that the JDBC driver can understand.

See the JDBC API Specification for more details.

9.5 The SQLPermission Class

The SQLPermission class represents a set of permissions that a codebase may be granted.

Currently the only permission defined is setLog. The SecurityManager will check for the setLog permission when an Applet calls one of the DriverManager methods setLogWriter and setLogStream. If the codebase does not have the setLog permission a java.lang.SecurityException exception will be thrown.

See the JDBC API Specification for more details.

9.6 The DataSource Interface

The DataSource interface, introduced in JDBC 2.0 Optional Package, is the preferred approach to obtaining data source connections. A JDBC driver that implements the Datasource interface returns connections that implement the same interface, Connection, as those returned by a DriverManager using the Driver interface. Using a Datasource object increases application portability by making it possible for an application to use a logical name for a data source instead of having to supply information specific to a particular driver. A logical name is mapped to a DataSource object via a naming service that uses the Java Naming and Directory InterfaceTM (JNDI). The DataSource object, represents a physical data source and provides connections to that data source. If the data source or information about it changes, the properties of the DataSource object can simply be modified to reflect the changes; no change in application code is necessary.

The DataSource interface can be implemented so that it transparently provides the following:

Increased performance and scalability through connection pooling

Support for distributed transactions through the XADataSource interface

Note - A DataSource implementation must include a no-argument constructor

The next three sections discuss (1) basic DataSource properties, (2) how logical naming using the JNDI API improves an applications portability and makes it easier to maintain, and (3) how to obtain a connection.

Connection pooling and distributed transactions will be discussed in Chapter 11 "Connection Pooling" and Chapter 12 "Distributed Transactions".

9.6.1 DataSource Properties

The JDBC API defines a set of properties to identify and describe a DataSource implementation. The actual set required for a specific implementation depends on the type of DataSource object, that is, whether it is a basic DataSource object, a ConnectionPoolDataSource object, or an XADataSource object. The only property required for all DataSource implementations is description.

The following table describes the standard DataSource properties:

Property Name	Туре	Description
databaseName	String	name of a particular database on a server
dataSourceName	String	a data source name; used to name an underlying XADataSource object or ConnectionPoolDataSource object when pooling of connections is done
description	String	description of this data source
networkProtocol	String	network protocol used to communicate with the server
password	String	a database password
portNumber	int	port number where a server is listening for requests
roleName	String	the initial SQL rolename
serverName	String	database server name
user	String	user's account name

 TABLE 9-1
 Standard Data Source Properties

DataSource properties follow the convention specified for properties of JavaBeansTM components in the JavaBeans 1.01 Specification. DataSource implementations may augment this set with implementation-specific properties. If new properties are added, they must be given names that do not conflict with the standard property names.

DataSource implementations must provide "getter" and "setter" methods for each property they support. These properties typically are initialized when the DataSource object is deployed, as in CODE EXAMPLE 9-5, in which a VendorDataSource object implements the DataSource interface.

VendorDataSource vds = new VendorDataSource(); vds.setServerName("my_database_server"); String name = vds.getServerName();

CODE EXAMPLE 9-5 Setting and getting a DataSource property

DataSource properties are not intended to be directly accessible by JDBC clients. This design is reinforced by defining the access methods on the implementation class rather than on the public DataSource interface used by applications. Furthermore, the object that the client manipulates can be a wrapper that only implements the DataSource interface. The setter and getter methods for the properties need not be exposed to the client.

Management tools that need to manipulate the properties of a DataSource implementation can access those properties using introspection.

9.6.2 The JNDI API and Application Portability

The Java Naming and Directory Interface (JNDI) API provides a uniform way for applications to access remote services over the network. This section describes how it is used to register and access a JDBC DataSource object. See the JNDI specification for a complete description of this interface.

Using the JNDI API, applications can access a DataSource object by specifying its logical name. A naming service using the JNDI API maps this logical name to a corresponding data source. This scheme greatly enhances portability because any of the DataSource properties, such as portNumber or serverName, can be changed without impacting the JDBC client code. In fact, the application can be re-directed to a different underlying data source in a completely transparent fashion. This is particularly useful in the three-tier environment, where an application server hides the details of accessing different data sources.

CODE EXAMPLE 9-6 illustrates the use of a JNDI-based naming service to deploy a new VendorDataSource object.

```
// Create a VendorDataSource object and set some properties
VendorDataSource vds = new VendorDataSource();
vds.setServerName("my_database_server");
vds.setDatabaseName("my_database");
vds.setDescription("data source for inventory and personnel");
// Use the JNDI API to register the new VendorDataSource object.
// Reference the root JNDI naming context and then bind the
// logical name "jdbc/AcmeDB" to the new VendorDataSource object.
Context ctx = new InitialContext();
ctx.bind("jdbc/AcmeDB", vds);
CODE EXAMPLE 9-6 Registering a DataSource object with a JNDI-based naming service
```

Note – Java EE components use a special convention for naming their data sources – see Chapter 5 "Naming" in the Java EE platform specification for more details.

9.6.3 Getting a Connection with a DataSource Object

Once a DataSource object has been registered with a JNDI-based naming service, an application can use it to obtain a connection to the physical data source that it represents, as is done in CODE EXAMPLE 9-7.

```
// Get the initial JNDI naming context
Context ctx = new InitialContext();
```

// Get the DataSource object associated with the logical name
// "jdbc/AcmeDB" and use it to obtain a database connection
DataSource ds = (DataSource)ctx.lookup("jdbc/AcmeDB");
Connection con = ds.getConnection("user", "pwd");

CODE EXAMPLE 9-7 Getting a Connection object using a DataSource object

The DataSource implementation bound to the name "jdbc/AcmeDB" can be modified or replaced without affecting the application code.

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9.6.4 Closing Connection Objects

The methods Connection.close(), Connection.isclosed() and Connection.isValid() may be used close a Connection and to determine whether a Connection has been closed or is still valid.

9.6.4.1 Connection.close

An application calls the method <code>Connection.close()</code> to indicate that it has finished using a connection. All <code>Statement</code> objects created from a given <code>Connection</code> object will be closed when the <code>close</code> method for the <code>Connection</code> object is called.

Once a Connection has been closed, any attempt to access any of its methods with the exception of the close(), isClosed() or isValid() methods will result in a SQLException being thrown.

9.6.4.2 Connection.isClosed

The Connection.isClosed() method indicates whether the method Connection.close() has been called by an application. This method generally cannot be used to determine whether a connection to a database is valid.

Note – Some JDBC implementations may have enhanced isClosed() to determine whether a connection to a database is valid. For maximum portability, The Connection.isValid() method should be used.

9.6.4.3 Connection.isValid

The Connection.isValid() method indicates whether the Connection is still valid. If Connection.isValid() returns true, the Connection is still valid. If a value of false is returned, the Connection is not valid and any attempt to access any of its methods with the exception of the close(), isClosed() or isValid() methods will result in a SQLException being thrown.

CHAPTER **10**

Transactions

Transactions are used to provide data integrity, correct application semantics, and a consistent view of data during concurrent access. All JDBC compliant drivers are required to provide transaction support. Transaction management in the JDBC API mirrors the SQL:2003 specification and includes these concepts:

- Auto-commit mode
- Transaction isolation levels
- Savepoints

This chapter describes transaction semantics associated with a single Connection object. Transactions involving multiple Connection objects are discussed in Chapter 12 "Distributed Transactions".

10.1 Transaction Boundaries and Autocommit

When to start a new transaction is a decision made implicitly by either the JDBC driver or the underlying data source. Although some data sources implement an explicit "begin transaction" statement, there is no JDBC API to do so. Typically, a new transaction is started when the current SQL statement requires one and there is no transaction already in place. Whether or not a given SQL statement requires a transaction is also specified by SQL:2003.

The Connection attribute *auto-commit* specifies when to end transactions. Enabling auto-commit causes a transaction commit after each individual SQL statement as soon as that statement is complete. The point at which a statement is considered to be "complete" depends on the type of SQL statement as well as what the application does after executing it:

- For Data Manipulation Language (DML) statements such as Insert, Update, Delete, and DDL statements, the statement is complete as soon as it has finished executing.
- For Select statements, the statement is complete when the associated result set is closed.
- For CallableStatement objects or for statements that return multiple results, the statement is complete when all of the associated result sets have been closed, and all update counts and output parameters have been retrieved.

10.1.1 Disabling Auto-commit Mode

CODE EXAMPLE 10-1 shows how to disable auto-commit mode.

```
// Assume con is a Connection object
con.setAutoCommit(false);
```

CODE EXAMPLE 10-1 Setting auto-commit off

When auto-commit is disabled, each transaction must be explicitly committed by calling the Connection method commit or explicitly rolled back by calling the Connection method rollback, respectively. This is appropriate for cases where transaction management is being done in a layer above the driver, such as:

- when the application needs to group multiple SQL statements into a single transaction
- when the transaction is being managed by the application server

The default is for auto-commit mode to be enabled when the Connection object is created. If the value of auto-commit is changed in the middle of a transaction, the current transaction is committed. If setAutoCommit is called and the value for auto-commit is not changed from its current value, it is treated as a no-op.

It is an error to enable auto-commit for a connection participating in a distributed transaction, as described in Chapter 12 "Distributed Transactions".

10.2 Transaction Isolation Levels

Transaction isolation levels specify what data is "visible" to the statements within a transaction. They directly impact the level of concurrent access by defining what interaction, if any, is possible between transactions against the same target data source. Possible interaction between concurrent transactions is categorized as follows:

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- *dirty reads* occur when transactions are allowed to see uncommitted changes to the data. In other words, changes made inside a transaction are visible outside the transaction before it is committed. If the changes are rolled back instead of being committed, it is possible for other transactions to have done work based on incorrect, transient data.
- *nonrepeatable reads* occur when:
 - a. Transaction A reads a row
 - b. Transaction B changes the row
 - c. Transaction A reads the same row a second time and gets different results
- *phantom reads* occur when:
 - a. Transaction A reads all rows that satisfy a WHERE condition
 - b. Transaction B inserts an additional row that satisfies the same condition
 - c. Transaction A reevaluates the WHERE condition and picks up the additional "phantom" row

JDBC augments the four levels of transaction isolation defined by SQL:2003, by adding TRANSACTION_NONE. From least restrictive to most restrictive, the transaction isolation levels are:

- 1. TRANSACTION_NONE indicates that the driver does not support transactions, which means that it is not a JDBC compliant driver.
- 2. TRANSACTION_READ_UNCOMMITTED allows transactions to see uncommitted changes to the data. This means that dirty reads, nonrepeatable reads, and phantom reads are possible.
- 3. TRANSACTION_READ_COMMITTED means that any changes made inside a transaction are not visible outside the transaction until the transaction is committed. This prevents dirty reads, but nonrepeatable reads and phantom reads are still possible.
- 4. TRANSACTION_REPEATABLE_READ disallows dirty reads and nonrepeatable reads. Phantom read are still possible.
- 5. TRANSACTION_SERIALIZABLE specifies that dirty reads, nonrepeatable reads, and phantom reads are prevented.

10.2.1 Using the setTransactionIsolation Method

The default transaction level for a Connection object is determined by the driver supplying the connection. Typically, it is the default transaction level supported by the underlying data source.

The Connection method setTransactionIsolation is provided to allow JDBC clients to change the transaction isolation level for a given Connection object. The new isolation level remains in effect for the remainder of the session or until the next invocation of the setTransactionIsolation method.

The result of invoking the method setTransactionIsolation in the middle of a transaction is implementation-defined.

The return value of the method getTransactionIsolation should reflect the change in isolation level when it actually occurs. It is recommended that drivers implement the setTransactionIsolation method to change the isolation level starting with the next transaction. Committing the current transaction to make the effect immediate is also a valid implementation.

It is possible for a given JDBC driver to not support all four transaction isolation levels (not counting TRANSACTION_NONE). If a driver does not support the isolation level specified in an invocation of setTransactionIsolation, it is allowed to substitute a higher, more restrictive transaction isolation level. If a driver is unable to substitute a higher transaction level, it throws an SQLException. The DatabaseMetaData method supportsTransactionIsolationLevel may be used to determine whether or not the driver supports a given level.

10.2.2 Performance Considerations

As the transaction isolation level increases, more locking and other DBMS overhead is required to ensure the correct semantics. This in turn lowers the degree of concurrent access that can be supported. As a result, applications may see decreased performance when they use a higher transaction isolation level. For this reason, the transaction manager, whether it is the application itself or part of the application server, should weigh the need for data consistency against the requirements for performance when determining which transaction isolation level is appropriate.

10.3 Savepoints

Savepoints provide finer-grained control of transactions by marking intermediate points within a transaction. Once a savepoint has been set, the transaction can be rolled back to that savepoint without affecting preceding work.

The DatabaseMetaData.supportsSavepoints method can be used to determine whether a JDBC driver and DBMS support savepoints.

10.3.1 Setting and Rolling Back to a Savepoint

The method Connection.setSavepoint can be used to set a savepoint within the current transaction. A transaction will be started if setSavePoint is invoked and there is not an active transaction. The Connection.rollback method has been overloaded to take a savepoint argument.

CODE EXAMPLE 10-2 inserts a row into a table, sets the savepoint *svpt1*, and then inserts a second row. When the transaction is later rolled back to *svpt1*, the second insertion is undone, but the first insertion remains intact. In other words, when the transaction is committed, only the row containing 'FIRST' will be added to TAB1.

CODE EXAMPLE 10-2 Rolling back a transaction to a savepoint

10.3.2 Releasing a Savepoint

The method Connection.releaseSavepoint takes a Savepoint object as a parameter and removes it and any subsequent savepoints from the current transaction.

Once a savepoint has been released, attempting to reference it in a rollback operation will cause an SQLException to be thrown.

Any savepoints that have been created in a transaction are automatically released and become invalid when the transaction is committed or when the entire transaction is rolled back.

Rolling a transaction back to a savepoint automatically releases and makes invalid any other savepoints that were created after the savepoint in question.

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CHAPTER **11**

Connection Pooling

In a basic DataSource implementation, there is a 1:1 correspondence between the client's Connection object and the physical database connection. When the Connection object is closed, the physical connection is dropped. Thus, the overhead of opening, initializing, and closing the physical connection is incurred for each client session.

A connection pool solves this problem by maintaining a cache of physical database connections that can be reused across client sessions. Connection pooling greatly improves performance and scalability, particularly in a three-tier environment where multiple clients can share a smaller number of physical database connections. In FIGURE 11-1, the JDBC driver provides an implementation of ConnectionPoolDataSource that the application server uses to build and manage the connection pool.

The algorithm used to manage the connection pool is implementation-specific and varies with application servers. The application server provides its clients with an implementation of the DataSource interface that makes connection pooling transparent to the client. As a result, the client gets better performance and scalability while using the same JNDI and DataSource APIs as before.

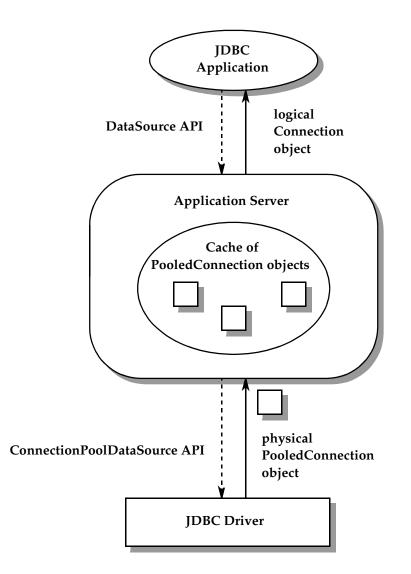


FIGURE 11-1 Connection pooling

The following sections introduce the ConnectionPoolDataSource interface, the PooledConnection interface, and the ConnectionEvent class. These pieces, which operate beneath the DataSource and Connection interfaces used by the client, are incorporated into a step-by-step description of a typical connection pooling implementation. This chapter also describes some important differences

between a basic DataSource object and one that implements connection pooling. In addition, it discusses how a pooled connection can maintain a pool of reusable PreparedStatement objects.

Although much of the discussion in this chapter assumes a three-tier environment, connection pooling is also relevant in a two-tier environment. In a two-tier environment, the JDBC driver implements both the DataSource and ConnectionPoolDataSource interfaces. This implementation allows an application that opens and closes multiple connections to benefit from connection pooling.

11.1 ConnectionPoolDataSource and PooledConnection

Typically, a JDBC driver implements the ConnectionPoolDataSource interface, and the application server uses it to obtain PooledConnection objects. CODE EXAMPLE 11-1 shows the signatures for the two versions of the getPooledConnection method.

CODE EXAMPLE 11-1 The ConnectionPoolDataSource interface

A PooledConnection object represents a physical connection to a data source. The JDBC driver's implementation of PooledConnection encapsulates all of the details of maintaining that connection.

An application server caches and reuses <code>PooledConnection</code> objects within its implementation of the <code>DataSource</code> interface. When a client calls the method <code>DataSource.getConnection</code>, the application server uses the physical <code>PooledConnection</code> object to obtain a logical <code>Connection</code> object. CODE EXAMPLE 11-2 shows the <code>PooledConnection</code> interface definition.

```
public interface PooledConnection {
    Connection getConnection() throws SQLException;
    void close() throws SQLException;
    void addConnectionEventListener(
        ConnectionEventListener listener);
    void addStatementEventListener listener);
    void removeConnectionEventListener(
        ConnectionEventListener listener);
    void removeStatementEventListener(
        StatementEventListener listener);
```

}

CODE EXAMPLE 11-2 The PooledConnection interface

When an application is finished using a connection, it closes the logical connection using the method Connection.close. This closes the logical connection but does not close the physical connection. Instead, the physical connection is returned to the pool so that it can be reused.

Connection pooling is completely transparent to the client: A client obtains a pooled connection and uses it just the same way it obtains and uses a non pooled connection.

Note – When Connection.closed is called when using Connection pooling, any properties that were set by Connection.setClientInfo will be cleared.

11.2 Connection Events

Recall that when an application calls the method Connection.close, the underlying physical connection—the PooledConnection object—becomes available for reuse. JavaBeans-style events are used to notify the connection pool manager (the application server) that a PooledConnection object can be recycled.

In order to be notified of an event on a PooledConnection object, the connection pool manager must implement the ConnectionEventListener interface and then be registered as a listener by that PooledConnection object. The

ConnectionEventListener interface defines the following two methods, which correspond to the two kinds of events that can occur on a PooledConnection object:

- connectionClosed triggered when the logical Connection object associated with this PooledConnection object is closed, that is, the application called the method Connection.close
- connectionErrorOccurred triggered when a fatal error, such as the server crashing, causes the connection to be lost

A connection pool manager registers itself as a listener for a PooledConnection object using the PooledConnection.addConnectionEventListener method. Typically, a connection pool manager registers itself as a ConnectionEventListener before returning a Connection object to an application.

The driver invokes the ConnectionEventListener methods connectionClosed and connectionErrorOccurred when the corresponding events occur. Both methods take a ConnectionEvent object as a parameter, which can be used to determine which PooledConnection object was closed or had an error. When the JDBC application closes its logical connection, the JDBC driver notifies the connection pool manager (the listener) by calling the listener's implementation of the method connectionClosed. At this point, the connection pool manager can return the PooledConnection object to the pool for reuse.

When an error occurs, the JDBC driver notifies the listener by calling its connectionErrorOccurred method and then throws an SQLException object to the application to notify it of the same error. In the event of a fatal error, the bad PooledConnection object is not returned to the pool. Instead, the connection pool manager calls the PooledConnection.close method on the PooledConnection object to close the physical connection.

11.3 Connection Pooling in a Three-tier Environment

The following sequence of steps outlines what happens when a JDBC client requests a connection from a DataSource object that implements connection pooling:

- The client calls DataSource.getConnection.
- The application server providing the DataSource implementation looks in its connection pool to see if there is a suitable PooledConnection object— a physical database connection—available. Determining the suitability of a given PooledConnection object may include matching the client's user authentication

information or application type as well as using other implementation-specific criteria. The lookup method and other methods associated with managing the connection pool are specific to the application server.

- If there are no suitable PooledConnection objects available, the application server calls the ConnectionPoolDataSource.getPooledConnection method to get a new physical connection. The JDBC driver implementing ConnectionPoolDataSource creates a new PooledConnection object and returns it to the application server.
- Regardless of whether the PooledConnection was retrieved from the pool or was newly created, the application server does some internal bookkeeping to indicate that the physical connection is now in use.
- The application server calls the method PooledConnection.getConnection to get a logical Connection object. This logical Connection object is actually a "handle" to a physical PooledConnection object, and it is this handle that is returned by the DataSource.getConnection method when connection pooling is in effect.
- The application server registers itself as a ConnectionEventListener by calling the method PooledConnection.addConnectionEventListener. This is done so that the application server will be notified when the PooledConnection object is available for reuse.
- The logical Connection object is returned to the JDBC client, which uses the same Connection API as in the basic DataSource case. Note that the underlying PooledConnection object cannot be reused until the client calls the method Connection.close.

Connection pooling can also be implemented in a two-tier environment where there is no application server. In this case, the JDBC driver provides both the implementation of DataSource which is visible to the client and the underlying ConnectionPoolDataSource implementation.

11.4 DataSource Implementations and Connection Pooling

Aside from improved performance and scalability, a JDBC application should not see any difference between accessing a DataSource object that implements connection pooling and one that does not. However, there are some important differences in the application server and driver level implementations.

A basic DataSource implementation, that is, one that does not implement connection pooling, is typically provided by a JDBC driver vendor. In a basic DataSource implementation, the following are true:

- The DataSource.getConnection method creates a new Connection object that represents a physical connection and encapsulates all of the work to set up and manage that connection.
- The Connection.close method shuts down the physical connection and frees the associated resources.

In a DataSource implementation that includes connection pooling, a great deal happens behind the scenes. In such an implementation, the following are true:

- The DataSource implementation includes an implementation-specific connection pooling module that manages a cache of PooledConnection objects. The DataSource object is typically implemented by the application server as a layer on top of the driver's implementations of the ConnectionPoolDataSource and PooledConnection interfaces.
- The DataSource.getConnection method calls
 PooledConnection.getConnection to get a logical handle to an underlying
 physical connection. The overhead of setting up a new physical connection is
 incurred only if there are no existing connections available in the connection pool.
 When a new physical connection is needed, the connection pool manager will call
 the ConnectionPoolDataSource method getPooledConnection to create
 one. The work to manage the physical connection is delegated to the
 PooledConnection object.
- The Connection.close method closes the logical handle, but the physical connection is maintained. The connection pool manager is notified that the underlying PooledConnection object is now available for reuse. If the application attempts to reuse the logical handle, the Connection implementation throws an SQLException.
- A single physical PooledConnection object may generate many logical Connection objects during its lifetime. For a given PooledConnection object, only the most recently produced logical Connection object will be valid. Any previously existing Connection object is automatically closed when the associated PooledConnection.getConnection method is called. Listeners (connection pool managers) are not notified in this case.

This gives the application server a way to take a connection away from a client. This is an unlikely scenario but may be useful if the application server is trying to force an orderly shutdown.

 A connection pool manager shuts down a physical connection by calling the method PooledConnection.close. This method is typically called only in certain circumstances: when the application server is undergoing an orderly shutdown, when the connection cache is being re initialized, or when the application server receives an event indicating that an unrecoverable error has occurred on the connection.

11.5 Deployment

Deploying a DataSource object that implements connection pooling requires that both a client-visible DataSource object and an underlying ConnectionPoolDataSource object be registered with a JNDI-based naming service.

The first step is to deploy the ConnectionPoolDataSource implementation, as is done in CODE EXAMPLE 11-3.

// Register the ConnectionPoolDS with JNDI, using the logical name
// "jdbc/pool/bookserver_pool"
Context ctx = new InitialContext();
ctx.bind("jdbc/pool/bookserver_pool", cpds);

CODE EXAMPLE 11-3 Deploying a ConnectionPoolDataSource object

Once this step is complete, the ConnectionPoolDataSource implementation is available as a foundation for the client-visible DataSource implementation. The DataSource implementation is deployed such that it references the ConnectionPoolDataSource implementation, as shown in CODE EXAMPLE 11-4.

// Register the DataSource implementation with JNDI, using the logical // name "jdbc/bookserver". Context ctx = new InitialContext(); ctx.bind("jdbc/bookserver", ds); CODE EXAMPLE 11-4 Deploying a DataSource object backed by a ConnectionPoolDataSource object

The DataSource object is now available for use in an application.

11.6 Reuse of Statements by Pooled Connections

The JDBC specification provides support for statement pooling. This feature, which allows an application to reuse a PreparedStatement object in much the same way it can reuse a connection, is made available through a pooled connection.

FIGURE 11-2 provides a logical view of how a pool of PreparedStatement objects can be associated with a PooledConnection object. As with the PooledConnection object itself, the PreparedStatement objects can be reused by multiple logical connections in a transparent manner.

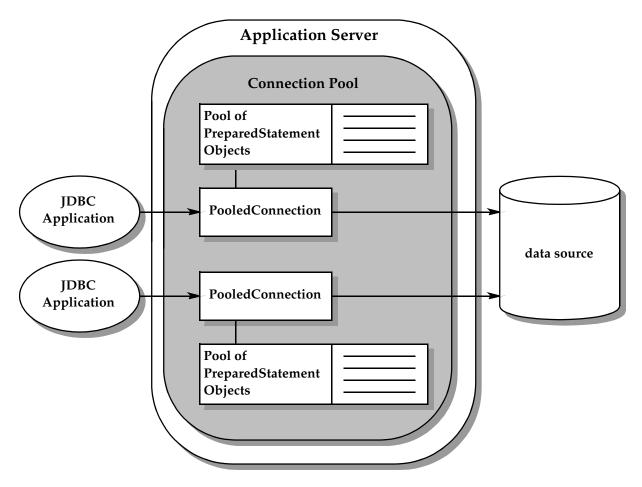


FIGURE 11-2 Logical view of prepared statements reused by pooled connections

In FIGURE 11-2, the connection pool and statement pool are implemented by the application server. However, this functionality could also be implemented by the driver or underlying data source. This discussion of statement pooling is meant to allow for any of these implementations.

11.6.1 Using a Pooled Statement

If a pooled connection reuses statements, the reuse must be completely transparent to an application. In other words, from the application's point of view, using a PreparedStatement object that participates in statement pooling is exactly the

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same as using one that does not. Statements are kept open for reuse entirely under the covers, so there is no change in application code. If an application closes a PreparedStatement object, it must still call Connection.prepareStatement in order to use it again. The only visible effect of statement pooling is a possible improvement in performance.

An application may find out whether a data source supports statement pooling by calling the DatabaseMetaData method supportsStatementPooling. If the return value is true, the application can then choose to use PreparedStatement objects knowing that they may be pooled.

In many cases, reusing statements is a significant optimization. This is especially true for complex prepared statements. However, it should also be noted that leaving large numbers of statements open may have an adverse impact on the use of resources.

11.6.2 Closing a Pooled Statement

An application closes a pooled statement exactly the same way it closes a non pooled statement. Whether it is pooled or not, a statement that has been closed is no longer available for use by the application, and an attempt to reuse it will cause an exception to be thrown.

The following methods can close a pooled statement:

- Statement.close called by an application; if the statement is being pooled, closes the logical statement used by the application but does not close the physical statement being pooled
- Connection.close called by an application
 - Non pooled connection closes the physical connection and all statements created by that connection. This is necessary because the garbage collection mechanism is unable to detect when externally managed resources can be released.
 - Pooled connection closes the logical connection and the logical statements it returned but leaves open the underlying PooledConnection object and any associated pooled statements
- PooledConnection.close called by the connection pool manager to close the physical connection and the associated physical statements being pooled by the PooledConnection object

An application cannot directly close a physical statement that is being pooled; instead, this is done by the connection pool manager. The method PooledConnection.close closes the connection and all of the statements open on a given connection, which releases the resources associated with those statements. An application also has no direct control over how statements are pooled. A pool of statements is associated with a PooledConnection object, whose behavior is determined by the properties of the ConnectionPoolDataSource object that produced it. Section 11.8 "ConnectionPoolDataSource Properties" discusses these properties.

11.7 Statement Events

If the connection pool manager supports Statement pooling for PreparedStatement objects, it must implement the StatementEventListener interface and then be registered as a listener by that PooledConnection object. The StatementEventListener interface defines the following two methods, which correspond to the two kinds of events that can occur on a PreparedStatement object:

- statementClosed triggered when the logical PreparedStatement object associated with this PooledConnection object is closed, that is, the application called the method PreparedStatement.close
- statementErrorOccurred triggered when a JDBC driver determines that a PreparedStatement object is no longer valid

A connection pool manager registers itself as a listener for a PreparedStatement object using the PooledConnection.addStatementEventListener method. Typically, a connection pool manager registers itself as a

StatementEventListener before returning a PreparedStatement object to an application.

The driver invokes the StatementEventListener methods statementClosed and statementErrorOccurred when the corresponding events occur. Both methods take a statementEvent object as a parameter, which can be used to determine which PreparedStatement object was closed or had an error. When the JDBC application closes its logical prepared statement, the JDBC driver notifies the connection pool manager (the listener) by calling the listener's implementation of the method statementClosed. At this point, the connection pool manager can return the PreparedStatement object to the pool for reuse.

When an error occurs that makes a PreparedStatement object invalid, the JDBC driver notifies the listener by calling its statementErrorOccurred method and then throws an SQLException object to the application to notify it of the same error.

11.8 ConnectionPoolDataSource Properties

As with the DataSource interface, the JDBC API defines a set of properties that can be used to configure the behavior of connection pools. These are shown in TABLE 11-1:

Property Name	Туре	Description
maxStatements	int	The total number of statements that the pool should keep open. 0 (zero) indicates that caching of statements is disabled.
initialPoolSize	int	The number of physical connections the pool should contain when it is created
minPoolSize	int	The number of physical connections the pool should keep available at all times. 0 (zero) indicates that connections should be created as needed.
maxPoolSize	int	The maximum number of physical connections that the pool should contain. 0 (zero) indicates no maximum size.
maxIdleTime	int	The number of seconds that a physical connection should remain unused in the pool before the connection is closed. 0 (zero) indicates no limit.
propertyCycle	int	The interval, in seconds, that the pool should wait before enforcing the current policy defined by the values of the above connection pool properties

 TABLE 11-1
 Standard Connection Pool Properties

Connection pool configuration properties follow the convention specified for JavaBeans components in the JavaBeans specification. Connection pool vendors may choose to augment this set with implementation-specific properties. If so, the additional properties must be given names that do not conflict with the standard property names.

Like DataSource implementations, ConnectionPoolDataSource implementations must provide "getter" and "setter" methods for each property they support. These properties are typically initialized when the ConnectionPoolDataSource object is deployed. CODE EXAMPLE 11-5 illustrates setting properties in a vendor's implementation of the ConnectionPoolDataSource interface.

```
VendorConnectionPoolDS vcp = new VendorConnectionPoolDS();
vcp.setMaxStatements(25);
vcp.setInitialPoolSize(10);
vcp.setMinPoolSize(1);
vcp.setMaxPoolSize(0);
vcp.setMaxIdleTime(0);
vcp.setPropertyCycle(300);
```

CODE EXAMPLE 11-5 Setting connection pool configuration properties

The properties set on a ConnectionPoolDataSource object apply to the PooledConnection objects that it creates. An application server managing a pool of PooledConnection objects uses these properties to determine how to manage its pool.

ConnectionPoolDataSource configuration properties are not intended to be directly accessible by JDBC clients. Management tools that need to manipulate the properties of a ConnectionPoolDataSource implementation can access those properties using introspection.

CHAPTER **12**

Distributed Transactions

Up to this point, the discussion of transactions has focused on the local case transactions involving a single data source. This chapter introduces the distributed case where a single transaction involves multiple connections to one or more underlying data sources.

The following discussion includes these topics:

- distributed transaction infrastructure
- transaction managers and resource managers
- the XADataSource, XAConnection, and XAResource interfaces
- two-phase commit

Transaction management in the JDBC API is designed to fit with the Java Transaction API^{TM} (JTATM). The examples presented here are high-level; the JTA specification should be consulted for a more substantial discussion.

12.1 Infrastructure

Distributed transactions require an infrastructure that provides these roles:

- Transaction manager controls transaction boundaries and manages the twophase commit protocol. This typically will be an implementation of JTA.
- JDBC drivers that implement the XADataSource, XAConnection, and XAResource interfaces. These are described in the next section.
- An application-visible implementation of DataSource to "sit on top of" each XADataSource object and interact with the transaction manager. The DataSource implementation is typically provided by an application server.

Resource manager(s) to manage the underlying data. In the context of the JDBC API, a resource manager is a DBMS server. The term "resource manager" is borrowed from JTA to emphasize the point that distributed transactions using the JDBC API follow the architecture specified in that document.

This infrastructure is most often implemented in a three-tier architecture that includes the following:

- 1. A client tier
- 2. A middle tier that includes applications, an EJB server working with an external transaction manager, and a set of JDBC drivers
- 3. Multiple resource managers

Distributed transactions can also be implemented in two tiers. In a two-tier architecture, the application itself acts as the transaction manager and interacts directly with the JDBC drivers' XADataSource implementations.

The following diagram illustrates the distributed transaction infrastructure:

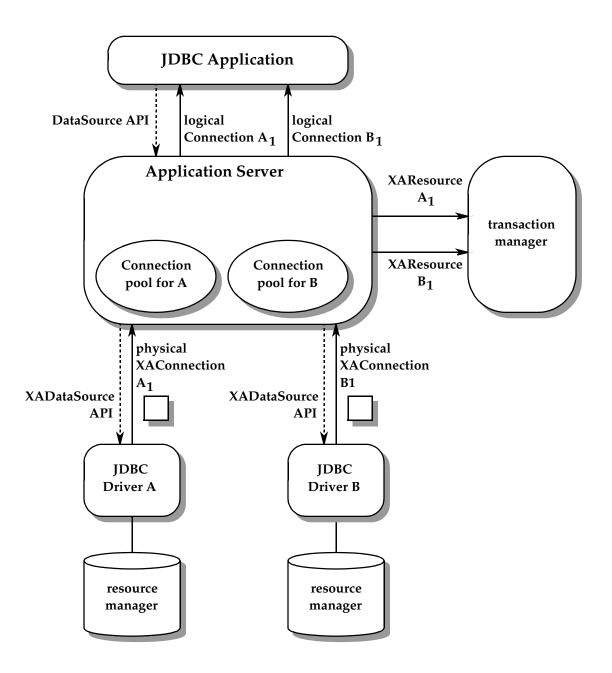


FIGURE 12-1 Infrastructure for distributed transactions

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The following sections provide more detail on the components of this architecture.

12.2 XADataSource and XAConnection

The XADataSource and XAConnection interfaces, which are defined in the package javax.sql, are implemented by JDBC drivers that support distributed transactions. An XAConnection object is a pooled connection that can participate in a distributed transaction. More precisely, XAConnection extends the PooledConnection interface by adding the method getXAResource. This method produces an XAResource object that can be used by a transaction manager to coordinate the work done on this connection with the other participants in the distributed transaction. CODE EXAMPLE 12-1 gives the definition of the XAConnection interface.

public interface XAConnection extends PooledConnection {
 javax.transaction.xa.XAResource getXAResource()
 throws SQLException;

}

CODE EXAMPLE 12-1 The XAConnection interface

Because they extend the PooledConnection interface, XAConnection objects support all the methods of PooledConnection objects. They are reusable physical connections to an underlying data source and produce logical connection handles that can be passed back to a JDBC application.

XAConnection objects are produced by an XADataSource object. There is some similarity between ConnectionPoolDataSource objects and XADataSource objects in that they are both implemented below a DataSource layer that is visible to the JDBC application. This architecture allows JDBC drivers to support distributed transactions in a way that is transparent to the application. CODE EXAMPLE 12-2 shows the signatures for the two getXAConnection methods defined in XADataSource.

```
public interface XADataSource {
    XAConnection getXAConnection() throws SQLException;
    XAConnection getXAConnection(String user,
        String password) throws SQLException;
    ...
}
```

CODE EXAMPLE 12-2 The XADataSource interface

Typically, DataSource implementations built on top of an XADataSource implementation will also include a connection pooling module.

12.2.1 Deploying an XADataSource Object

Deploying an XADataSource object is done in exactly the same manner as previously described for ConnectionPoolDataSource objects. The two-step process includes deploying the XADataSource object and the application-visible DataSource object, as is done in CODE EXAMPLE 12-3.

```
// com.acme.jdbc.XADataSource implements the
// XADataSource interface.
```

```
// Create an instance and set properties.
com.acme.jdbc.XADataSource xads = new com.acme.jdbc.XADataSource();
xads.setServerName("bookstore");
xads.setDatabaseName("bookinventory");
xads.setPortNumber(9040);
xads.setDescription("XADataSource for inventory");
```

```
// First register xads with a JNDI naming service, using the
// logical name "jdbc/xa/inventory_xa"
Context ctx = new InitialContext();
ctx.bind("jdbc/xa/inventory_xa", xads);
```

```
// Next register the overlying DataSource object for application
// access. com.acme.appserver.DataSource is an implementation of
// the DataSource interface.
```

```
ds.setDataSourceName("jdbc/xa/inventory_xa");
```

```
// Register the DataSource implementation with a JNDI naming service,
// using the logical name "jdbc/inventory".
ctx.bind("jdbc/inventory", ds);
```

CODE EXAMPLE 12-3 Deploying a DataSource object backed by an XADataSource object

12.2.2 Getting a Connection

As in the connection pooling case, the application call to the method DataSource.getConnection returns a logical handle produced by the physical XAConnection object. The application code to get a logical connection is shown in CODE EXAMPLE 12-4.

Context ctx = new InitialContext(); DataSource ds = (DataSource)ctx.lookup("jdbc/inventory"); Connection con = ds.getConnection("myID", "mypasswd"); CODE EXAMPLE 12-4 Application code to get a logical connection

CODE EXAMPLE 12-5 is an example of code from the middle-tier server's implementation of the method DataSource.getConnection.

// Assume xads is a driver's implementation of XADataSource XADataSource xads = (XADataSource)ctx.lookup("jdbc/xa/" +

"inventory_xa");

 $//\ xacon$ implements XAConnection

XAConnection xacon = xads.getXAConnection("myID", "mypasswd");
// Get a logical connection to pass back up to the application
Connection con = xacon.getConnection();

CODE EXAMPLE 12-5 Getting a logical connection from an XAConnection object

12.3 XAResource

The XAResource interface is defined in the JTA specification and is the mapping in the Java programming language of the X/Open Group XA interface. An XAResource object is produced by calling the XAConnection.getXAResource method and is used to associate an XAConnection object with a distributed transaction. A given XAConnection object may be associated with at most one

transaction at a time. The JDBC driver maintains a one-to-one correspondence between an XAResource object and its associated XAConnection object; that is, multiple calls to the getXAResource method must all return the same object.

In a typical scenario, the middle-tier application server calls the method XAConnection.getXAResource and passes the returned object to an external transaction manager. The transaction manager uses the XAResource object exclusively—it does not access an XAConnection object directly.

The transaction manager coordinates the work of multiple XAResource objects, each of which represents a resource manager participating in the distributed transaction. Note that two XAResource objects may "point" to the same resource manager, that is, they may be associated with XAConnection objects that were produced by the same XADataSource.

The following XAResource methods are used by the transaction manager to implement a two-phase commit protocol. Each method takes an xid parameter that identifies the distributed transaction:

- start tells the resource manager that the subsequent operations are part of the distributed transaction.
- end marks the end of this resource manager's part of the distributed transaction.
- prepare gets the resource manager's vote on whether to commit or roll back the distributed transaction.
- commit tells the resource manager to commit its part of the distributed transaction. This method is invoked only if all the participating resource managers voted to commit the transaction.
- rollback tells the resource manager to roll back its part of the distributed transaction. This method is invoked if one or more of the participating resource managers voted to roll back the transaction.

See the JTA specification for a complete description of the XAResouce interface.

12.4 Transaction Management

Participation in a distributed transaction is defined as the work done between invocations of the methods XAResource.start and XAResource.end. Outside these boundaries, the transaction mode is local, and a connection behaves exactly like a local connection.

With one exception, there is no difference in how an application participating in a distributed transaction is coded. In contrast to the local case, the boundaries of a distributed transaction must be controlled by an external transaction manager that is

coordinating the work of multiple connections. For this reason, it is an error for applications to call any of the following Connection methods while they are participating in a distributed transaction:

- setAutoCommit(true)
- commit
- rollback
- setSavepoint

The JDBC driver throws an SQLException if one of these operations is attempted on a connection that is participating in a distributed transaction. If the connection is later used for a local transaction, these operations are legal at that point.

Applications should also refrain from calling

Connection.setTransactionIsolation within the bounds of a distributed transaction. The resulting behavior is implementation-defined.

If a connection has auto-commit mode already enabled at the time it joins a global transaction, the attribute will be ignored. The auto-commit behavior will resume when the connection returns to local transaction mode.

12.4.1 Two-phase Commit

The following steps outline how a transaction manager uses XAResource objects to implement the two-phase commit protocol. These steps assume a three-tier architecture where an application server is working with an external transaction manager:

1. The application server gets XAResource objects from two different connections:

// XAConA connects to resource manager A

javax.transaction.xa.XAResource resourceA = XAConA.getXAResource();

// XAConB connects to resource manager B
javax.transaction.xa.XAResource resourceB = XAConB.getXAResource();

CODE EXAMPLE 12-6 Getting the XAResource object from an XAConnection object

- 2. The application server passes the XAResource objects to the transaction manager. The transaction manager does not access the associated XAConnection objects directly.
- 3. The transaction manager uses the XAResource objects to assign a piece of the transaction to each of the associated resource managers. The transaction is identified by *xid*, which represents the identifier generated by the transaction manager when the transaction is created.

```
// Send work to resource manager A. The TMNOFLAGS argument indicates
// we are starting a new branch of the transaction, not joining or
// resuming an existing branch.
resourceA.start(xid, javax.transaction.xa.TMNOFLAGS);
// do work with resource manager A
...
// tell resource manager A that it's done, and no errors have occurred
resourceA.end(xid, javax.transaction.xa.TMSUCCESS);
// do work with resource manager B.
resourceB.start(xid, javax.transaction.xa.TMNOFLAGS);
// B's part of the distributed transaction
...
resourceB.end(xid, javax.transaction.xa.TMSUCCESS);
CODE EXAMPLE 12-7 Starting and ending transaction branches using the XAResource
interface
4. The transaction manager initiates the two-phase commit protocol by asking each
participant to vote:
```

resourceA.prepare(xid); resourceB.prepare(xid);

CODE EXAMPLE 12-8 Initiating two-phase commit

A participating resource manager can vote to roll back the transaction by throwing a javax.transaction.xa.XAException.

5. If both participants vote to commit, the transaction manager tells each one to commit its piece of the distributed transaction (the second parameter tells the resource manager not to use a one phase commit protocol on behalf of the xid):

```
resourceA.commit(xid, false);
resourceB.commit(xid, false);
```

CODE EXAMPLE 12-9 Committing the distributed transaction

6. If either resource manager votes to roll back, the transaction manager tells each one to roll back its piece of the transaction:

```
resourceA.rollback(xid);
resourceB.rollback(xid);
```

CODE EXAMPLE 12-10 Rolling back the distributed transaction

The transaction manager is not required to use the same XAResource object to commit/rollback a transaction branch as was used to execute the branch. If different XAResource objects are used, however, they must be associated with XAConnection objects that connect to the same resource manager.

Note – Steps 1-6 also apply to the case where *XACONA* and *XACONB* are two physical connections to the same resource manager.

12.5 Closing the Connection

In a typical distributed transaction environment, the middle-tier server needs to be notified when an application has finished using a connection. As in the earlier discussion of PooledConnection objects, the middle-tier server will add itself as a ConnectionEventListener so that it will be notified when the application calls the method Connection.close. At this point, the server will notify the transaction manager so that it can end the transaction branch for the corresponding XAResource object. If the server's DataSource implementation includes connection pooling, the connection pooling module will be notified that it can return the physical XAConnection object to the pool.

Note – A distributed transaction may still be active after a participating Connection object is closed. This is not true for local transactions.

12.6 Limitations of the XAResource Interface

The javax.transaction.xa.XAResource interface is limited to defining only the set of methods needed to join and participate in global transactions, as defined by the X/Open XA standard. This allows any resource manager that implements the interface to participate with any other resource manager or transaction manager that has the same level of support.

Functionality that is not defined in the X/Open standard is correspondingly not defined in the XAResource interface. Resource managers that provide for support of features not defined in the X/Open XA standard, such as setting isolation levels in global transactions, will have to do so in an implementation-defined way.

Users who use implementation-defined features should be aware that they will limit the portability of their applications.

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CHAPTER 13

Statements

This section describes the Statement interface and its subclasses, PreparedStatement and CallableStatement. It also describes related topics, including escape syntax, performance hints, and auto-generated keys.

13.1 The Statement Interface

The Statement interface defines methods for executing SQL statements that do not contain parameter markers. The PreparedStatement interface adds methods for setting input parameters, and the CallableStatement interface adds methods for retrieving output parameter values returned from stored procedures.

Note – Any reference to the Statement interface within this specification includes its subclasses PreparedStatement and CallableStatement unless stated otherwise.

13.1.1 Creating Statements

Statement objects are created by Connection objects, as is done in CODE EXAMPLE 13-1.

Connection conn = dataSource.getConnection(user, passwd);

Statement stmt = conn.createStatement()

CODE EXAMPLE 13-1 Creating a Statement object

Each Connection object can create multiple Statement objects that may be used concurrently by the program. This is demonstrated in CODE EXAMPLE 13-2.

// get a connection from the DataSource object ds

Connection conn = ds.getConnection(user, passwd);
// create two instances of Statement
Statement stmt1 = conn.createStatement();
Statement stmt2 = conn.createStatement();

CODE EXAMPLE 13-2 Creating multiple Statement objects from a single connection

13.1.1.1 Setting ResultSet Characteristics

Additional constructors may be used to set the type and concurrency or the type, concurrency, and holdability of any result sets produced by a statement. See Chapter 15 "Result Sets" for more on the ResultSet interface.

CODE EXAMPLE 13-3 creates a Statement object that returns result sets that are scrollable, that are insensitive to changes made while the ResultSet object is open, that can be updated, and that do not close the ResultSet objects when commit is called.

Connection conn = ds.getConnection(user, passwd);

CODE EXAMPLE 13-3 Creating a scrollable, insensitive, updatable result set that stays open after the method commit is called

See Chapter 15 "Result Sets" for more information on ResultSet types.

13.1.2 Executing Statement Objects

The method used to execute a Statement object depends on the type of SQL statement being executed. If the Statement object represents an SQL query returning a ResultSet object, the method executeQuery should be used. If the SQL is known to be a DDL statement or a DML statement returning an update count, the method executeUpdate should be used. If the type of the SQL statement is not known, the method execute should be used.

13.1.2.1 Returning a ResultSet object

CODE EXAMPLE 13-4 shows the execution of an SQL string returning a ResultSet object.

Statement stmt = conn.createStatement();

CODE EXAMPLE 13-4 Executing a Statement object that returns a ResultSet object

If the SQL string being executed does not return a ResultSet object, the method executeQuery throws an SQLException.

13.1.2.2 Returning an Update Count

In CODE EXAMPLE 13-5, the SQL statement being executed returns the number of rows affected by the update for SQL Data Manipulation Language (DML) statements or 0 for SQL statements that return nothing.

Statement stmt = conn.createStatement();

```
int rows = stmt.executeUpdate("update STOCK set ORDER = 'Y' " +
    "where SUPPLY = 0");
if (rows > 0) {
    ...
}
```

CODE EXAMPLE 13-5 Executing a Statement object that returns an update count

The method executeUpdate throws an SQLException if the SQL string being executed returns a ResultSet.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method executeLargeUpdate.

13.1.2.3 Returning Unknown or Multiple Results

If there are multiple results or if the type or number of results returned by a Statement object are not known until run time, the Statement object should be executed with the method execute. The methods getMoreResults, getUpdateCount, and getResultSet can be used to retrieve all the results.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method getLargeUpdateCount.

The method execute returns true if the first result is a ResultSet object and false if it is an update count.

When the method execute returns true, the method getResultSet is called to retrieve the ResultSet object. When execute returns false, the method getUpdateCount returns an int. If this number is greater than or equal to zero, it indicates the update count returned by the statement. If it is -1, it indicates that there are no more results.

If multiple results are being returned, the method getMoreResults can be called to get the next result. As with the method execute, getMoreResults will return true if the next result is a ResultSet object and false if the next result is an update count or no more result are available.

CODE EXAMPLE 13-6 shows how to retrieve all the results from a Statment object.

```
Statement stmt = conn.createStatement();
boolean retval = cstmt.execute(sql_queries);
ResultSet rs;
int count;
do {
                 if (retval == false) {
                     count = stmt.getUpdateCount();
                     if (count == -1) {
                         // no more results
                         break;
                     } else {
                         // process update count
                     }
                  } else { // ResultSet
                     rs = stmt.getResultSet();
                     // process ResultSet
```

retval = stmt.getMoreResults();

while (true);

CODE EXAMPLE 13-6 Executing a statement that returns multiple results

}

By default, each call to the method getMoreResults closes any previous ResultSet object returned by the method getResultSet. However, the method getMoreResults may take a parameter that specifies whether a ResultSet object returned by getResultSet should be closed. The Statement interface defines three constants that can be supplied to the method getMoreResults:

- CLOSE_CURRENT_RESULT indicates that the current ResultSet object should be closed when the next ResultSet object is returned
- KEEP_CURRENT_RESULT indicates that the current ResultSet object should
 not be closed when the next ResultSet object is returned
- CLOSE_ALL_RESULTS indicates that any ResultSet objects that have been kept open should be closed when the next result is returned

If the current result is an update count and not a ResultSet object, any parameter passed to getMoreResults is ignored.

To determine whether a driver implements this feature, an application can call the DatabaseMetaData method supportsMultipleOpenResults.

```
ResultSet rs1 = stmt.getResultSet();
rs1.next();
...
retval = stmt.getMoreResults(Statement.KEEP_CURRENT_RESULT);
if (retval == true) {
    ResultSet rs2 = stmt.getResultSet();
    rs2.next();
    ...
    rs1.next();
}
retval = stmt.getMoreResults(Statement.CLOSE_ALL_RESULTS);
...
CODE EXAMPLE 13-7 Keeping multiple results from a Statement object open
```

13.1.3 Limiting the execution time for Statement Objects

The setQueryTimeout method may be used to specify the minimum amount of time before a a JDBC driver attempts to cancel a running statement. A JDBC driver must apply this limit to the execute, executeBatch, executeQuery and executeUpdate methods. Once the data source has had an opportunity to process the request to terminate the running command, a SQLException will be thrown to the client and no additional processing can occur against the previously running command without re-executing the Statement.

Note – Some JDBC driver implementations may also apply this limit to ResultSet methods. Please consult your driver vendor documentation for details.

Note – In the case of Statement batching, it is implementation defined as to whether the time-out is applied to individual SQL commands added via the addBatch method or to the entire batch of SQL commands invoked by the executeBatch method.

13.1.4 Closing Statement Objects

An application calls the method Statement.close to indicate that it has finished processing a statement. All Statement objects will be closed when the connection that created them is closed. However, it is good coding practice for applications to close statements as soon as they have finished processing them. This allows any external resources that the statement is using to be released immediately.

Closing a Statement object will close and invalidate any instances of ResultSet produced by that Statement object. The resources held by the ResultSet object may not be released until garbage collection runs again, so it is a good practice to explicitly close ResultSet objects when they are no longer needed.

Once a Statement has been closed, any attempt to access any of its methods with the exception of the isClosed or close methods will result in a SQLException being thrown.

These comments about closing Statement objects apply to PreparedStatement and CallableStatement objects as well.

13.2 The PreparedStatement Interface

The PreparedStatement interface extends Statement, adding the ability to set values for parameter markers contained within the statement.

PreparedStatement objects represent SQL statements that can be prepared, or precompiled, for execution once and then executed multiple times. Parameter markers, represented by "?" in the SQL string, are used to specify input values to the statement that may vary at runtime.

13.2.1 Creating a PreparedStatement Object

An instance of PreparedStatement is created in the same manner as a Statement object, except that the SQL command is supplied when the statement is created:

Connection conn = ds.getConnection(user, passwd);

CODE EXAMPLE 13-8 Creating a PreparedStatement object with three placeholder markers

13.2.1.1 Setting ResultSet Characteristics

As with createStatement, the method prepareStatement defines a constructor that can be used to specify the characteristics of result sets produced by that prepared statement.

Connection conn = ds.getConnection(user, passwd);

updatable result sets

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13.2.2 Setting Parameters

The PreparedStatement interface defines setter methods that are used to substitute values for each of the parameter markers in the precompiled SQL string. The names of the methods follow the pattern "set<Type>".

For example, the method setString is used to specify a value for a parameter marker that expects a string. Each of these setter methods takes at least two parameters. The first is always an int equal to the ordinal position of the parameter to be set, starting at 1. The second and any remaining parameters specify the value to be assigned to the parameter.

CODE EXAMPLE 13-10 Setting parameters in a PreparedStatement object

A value must be provided for each parameter marker in the PreparedStatement object before it can be executed. The methods used to execute a PreparedStatement object (executeQuery, executeUpdate and execute) will throw an SQLException if a value is not supplied for a parameter marker.

The values set for the parameter markers of a PreparedStatement object are not reset when it is executed. The method clearParameters can be called to explicitly clear the values that have been set. Setting a parameter with a different value will replace the previous value with the new one.

Note — If, in the execution of a PreparedStatement object, the JDBC driver reads values set for the parameter markers by the methods setAsciiStream, setBinaryStream, setCharacterStream, setNCharacterStream or setUnicodeStream, those parameters must be reset prior to the next execution of the PreparedStatement object otherwise a SQLException will be thrown. A SQLException will also be thrown if the same stream is used by multiple parameter markers within the same PreparedStatement object execution.

Note – For any given Statement, an application should not modify the value argument passed to a setXXX method after the setXXX method is called and before the subsequent execute, executeQuery, executeUpdate, executeBatch or clearParameters method is called. An application may modify the value argument after the execute, executeQuery, executeUpdate, executeBatch or clearParameters method is called, if there is a subsequent setXXX method call that overwrites the previous value or if the Statement is not reused. Failure to conform to this restriction may result in unpredictable behavior.

13.2.2.1 Type Conversions

The data type specified in a PreparedStatement setter method is a data type in the Java programming language. The JDBC driver is responsible for mapping this to the corresponding JDBC type (one of the SQL types defined in java.sql.Types) so that it is the appropriate type to be sent to the data source. The default mapping is specified in Appendix B TABLE B-2.

13.2.2.2 National Character Set Conversions

SQL:2003 provides support for national character set types, which are described in the SQL:2003 specification to be an implementation defined character set. The following JDBC Types may be used to access national character set types: NCHAR, NVARCHAR, LONGNVARCHAR, and NCLOB. These types are analogous to the types CHAR, VARCHAR, LONGVARCHAR and CLOB, except that the values are encoded using an alternate character set, the national character set. Since Java types encode character data using UTF-16, there is no reason to use an alternate Java type to hold these values. However, there may be an advantage to distinguishing CLOB from NCLOB. The JDBC specification uses Strings to represent NCHAR, NVARCHAR, and LONGNVARCHAR data, automatically converting between the Java character set and the national character set. JDBC uses NClob to represent NCLOB values. There is no automatic conversion between Clob and NClob values. Please refer to the Java API docs for java.lang.Character for additional information on how the Java Language uses Unicode.

For maximum portability, an application must indicate to the JDBC driver when a particular value corresponds to a national character type. When specifying a value for a parameter marker which is a national character type, the application would call the setNString, setNCharacterStream, setNClob, or setObject method. If the setObject method is used , the target data type must be specified as Types.NCHAR, Types.NCLOB, Types.NVARCHAR, or Types.LONGNVARCHAR. In the event that an application does not indicate that a parameter marker value corresponds to a national character type, the JDBC driver may interpret the value incorrectly, resulting in the possibility of a data conversion error. In situations where the JDBC driver can detect that a data conversion error might occur, the call to the setXXX method will result in a SQLException being thrown. It might not always possible for the driver to detect that a data conversion error may occur.

If the driver does not support national character types, an attempt to invoke the methods setNString, setNCharacterStream, setNClob or setObject, specifying a target data type as a national character set, may result in a SQLException being thrown.

To retrieve a national character value, an application would call the method getNString, getNClob, getNCharacterStream, or getObject.

13.2.2.3 Type Conversions Using the Method setObject

The method setObject can be used to convert an object in the Java programming language to a JDBC type.

The conversion is explicit when setObject is passed a Java Object and a JDBC data type. The driver will attempt to convert the Object to the specified JDBC type before passing it to the data source. If the object cannot be converted to the target type, an SQLException object is thrown. In CODE EXAMPLE 13-11, a Java Object of type Integer is being converted to the JDBC type SHORT.

Integer value = new Integer(15);
ps.setObject(1, value, java.sql.Types.SHORT);

CODE EXAMPLE 13-11 Converting an Integer object to an SQL SHORT

If setObject is called without a type parameter, the Java Object is implicitly mapped using the default mapping for that object type.

Integer value = new Integer(15);

// value is mapped to java.sql.Types.INTEGER
ps.setObject(1, value);

CODE EXAMPLE 13-12 The method setObject using the default mapping

The default mapping is described in Appendix B TABLE B-4

Note – The method setObject will do custom mapping for SQL UDTs that have a custom mapping. See Chapter 17 "Customized Type Mapping" for more information.

13.2.2.4 Setting NULL Parameters

The method setNull can be used to set any parameter to JDBC NULL. It takes two parameters, the ordinal position of the parameter marker, and the JDBC type of the parameter.

ps.setNull(2, java.sql.Types.VARCHAR);

CODE EXAMPLE 13-13 Setting a String parameter to JDBC NULL

If a Java null is passed to any of the setter methods that take a Java object, the parameter will be set to JDBC NULL.

Note — Not all databases allow for a non-typed Null to be sent to the underly data source. For maximum portability, the setNull or the setObject(int parameterIndex, Object x, int sqlType) method should be used instead of setObject(int parameterIndex, Object x).

13.2.2.5 Clearing Parameters

The values set for IN parameter markers of a PreparedStatement object can be explicitly cleared by invoking the clearParameters method. Any resources that are used by PreparedStatement objects to represent the set values are also released.

13.2.3 Describing Outputs and Inputs of a PreparedStatement Object

The method PreparedStatement.getMetaData retrieves a ResultSetMetaData object containing a description of the columns that will be returned by a prepared statement when is it executed. The ResultSetMetaData object contains a record for each column being returned. Methods in the ResultSetMetaData interface provide information about the number of columns being returned and the characteristics of each column.

```
PreparedStatement pstmt = conn.prepareStatement(
                "SELECT * FROM CATALOG");
ResultSetMetaData rsmd = pstmt.getMetaData();
int colCount = rsmd.getColumnCount();
int colType;
String colLabel;
for (int i = 1; i <= colCount; i++) {
                colType = rsmd.getColumnType(i);
                colLabel = rsmd.getColumnLabel(i);
                ...</pre>
```

CODE EXAMPLE 13-14 Creating a ResultSetMetaData object and retrieving column information from it

The method PreparedStatement.getParameterMetaData returns a ParameterMetaData object describing the parameter markers that appear in the PreparedStatement object. Methods in the ParameterMetaData interface provide information about the number of parameters and their characteristics.

```
PreparedStatement pstmt = conn.prepareStatement(
    "SELECT * FROM BOOKLIST WHERE ISBN = ?");
```

. . .

}

```
ParameterMetaData pmd = pstmt.getParameterMetaData();
int colType = pmd.getParameterType(1);
...
```

CODE EXAMPLE 13-15 Creating a ParameterMetaData object and retrieving parameter information from it

See the API specification for more details.

13.2.4 Executing a PreparedStatement Object

As with Statement objects, the method used to execute a PreparedStatement object depends on the type of SQL statement being executed. If the PreparedStatement object is a query returning a ResultSet object, it should be executed with the method executeQuery. If it is a DML statement returning an update count, it should be executed with the method executeUpdate. The method execute should be used only if the return type of the statement is unknown.

If any of the PreparedStatement execute methods is called with an SQL string as a parameter, an SQLException is thrown.

13.2.4.1 Returning a ResultSet Object

CODE EXAMPLE 13-16 shows a query being prepared and then executed multiple times.

pstmt.close();

CODE EXAMPLE 13-16 Preparing and executing a statement returning a result set

If the statement being executed does not return a ResultSet object an SQLException is thrown by executeQuery.

13.2.4.2 Returning an Update Count

In CODE EXAMPLE 13-17, the SQL statement being prepared and executed returns the number of rows affected by the update for SQL Data Manipulation Language (DML) statements or 0 for SQL statements that return nothing.

CODE EXAMPLE 13-17 Preparing and executing a statement returning an update count

If the statement being executed returns a ResultSet object, an SQLException is thrown.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method executeLargeUpdate.

13.2.4.3 Returning Unknown or Multiple Results

If there are multiple results or if the type or number of results returned by a PreparedStatement object are not known until run time, the PreparedStatement object should be executed with the method execute. The methods getMoreResults, getUpdateCount, and getResultSet can be used to retrieve all the results.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method getLargeUpdateCount.

CODE EXAMPLE 13-18 shows how to retrieve all the results from a PreparedStatment object.

```
PreparedStatement pstmt = conn.prepareStatement(sqlStatement);
boolean retval = pstmt.execute();
ResultSet rs;
int count;
do {
    if (retval == false) {
        count = pstmt.getUpdateCount();
        if (count == -1) {
```

```
// no more results
    break;
    } else {
        // process update count
    }
} else { // ResultSet
    rs = pstmt.getResultSet();
    // process ResultSet
}
retval = cstmt.getMoreResults();
```

while (true);

CODE EXAMPLE 13-18 Executing a prepared statement that returns multiple results

13.3 The CallableStatement Interface

The CallableStatement interface extends PreparedStatement with methods for executing and retrieving results from stored procedures.

13.3.1 Creating a CallableStatement Object

As with Statement and PreparedStatement objects, CallableStatement objects are created by Connection objects. CODE EXAMPLE 13-19 shows the creation of a CallableStatement object for calling the stored procedure 'validate', which has a return parameter and two other parameters.

CODE EXAMPLE 13-19 Creating a CallableStatement object

All the examples in this chapter use the escape syntax for calling stored procedures. See "Stored Procedures and Functions" on page 116.

13.3.2 Setting Parameters

CallableStatement objects may take three types of parameters: IN, OUT, and INOUT. The parameter can be specified as either an ordinal parameter or a named parameter. A value must be set for each parameter marker in the statement that represents an IN or INOUT parameter. The registerOutParameter method must be called for each parameter marker which represents an OUT or INOUT parameter.

The number, type, and attributes of parameters to a stored procedure can be determined using the DatabaseMetaData method getProcedureColumns.

Parameter ordinals, which are integers passed to the appropriate setter method, refer to the parameter markers ("?") in the statement, starting at one. Literal parameter values in the statement do not increment the ordinal value of the parameter markers. In CODE EXAMPLE 13-20, the two parameter markers have the ordinal values 1 and 2.

```
CallableStatement cstmt = con.prepareCall(
"{CALL PROC(?, "Literal_Value", ?)}");
cstmt.setString(1, "First");
cstmt.setString(2, "Third");
```

CODE EXAMPLE 13-20 Specifying ordinal parameters

Named parameters can also be used to specify specific parameters. This is especially useful when a procedure has many parameters with default values. Named parameters can be used to specify only the values that have no default value. The name of a parameter corresponds to the COLUMN_NAME field returned by DatabaseMetaData.getProcedureColumns.

In CODE EXAMPLE 13-21, the procedure COMPLEX_PROC takes ten parameters, but only the first and fifth parameters, PARAM_1 and PARAM_5, are required.

CODE EXAMPLE 13-21 Specifying two input parameters to a stored procedure

Additional methods in the CallableStatement interface allow parameters to be registered and retrieved by name.

The DatabaseMetaData.supportsNamedParameters method can be called to determine if a JDBC driver and underlying data source support specifying named parameters.

It is not possible to combine setting parameters with ordinals and with names in the same statement. If ordinals and names are used for parameters in the same statement, an SQLException is thrown.

Note – In some cases it may not be possible to provide only some of the parameters for a procedure. For example, if the procedure name is overloaded, the data source determines which procedure to call based on the number of parameters. Enough parameters must be provided to allow the data source to resolve any ambiguity.

13.3.2.1 IN Parameters

IN parameters are assigned values using the setter methods as described in "Setting Parameters" on page 100. In CODE EXAMPLE 13-22, a string parameter and a date parameter are set.

cstmt.setString(1, "October"); cstmt.setDate(2, date);

CODE EXAMPLE 13-22 Setting IN parameters

13.3.2.2 OUT Parameters

The method registerOutParameter must be called to set the type for each OUT parameter before a CallableStatement object is executed. When the stored procedure returns from execution, it will use these types to set the values for any OUT parameters.

The values of OUT parameters can be retrieved using the appropriate getter methods defined in the CallableStatement interface. CODE EXAMPLE 13-23 shows the execution of a stored procedure with two OUT parameters, a string and float, and the retrieval of the OUT parameter values.

CODE EXAMPLE 13-23 Registering and retrieving OUT parameters

13.3.2.3 INOUT Parameters

Parameters that are both input and output parameters must be both set by using the appropriate setter method and also registered by calling the registerOutParameter method. The type implied by the setter method (see TABLE B-1 in Appendix B "Data Type Conversion Tables") and the type supplied to the method registerOutParameter must be the same.

CODE EXAMPLE 13-24 shows the stored procedure calc, which takes one INOUT float parameter.

```
CallableStatement cstmt = conn.prepareCall("{CALL CALC(?)}");
cstmt.setFloat(1, 1237.98f);
ctsmt.registerOutParameter(1, java.sql.Types.FLOAT);
cstmt.execute();
float f = cstmt.getFloat(1);
```

CODE EXAMPLE 13-24 Executing a CallableStatement object with an INOUT parameter

13.3.2.4 Clearing Parameters

The values set for IN parameter markers or registered for OUT parameter markers of a CallableStatement object can be explicitly cleared by invoking the clearParameters method. Any resources that are used by CallableStatement objects to represent the set or registered values are also released.

13.3.3 Executing a CallableStatement Object

As with Statement and PreparedStatement objects, the method used to execute a CallableStatement object depends on whether it returns a single ResultSet object, an update count, or multiple mixed results.

13.3.3.1 Returning a Single ResultSet Object

CODE EXAMPLE 13-25 shows the execution of a CallableStatement object that takes one input parameter and returns a single ResultSet object.

```
CallableStatement cstmt = conn.prepareCall("{CALL GETINFO(?)}");
cstmt.setLong(1, 1309944422);
ResultSet rs = cstmt.executeQuery();
```

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CODE EXAMPLE 13-25 Executing a CallableStatement object that returns a single result set

The method executeQuery throws an SQLException if the stored procedure does not return a ResultSet object.

13.3.3.2 Returning an Update Count

CODE EXAMPLE 13-26 shows the execution of a CallableStatement object that returns an update count.

CallableStatement cstmt = conn.prepareCall("{call GETCOUNT(?)}");

```
cstmt.setString(1, "Smith");
int count = cstmt.executeUpdate();
cstmt.close();
```

CODE EXAMPLE 13-26 Executing a CallableStatement object returning an update count

If the stored procedure returns a ResultSet, the method executeUpdate throws an SQLException.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method executeLargeUpdate.

13.3.3.3 Returning Unknown or Multiple Results

If there are multiple results or if the type or number of results returned by a CallableStatement object are not known until run time, the CallableStatement object should be executed with the method execute. The methods getMoreResults, getUpdateCount, and getResultSet can be used to retrieve all the results.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method getLargeUpdateCount.

```
CODE EXAMPLE 13-27 shows how to retrieve all the results from a
CallableStatment object.
CallableStatement cstmt = conn.prepareCall(procCall);
boolean retval = cstmt.execute();
ResultSet rs;
int count;
do {
                  if (retval == false) {
                      count = cstmt.getUpdateCount();
                      if (count == -1) {
                         // no more results
                         break;
                      } else {
                          // process update count
                      }
                  } else { // ResultSet
                      rs = cstmt.getResultSet();
                      // process ResultSet
                  }
                  retval = cstmt.getMoreResults();
```

while (true);

CODE EXAMPLE 13-27 Executing a callable statement that returns multiple results

13.3.3.4 REF Cursor Support

The REF CURSOR data type is supported by several databases. To return a REF CURSOR from a stored procedure, the *CallableStatement* method *registerOutParameter* may be used specifying Types.REF_CURSOR as the data type to be returned. The *CallableStatement* method *getObject*, specifying *ResultSet* as the type to convert the returned object to, would be called to retrieve the *ResultSet* representing the REF CURSOR. The returned result set is a forward, read-only result set.

If *registerOutParameter* is called specifying Types.REF_CURSOR and the JDBC driver does not support this data type, a *SQLFeatureNotSupportedException* will be thrown.

CallableStatement cstmt = conn.prepareCall(" { call mySproc(?) }");

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```
cstmt.registerOutParameter(1, Types.REF_CURSOR);
cstmt.executeQuery();
ResultSet rs = cstmt.getObject(1, ResultSet.class);
while (rs.next ()) {
    System.out.println("Name="+ rs.getString(1));
}
CODE EXAMPLE 13-28 Executing a callable statement that returns a ResultSet using a REF
    CURSOR
```

13.4 Escape Syntax

The SQL string used in a Statement object may include JDBC *escape syntax*. Escape syntax allows the driver to more easily scan for syntax that requires special processing. Implementing this special processing in the driver layer improves application portability.

Special escape processing might be needed for the following:

- commonly used features that do not have standard syntax defined by SQL, or where the native syntax supported by the underlying data source varies widely among vendors. The driver may translate the escape syntax to a specific native syntax in this case.
- features that are not supported by the underlying data source but are implemented by the driver.

Escape processing for a Statement object is turned on or off using the method setEscapeProcessing, with the default being on. The RowSet interface also includes a setEscapeProcessing method. The RowSet method applies to the SQL string used to populate a RowSet object. The setEscapeProcessing method does not work for a PreparedStatement object because its SQL string may have been precompiled when the PreparedStatement object was created.

JDBC defines escape syntax for the following:

- scalar functions
- date and time literals
- outer joins
- calling stored procedures and functions
- escape characters for LIKE clauses

13.4.1 **Scalar Functions**

Almost all underlying data sources support numeric, string, time, date, system, and conversion functions on scalar values. The escape syntax to access a scalar function is:

{fn <function-name> (argument list)}

For example, the following code calls the function concat with two arguments to be concatenated:

{fn concat("Hot", "Java")}

The following syntax gets the name of the current database user:

{fn user()}

Scalar functions may be supported by different data sources with slightly different native syntax, and they may not be supported by all drivers. The driver will either map the escaped function call into the native syntax or implement the function directly.

Various DatabaseMetaData methods list the functions that are supported. For example, the method getNumericFunctions returns a comma-separated list of the Open Group CLI names of numeric functions, the method getStringFunctions returns string functions, and so on.

Appendix C "Scalar Functions" provides a list of the scalar functions a driver is expected to support. A driver is required to implement these functions only if the data source supports them, however.

The escape syntax for scalar functions must only be used to invoke the scalar functions defined in Appendix C "Scalar Functions". The escape syntax is not intended to be used to invoke user-defined or vendor specific scalar functions.

13.4.2 **Date and Time Literals**

Data sources differ widely in the syntax they use for date, time, and timestamp literals. The JDBC API supports ISO standard format for the syntax of these literals, using an escape clause that the driver translates to native syntax.

The escape syntax for date literals is:

{d 'yyyy-mm-dd'}

The driver will replace the escape clause with the equivalent native representation. For example, the driver might replace {d '1999-02-28'} with '28-FEB-99' if that is the appropriate format for the underlying data source.

The escape syntax for TIME and TIMESTAMP literals are:

{t 'hh:mm:ss'}

{ts 'yyyy-mm-dd hh:mm:ss.f . . .'}

The fractional seconds (.f...) portion of the timestamp can be omitted.

Note – The leading zero may be omitted when specifying the mm or dd in date or timestamp literals

13.4.3 **Outer Joins**

Outer joins are an advanced feature and are not supported by all data sources. Consult relevant SQL documentation for an explanation of outer joins.

The escape syntax for an outer join is:

{oj <outer-join>}

where <outer-join> has the form:

table {LEFT | RIGHT | FULL} OUTER JOIN {table | <outer-join>} ON search-condition

(Note that curly braces ({}) in the preceding line indicate that one of the items between them must be used; they are not part of the syntax.) The following SELECT statement uses the escape syntax for an outer join.

```
Statement stmt = con.createStatement();
stmt.executeQuery("SELECT * FROM {oj TABLE1 " +
          "LEFT OUTER JOIN TABLE2 ON DEPT_NO = 003420930}");
```

The JDBC API provides three DatabaseMetaData methods for determining the kinds of outer joins a driver supports: supportsOuterJoins, supportsFullOuterJoins, and supportsLimitedOuterJoins.

13.4.4 Stored Procedures and Functions

If a database supports stored procedures, they can be invoked using JDBC escape syntax as follows:

{call <procedure_name> [(<argument-list>)]}

or, where a procedure returns a result parameter:

{? = call <procedure_name> [(<argument-list>)]}

The square brackets indicate that the (argument-list) portion is optional. Input arguments may be either literals or parameter markers. See "Setting Parameters" on page 108 for information on parameters.

The method DatabaseMetaData.supportsStoredProcedures returns true if the database supports stored procedures.

JDBC drivers may optionally provide support for invoking user-defined or vendor defined functions using the escape syntax for stored procedures.

The method DatabaseMetaData.supportsStoredFunctionsUsingCallSyntax returns true if the database supports invoking user-defined or vendor defined functions using the escape syntax for stored procedures. Please consult the documentation for your JDBC driver for additional information

13.4.5 **LIKE Escape Characters**

The percent sign (%) and underscore (_) characters are wild card characters in SQL LIKE clauses (% matches zero or more characters, and _ matches exactly one character). In order to interpret them literally, they can be preceded by a backslash (\), which is a special escape character in strings. One can specify which character to use as the escape character by including the following syntax at the end of a LIKE predicate:

{escape '<escape-character>'}

For example, the following query uses the backslash as an escape character, and finds identifier names that begin with an underscore. Note that the Java compiler will not recognize the backslash as a character unless it is preceded by a backslash.

13.4.6 Limiting Returned Rows Escape

The escape syntax for limiting the number of rows returned by a query is:

{limit <limit clause>}

where the format for the <limit clause> is:

rows [offset row_offset]

The square brackets indicate that the 'offset row_offset' portion is optional. The value given for rows indicates the maximum number of rows to be returned from this query. The row_offset indicates the number of rows to skip from the rows returned from the query before begining to return rows. A value of 0 for row_offset means do not skip any rows. The value for rows and row_offset must be a 0 or greater integer value.

CODE EXAMPLE 13-29 Using the limit Escape Syntax

Note – A value of 0 for rows may return no rows or all rows depending on the underlying database.

13.5 Performance Hints

The Statement interface has two methods that can be used to provide hints to a JDBC driver: setFetchDirection and setFetchSize. The values supplied to these methods are applied to each result set produced by the statement. The methods of the same name in the ResultSet interface can be used to supply hints for just that result set.

Hints provided to the driver via this interface may be ignored by the driver if they are not appropriate.

The methods getFetchDirection and getFetchSize return the current value of the hints. If either of these methods is called before the corresponding setter method has been called, the value returned is implementation-defined.

13.6 Retrieving Auto Generated Values

Many database systems have a mechanism that automatically generates a value when a row is inserted. The value that is generated may or may not be unique or represent a key value depending on the executed SQL, table definition and the configuration of the data source. The method Statement.getGeneratedKeys, which can be called to retrieve the generated value, returns a ResultSet object with a column for each automatically generated value. The methods execute, executeUpdate or Connection.prepareStatement accept an optional parameter, which can be used to indicate that any auto generated values should be returned when the statement is executed or prepared.

CODE EXAMPLE 13-30 Retrieving auto generated keys

Additional methods allow the ordinals or names of the columns that should be returned to be specified as an array. If the columns are not specified, the JDBC driver implementation will determine the columns or value to return.

In CODE EXAMPLE 13-31 the Statement method executeUpdate is called with two parameters, the first is the SQL statement to be executed, the second is an array of String containing the column name that should be returned when getGeneratedKeys is called:

```
String keyColumn[] = {"ORDER_ID"};
...
Statement stmt = conn.createStatement();
```

The result of invoking the method getGeneratedKeys when auto-commit is true is implementation-defined. In order to increase application portability when retrieving auto generated values, the Connection auto-commit attribute should be set to false.

It is implementation-defined as to whether getGeneratedKeys will return generated values after invoking the executeBatch method.

See the API Specification for more details.

Calling ResultSet.getMetaData on the ResultSet object returned by getGeneratedKeys will produce a ResultSetMetaData object that can be used to determine the number, type and properties of the generated value.

In some cases, such as in an insert select statement, more than one value may be returned. The ResultSet object returned by getGeneratedKeys will contain a row for each value that a statement generated. If no values are generated, an empty result set will be returned.

The concurrency of the ResultSet object returned by getGeneratedKeys must be CONCUR_READ_ONLY. The type of the ResultSet object must be either TYPE_FORWARD_ONLY or TYPE_SCROLL_INSENSITIVE.

The method DatabaseMetaData.supportsGetGeneratedKeys returns true if a JDBC driver and underlying data source support the retrieval of automatically generated values. If a value of true is returned by the call to supportsGetGeneratedKeys, a JDBC driver must support the return of autogenerated values for SQL INSERT statements. Some JDBC driver implementations might also support auto-generated values with SQL statements other than INSERT. Please consult your JDBC driver documentation for details.

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CHAPTER **14**

Batch Updates

The batch update facility allows multiple SQL statements to be submitted to a data source for processing at once. Submitting multiple SQL statements, instead of individually, can greatly improve performance. Statement, PreparedStatement, and CallableStatement objects can be used to submit batch updates.

14.1 Description of Batch Updates

14.1.1 Statements

The batch update facility allows a Statement object to submit a set of heterogeneous SQL statements together as a single unit, or batch, to the underlying data source.

Since the JDBC 2.0 API, a Statement object has had the ability to keep track of a list of commands—or batch—that can be submitted together for execution. When a Statement object is created, its associated batch is empty. An application adds commands to a statement's batch one at a time by calling the method Statement.addBatch and providing it with the SQL statement to be added. Any of the commands added to a batch must return a simple update count and must not return a ResultSet.

If an application decides not to submit a batch of commands that has been constructed for a statement, it can call the method Statement.clearBatch to clear the batch of all commands.

In CODE EXAMPLE 14-1, all of the SQL statements required to insert a new employee into a fictitious company database are submitted as a single batch.

```
// turn off autocommit
con.setAutoCommit(false);
Statement stmt = con.createStatement();
stmt.addBatch("INSERT INTO employees VALUES (1000, 'Joe Jones')");
stmt.addBatch("INSERT INTO departments VALUES (260, 'Shoe')");
stmt.addBatch("INSERT INTO emp_dept VALUES (1000, 260)");
```

```
// submit a batch of update commands for execution
int[] updateCounts = stmt.executeBatch();
```

CODE EXAMPLE 14-1 Creating and executing a batch of insert statements

In the example, auto-commit mode is disabled to prevent the driver from committing the transaction when Statement.executeBatch is called. Disabling auto-commit allows an application to decide whether or not to commit the transaction in the event that an error occurs and some of the commands in a batch cannot be processed successfully. For this reason, auto-commit should always be turned off when batch updates are done. The commit behavior of executeBatch is always implementation-defined when an error occurs and auto-commit is true.

It is not possible to set a savepoint "within" a batch of statements to enable partial recovery. If a savepoint is set any time before the method executeBatch is called, it is set before any of the statements that have been added to the batch are executed.

Although the focus in this section is on using Statement objects to do batch updates, the discussion that follows applies to PreparedStatment and CallableStatement objects as well.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method executeLargeBatch.

14.1.2 Successful Execution

The Statement.executeBatch method submits a statement's batch to the underlying data source for execution. Batch commands are executed serially (at least logically) in the order in which they were added to the batch. When all of the commands in a batch execute successfully, the method executeBatch returns an integer array containing one entry for each command in the batch.

The entries in the array are ordered according to the order in which the commands were processed (which, again, is the same as the order in which the commands were originally added to the batch). When all of the commands in a batch have been executed successfully, an entry in the array of update counts may have the following values :

- 0 or greater the command was processed successfully and the value is an update count indicating the number of rows in the database that were affected by the command's execution
- Statement.SUCCESS_NO_INFO the command was processed successfully, but the number of rows affected is unknown

Calling the method executeBatch closes the calling Statement object's current result set if one is open. The statement's batch is reset to empty once executeBatch returns. The behavior of the methods executeQuery, executeUpdate, and execute is implementation-defined when a statement's batch is non-empty.

Only DDL and DML commands that return a simple update count may be executed as part of a batch. The method executeBatch throws a BatchUpdateException if any of the commands in the batch fail to execute properly or if a command attempts to return a result set. When a BatchUpdateException is thrown, an application can call the BatchUpdateException.getUpdateCounts method to obtain an integer array of update counts that describes the outcome of the batch execution.

Note – It is implementation-defined as to whether

Statement.getGeneratedKeys will return generated values after invoking the executeBatch or executeLargeBatch methods.

14.1.3 Handling Failures during Execution

A JDBC driver may or may not continue processing the remaining commands in a batch once execution of a command fails. However, a JDBC driver must always provide the same behavior with a particular data source. For example, a driver cannot continue processing after a failure for one batch and not continue processing for another batch.

If a driver stops processing after the first failure, the array returned by the method <code>BatchUpdateException.getUpdateCounts</code> will always contain fewer entries than there were statements in the batch. Since statements are executed in the order that they are added to the batch, if the array contains N elements, this means that the first N elements in the batch were processed successfully when <code>executeBatch</code> was called.

When a driver continues processing in the presence of failures, the number of elements in the array returned by the method

BatchUpdateException.getUpdateCounts always equals the number of commands in the batch. When a BatchUpdateException object is thrown and the driver continues processing after a failure, the array of update counts will contain the following BatchUpdateException constant:

 Statement.EXECUTE_FAILED — the command failed to execute successfully. This value is also returned for commands that could not be processed for some reason—such commands fail implicitly.

JDBC drivers that do not continue processing after a failure never return Statement.EXECUTE_FAILED in an update count array. Drivers of this type simply return a status array containing an entry for each command that was processed successfully.

A JDBC technology-based application can distinguish a JDBC driver that continues processing after a failure from one that does not by examining the size of the array returned by BatchUpdateException.getUpdateCounts. A JDBC driver that continues processing always returns an array containing one entry for each element in the batch. A JDBC driver that does not continue processing after a failure will always return an array whose number of entries is less than the number of commands in the batch.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method BatchUpdateException.getLargeUpdateCounts.

14.1.4 PreparedStatement Objects

When a PreparedStatement object is used, a command in a batch consists of a parameterized SQL statement and an associated set of parameters. The batch update facility is used with a PreparedStatement object to associate multiple sets of input parameter values with a single PreparedStatement object. The sets of parameter values together with their associated parameterized update commands can then be sent to the underlying data source engine for execution as a single unit.

CODE EXAMPLE 14-2 inserts two new employee records into a database as a single batch. The PreparedStatement interface setter methods are used to create each parameter set, one for each employee. The PreparedStatement.addBatch method adds a set of parameters to the current command.

// turn off autocommit
con.setAutoCommit(false);

```
PreparedStatement stmt = con.prepareStatement(
              "INSERT INTO employees VALUES (?, ?)");
stmt.setInt(1, 2000);
stmt.setString(2, "Kelly Kaufmann");
stmt.addBatch();
stmt.setInt(1, 3000);
stmt.setString(2, "Bill Barnes");
stmt.addBatch();
// submit the batch for execution
int[] updateCounts = stmt.executeBatch();
```

CODE EXAMPLE 14-2 Creating and executing a batch of prepared statements

Finally, the method PreparedStatement.executeBatch is called to submit the updates to the underlying data source. Calling this method clears the statement's associated list of commands. The array returned by PreparedStatement.executeBatch contains an element for each set of parameters in the batch, similar to the case for Statement objects. Each element contains either an update count or the generic 'success' indicator SUCCESS_NO_INFO.

Error handling in the case of PreparedStatement objects is the same as error handling in the case of Statement objects. Some drivers may stop processing as soon as an error occurs, while others may continue processing the rest of the batch.

As with Statement objects, the number of elements in the array returned by BatchUpdateException.getUpdateCounts indicates whether or not the driver continues processing after a failure. The same three array element values are possible: 0 or higher, Statement.SUCCESS_NO_INFO, or Statement.EXECUTE_FAILED. The order of the entries in the array is the same

order as the order in which commands were added to the batch.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the methods <code>executeLargeBatch</code> and <code>BatchUpdateException.getLargeUpdateCounts.</code>

14.1.5 CallableStatement Objects

The batch update facility works the same with CallableStatement objects as it does with PreparedStatement objects. Multiple sets of input parameter values may be associated with a CallableStatement object and sent to the underlying data source together.

Stored procedures invoked using the batch update facility with a callable statement must return a maximum of one update counts, if no update count is returned the array element value will be Statement.SUCCESS_NO_INFO. Additionally, a batchable stored procedure may not have OUT or INOUT parameters. The CallableStatement.executeBatch method throws an SQLException, not a sub-class of SQLException, if this restriction is violated. Error handling is analogous to that for PreparedStatement objects.

Note – If your database supports returning an update count that may exceed Integer.MAX_VALUE, use the method executeLargeBatch.

CHAPTER 15

Result Sets

The ResultSet interface provides methods for retrieving and manipulating the results of executed queries.

15.1 Kinds of ResultSet Objects

ResultSet objects can have different functionality and characteristics. These characteristics are result set type, result set concurrency, and cursor holdability.

15.1.1 ResultSet Types

The type of a ResultSet object determines the level of its functionality in two main areas: (1) the ways in which the cursor can be manipulated and (2) how concurrent changes made to the underlying data source are reflected by the ResultSet object. The latter is called the *sensitivity* of the ResultSet object.

The three different ResultSet types are described below.

- 1. TYPE_FORWARD_ONLY
 - The result set is not scrollable; its cursor moves forward only, from before the first row to after the last row.
 - The rows contained in the result set depend on how the underlying database materializes the results. That is, it contains the rows that satisfy the query at either the time the query is executed or as the rows are retrieved.
- 2. TYPE_SCROLL_INSENSITIVE
 - The result set is scrollable; its cursor can move both forward and backward relative to the current position, and it can move to an absolute position.

- The result set is insensitive to changes made to the underlying data source while it is open. It contains the rows that satisfy the query at either the time the query is executed or as the rows are retrieved.
- 3. TYPE_SCROLL_SENSITIVE
 - The result set is scrollable; its cursor can move both forward and backward relative to the current position, and it can move to an absolute position.
 - The result set reflects changes made to the underlying data source while the result set remains open.

The default ResultSet type is TYPE_FORWARD_ONLY.

The method DatabaseMetaData.supportsResultSetType returns true if the specified type is supported by the driver and false otherwise.

If the driver does not support the type supplied to the methods createStatement, prepareStatement, or prepareCall, it generates an SQLWarning on the Connection object that is creating the statement. When the statement is executed, the driver returns a ResultSet object of a type that most closely matches the requested type. An application can find out the type of a ResultSet object by calling the method ResultSet.getType.

15.1.2 ResultSet Concurrency

The concurrency of a ResultSet object determines what level of update functionality is supported.

The two concurrency levels are:

CONCUR_READ_ONLY

The ResultSet object cannot be updated using the ResultSet interface.

CONCUR_UPDATABLE

The ResultSet object can be updated using the ResultSet interface.

The default ResultSet concurrency is CONCUR_READ_ONLY.

The method DatabaseMetaData.supportsResultSetConcurrency returns true if the specified concurrency level is supported by the driver and false otherwise.

If the driver does not support the concurrency level supplied to the methods createStatement, prepareStatement, or prepareCall, it generates an SQLWarning on the Connection object that is creating the statement. An application can find out the concurrency of a ResultSet object by calling the method ResultSet.getConcurrency.

If the driver cannot return a ResultSet object at the requested type and concurrency, it determines the appropriate type before determining the concurrency.

15.1.3 ResultSet Holdability

Calling the method Connection.commit can close the ResultSet objects that have been created during the current transaction. In some cases, however, this may not be the desired behaviour. The ResultSet property holdability gives the application control over whether ResultSet objects (cursors) are closed when commit is called.

The following ResultSet constants may be supplied to the Connection methods createStatement, prepareStatement, and prepareCall:

1. HOLD_CURSORS_OVER_COMMIT

- ResultSet objects (cursors) are not closed; they are held open when the method commit is called.
- 2. CLOSE_CURSORS_AT_COMMIT
- ResultSet objects (cursors) are closed when commit is called. Closing cursors at commit can result in better performance for some applications.

15.1.3.1 Determining ResultSet Holdability

The default holdability of ResultSet objects is implementation defined. The DatabaseMetaData method getResultSetHoldability can be called to determine the default holdability of result sets returned by the underlying data source.

If the driver does not support the holdability level supplied to the methods createStatement, prepareStatement, or prepareCall, it generates an SQLWarning on the Connection object that is creating the statement. In the case of a SQL CALL statement, the holdability of any returned ResultSets are determined by the stored procedure, independent of the holdability level specified to the SQL CALL statement.

It is the application's responsibility, not the JDBC driver implementation, to validate the holdability of the returned ResultSet. An application can find out the holdability of a ResultSet object by calling the method ResultSet.getHoldability.

15.1.4 Specifying ResultSet Type, Concurrency and Holdability

The parameters supplied to the methods Connection.createStatement, Connection.prepareStatement, and Connection.prepareCall determine the type, concurrency, and holdability of ResultSet objects that the statement produces. CODE EXAMPLE 15-1 creates a Statement object that will return scrollable, read-only ResultSet objects that are insensitive to updates made to the data source and that will be closed when the transaction in which they were created is committed.

The Statement, PreparedStatement and CallableStatement interfaces also provide setter and getter methods for each of these properties.

15.2 Creating and Manipulating ResultSet Objects

15.2.1 Creating ResultSet Objects

A ResultSet object is most often created as the result of executing a Statement object. The Statement methods executeQuery and getResultSet both return a ResultSet object, as do various DatabaseMetaData methods. CODE EXAMPLE 15-2 executes an SQL statement returning a ResultSet object.

CODE EXAMPLE 15-2 Executing a query returning a ResultSet object

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For each book in the table booklist, the ResultSet object will contain a row consisting of three columns, author, title, and isbn. The following sections detail how these rows and columns can be retrieved.

15.2.2 Cursor Movement

A ResultSet object maintains a cursor, which points to its current row of data. When a ResultSet object is first created, the cursor is positioned before the first row. The following methods can be used to move the cursor:

- next() moves the cursor forward one row. Returns true if the cursor is now
 positioned on a row and false if the cursor is positioned after the last row.
- previous() moves the cursor backwards one row. Returns true if the cursor is now positioned on a row and false if the cursor is positioned before the first row.
- first() moves the cursor to the first row in the ResultSet object. Returns true if the cursor is now positioned on the first row and false if the ResultSet object does not contain any rows.
- last() moves the cursor to the last row in the ResultSet object. Returns true if the cursor is now positioned on the last row and false if the ResultSet object does not contain any rows.
- beforeFirst() positions the cursor at the start of the ResultSet object, before the first row. If the ResultSet object does not contain any rows, this method has no effect.
- afterLast() positions the cursor at the end of the ResultSet object, after the last row. If the ResultSet object does not contain any rows, this method has no effect.
- relative(int rows) moves the cursor relative to its current position.

If rows is 0 (zero), the cursor is unchanged. If rows is positive, the cursor is moved forward rows rows. If the cursor is less than the specified number of rows from the last row, the cursor is positioned after the last row. If rows is negative, the cursor is moved backward rows rows. If the cursor is less than rows rows from the first row, the cursor is positioned before the first row.

The method relative returns true if the cursor is positioned on a valid row and false otherwise.

If rows is 1, relative is identical to the method next. If rows is -1, relative is identical to the method previous.

 absolute(int row) — positions the cursor on the row-th row of the ResultSet object. If row is positive, the cursor is moved row rows from the beginning of the ResultSet object. The first row is 1, the second 2, and so on. If row is greater than the number of rows in the ResultSet object, the cursor is positioned after the last row.

If row is negative, the cursor is moved row rows from the end of the ResultSet object. The last row is -1, the penultimate -2, and so on. If row is greater than the number of rows in the ResultSet object, the cursor is positioned before the first row.

Calling absolute(0) moves the cursor before the first row.

For a ResultSet object that is of type TYPE_FORWARD_ONLY, the only valid cursor movement method is next. All other cursor movement methods throw an SQLException.

15.2.3 Retrieving Values

The ResultSet interface provides methods for retrieving the values of columns from the row where the cursor is currently positioned.

Two getter methods exist for each JDBC type: one that takes the column index as its first parameter and one that takes the column label.

The columns are numbered from left to right, as they appear in the select list of the query, starting at 1.

Column labels supplied to getter methods are case insensitive. If a select list contains the same column more than once, the first instance of the column will be returned.

The index of the first instance of a column label can be retrieved using the method findColumn. If the specified column is not found, the method findColumn throws an SQLException.

ResultSet rs = stmt.executeQuery(sqlstring); int colIdx = rs.findColumn("ISBN");

CODE EXAMPLE 15-3 Mapping a column label to a column index

15.2.3.1 Data Type Conversions

The recommended ResultSet getter method for each JDBC type is shown in B.6 on page B-198. This table also shows all of the possible conversions that a JDBC driver may support. The method DataBaseMetaData.supportsConvert(int fromType, int toType) returns true if the driver supports the given conversion.

15.2.3.2 ResultSet Metadata

When the ResultSet method getMetaData is called on a ResultSet object, it returns a ResultSetMetaData object describing the columns of that ResultSet object. In cases where the SQL statement being executed is unknown until runtime, the result set metadata can be used to determine which of the getter methods should be used to retrieve the data. In CODE EXAMPLE 15-4, result set metadata is used to determine the type of each column in the result set.

CODE EXAMPLE 15-4 Retrieving result set metadata

15.2.3.3 Retrieving NULL values

The method wasNull can be called to determine if the last value retrieved was a SQL <code>NULL</code> in the database.

When the column value in the database is SQL NULL, it may be returned to the Java application as null, 0, or false, depending on the type of the column value. Column values that map to Java Object types are returned as a Java null; those that map to numeric types are returned as 0; those that map to a Java boolean are returned as false. Therefore, it may be necessary to call the wasNull method to determine whether the last value retrieved was a SQL NULL.

15.2.4 Modifying ResultSet Objects

ResultSet objects with concurrency CONCUR_UPDATABLE can be updated using ResultSet methods. Columns can be updated and rows can be deleted using methods defined in the ResultSet interface. New rows may also be inserted if a JDBC driver supports these optional ResultSet interface methods.

15.2.4.1 Updating a Row

Updating a row in a ResultSet object is a two-phase process. First, the new value for each column being updated is set, and then the change is applied to the row. The row in the underlying data source is not updated until the second phase is completed.

The ResultSet interface contains two update methods for each JDBC type, one specifying the column to be updated as an index and one specifying the column label as it appears in the select list.

Column labels supplied to updater methods are case insensitive. If a select list contains the same column more than once, the first instance of the column will be updated.

If an update method is called on a ResultSet whose concurrency level is ResultSet.CONCUR_READ_ONLY, then a SQLException must be thrown.

The method updateRow is used to apply all column changes to the current row, and to clear the record of changes made by prior update methods. The changes are not made to the row until updateRow has been called. If updateRow is called on a ResultSet whose concurrency level is ResultSet.CONCUR_READ_ONLY, then a SQLException must be thrown. If the concurrency level is ResultSet.CONCUR_UPDATABLE and updateRow is called without changes being made to the row, the call will be considered a no-op.

The method cancelRowUpdates can be used to back out changes made to the row before the method updateRow is called. CODE EXAMPLE 15-5 shows the current row being updated to change the value of the column "author" to "Zamyatin, Evgenii Ivanovich":

CODE EXAMPLE 15-5 Updating a row in a ResultSet object

The method DatabaseMetaData.ownUpdatesAreVisible(int type) returns true if a ResultSet object of the specified type is able to see its own updates and false otherwise.

The method DatabaseMetaData.othersUpdatesAreVisible(int type) checks whether updates made by others (another transaction or another update operation in the same transaction) are visible to ResultSet objects of the specified type. This method returns true if a row updated by others is visible and false if it is not.

A ResultSet object may be able to use the method rowUpdated to detect rows that have had the method updateRow called on them. The method DatabaseMetaData.updatesAreDetected(int type) returns true if a ResultSet object of the specified type can determine if a row is updated using the method rowUpdated and false otherwise.

For any given ResultSet, an application should not modify the value argument passed to a updateXXX method after the updateXXX method is called and before the subsequent updateRow or cancelRowUpdates method is called. An application may modify the value argument after the updateRow or cancelRowUpdates method is called, if there is updateXXX that overwrites the previous value or if the update row is not reused. Failure to conform to this restriction may result in unpredictable behavior.

15.2.4.2 Deleting a Row

A row in a ResultSet object can be deleted using the method deleteRow. CODE EXAMPLE 15-6 shows the fourth row of the ResultSet *rs* being deleted.

```
rs.absolute(4);
rs.deleteRow();
```

CODE EXAMPLE 15-6 Deleting a row in a ResultSet object

After the method deleteRow has been called, the current row is deleted in the underlying data source. This deletion is visible as a change in the open ResultSet object if the row is either removed or replaced by an empty or invalid row.

If the deleted row is removed or replaced by an empty row, the method DatabaseMetaData.ownDeletesAreVisible(int type) will return true. It returns false if the ResultSet object still contains the deleted row, which means that the deletion is not visible as a change to ResultSet objects of the given type.

The method DatabaseMetaData.othersDeletesAreVisible(int type) checks whether deletions made by others (another transaction or another delete operation in the same transaction) are visible to ResultSet objects of the specified type. This method returns true if a row deleted by others is visible and false if it is not.

If a ResultSet object can detect deletions, the ResultSet method rowDeleted returns true when the current row has been deleted and false when it has not. However, rowDeleted also returns false if the ResultSet object cannot detect deletions. The method DatabaseMetaData.deletesAreDetected(int type) can be called to see whether a ResultSet object of the specified type can call the method rowDeleted to detect a deletion that is visible. The method deletesAreDetected returns false if a row deleted from the ResultSet object is removed from it and true if the deleted row is replaced by an empty or invalid row.

In CODE EXAMPLE 15-7, application code uses metadata to process a ResultSet object that may contain deleted rows.

```
if (dbmd.ownDeletesAreVisible(ResultSet.TYPE_SCROLL_INSENSITIVE) &&
    dbmd.deletesAreDetected(ResultSet.TYPE_SCROLL_INSENSITIVE)) {
    while (rs.next) {
                 if (rs.rowDeleted()) {
                      continue;
                  } else {
                     // process row
                      . . .
                  }
    }
} else {
    // if up-to-date data is needed, it is better to close this
    // ResultSet object and reexecute the query to get an updated
    // ResultSet object
    . . .
    rs.close();
    break;
}
```

CODE EXAMPLE 15-7 Processing a ResultSet object containing deleted rows

Note – CODE EXAMPLE 15-7 does not cover the case where ownDeletesAreVisible returns true and deletesAreDetected returns false. This will cause an SQLException to be thrown when the cursor is positioned on a deleted row, so an implementation with these characteristics requires that an application handle the exception. Such an implementation does not appear to be a very likely.

After the method deleteRow has been called, the cursor will be positioned before the next valid row. If the deleted row is the last row, the cursor will be positioned after the last row.

15.2.4.3 Inserting a Row

New rows may be inserted using the ResultSet interface providing the JDBC driver supports these optional methods. If the JDBC driver does not support inserting rows using the ResultSet interface, a SQLFeatureNotSupportedException must be thrown when the optional methods are invoked. New rows are constructed in a special *insert row*. The steps to insert a new row are:

- 1. Move the cursor to the insert row
- 2. Set the values for the columns of the row using the ResultSet interface update methods
- 3. Insert the new row into the ResultSet object

CODE EXAMPLE 15-8 shows the steps necessary to insert a new row into the table <code>booklist</code>.

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rs.moveToCurrentRow();

CODE EXAMPLE 15-8 Inserting a new row into a ResultSet object

Each column in the insert row that does not allow null as a value and does not have a default value must be given a value using the appropriate update method. If this is not the case, the method insertRow will throw an SQLException.

The method DatabaseMetaData.ownInsertsAreVisible(int type) will return true if newly inserted rows can be seen in result sets of the specified type.

The method DatabaseMetaData.othersInsertsAreVisible(int type) checks whether inserts made by others (another transaction or another insert operation in the same transaction) are visible to ResultSet objects of the specified type. This method returns true if a row inserted by others is visible and false if it is not.

If the ResultSet objects of the specified type can identify newly inserted rows, the method DatabaseMetaData.insertsAreDetected(int type) will return true. This indicates that the inserted rows are visible to the ResultSet object.

For any given ResultSet, an application should not modify the value argument passed to a updateXXX method after the updateXXX method is called and before the subsequent insertRow method is called. An application may modify the value argument after the insertRow method is called, if there is updateXXX that overwrites the previous value or if the insert row is not reused. Failure to conform to this restriction may result in unpredictable behavior.

15.2.4.4 Positioned Updates and Deletes

JDBC drivers or DBMSs that do not support performing updates via the ResultSet interface may support positioned updates and deletes via SQL commands. This method of updating a row relies on using named cursors to allow multiple statements to act on a single result set. CODE EXAMPLE 15-9 shows the use of the method setCursorName to associate a cursor with a Statement object and then the use of the method getCursorName to retrieve the name for use by a second Statement object.

```
Statement stmt1 = conn.createStatement();
stmt1.setCursorName("CURSOR1");
ResultSet rs = stmt1.executeQuery("select author, title, isbn " +
                             "from booklist for update of author");
// move to the row we want to update
while ( ... ) {
```

```
rs.next()
```

```
}
String cursorName = rs.getCursorName();
Statement stmt2 = conn.createStatement();
// now update the row
int updateCount = stmt2.executeUpdate("update booklist " +
         "set author = 'Zamyatin, Evgenii Ivanovich' " +
         "where current of " + cursorName);
```

CODE EXAMPLE 15-9 Updating a row using positioned updates

The method DatabaseMetaData.supportsPositionedUpdates returns true if the JDBC driver and DBMS support this facility.

15.2.5 Closing a ResultSet Object

A ResultSet object is explicitly closed when

- The close method on the ResultSet is executed, thereby releasing any external resources
- The Statement or Connection object that produced the ResultSet is explicitly closed

A ResultSet object is implicitly closed when

- The associated Statement object is re-executed
- The ResultSet is created with a Holdability of CLOSE_CURSORS_AT_COMMIT and an implicit or explicit commit occurs

Note – Some JDBC driver implementations may also implicitly close the ResultSet when the ResultSet type is TYPE_FORWARD_ONLY and the next method of ResultSet returns false.

Once a ResultSet has been closed, any attempt to access any of its methods with the exception of the isClosed or close methods will result in a SQLException being thrown. ResultSetMetaData instances that were created by a ResultSet that has been closed are still accessible.

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Note – The closing of a ResultSet object does not close the Blob, Clob, NClob or SQLXML objects created by the ResultSet. Blob, Clob, NClob and SQLXML objects remain valid for at least the duration of the transation in which they are created, unless their free method is invoked.

CHAPTER 16

Advanced Data Types

Chapter 16 "Advanced Data Types" and Chapter 17 "Customized Type Mapping" discuss additions to the JDBC API that allow an application written in the Java programming language to access SQL:2003 data types, such as binary large objects and structured types. This chapter also describes the use of the RowId data type which is supported by many data sources even though it is not currently defined as an SQL:2003 data type. If a data source does not support an advanced data type described in these two chapters, a driver for that data source is not required to implement the methods and interfaces associated with that data type.

16.1 Taxonomy of SQL Types

The latest version of the ANSI/ISO SQL standard is commonly referred to as *SQL*:2003. The JDBC API incorporates a model of the SQL:2003 data types that includes only those properties that are essential to exchanging data between a database and an application written in the Java programming language.

SQL:2003 specifies these data types:

- SQL92 built-in types—the familiar SQL 'column types'
 - CHAR
 - FLOAT
 - DATE
 - and so on
- SQL99 built-in types types added by SQL99
 - BOOLEAN a truth value
 - BLOB a Binary Large OBject
 - CLOB a Character Large OBject

- New built-in types new types added by SQL:2003
 - XML a XML Object
- User Defined Types
 - Structured type a user-defined type; for example:

CREATE TYPE PLANE_POINT AS (X FLOAT, Y FLOAT) NOT FINAL

- DISTINCT type a user-defined type based on a built-in type; for example:
 CREATE TYPE MONEY AS NUMERIC(10,2) FINAL
- Constructed types new types based on a given base type
 - REF(structured-type) a pointer that persistently denotes an instance of a structured type that resides in the database
 - base-type ARRAY[n] an array of n base-type elements
- Locators entities that are logical pointers to data that resides on the database server. A LOCATOR exists in the client environment and is a transient, logical pointer to data on the server. A locator typically refers to data that is too large to materialize on the client, such as images or audio. There are operators defined at the SQL level to retrieve random-access pieces of the data denoted by the locator.
 - LOCATOR(structured-type) locator to a structured instance in server
 - LOCATOR(array) locator to an array in server
 - LOCATOR (blob) locator to a Binary Large Object in server
 - LOCATOR(clob) locator to a Character Large Object in server
- Type for managing data external to the data source
 - Datalink a reference to data external to the data source that is managed by the data source. Datalink values are part of SQL MED (Management of External Data), a part of the SQL ANSI/ISO standard specification. Having the data source manage the reference to external data has several advantages:
 - i. Referential integrity the referenced data can no longer be deleted or renamed directly through file system APIs
 - ii. Access control access to the data may be configured such that it is controlled by the data source instead of the file system
 - iii. Coordinated backup and recovery fields referenced by Datalink values may be included in the data source's backup process
 - iv. Transaction consistency changes that affect both relational and external data are executed in a transactional context to preserve the integrity and consistency of the data

The remainder of this chapter discusses the default mechanism provided by the JDBC API for accessing each of the SQL data types mentioned above. The JDBC API also provides a means of customizing the mapping of SQL DISTINCT and structured types into Java classes. This mechanism is discussed in Chapter 17 "Customized Type Mapping".

16.2 Mapping of Advanced Data Types

The JDBC API provides default mappings for advanced data types. Except for the DISTINCT and DATALINK types, these default mappings take the form of interfaces. The following list gives the data types and the interfaces to which they are mapped.

- BLOB the Blob interface
- CLOB the Clob interface
- NCLOB the NClob interface
- ARRAY the Array interface
- XML the SQLXML interface
- Structured types the Struct interface
- REF(structured type) the Ref interface
- ROWID the RowId interface

The other advanced data types with default mappings to the Java programming language are:

- DISTINCT the type to which the base type is mapped. For example, a
 DISTINCT value based on an SQL NUMERIC type maps to a
 java.math.BigDecimal type because NUMERIC maps to BigDecimal in the
 Java programming language.
- DATALINK a java.net.URL object.

16.3 Blob, Clob and NClob Objects

16.3.1 Blob, Clob and NClob Implementations

An implementation of a Blob, Clob or NClob object may either be locator based or result in the object being fully materialized on the client.

By default, a JDBC driver should implement the Blob, Clob and NClob interfaces using the appropriate locator type. An application does not deal directly with the locator types that are defined in SQL.

For locator based implementations, Blob, Clob and NClob objects remain valid for at least the duration of the transaction in which they are created, unless their free method is invoked or they are garbage collected.

For implementations that fully materialize the Large Object (LOB), the Blob, Clob and NClob objects will remain valid until such time as the free method is called or the LOB is garbage collected.

Portable applications should not depend upon the LOB persisting past the end of the transaction.

16.3.2 Creating Blob, Clob and NClob Objects

The Connection interface provides support for the creation of Blob, Clob and NClob objects using the methods createBlob, createClob and createNClob. The object that is created does not contain any data. Data may be added to the object by calling one of the setXXX methods on the Blob, Clob or NClob interface.

In CODE EXAMPLE 16-1, the method Connection.createBlob is used to create an empty Blob object. Blob.setBytes is used to write data to a Blob object.

```
Connection con = DriverManager.getConnection(url, props);
Blob aBlob = con.createBlob();
int numWritten = aBlob.setBytes(1, val);
CODE EXAMPLE 16-1 Creating and writing bytes to a Blob object
```

16.3.3 Retrieving BLOB, Clob and NClob Values in a ResultSet

The binary large object (BLOB) and character large object (CLOB and NCLOB) data types are treated similarly to the more primitive built-in types. Values of these types can be retrieved by calling the getBlob, getClob and getNClob methods in the ResultSet and CallableStatement interfaces.

For example, CODE EXAMPLE 16-2 retrieves a BLOB value from the first column of the ResultSet *rs* and a CLOB value from the second column.

Blob blob = rs.getBlob(1); Clob clob = rs.getClob(2);

CODE EXAMPLE 16-2 Retrieving BLOB and CLOB values

The Blob interface contains operations for returning the length of the BLOB value, a specific range of bytes contained in the BLOB value, and so on. The Clob interface contains corresponding operations that are character based. The API documentation gives more details.

16.3.4 Accessing Blob, Clob and NClob Object Data

The Blob, Clob and NClob interfaces provide methods to access their internal content. It is also possible to access a subset of the data contained within a Blob, Clob and NClob object.

The example, CODE EXAMPLE 16-3, retrieves a 100 bytes of data from a BLOB and CLOB object starting at offset 250.

InputStream is = aBlob.getBinaryStream(250, 100);

BufferedReader br = aClob.getCharacterStream(250, 100);

CODE EXAMPLE 16-3 Retrieving a data subset from a BLOB and CLOB object

16.3.5 Storing Blob, Clob and NClob Objects

A Blob, Clob or NClob object can be passed as an input parameter to a PreparedStatement object just like other data types. The method setBlob sets a PreparedStatement parameter with a Blob object, the method setClob sets a Clob object and the method setNClob sets a NClob object as a parameter. In CODE EXAMPLE 16-4, *authorImage* is an instance of java.sql.Blob retrieved from another SQL statement, and *authorBio* is a an instance of java.sql.Clob retrieved from another SQL statement.

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CODE EXAMPLE 16-4 Setting Blob and Clob objects as parameters to a PreparedStatement object

The setBinaryStream and setObject methods may also be used to set a Blob object as a parameter in a PreparedStatement object. The setAsciiStream, setCharacterStream, and setObject methods are alternate means of setting a Clob object as a parameter. The methods setNCharacterStream, and setObject provide an alternate means of setting a NClob object as a parameter.

The updateBlob, updateClob and updateNClob methods can be used to update a column value in an updatable result set.

Note – For maximum portability, applications should only rely on the storing of locator-based Blob, Clob and NClob objects within the connection that created the LOB.

16.3.6 Altering Blob, Clob and NClob Objects

The Blob, Clob and NClob interfaces provide methods to alter their internal content. In CODE EXAMPLE 16-5, the method setBytes is used to write the first five bytes of the Blob object retrieved from the column DATA.

```
byte[] val = {0,1,2,3,4};
...
Blob data = rs.getBlob("DATA");
int numWritten = data.setBytes(1, val);
if (dbmd.locatorsUpdateCopy() == true) {
        PreparedStatement ps = conn.prepareStatement(
        "UPDATE datatab SET data = ?");
        ps.setBlob("DATA", data);
        ps.executeUpdate();
}
```

CODE EXAMPLE 16-5 Writing bytes to a Blob object

Similarly, the Clob or NClob methods setString and truncate can be used to change the value of a column containing a Clob or a NClob object.

The semantics of updates made to LOB objects are implementation defined. In some implementations, the changes may be made to a copy of the LOB, and in others the changes are made directly to the LOB. In implementations where the changes are made to a copy of the LOB, a separate update statement must be issued to update the LOB stored in the DBMS.

The method locatorsUpdateCopy in the DatabaseMetaData interface returns true if the implementation updates a copy of the LOB and false if updates are made directly to the LOB. CODE EXAMPLE 16-5 shows a typical use of the locatorsUpdateCopy method.

16.3.7 Releasing Blob, Clob and NClob Resources

Blob, Clob and NClob objects remain valid for at least the duration of the transaction in which they are created. This could potentially result in an application running out of resources during a long running transaction. Applications may release Blob, Clob and NClob resources by invoking their free method.

In CODE EXAMPLE 16-6, the method Clob.free is used to release the resources held for a previously created Clob object.

```
Clob aClob = con.createClob();
int numWritten = aClob.setString(1, val);
aClob.free();
```

CODE EXAMPLE 16-6 releasing resources for a Clob object

16.4 SQLXML Objects

16.4.1 Creating SQLXML Objects

The Connection interface provides support for the creation of SQLXML objects using the method createSQLXML. The object that is created does not contain any data. Data may be added to the object by calling the setString, setBinaryStream, setCharacterStream or setResult method on the SQLXML interface.

In CODE EXAMPLE 16-7, the method Connection.createSQLXML is used to create an empty SQLXML object. SQLXML.setString is used to write data to the SQLXML object that was created.

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```
Connection con = DriverManager.getConnection(url, props);
SQLXML sqlxml = con.createSQLXML();
sqlxml.setString(val);
CODE EXAMPLE 16-7 Creating and writing bytes to a SQLXML object
```

16.4.2 Retrieving SQLXML values in a ResultSet

The SQLXML data type is treated similarly to the more primitive built-in types. A SQLXML value can be retrieved by calling the getSQLXML method in the ResultSet or CallableStatement interface.

For example, CODE EXAMPLE 16-8 retrieves a SQLXML value from the first column of the ResultSet *rs*.

SQLXML xmlVar = rs.getSQLXML(1);

CODE EXAMPLE 16-8 Retrieving a SQLXML value

SQLXML objects remain valid for at least the duration of the transaction in which they are created, unless their free method is invoked.

16.4.3 Accessing SQLXML Object Data

The SQLXML interface provides the getString, getBinaryStream, getCharacterStream and getSource methods to access its internal content. The example, CODE EXAMPLE 16-9, retrieves the contents of an SQLXML object using the getString method.

SQLXML xmlVal= rs.getSQLXML(1); String val = xmlVal.getString();

CODE EXAMPLE 16-9 Retrieving a data from a SQLXML object using getString

The getBinaryStream or getCharacterStream methods can be used to obtain an InputStream or a Reader that can be passed directly to an XML parser. CODE EXAMPLE 16-10 obtains an InputStream from an SQLXML Object and then processes the stream using a DOM parser.

```
SQLXML sqlxml = rs.getSQLXML(column);
InputStream binaryStream = sqlxml.getBinaryStream();
DocumentBuilder parser =
DocumentBuilderFactory.newInstance().newDocumentBuilder();
Document result = parser.parse(binaryStream);
```

CODE EXAMPLE 16-10 Returning an InputStream which can be used by an XML parser

The getSource method returns a javax.xml.transform.Source object. Sources are used as inputs to XML parsers and XSLT transformers.

The example, CODE EXAMPLE 16-11, retrieves and parses the data from an SQLXML object using the SAXSource object returned by the invocation of the getSource method:

SQLXML xmlVal= rs.getSQLXML(1); SAXSource saxSource = sqlxml.getSource(SAXSource.class); XMLReader xmlReader = saxSource.getXMLReader(); xmlReader.setContentHandler(myHandler); xmlReader.parse(saxSource.getInputSource());

CODE EXAMPLE 16-11 Using getSource to access SQLXML data

16.4.4 Storing SQLXML Objects

A SQLXML object can be passed as an input parameter to a PreparedStatement object just like other data types. The method setSQLXML sets the designated PreparedStatement parameter with a SQLXML object.

In CODE EXAMPLE 16-12, *authorData* is an instance of java.sql.SQLXML whose data was initialized previously.

PreparedStatement pstmt = conn.prepareStatement(

"INSERT INTO bio (xmlData, authId) VALUES (?, ?)");

pstmt.setSQLXML(1, authorData);

pstmt.setInt(2, authorId);

CODE EXAMPLE 16-12 Setting an SQLXML object as a parameter to a PreparedStatement object

The ${\tt updateSQLXML}~$ method can be used to update a column value in an updatable result set.

If the java.xml.transform.Result, Writer or OutputStream for the SQLXML object has not been closed prior to calling setSQLXML or updateSQLXML, a SQLException will be thrown.

16.4.5 Initializing SQLXML Objects

The SQLXML interface provides the methods setString, setBinaryStream, setCharacterStream or setResult to initialize the content for an SQLXML object that has been created by calling the Connection.createSQLXML method.

CODE EXAMPLE 16-13 uses the method setResult to return a SAXResult object to populate a newly created SQLXML object.

```
SQLXML sqlxml = con.createSQLXML();
SAXResult saxResult = sqlxml.setResult(SAXResult.class);
ContentHandler contentHandler =
saxResult.getXMLReader().getContentHandler();
contentHandler.startDocument();
// set the XML elements and attributes into the result
contentHandler.endDocument();
```

CODE EXAMPLE 16-13 Using the setResult method to obtain a SAXResult object

CODE EXAMPLE 16-14 uses the setCharacterStream method to obtain a java.io.Writer object in order to initialize a SQLXML object.

```
SQLXML sqlxml = con.createSQLXML();
Writer out= sqlxml.setCharacterStream();
BufferedReader in = new BufferedReader(new FileReader("xml/
foo.xml"));
String line= null;
while((line = in.readLine() != null) {
    out.write(line);
```

}

CODE EXAMPLE 16-14 Using setCharacterStream to initialize a SQLXML object

Similarly, the SQLXML setString method can be used to initialize an SQLXML object.

```
If an attempt is made to call the setString, setBinaryStream,
setCharacterStream and setResult methods on an SQLXML object that has
previously been initialized, a SQLException will be thrown. If more than one call
to setBinaryStream, setCharacterStream and setResult occurs for the same
SQLXML object, a SQLException is thrown and the previously returned
javax.xml.transform.Result, Writer or OutputStream object is not
effected.
```

16.4.6 Releasing SQLXML Resources

SQLXML objects remain valid for at least the duration of the transaction in which they are created. This could potentially result in an application running out of resources during a long running transaction. Applications may release SQLXML resources by invoking their free method.

In CODE EXAMPLE 16-15, the method SQLXML.free is used to release the resources held for a previously created SQLXML object.

SQLXML xmlVar = con.createSQLXML();

xmlVar.setString(val); xmlVar.free();

CODE EXAMPLE 16-15 releasing resources for a SQLXML object

16.5 Array Objects

16.5.1 Array Implementations

An implementation of a Array object may either be locator based or result in the object being fully materialized on the client.

By default, a JDBC driver should implement the Array interface using the appropriate locator type. An application does not deal directly with the locator type that is defined in SQL.

For locator based implementations, Array objects remain valid for at least the duration of the transaction in which they are created, unless their free method is invoked or they are garbage collected.

For implementations that fully materialize the Array objects, the objects will remain valid until such time as the free method is called or the object is garbage collected.

Portable applications should not depend upon the Array object persisting past the end of the transaction.

16.5.2 Creating Array Objects

The Connection interface provides support for the creation of Array objects using the method createArrayOf.

In CODE EXAMPLE 16-16, the method Connection.createArrayOf is used to create an Array object whose SQL type is VARCHAR.

```
//The following Array object would be used with a table
//created such as:
//CREATE TABLE COFFEESHOP (SHOPID INTEGER,
// COFFEE_TYPES VARCHAR(15) ARRAY[10])
//
Connection con = DriverManager.getConnection(url, props);
String [] coffees= {"Espresso", "Colombian", "French Roast"};
Array aArray = con.createArrayOf("VARCHAR", coffees);
```

CODE EXAMPLE 16-16 Creating an Array object

16.5.3 Retrieving Array Objects

Data of type SQL ARRAY can be retrieved by calling the getArray method of the ResultSet and CallableStatement interfaces. For example, the following line of code retrieves an Array value from the first column of the ResultSet *rs*.

```
Array a = rs.getArray(1);
```

By default, a JDBC driver should implement the Array interface using an SQL LOCATOR(array) internally. Also by default, Array objects remain valid only during the transaction in which they are created.

The Array object returned to an application by the ResultSet.getArray and CallableStatement.getArray methods is a logical pointer to the SQL ARRAY value in the database; it does not contain the contents of the SQL ARRAY value. The Array interface provides several versions of the methods getArray and

getResultSet that return the contents of an SQL ARRAY value to the client as a materialized Java programming language array (Java array) or as a ResultSet object. The API documentation gives complete details.

16.5.4 Storing Array Objects

The PreparedStatement methods setArray and setObject may be called to pass an Array value as an input parameter to a PreparedStatement object. CODE EXAMPLE 16-17 sets the Array object member_array, which was retrieved from another table in the database, as the second parameter to the PreparedStatement pstmt.

```
PreparedStatement pstmt = conn.prepareStatement(
               "INSERT INTO dept (name, members) VALUES (?, ?)");
pstmt.setString(1, "biology");
pstmt.setArray(2, member_array);
pstmt.executeUpdate();
```

CODE EXAMPLE 16-17 Storing an Array object

A Java array may be passed as an input parameter by calling the method PreparedSatement.setObject.

Note – For maximum portability, applications should only rely on the storing of locator-based Array objects within the connection that created the Array.

16.5.5 Updating Array Objects

The ResultSet methods updateArray and updateObject can be used to update a column value.

CODE EXAMPLE 16-18 uses the method ResultSet.updateArray to update the value of the column LATEST_NUMBERS in one ResultSet object with an Array object retrieved from the column NUMBERS in another ResultSet object.

```
// retrieve a column containing an SQL ARRAY value from ResultSet rs
java.sql.Array num = rs.getArray("NUMBERS");
...
// update the column "LATEST_NUMBERS" in a second ResultSet
// with the value retrieved...
```

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rs2.updateArray("LATEST_NUMBERS", num);

rs2.updateRow();

CODE EXAMPLE 16-18 Updating a column with an Array object

16.5.6 Releasing Array Resources

Array objects remain valid for at least the duration of the transaction in which they are created. This could potentially result in an application running out of resources during a long running transaction. Applications may release Array resources by invoking their free method.

In CODE EXAMPLE 16-19, the method Array.free is used to release the resources held for a previously created Array object.

```
Array aArray = con.createArrayOf("VARCHAR", coffees);
```

• • •

```
aArray.free();
```

CODE EXAMPLE 16-19 releasing resources for a Array object

16.6 Ref Objects

16.6.1 Retrieving REF Values

An SQL REF (structured type) value can be retrieved as a Ref object by calling the getRef method of the ResultSet and CallableStatement interfaces. For example, in CODE EXAMPLE 16-20, the ResultSet *rs* contains a reference to an instance of the SQL structured type dog that is stored in the table dogs. The code retrieves this REF (dog) from the first column of *rs*.

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An SQL REF value is a pointer; therefore, a Ref object, which is the mapping of a REF value, is likewise a pointer and does not contain the data of the structured type instance to which it refers. A Ref object remains valid while the session or connection on which it is created is open.

16.6.2 Retrieving the Referenced Value

The Ref object returned from the method getRef is a reference to an instance of a structured type in the underlying data source. The methods getObject() and getObject(Map map) can be used to retrieve the structured type instance that is referenced. CODE EXAMPLE 16-21 shows how a reference to an instance of the structured type Address can be dereferenced to retrieve the instance of Address. This example would require that a map, mapping Address to its SQL type, had been supplied to the Connection using the method setMap.

Ref ref = rs.getRef(1);
Address addr = (Address)ref.getObject();

CODE EXAMPLE 16-21 Retrieving the structured type instance referenced by a Ref object

16.6.3 Storing Ref Objects

The PreparedStatement.setRef method may be called to pass a Ref object as an input parameter to a PreparedStatement object.

16.6.4 Storing the Referenced Value

An instance of a structured type retrieved with the method ResultSet.getRef or CallableStatement.getRef is stored using the Ref.setObject method. In CODE EXAMPLE 16-22, the table DOGS stores instances of the structured type DOG. The SELECT statement selects the REF (DOG) that refers to the instance in which the name is Rover. The referenced instance of the type DOG is retrieved using getValue. The parameter map describes a mapping from the SQL type DOG to the Java class Dog, which implements the SQLData interface.

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```
// manipulate instance of Dog
dog.setAge(14);
...
// store updated Dog
rover.setObject((Object)dog);
```

CODE EXAMPLE 16-22 Retrieving and storing the structured type instance referenced by a Ref object

16.6.5 Metadata

The type REF is defined in the class java.sql.Types. This value is returned by methods such as DatabaseMetaData.getTypeInfo and DatabaseMetaData.getColumns when a JDBC driver supports the Ref data type.

16.7 Distinct Types

An SQL DISTINCT type is a new user defined data type that is based on one of the primitive types. C and C++ programmers can think of it as being similar to a typedef.

16.7.1 Retrieving Distinct Types

By default, a column of SQL type DISTINCT is retrieved by calling any getter method that is appropriate to the type on which it is based. For example, the following type declaration creates the type MONEY, which is based on the SQL type NUMERIC.

CREATE TYPE MONEY AS NUMERIC(10,2) FINAL

CODE EXAMPLE 16-23 Creating a distinct type

CODE EXAMPLE 16-24 uses the method getBigDecimal to retrieve a MONEY value because the underlying SQL NUMERIC type is mapped to the java.math.BigDecimal type.

java.math.BigDecimal bd = rs.getBigDecimal(1);

CODE EXAMPLE 16-24 Retrieving a distinct type

16.7.2 Storing Distinct Types

Any setter method in the PreparedStatement interface that is appropriate for the base type of an SQL DISTINCT type may be used to pass an input parameter of that distinct type to a prepared statement. For example, given the definition of type MONEY in CODE EXAMPLE 16-23, the method PreparedStatement.setBigDecimal would be used.

16.7.3 Metadata

The type code DISTINCT is defined in the class java.sql.Types. This value is returned by methods such as DatabaseMetaData.getTypeInfo and DatabaseMetaData.getColumns when a JDBC driver supports this data type.

An SQL DISTINCT type must be defined as part of a particular database schema before it can be used in a schema table definition. Information on schema-specific user-defined types—of which DISTINCT types are one particular kind—can be retrieved by calling the DatabaseMetaData.getUDTs method. For example, CODE EXAMPLE 16-25 returns descriptions of all the SQL DISTINCT types defined in the catalog-name.schema-name schema. If the driver does not support UDTs or no matching UDTs are found, the getUDTs method returns an empty result set.

CODE EXAMPLE 16-25 Querying a DatabaseMetaData object for distinct types

Each row in the ResultSet object returned by the method getUDTs describes a UDT. Each row contains the following columns:

TYPE_CAT	String => the type's catalog (may be null)	
TYPE_SCHEM	String => the type's schema (may be null)	
TYPE_NAME	String => the SQL type name	
CLASS_NAME	String => a Java class name	
DATA_TYPE	<pre>short => value defined in java.sql.Types, such as DISTINCT</pre>	
REMARKS	String => explanatory comment on the type	
BASE_TYPE	<pre>short => value defined in java.sql.Types, for DISTINCT or reference types (may be null)</pre>	

Most of the columns above should be self-explanatory. The TYPE_NAME is the SQL type name given to the DISTINCT type—MONEY in the example above. This is the name used in a CREATE TABLE statement to specify a column of this type.

When DATA_TYPE is Types.DISTINCT, the CLASS_NAME column contains a fully qualified Java class name. Instances of this class will be created if getObject is called on a column of this DISTINCT type. For example, CLASS_NAME would default to java.math.BigDecimal in the case of MONEY above. The JDBC API does not prohibit a driver from returning a subtype of the class named by CLASS_NAME. The CLASS_NAME value reflects a custom type mapping when one is used. See Chapter 17 "Customized Type Mapping" for details.

16.8 Structured Types

16.8.1 Creating Structured Objects

The Connection interface provides support for the creation of Struct objects using the method createStruct.

In CODE EXAMPLE 16-26, the method Connection.createStruct is used to create an STRUCT object whose SQL type is EMPLOYEE.

```
//EMPLOYEE was created as:
//CREATE TYPE EMPLOYEE(EMPID INTEGER, FNAME VARCHAR(15),
//LNAME VARCHAR(20))
//
Connection con = DriverManager.getConnection(url, props);
Object [] employee= {100, "John", "Doe"};
Struct aStruct = con.createStruct("EMPLOYEE", employee);
CODE EXAMPLE 16-26 Creating an Struct object
```

16.8.2 Retrieving Structured Types

An SQL structured type value is always retrieved by calling the method getObject. By default, getObject returns a value of type Struct for a structured type. For example, the following line of code retrieves a Struct value from the first column of the current row of the ResultSet object rs.

Struct struct = (Struct)rs.getObject(1);

The Struct interface contains methods for retrieving the attributes of a structured type as an array of java.lang.Object values. By default, a JDBC driver materializes the contents of a Struct prior to returning a reference to it to the application. Also, by default a Struct object is considered valid as long as the Java application maintains a reference to it.

16.8.3 Storing Structured Types

The PreparedStatement.setObject method may be called to pass a Struct object as an input parameter to a prepared statement.

Note – For maximum portability, applications should only rely on the storing of locator-based structured type objects within the connection that created the structured type.

16.8.4 Metadata

The type code STRUCT is defined in the class java.sql.Types. This value is returned by methods such as DatabaseMetaData.getTypeInfo and DatabaseMetaData.getColumns when a JDBC driver supports structured data types.

An SQL structured type must be defined as part of a particular database schema before it can be used in a schema table definition. Information on schema-specific user-defined types—of which STRUCT types are one particular kind—can be retrieved by calling the DatabaseMetaData.getUDTs method. For example, CODE EXAMPLE 16-27 returns descriptions of all the SQL structured types defined in the catalog-name.schema-name schema.

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CODE EXAMPLE 16-27 Querying a DatabaseMetaData object for structured types

If the driver does not support UDTs or no matching UDTs are found, an empty result set is returned. See section 16.7.3 for a description of the result set returned by the method getUDTs.

When the DATA_TYPE returned by getUDTs is Types.STRUCT, the CLASS_NAME column contains the fully qualified Java class name of a Java class. Instances of this class are manufactured by the JDBC driver when getObject is called on a column of this STRUCT type. Thus, CLASS_NAME defaults to java.sql.Struct for structured types. If there is a custom mapping for the STRUCT type, CLASS_NAME will be the implementation of the interface SQLData that specifies the mapping. The JDBC API does not prohibit a driver from returning a subtype of the class named by CLASS_NAME. Chapter 17 "Customized Type Mapping" provides more information about implementations of the SQLData interface.

16.9 Datalinks

A DATALINK value references a file outside of the underlying data source that the data source manages.

16.9.1 Retrieving References to External Data

A reference to external data being managed by the data source can be retrieved using the method ResultSet.getURL. The java.net.URL object that is returned can be used to manipulate the data.

java.net.URL url = rs.getURL(1);

CODE EXAMPLE 16-28 Retrieving a reference to an external data object

In cases where the type of URL returned by the methods getObject or getURL is not supported by the Java platform, the URL can be retrieved as a String by calling the method getString.

16.9.2 Storing References to External Data

The method PreparedStatement.setURL can be used to pass a java.net.URL object to a prepared statement. In cases where the type of URL being set is not supported by the Java platform, the URL can be stored using the setString method.

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16.9.3 Metadata

The type code DATALINK is defined in the class java.sql.Types. This value is returned by methods such as DatabaseMetaData.getTypeInfo and DatabaseMetaData.getColumns when a JDBC driver supports the Datalink data type for references to external files.

16.10 RowId Objects

16.10.1 Lifetime of RowId Validity

A RowId may be thought of as the address for a given row. The address may be logical or physical, however this is determined by the originating data source. A RowId object may be valid so long as the identified row is not deleted and the lifetime of the RowId is within the bounds of the lifetime specified by that RowId's data source.

RowId object lifetime validity may be determined by calling the DatabaseMetaData.getRowIdLifetime() method, which returns a value of the RowIdLifetime enumerated data-type.

RowldLifeTime Enumerated Datatype	Specification
ROWID_UNSUPPORTED	Indicates that this data source does not support the ROWID type.
ROWID_VALID_OTHER	Indicates that the lifetime of a RowId from this data source is implementation dependant.
ROWID_VALID_TRANSACTION	Indicates that the lifetime of a RowId from this data source is at least the containing transaction as long as the identified row is not deleted.
ROWID_VALID_SESSION	Indicates that the lifetime of a RowId from this data source is at least the containing session as long as the identified row is not deleted.
ROWID_VALID_FOREVER	Indicates that the lifetime of a RowId from this data source is, effectively, unlimited as long as the identified row is not deleted.

TABLE 16-1Standard RowId life-time validities

16.10.2 Retrieving RowId Values

A RowId may be retrieved using the getter methods defined in ResultSet and CallableStatement. The returned java.sql.RowId object that is returned is an immutable object that can be used for subsequent referrals as a unique identifier to a row.

java.sql.RowId rowId_1 = rs.getRowId(1);

CODE EXAMPLE 16-29 Retrieving a RowId for a ResultSet object, rs

16.10.3 Using RowId Values

A RowId value may be used in a parameterized PreparedStatement to set a parameter with a RowId object.

```
Connection conn = ds.getConnection(user, passwd);
PreparedStatement ps = conn.prepareStatement("INSERT INTO BOOKLIST" +
                    "(ID, AUTHOR, TITLE, ISBN) VALUES (?, ?, ?,
?)");
ps.setRowId(1, rowId_1);
```

CODE EXAMPLE 16-30 Setting a PreparedStatement RowId parameter

A RowId value may also be used in an updatable ResultSet to update a column with a specific RowId value.

```
ResultSet rs = ...
rs.next();
rs.updateRowId(1, rowId_1);
```

CODE EXAMPLE 16-31 Setting a RowId value in the current row of a ResultSet

A RowId object value is typically not portable between data sources and should be considered as specific to the data source when using the set or update method in PreparedStatement and ResultSet objects respectively. It is therefore inadvisable to get a RowId from a ResultSet object with a connection 'Foo' and then attempt to use the RowId in a unrelated ResultSet object with a connection 'Bar'.

CHAPTER 17

Customized Type Mapping

This chapter describes the support that the JDBC API provides for mapping SQL structured and distinct types to classes in the Java programming language. Because the mechanism for this custom mapping is an extension of the existing getObject and setObject mechanism, it involves minimal extensions to the JDBC API from the user's point of view.

17.1 The Type Mapping

The SQL user-defined types (UDTs), structured types and DISTINCT types, can be given a custom mapping to a class in the Java programming language. The default is for a driver to use the default mappings between SQL data types and types in the Java programming language. The default mapping for an SQL structured type is to the interface Struct; the default mapping for an SQL DISTINCT type is to the type to which the underlying type is mapped. If a custom mapping has been set up for a UDT, the driver will use the custom mapping instead of the default mapping when an application calls the getObject or setObject methods on that UDT.

Setting up a custom mapping requires two things:

- Writing an implementation of the SQLData interface for the UDT. This class typically maps the attribute(s) of an SQL structured type (or the single attribute of a DISTINCT type) to fields. There is, however, great latitude allowed in how a UDT is custom mapped. It is expected that most SQLData implementations will be created using a tool.
- 2. Putting an entry in a java.util.Map object. The entry must contain the following two items:
 - a. The fully qualified name of the SQL UDT that is to be mapped.

b. The Class object for the SQLData implementation. It is an error if the class listed in a type map entry does not implement the SQLData interface.

For example, if the UDT is named mySchemaName.AUTHORS and the SQLData implementation is the class Authors, the entry for the type map associated with the Connection object *conn* would look like CODE EXAMPLE 17-1.

java.util.Map map = conn.getTypeMap(); map.put("mySchemaName.AUTHORS", Class.forName("Authors")); conn.setTypeMap(map);

CODE EXAMPLE 17-1 Putting an entry in a connection's type map

The method Connection.getTypeMap returns the type map associated with the Connection object *conn*; the method Connection.setTypeMap sets the given java.util.Map object as the type map for *conn*.

When an SQL value with a custom mapping is being retrieved (by the method ResultSet.getObject, CallableStatement.getObject, or any of the other methods that materialize an SQL value's data on the client), the driver will check to see if there is an entry in the connection's type map for the SQL value that is to be retrieved. If there is, the driver will map the SQL UDT to the class specified in the type map. If there is no entry for the UDT in the connection's type map, the UDT is mapped to the default mapping.

Certain methods may take a type map as a parameter. A type map supplied as a parameter supersedes the type map associated with the connection. A UDT that does not have an entry in the type map supplied as a parameter will be mapped to the default mapping. When a type map is explicitly supplied to a method, the connection's type map is never used.

17.2 Class Conventions

A class that appears in a type map entry must do the following:

- 1. Implement the interface java.sql.SQLData
- 2. Provide a niladic constructor, that is, a constructor that takes no parameters

The SQLData interface contains methods that convert instances of SQL UDTs to Java class instances and that convert Java class instances back to SQL UDTs. For example, the method SQLData.readSQL reads a stream of data values and builds a Java object, while the method SQLData.writeSQL writes a sequence of values from a Java object to a stream. These methods will typically be generated by a tool that understands the database schema.

This stream-based approach for exchanging data between SQL and the Java programming language is conceptually similar to Java object serialization. The data are read from and written to an SQL data stream provided by the JDBC driver. The SQL data stream may be implemented on various network protocols and data formats. It may be implemented on any logical data representation in which the leaf SQL data items (of which SQL structured types are composed) can be read from (written to) the data stream in a "depth-first" traversal of the structured types. That is, each attribute value, which may itself be a structured type, appears fully (its structure recursively elaborated) in the stream before the next attribute. In addition, the attributes of an SQL structured type must appear in the stream in the order in which they are declared in the type definition. For data of SQL structured types that use inheritance, the attributes of a supertype must appear before attributes of a subtype.

If multiple inheritance is used, then the attributes of supertypes should appear in the stream in the order in which the supertypes are listed in the type declaration. This protocol does not require the database server to have any knowledge of the Java programming language. However, as there is no support for multiple inheritance in SQL:2003, this issue should not arise.

17.3 Streams of SQL Data

This section describes the stream interfaces, SQLInput and SQLOutput, which support customization of the mapping of SQL UDTs to Java data types.

17.3.1 Retrieving Data

In a custom mapping, when data of SQL structured and distinct types are retrieved from the database, they "arrive" in a stream implementing the SQLInput interface. The SQLInput interface contains methods for reading individual data values sequentially from the stream. CODE EXAMPLE 17-2 illustrates how a driver can use an SQLInput stream to provide values for the fields of an SQLData object. The SQLData object—the this object in the example—contains three persistent fields: the String *str*, the Blob object *blob*, and the Employee object *emp*.

```
SQLInput sqlin;
...
this.str = sqlin.readString();
this.blob = sqlin.readBlob();
```

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this.emp = (Employee)sqlin.readObject();

CODE EXAMPLE 17-2 Retrieving data using the SQLInput interface

The SQLInput.readString method reads a String value from the stream; the SQLInput.readBlob method reads a Blob value from the stream. By default, the Blob interface is implemented using an SQL locator, so calling the method readBlob doesn't materialize the SQL BLOB contents on the client. The SQLInput.readObject method retrieves an object reference from the stream. In the example, the Object returned is narrowed to an Employee object.

There are a number of additional methods defined on the SQLInput interface for reading each of the types (readLong, readBytes, and so on). The SQLInput.wasNull method can be called to check whether the last value read was SQL NULL in the database.

17.3.2 Storing Data

When an instance of a class that implements SQLData is passed to a driver as an input parameter via the setObject method, the JDBC driver calls the object's SQLData.writeSQL method. It also creates an SQLOutput stream to which the method writeSQL writes the attributes of the custom mapped UDT. The method writeSQL will typically have been generated by a tool from an SQL type definition. CODE EXAMPLE 17-3 illustrates the use of the SQLOutput object *SQLData*.

sqlout.writeString(this.str); sqlout.writeBlob(this.blob); sqlout.writeObject(this.emp);

CODE EXAMPLE 17-3 Storing data using the SQLOutput interface

The example shows how the contents of an SQLData object can be written to an SQLOutput stream. The SQLData object—the this object in the example—contains three persistent fields: the String *str*, the Blob object *blob*, and the Employee object *emp*. Each field is written in turn to the SQLOutput stream, *SQLData*. The SQLOutput interface contains methods for writing each of the types defined in the JDBC API.

17.4 Examples

This section gives examples of SQL code as well as code in the Java programming language. SQL code is used for creating structured types, creating tables for instances of those types, populating the tables with instances of the structured types, and creating an SQL DISTINCT type. This code sets up the SQL values that will be mapped to classes in the Java programming language.

The examples of code in the Java programming language create implementations of the SQLData interface for the newly created SQL UDTs and also show how a class in the Java programming language can mirror SQL inheritance for structured types.

17.4.1 An SQL Structured Type

CODE EXAMPLE 17-4, which defines the structured types PERSON, FULLNAME, and RESIDENCE, shows that it is possible for an attribute to be a REF value or another structured type. PERSON and RESIDENCE each have an attribute that is a REF value, and the REF value in one structured type references the other structured type. Note also that FULLNAME is used as an attribute of PERSON.

```
CREATE TYPE RESIDENCE AS
(
DOOR NUMERIC(6),
STREET VARCHAR(100),
CITY VARCHAR(50),
OCCUPANT REF(PERSON)
) NOT FINAL
CREATE TYPE FULLNAME AS
(
FIRST VARCHAR(50),
LAST VARCHAR(50)
) NOT FINAL
CREATE TYPE PERSON AS
(
NAME FULLNAME,
```

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```
HEIGHT REAL,
WEIGHT REAL,
HOME REF(RESIDENCE)
```

) NOT FINAL

CODE EXAMPLE 17-4 Creating SQL structured types

The types created in CODE EXAMPLE 17-4 are presumed to be created in the current schema for the following examples.

CODE EXAMPLE 17-5 creates two tables that are maintained by the DBMS automatically. The CREATE statements do two things:

- 1. Create tables that store instances of the structured types named in the OF part of the statement (RESIDENCE in the first one, PERSON in the second). Each of the subsequent INSERT INTO statements adds a new row representing an instance of the UDT.
- 2. Create a REF value that is a pointer to each instance that is inserted into the table. As indicated in the CREATE statement, the REF value is generated by the system, which is done implicitly. Because REF values are stored in the table, they are persistent pointers. This contrasts with LOCATOR types, which are logical pointers but exist only as long as the transactions in which they are created.

CREATE TABLE HOMES OF RESIDENCE (REF IS OID SYSTEM GENERATED, OCCUPANT WITH OPTIONS SCOPE PEOPLE) CREATE TABLE PEOPLE OF PERSON (REF IS OID SYSTEM GENERATED, HOME WITH OPTIONS SCOPE HOMES)

CODE EXAMPLE 17-5 Creating tables to store instances of a structured type

CODE EXAMPLE 17-6 uses INSERT INTO statements to populate the tables created in CODE EXAMPLE 17-5. For example, the INSERT INTO PEOPLE statement inserts an instance of the UDT PERSON into the table PEOPLE. When this command is executed, the DBMS will also automatically generate a REF value that is a pointer to this instance of PERSON and store it in the column OID (the column name specified in the CREATE statement that created the table PEOPLE).

Each column value in these special tables is an attribute of the UDT, which may itself be a UDT. For example, the first attribute of the UDT PERSON is the value in the column NAME, which must be an instance of the UDT FULLNAME. The example assumes that the UDT FULLNAME has an additional two parameter constructor.

A column value may also be a reference to an SQL structured type. For example, the attribute <code>OCCUPANT</code> of the UDT <code>RESIDENCE</code> is of type <code>REF(PERSON)</code>. It takes an SQL <code>SELECT</code> statement to retrieve the <code>REF</code> value from the table <code>HOMES</code> and use it as

```
the value for OCCUPANT, which is shown at the end of CODE EXAMPLE 17-6.
INSERT INTO PEOPLE (NAME, HEIGHT, WEIGHT) VALUES
(
                  NEW FULLNAME ('DAFFY', 'DUCK'),
                  4,
                  58
);
INSERT INTO HOMES (DOOR, STREET, CITY, OCCUPANT) VALUES
(
                  1234,
                  'CARTOON LANE',
                  'LOS ANGELES',
                   (SELECT OID FROM PEOPLE P WHERE P.NAME.FIRST =
'DAFFY')
)
UPDATE PEOPLE SET HOME = (SELECT OID FROM HOMES H WHERE
        H.OCCUPANT->NAME.FIRST = 'DAFFY') WHERE
        FULLNAME.FIRST = 'DAFFY'
CODE EXAMPLE 17-6 Populating and updating tables that store instances of structured
                types
```

17.4.2 SQLData Implementations

The Java classes defined in CODE EXAMPLE 17-7 are mappings of the SQL structured types used in the examples in Section 17.4.1. We expect that such classes will typically be generated by a tool that reads the definitions of those structured types from the catalog tables and, subject to customizations that a user of the tool may provide for name mappings and type mappings of primitive fields, will generate Java classes like those in the example.

In each implementation of SQLData, the method SQLData.readSQL reads the attributes in the order in which they appear in the SQL definition of the structured type. Attributes are also read in "row order, depth-first" order, where the complete structure of each attribute is read recursively before the next attribute is read. The method SQLData.writeSQL writes each attribute to the output stream in the same order.

```
public class Residence implements SQLData {
    public int door;
    public String street;
    public String city;
    public Ref occupant;
   private String sql_type;
    public String getSQLTypeName() { return sql_type; }
    public void readSQL (SQLInput stream, String type)
                 throws SQLException {
      sql_type = type;
     door = stream.readInt();
      street = stream.readString();
      city = stream.readString();
      occupant = stream.readRef();
    }
   public void writeSQL (SQLOutput stream) throws SQLException {
      stream.writeInt(door);
      stream.writeString(street);
      stream.writeString(city);
      stream.writeRef(occupant);
    }
}
public class Fullname implements SQLData {
    public String first;
    public String last;
    private String sql_type;
    public String getSQLTypeName() { return sql_type; }
    public void readSQL (SQLInput stream, String type)
                 throws SQLException {
      sql_type = type;
```

```
first = stream.readString();
      last = stream.readString();
    }
   public void writeSQL (SQLOutput stream) throws SQLException {
      stream.writeString(first);
      stream.writeString(last);
    }
}
public class Person implements SQLData {
   Fullname name;
   float height;
    float weight;
   Ref home;
   private String sql_type;
    public String getSQLTypeName() { return sql_type; }
    public void readSQL (SQLInput stream, String type)
                 throws SQLException {
      sql_type = type;
      name = (Fullname)stream.readObject();
      height = stream.readFloat();
      weight = stream.readFloat();
      home = stream.readRef();
    }
   public void writeSQL (SQLOutput stream)
                 throws SQLException {
      stream.writeObject(name);
      stream.writeFloat(height);
      stream.writeFloat(weight);
      stream.writeRef(home);
    }
}
```

CODE EXAMPLE 17-7 Classes implementing the SQLData interface

CODE EXAMPLE 17-8 puts entries for custom mappings in the connection's type map. Then it retrieves the Ref instance stored in the OCCUPANT column of the table HOMES. This Ref instance is set as a parameter in the where clause of the query to get the name of the occupant. When the method getObject is called to retrieve an instance of FULLNAME, the driver looks in the connections type map and uses the SQLData implementation, Fullname, to custom map the FULLNAME value.

```
// set up mappings for the connection
try {
    java.util.Map map = con.getTypeMap();
    map.put("S.RESIDENCE", Class.forName("Residence"));
    map.put("S.FULLNAME", Class.forName("Fullname"));
    map.put("S.PERSON", Class.forName("Person"));
  }
catch (ClassNotFoundException ex) {}
PreparedStatement pstmt;
ResultSet rs;
pstmt = con.prepareStatement("SELECT OCCUPANT FROM HOMES");
rs = pstmt.executeQuery();
rs.next();
Ref ref = rs.getRef(1);
pstmt = con.prepareStatement(
            "SELECT FULLNAME FROM PEOPLE WHERE OID = ?");
pstmt.setRef(1, ref);
rs = pstmt.executeQuery(); rs.next();
Fullname who = (Fullname)rs.getObject(1);
// prints "Daffy Duck"
System.out.println(who.first + " " + who.last);
```

```
CODE EXAMPLE 17-8 Retrieving a custom mapping
```

17.4.3 Mirroring SQL Inheritance in the Java Programming Language

SQL structured types may be defined to form an inheritance hierarchy. For example, consider SQL type STUDENT, which inherits from PERSON:

```
CREATE TYPE PERSON AS

(NAME VARCHAR(20),

BIRTH DATE)

NOT FINAL;

CREATE TYPE STUDENT UNDER PERSON AS

(GPA NUMERIC(4,2))

NOT FINAL;
```

CODE EXAMPLE 17-9 Creating a hierarchy of SQL types

The following Java classes can represent data of those SQL types. Class Student extends Person, mirroring the SQL type hierarchy. Methods SQLData.readSQL and SQLData.writeSQL of the subclass cascade each call to the corresponding method in its superclass in order to read or write the superclass attributes before reading or writing the subclass attributes.

```
data.writeString(name);
    data.writeDate(birth);
  }
}
public class Student extends Person {
  public BigDecimal GPA;
  private String sql_type;
  public String getSQLTypeName() { return sql_type; }
  public void readSQL (SQLInput data, String type)
              throws SQLException {
    sql_type = type;
    super.readSQL(data, type);
    GPA = data.readBigDecimal();
  }
  public void writeSQL (SQLOutput data)
  throws SQLException {
    super.writeSQL(data);
    data.writeBigDecimal(GPA);
  }
}
```

CODE EXAMPLE 17-10 Mirroring SQL type hierarchies in Java classes

The Java class hierarchy need not mirror the SQL inheritance hierarchy. For example, the class Student above could have been declared without a superclass. In this case, Student could contain fields to hold the inherited attributes of the SQL type STUDENT as well as the attributes declared by STUDENT itself.

17.4.4 Example Mapping of SQL DISTINCT Type

CODE EXAMPLE 17-11 illustrates creating an SQL DISTINCT type, MONEY, and CODE EXAMPLE 17-12 illustrates a Java class, Money, that represents it.

CODE EXAMPLE 17-12 Java class that represents a ${\tt DISTINCT}$ type

17.5 Effect of Transform Groups

Transform groups (SQL:2003) can be used to convert a user-defined SQL type into predefined SQL types. This transformation is performed by the underlying data source before it is returned to the JDBC driver.

If transform groups are used for a user-defined type, and the application has not defined a mapping for that type to a Java class, then the ResultSetMetaData method getColumnClass should return the Java class corresponding to the data type produced by the transformation function (that is, String for a VARCHAR).

Note – This is consistent with the behavior for DISTINCT types.

If transform groups are used for a UDT, and the application has defined a mapping for that type to a Java class, then the SQLInput stream delivered by the JDBC driver during an invocation of the method readSQL contains only a single value, that is, the result produced by the transformation function. The same model holds for the method writeSQL.

17.6 Generality of the Approach

Users have great flexibility in customizing the Java classes that represent SQL structured and DISTINCT types. They control the mappings of built-in SQL attribute types to Java field types. They control the mappings of SQL names (of types and attributes) to Java names (of classes and fields). Users may add (to Java classes that represent SQL types) fields and methods that implement domain-specific functionality. Users can generate JavaBeans components as the classes that represent SQL types.

A user can even map a single SQL type to different Java classes, depending on arbitrary conditions. To do that, the user must customize the implementation of SQLData.readSQL to construct and return objects of different classes under different conditions.

Similarly, the user can map a single SQL value to a graph of Java objects. Again, that is accomplished by customizing the implementation of the method SQLData.readSQL to construct multiple objects and distribute the SQL attributes into fields of those objects.

A customization of the SQLData.readSQL method could populate a connection's type map incrementally. This flexibility will allow users to map SQL types appropriately for different kinds of applications.

17.7 NULL Data

An application uses the existing getObject and setObject mechanism to retrieve and store SQLData values. We note that when the second parameter, x, of method PreparedStatement.setObject has the value null, the driver executes the SQL statement as if the SQL literal NULL had appeared in its place.

void setObject (int i, Object x) throws SQLException;

When parameter x is null, there is no enforcement that the corresponding argument expression is of a Java type that could successfully be passed to that SQL statement if its value were not null. The Java programming language null carries no type information. For example, a null Java programming language variable of class AntiMatter could be passed as an argument to an SQL statement that requires a value of SQL type MATTER, and no error would result, even though the relevant type map object did not permit the translation of MATTER to AntiMatter.

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CHAPTER **18**

Relationship to Connectors

The Java EE Connector Architecture Specification defines a set of contracts that allow a resource adapter to extend a container in a pluggable way. A resource adapter provides connectivity to an external system from the application server. The resource adapter's functionality is similar to that provided by the JDBC interfaces used in the Java EE platform to establish a connection with a data source. These interfaces, which the Connector specification refers to as the *service provider interface* (SPI), are the following:

- DataSource
- ConnectionPoolDataSource
- XADataSource

Additionally, the Connector Architecture defines a packaging format to allow a resource adapter to be deployed into a Java EE compliant application server.

18.1 System Contracts

The system contracts defined in the Connector specification describe the interface between an application server and one or more resource adapters. This interface allows a resource adapter to be bundled in such a way that it can be used by any application server that supports the system contracts.

The following standard contracts are defined between an application server and a data source system:

 A connection management contract that enables application components to connect to a data source.

The connection management contract is equivalent to the services described by the JDBC interfaces DataSource and ConnectionPoolDataSource.

• A transaction management contract between the transaction manager and a data source supporting transactional access to its resources.

The transaction contract is equivalent to the services described by the JDBC interface XADataSource.

• A security contract that enables secure access to a data source.

The security contract does not have an equivalent in the JDBC API. Authentication in the JDBC API always consists of providing a user name and a password.

The JDBC specification does not make a distinction between its application programming interface (API) and the SPI. However, a driver can map the JDBC interfaces in the SPI to the Connector system contracts.

18.2 Mapping Connector System Contracts to JDBC Interfaces

Driver vendors who want to supply JDBC drivers that use the Connector system contracts have several options:

- 1. To write a set of classes that wrap a JDBC driver and implement the Connector system contracts. Constructing these wrappers is fairly straightforward and should allow JDBC driver vendors to provide resource adapters quickly enough so that they are available when application server vendors have implemented the Connector contracts.
- 2. To implement the Connector system contracts natively. This approach avoids the overhead of wrapper classes, but the implementation effort may be more involved and time-consuming. This alternative is a more long-term option.

Either approach will allow JDBC driver vendors to package their drivers as resource adapters and get all the benefits of pluggability, packaging, and deployment.

Note – There are no plans to deprecate or remove the current JDBC interfaces, DataSource, ConnectionPoolDataSource and XADataSource.

18.3 Packaging JDBC Drivers in Connector RAR File Format

Resource adapters can be packaged, along with a deployment descriptor, into a Resource adapter ARchive, or RAR file. The RAR file contains the Java classes/ interfaces, native libraries, deployment descriptor, and other resources needed to deploy the adapter.

The deployment descriptor maps the classes in the resource adapter to the specific roles that they perform. The descriptor also details the capabilities of the resource adapter in terms of what level of transactional support it provides, the kind of security it supports, and so on.

CODE EXAMPLE 18-1 is an example of a deployment descriptor for a JDBC driver. The class com.acme.JdbcManagedConnectionFactory could be supported by an implementation of javax.sql.XADataSource. The resource adapter section contains information on the level of transaction support, the mechanism used for authentication, and configuration information for deploying the data source in the JNDI namespace.

<?xml version="1.0" encoding="UTF-8"?>

<connector xmlns="http://java.sun.com/xml/ns/j2ee" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

xsi:schemaLocation="http://java.sun.com/xml/ns/j2ee http:/
/java.sun.com/xml/ns/j2ee/connector_1_6.xsd"

version="1.6">

 $<\!$ description>Resource adapter wrapping Datasource implementation of driver</br/>/description>

<display-name>Acme JDBC Adapter</display-name>

<vendor-name>Acme Software Inc</vendor-name>

<eis-type>JDBC Database</eis-type>

<resourceadapter-version>1.0</resourceadapter-version>

<license>

<license-required>false</license-required>

</license>

<resourceadapter>

<resourceadapter-class>

com.acme.JdbcResourceAdapter

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</resourceadapter-class> <outbound-resourceadapter> <connection-definition> <managedconnectionfactory-class> com.acme.JdbcManagedConnectionFactory </managedconnectionfactory-class> <connectionfactory-interface> javax.sql.DataSource </connectionfactory-interface> <connectionfactory-impl-class> com.acme.JdbcDataSource </connectionfactory-impl-class> <connection-interface> java.sql.Connection </connection-interface> <connection-impl-class> com.acme.JdbcConnection </connection-impl-class> <config-property> <config-property-name> XADataSourceName </config-property-name> <config-property-type> java.lang.String </config-property-type> <config-property-value> jdbc/XAAcme </config-property-value> </config-property> </connection-definition> <transaction-support> XATransaction </transaction-support>

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```
BasicPassword
```

```
</authentication-mechanism-type>
```

<credential-interface>

javax.resource.spi.security.PasswordCredential

</credential-interface>

</authentication-mechanism>

<reauthentication-support>

false

</reauthentication-support>

</outbound-resourceadapter>

</resourceadapter>

</connector>

CODE EXAMPLE 18-1 Example of a resource adapter deployment descriptor.

See the Connector specification for more details.

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CHAPTER 19

Wrapper Interface

The Wrapper interface provides a mechanism for JDBC users to be able to access an instance of a resource which has been wrapped for architectural reasons. This mechanism helps to eliminate the need to use non-standard means to access vendor specific resources.

The following JDBC interfaces are subinterfaces of the Wrapper interface:

- java.sql.Connection
- java.sql.DatabaseMetaData
- java.sql.ParameterMetaData
- java.sql.ResultSet
- java.sql.ResultSetMetaData
- java.sql.Statement
- javax.sql.Datasource

19.1 Wrapper interface methods

The following methods are available on the Wrapper interface:

- isWrapperFor
- unwrap

19.1.1 unwrap method

The unwrap method is used to return an object that implements the specified interface allowing access to vendor-specific methods. The object that is returned may either be the object found to implement the specified interface or a proxy for that object.

If the receiver implements the specified interface then that is the object which is returned. If the receiver is a wrapper and the wrapped object implements the interface then the wrapped object or a proxy for the object is returned. Otherwise the returned object is the result of calling unwrap recursively on the wrapped object. If the receiver is not a wrapper and does not implement the specified interface, then an SQLException is thrown.

19.1.2 isWrapperFor method

The isWrapperFor method can be used to determine if the instance implements the specified interface or if the instance is a wrapper for an object that does.

If the object implements the specified interface then a value of true is returned. If this instance is a wrapper, then the method isWrapperFor is recursively called on the wrapped object. If the instance does not implement the interface and is not a wrapper, a value of false is returned.

This method should be implemented as a low-cost operation compared to calling the unwrap method. If the isWrapperFor method returns true, then calling the unwrap method with the same interface must succeed.

CODE EXAMPLE 19-1 provides an example of using the Wrapper interface methods:

```
Statement stmt = conn.createStatement();
Class clzz = Class.forName("oracle.jdbc.OracleStatement");
if(stmt.isWrapperFor(clzz)) {
    OracleStatement os = (OracleStatement)stmt.unwrap(clzz);
    os.defineColumnType(1, Types.NUMBER);
}
```

CODE EXAMPLE 19-1 Using the isWrapper and unwrap methods

APPENDIX A

Revision History

Appendix TABLE A-1 presents a summary of the revisions made to this specification.

 TABLE A-1
 Revision History

Revision	Dash	Date	Comments
Maintenance Release	01	March 2014	Refer to Chapter 3 for all of the changes in this maintenance release.

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APPENDIX ${f B}$

Data Type Conversion Tables

This appendix describes mappings and conversions that drivers must support.

The following mappings and conversions are covered:

- JDBC Types Mapped to Java Types
- Java Types Mapped to JDBC Types
- JDBC Types Mapped to Java Object Types
- Java Object Types Mapped to JDBC Types
- Conversions by setObject and setNull from Java Object Types to JDBC Types
- Type Conversions Supported by ResultSet getter Methods

B.1 JDBC Types Mapped to Java Types

TABLE B-1 shows the conceptual correspondence between JDBC types and Java types. A programmer should write code with this mapping in mind. For example, if a value in the database is a SMALLINT, a short should be the data type used in a JDBC application.

All CallableStatement getter methods except for getObject use this mapping. The getObject methods for both the CallableStatement and ResultSet interfaces use the mapping in TABLE B-3.

JDBC Type	Java Type
CHAR	String
VARCHAR	String

 TABLE B-1
 JDBC Types Mapped to Java Types

TABLE B-1	JDBC Types Mapped to Java Types
-----------	---------------------------------

JDBC Type	Java Type
LONGVARCHAR	String
NUMERIC	java.math.BigDecimal
DECIMAL	java.math.BigDecimal
BIT	boolean
BOOLEAN	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
CLOB	java.sql.Clob
BLOB	java.sql.Blob
ARRAY	java.sql.array
DISTINCT	Mapping of underlying type
STRUCT	java.sql.Struct
REF	java.sql.Ref
DATALINK	java.net.URL
JAVA_OBJECT	Underlying Java class
ROWID	java.sql.RowId

 TABLE B-1
 JDBC Types Mapped to Java Types

JDBC Туре	Java Type
NCHAR	String
NVARCHAR	String
LONGNVARCHAR	String
NCLOB	java.sql.NClob
SQLXML	java.sql.SQLXML

B.2 Java Types Mapped to JDBC Types

TABLE B-2 shows the mapping a driver should use for the updater methods in the ResultSet interface and for IN parameters. PreparedStatement setter methods and RowSet setter methods use this table for mapping an IN parameter, which is a Java type, to the JDBC type that will be sent to the database. Note that the setObject methods for these two interfaces use the mapping shown in TABLE B-4.

Java Type	JDBC Type
String	CHAR, VARCHAR, LONGVARCHAR, NCHAR, NVARCHAR or LONGNVARCHAR
java.math.BigDecimal	NUMERIC
boolean	BIT or BOOLEAN
byte	TINYINT
short	SMALLINT
int	INTEGER
long	BIGINT
float	REAL
double	DOUBLE
byte[]	BINARY, VARBINARY, or LONGVARBINARY
java.sql.Date	DATE
java.sql.Time	TIME

 TABLE B-2
 Standard Mapping from Java Types to JDBC Types

Appendix B Data Type Conversion Tables 191

Java Type	JDBC Type
java.sql.Timestamp	TIMESTAMP
java.sql.Clob	CLOB
java.sql.Blob	BLOB
java.sql.Array	ARRAY
java.sql.Struct	STRUCT
java.sql.Ref	REF
java.net.URL	DATALINK
Java class	JAVA_OBJECT
java.sql.RowId	ROWID
java.sql.NClob	NCLOB
java.sql.SQLXML	SQLXML

 TABLE B-2
 Standard Mapping from Java Types to JDBC Types

B.3

JDBC Types Mapped to Java Object Types

ResultSet.getObject and CallableStatement.getObject use the mapping shown in TABLE B-3 for standard mappings.

Note – The JDBC 1.0 specification defined the Java object mapping for the SMALLINT and TINYINT JDBC types to be Integer. The Java language did not include the Byte and Short data types when the JDBC 1.0 specification was finalized. The mapping of SMALLINT and TINYINT to Integer is maintained to preserve backwards compatibility.

TABLE B-3	Mapping from	JDBC Types to	Java Object Types
-----------	--------------	---------------	-------------------

JDBC Type	Java Object Type
CHAR	String
VARCHAR	String

JDBC Туре	Java Object Type
LONGVARCHAR	String
NUMERIC	java.math.BigDecimal
DECIMAL	java.math.BigDecimal
BIT	Boolean
BOOLEAN	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
DISTINCT	Object type of underlying type
CLOB	java.sql.Clob
BLOB	java.sql.Blob
ARRAY	java.sql.Array
STRUCT	java.sql.Struct or java.sql.SQLData
REF	java.sql.Ref
DATALINK	java.net.URL
JAVA_OBJECT	Underlying Java class

 TABLE B-3
 Mapping from JDBC Types to Java Object Types

 TABLE B-3
 Mapping from JDBC Types to Java Object Types

JDBC Type	Java Object Type
ROWID	java.sql.RowId
NCHAR	String
NVARCHAR	String
LONGNVARCHAR	String
NCLOB	java.sql.NClob
SQLXML	java.sql.SQLXML

B.4 Java Object Types Mapped to JDBC Types

PreparedStatement.setObject, PreparedStatement.setNull, RowSet.setNull and RowSet.setObject use the mapping shown TABLE B-4 when no parameter specifying a target JDBC type is provided.

Java Object Type	JDBC Type
String	CHAR, VARCHAR, LONGVARCHAR, NCHAR, NVARCHAR or LONGNVARCHAR
java.math.BigDecimal	NUMERIC
Boolean	BIT or BOOLEAN
Byte	TINYINT
Short	SMALLINT
Integer	INTEGER
Long	BIGINT
Float	REAL
Double	DOUBLE
byte[]	BINARY, VARBINARY, or LONGVARBINARY
java.math.BigInteger	BIGINT

 TABLE B-4
 Mapping from Java Object Types to JDBC Types

Java Object Type	JDBC Type
java.sql.Date	DATE
java.sql.Time	TIME
java.sql.Timestamp	TIMESTAMP
java.sql.Clob	CLOB
java.sql.Blob	BLOB
java.sql.Array	ARRAY
java.sql.Struct	STRUCT
java.sql.Ref	REF
java.net.URL	DATALINK
Java class	JAVA_OBJECT
java.sql.RowId	ROWID
java.sql.NClob	NCLOB
java.sql.SQLXML	SQLXML
java.util.Calendar	TIMESTAMP
java.util.Date	TIMESTAMP
java.time.LocalDate	DATE
java.time.LocalTime	TIME
java.time.LocalDateTime	TIMESTAMP
java.time.OffsetTime	TIME_WITH_TIMEZONE
java.time.OffsetDatetime	TIMESTAMP_WITH_TIMEZONE

 TABLE B-4
 Mapping from Java Object Types to JDBC Types

Conversions by setObject and setNull from Java Object Types to JDBC Types

TABLE B-5 shows which JDBC types may be specified as the target JDBC type to the methods PreparedStatement.setObject, PreparedStatement.setNull, RowSet.setNull, and RowSet.setObject.

 TABLE B-5
 Conversions Performed by setObject and setNull Between Java Object Types

 and Target JDBC Types

Java Object Type	Supported JDBC Type
String	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR, BINARY, VARBINARY, LONVARBINARY, DATE, TIME, TIMESTAMP, NCHAR, NVARCHAR, LONGNVARCHAR
java.math.BigDecimal	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
Boolean	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
Byte	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
Short	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
Integer	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
Long	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
Float	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR

B.5

Java Object Type	Supported JDBC Type	
Double	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR	
byte[]	BINARY, VARBINARY, or LONGVARBINARY	
java.math.BigInteger	BIGINT, CHAR, VARCHAR, LONGVARCHAR	
java.sql.Date	CHAR, VARCHAR, LONGVARCHAR, DATE, TIMESTAMP	
java.sql.Time	CHAR, VARCHAR, LONGVARCHAR, TIME, TIMESTAMP	
java.sql.Timestamp	CHAR, VARCHAR, LONGVARCHAR, DATE, TIME, TIMESTAMP	
java.sql.Array	ARRAY	
java.sql.Blob	BLOB	
java.sql.Clob	CLOB	
java.sql.Struct	STRUCT	
java.sql.Ref	REF	
java.net.URL	DATALINK	
Java class	JAVA_OBJECT	
java.sql.RowId	ROWID	
java.sql.NClob	NCLOB	
java.sql.SQLXML	SQLXML	
java.util.Calendar	CHAR, VARCHAR, LONGVARCHAR, DATE, TIME, TIMESTAMP, ARRAY	
java.util.Date	CHAR, VARCHAR, LONGVARCHAR, DATE, TIME, TIMESTAMP, ARRAY	
java.time.LocalDate	CHAR, VARCHAR, LONGVARCHAR, DATE	
java.time.LocalTime	CHAR, VARCHAR, LONGVARCHAR, TIME	
java.time.LocalDateTime	CHAR, VARCHAR, LONGVARCHAR, DATE, TIME, TIMESTAMP	

 TABLE B-5
 Conversions Performed by setObject and setNull Between Java Object Types

 and Target JDBC Types
 Paraget SetObject and SetNull Between Java Object Types

 TABLE B-5
 Conversions Performed by setObject and setNull Between Java Object Types

 and Target JDBC Types
 Provide the set of the

Java Object Type	Supported JDBC Type
java.time.OffsetTime	CHAR, VARCHAR, LONGVARCHAR, TIME_WITH_TIMEZONE
java.time.OffsetDatetime	CHAR, VARCHAR, LONGVARCHAR, TIME_WITH_TIMEZONE, TIMESTAMP_WITH_TIMEZONE

B.6

Type Conversions Supported by ResultSet getter Methods

TABLE B-6 shows which JDBC types may be returned by ResultSet getter methods. This table also shows the conversions used by the SQLInput reader methods, except that they use only the recommended conversions.

TABLE B-6	Use of ResultSet getter Methods to Retrieve JDBC Data Types
-----------	---

Java Object Type	Recommended JDBC Type	Supported JDBC Type
getByte	TINYINT	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR, ROWID
getShort	SMALLINT	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
getInt	INTEGER	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
getLong	BIGINT	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR

Java Object Type	Recommended JDBC Type	Supported JDBC Type
getFloat	REAL	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
getDouble	FLOAT, DOUBLE	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
getBigDecimal	DECIMAL, NUMERIC	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
getBoolean	BIT, BOOLEAN	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR
getString	CHAR, VARCHAR	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR, BINARY, VARBINARY, LONVARBINARY, DATE, TIME, TIMESTAMP, DATALINK, NCHAR, NVARCHAR, LONGNVARCHAR
getNString	NCHAR, NVARCHAR	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR, BINARY, VARBINARY, LONVARBINARY, DATE, TIME, TIMESTAMP, DATALINK, NCHAR, NVARCHAR, LONGNVARCHAR
getBytes	BINARY, VARBINARY	BINARY, VARBINARY, Longvarbinary

 TABLE B-6
 Use of ResultSet getter Methods to Retrieve JDBC Data Types

Appendix B Data Type Conversion Tables 199

Java Object Type	Recommended JDBC Type	Supported JDBC Type
getDate	DATE	CHAR, VARCHAR, LONGVARCHAR, DATE, TIMESTAMP
getTime	TIME	CHAR, VARCHAR, LONGVARCHAR, TIME, TIMESTAMP
getTimestamp	TIMESTAMP	CHAR, VARCHAR, LONGVARCHAR, DATE, TIME, TIMESTAMP
getAsciiStream	LONGVARCHAR	CHAR, VARCHAR, Longvarchar, Binary, Varbinary, Longvarbinary, Clob, Nclob
getBinaryStream	LONGVARBINARY	BINARY, VARBINARY, Longvarbinary
getCharacterStream	LONGVARCHAR	CHAR, VARCHAR, LONGVARCHAR, BINARY, VARBINARY, LONGVARBINARY, CLOB, NCHAR, NVARCHAR, LONGNVARCHAR, NCLOB, SQLXML
getNCharacterStream	LONGNVARCHAR	CHAR, VARCHAR, LONGVARCHAR, BINARY, VARBINARY, LONGVARBINARY, CLOB, NCHAR, NVARCHAR, LONGNVARCHAR, NCLOB, SQLXML
getClob	CLOB	CLOB, NCLOB
getNClob	NCLOB	CLOB, NCLOB
getBlob	BLOB	BLOB
getArray	ARRAY	ARRAY
getRef	REF	REF
getURL	DATALINK	DATALINK

 TABLE B-6
 Use of ResultSet getter Methods to Retrieve JDBC Data Types

Java Object Type	Recommended JDBC Type	Supported JDBC Type
getObject	STRUCT, JAVA_OBJECT	TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, DECIMAL, NUMERIC, BIT, BOOLEAN, CHAR, VARCHAR, LONGVARCHAR, BINARY, VARBINARY, LONVARBINARY, DATE, TIME, TIMESTAMP, CLOB, BLOB, ARRAY, REF, DATALINK, STRUCT, JAVA_OBJECT, ROWID, NCHAR, NVARCHAR, LONGNVARCHAR, NCLOB, SQLXML, TIME_WITH_TIMEZONE, TIMESTAMP_WITH_TIMEZONE
getRowId	ROWID	ROWID
getSQLXML	SQLXML	SQLXML

 TABLE B-6
 Use of ResultSet getter Methods to Retrieve JDBC Data Types

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Appendix ${f C}$

Scalar Functions

The JDBC API supports escape syntax for numeric, string, time, date, system, and conversion functions on scalar values. These scalar functions may be used in SQL strings as described in Section 13.4.1 "Scalar Functions" on page 13-114. The Open Group CLI specification provides more information on the semantics of the scalar functions. The scalar functions are listed below for reference.

If a DBMS supports a scalar function, the driver should also. Because scalar functions are supported by different DBMSs with slightly different syntax, it is the driver's job either to map them into the appropriate syntax or to implement the functions directly in the driver.

A user should be able to find out which functions are supported by calling metadata methods. For example, the method DatabaseMetaData.getNumericFunctions returns a comma separated list of the Open Group CLI names of the numeric functions supported. Similarly, the method DatabaseMetaData.getStringFunctions returns a list of string functions supported, and so on.

The scalar functions are listed by category:

C.1 NUMERIC FUNCTIONS

Function Name

ABS(number) ACOS(float) ASIN(float) ATAN(float) ATAN2(float1, float2) CEILING(number) COS(float) COT(float)

Function Returns

Absolute value of number Arccosine, in radians, of float Arcsine, in radians, of float Arctangent, in radians, of float Arctangent, in radians, of float2 / float1 Smallest integer >= number Cosine of float radians Cotangent of float radians DEGREES(number) EXP(float) FLOOR(number) LOG(float) LOG10(float) MOD(integer1, integer2) PI() POWER(number, power) RADIANS(number) RADIANS(number) RAND(integer) ROUND(number, places) SIGN(number)

SIN(float) SQRT(float) TAN(float) TRUNCATE(number, places) Degrees in number radians Exponential function of float Largest integer <= number Base e logarithm of float Base 10 logarithm of float Remainder for integer1 / integer2 The constant pi number raised to (integer) power Radians in number degrees Random floating point for seed integer number rounded to places places -1 to indicate number is < 0; 0 to indicate number is = 0;1 to indicate number is > 0Sine of float radians Square root of float Tangent of float radians number truncated to places places

C.2 STRING FUNCTIONS

Function Name ASCII(string) CHAR(code)	<u>Function Returns</u> Integer representing the ASCII code value of the leftmost character in string Character with ASCII code value code, where code is between 0 and 255
CHAR_LENGTH(string [,CHARACTERS OCTETS])	Returns the length in characters of the string expression if it is a character datatype; otherwise returns the length in bytes of the string expression whose result is the smallest integer not less than the number of bits divided by 8
CHARACTER_LENGTH(string [,CHARACTERS OCTETS})	Synonym for CHAR_LENGTH(string)
CONCAT(string1, string2)	Character string formed by appending string2 to string1; if a string is null, the result is DBMS-dependent
DIFFERENCE(string1, string2)	Integer indicating the difference between the values returned by the function SOUNDEX for string1 and string2
INSERT(string1, start,	A character string formed by deleting length
length, string2)	characters from string1 beginning at start, and inserting string2 into string1 at start
LCASE(string)	Converts all uppercase characters in string to lowercase
LEFT(string, count)	The count leftmost characters from string
LENGTH(string	Number of characters in string, excluding trailing blanks,
[, CHARACTERS OCTETS])	
LOCATE(string1, string2[, start])	Position in string2 of the first occurrence of string1, searching from the begin- ning of string2; if start is specified, the search begins from position start. 0 is returned if string2 does not contain string1. Position 1 is the first character in string2.
LTRIM(string)	Characters of string with leading blank spaces removed

OCTET_LENGTH(string)	Returns the length in bytes of the string expression whose result is the smallest integer not less than the number of bits divided by 8
POSITION(substring IN string	
[, CHARACTERS OCTETS])	Returns the position of first occurrence of substr in string returned as an NU-
	MERIC with an implementation defined precision and a scale of 0
REPEAT(string, count)	A character string formed by repeating string count times
REPLACE(string1, string2,	Replaces all occurrences of string2 in string1
string3)	with string3
RIGHT(string, count)	The count rightmost characters in string
RTRIM(string)	The characters of string with no trailing blanks
SOUNDEX(string)	A character string, which is data source-dependent, representing the sound of
	the words in string; this could be a four-digit SOUNDEX code, a phonetic rep-
	resentation of each word, etc.
SPACE(count)	A character string consisting of count spaces
SUBSTRING(string, start, length	A character string formed by extracting length
[, CHARACTERS OCTETS})	characters from string beginning at start
UCASE(string)	Converts all lowercase characters in string to uppercase

Note – SQL 2003 Feature T061, "UCS Support", is required by the Database in order to support OCTETS

C.3 TIME and DATE FUNCTIONS

Function Name

Function Returns

Function Name	Function Returns
CURRENT_DATE[()]	Synonym for CURDATE()
CURRENT_TIME[()]	Synonym for CURTIME()
CURRENT_TIMESTAMP[()]	Synonym for NOW()
CURDATE()	The current date as a date value
CURTIME()	The current local time as a time value
DAYNAME(date)	A character string representing the day component of date; the name for the
	day is specific to the data source
DAYOFMONTH(date)	An integer from 1 to 31 representing the day of the month in date
DAYOFWEEK(date)	An integer from 1 to 7 representing the day of the week in date; 1 represents
	Sunday
DAYOFYEAR(date)	An integer from 1 to 366 representing the day of the year in date
EXTRACT(field FROM source)	Extract the field portion from the source. The source is a datetime value. The
	value for field may be one of the following:
	YEAR, MONTH, DAY, HOUR, MINUTE, SECOND
HOUR(time)	An integer from 0 to 23 representing the hour component of time
MINUTE(time)	An integer from 0 to 59 representing the minute component of time
MONTH(date)	An integer from 1 to 12 representing the month component of date
MONTHNAME(date)	A character string representing the month component of date; the name for
	the month is specific to the data source
NOW()	A timestamp value representing the current date and time

QUARTER(date)

SECOND(time) TIMESTAMPADD(interval, count, timestamp)

TIMESTAMPDIFF(interval, timestamp1, timestamp2)

WEEK(date) YEAR(date) An integer from 1 to 4 representing the quarter in date; 1 represents January 1 through March 31
An integer from 0 to 59 representing the second component of time A timestamp calculated by adding count number of interval(s) to timestamp; interval may be one of the following: SQL_TSI_FRAC_SECOND, SQL_TSI_SECOND, SQL_TSI_MINUTE, SQL_TSI_HOUR, SQL_TSI_DAY, SQL_TSI_WEEK, SQL_TSI_MONTH, SQL_TSI_QUARTER, or SQL_TSI_YEAR
An integer representing the number of interval
by which timestamp2 is greater than timestamp1; interval may be one of the following: SQL_TSI_FRAC_SECOND, SQL_TSI_SECOND, SQL_TSI_MIN-UTE, SQL_TSI_HOUR, SQL_TSI_DAY, SQL_TSI_SECOND, SQL_TSI_MIN-UTE, SQL_TSI_HOUR, SQL_TSI_DAY, SQL_TSI_WEEK, SQL_TSI_MONTH, SQL_TSI_QUARTER, or SQL_TSI_PAR
An integer from 1 to 53 representing the week of the year in date
An integer representing the year component of date

C.4 **SYSTEM FUNCTIONS**

<u>Function Name</u> DATABASE() IFNULL(expression, value)

USER()

Function Returns

Name of the database value if expression is null; expression if expression is not null User name in the DBMS

C.5 **CONVERSION FUNCTIONS**

<u>Function Name</u> CONVERT(value, SQLtype)

Function Returns

value converted to SQLtype where SQLtype may be one of the following SQL types:

SQL_BIGINT, SQL_BINARY, SQL_BIT, SQL_BLOB, SQL_BOOLEAN, SQL_CHAR, SQL_CLOB, SQL_DATE, SQL_DECIMAL, SQL_DATALINK, SQL_DOUBLE, SQL_FLOAT, SQL_INTEGER, SQL_LONGVARBINARY, SQL_LONGNVARCHAR, SQL_LONGVARCHAR, SQL_NCHAR, SQL_N-CLOB, SQL_NUMERIC, SQL_NVARCHAR, SQL_REAL, SQL_ROWID, SQL_SQLXML, SQL_SMALLINT, SQL_TIME, SQL_TIMESTAMP, SQL_TI-NYINT, SQL_VARBINARY, or SQL_VARCHAR

Note – Previous versions of the JDBC specification defined the SQLtype without the SQL_ prefix, for example BIGINT and BINARY. JDBC drivers should continue to support this form for SQLtype.

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APPENDIX D

Related Documents

This specification makes reference to the following documents.

Data Management: SQL Call Level Interface (X/Open SQL CLI) Available at http://www.opengroup.org.

Distributed Transaction Processes: The XA Specification (X/Open CAE) Available at http://www.opengroup.org.

JDBC RowSet 1.0.1 Implementations Specification. Available at http://jcp.org/en/jsr/detail?id=114.

JDBC 3.0 Specification (JDBC 3.0). Available at http://jcp.org/en/jsr/detail?id=54

JDBC 4.0 Specification (JDBC 4.0). Available at http://jcp.org/en/jsr/detail?id=221.

JDBC 2.1 API (JDBC 2.1). Available at http://www.oracle.com/technetwork/java/ download-141179.html.

JDBC 2.0 Standard Extension API (JDBC extension specification). Available at http://www.oracle.com/technetwork/java/download-141179.html

JDBC 1.22 API (JDBC 1.22). Available at http://www.oracle.com/technetwork/java/download-141179.html.

JavaBeans 1.01 Specification (JavaBeans specification). Available athttp://www.oracle.com/technetwork/java/javase/glasgow-139720.html.

Java Transaction API, Version 1.2 (JTA Specification). Available at http://www.oracle.com/technetwork/java/javaee/jta/index.html.

Java Naming and Directory Interface 1.2 Specification (JNDI specification). Available at http://www.oracle.com/technetwork/java/jndi/index.html.

Enterprise Java Beans Specification, Version 3.2 (EJB). Available at http://www.oracle.com/technetwork/java/javaee/ejb/.

Java EE Connector Architecture Specification, Version 1.7 http://jcp.org/en/jsr/detail?id=322.

The following documents are collectively refered to as SQL:2003:

ISO/IEC 9075-1:2003, Information technology - Database languages - SQL - Part 1: Framework (SQL/Framework).

ISO/IEC 9075-2:2003, Information technology - Database languages - SQL - Part 2: Foundation (SQL/Foundation).

ISO/IEC 9075-3:2003, Information technology - Database languages - SQL - Part 3: Call-Level Interface (SQL/CLI).

ISO/IEC 9075-4:2003, Information technology - Database languages - SQL - Part 4: Persistent Stored Modules (SQL/PSM).

ISO/IEC 9075-5:2003, Information technology - Database languages - SQL - Part 5: Host Language Bindings (SQL/Bindings).

ISO/IEC 9075-9:2003 Information technology - Database languages - SQL - Part 9: Management of External Data (SQL/MED)

ISO/IEC 9075-14:2003 Information technology - Database languages - SQL - Part 14: XML-Related Specifications (SQL/XML)

The following document is a reference for SQLJ:

ISO/IEC 9075-10:2003, Information technology - Database Languages SQL - Part 10: Object Language Bindings (SQL/OLB)



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