

Java™ Data Objects 3.0

JSR 243

9-April-2010

Java Data Objects Expert Group

Specification Lead: **Craig Russell,**
Sun Microsystems Inc.

Technical comments:
jdo-comments@sun.com
Process comments:
community-process@sun.com



Sun Microsystems, Inc.
4140 Network Circle
Santa Clara, California 95054
408 276-5638 fax: 408 276-7191

Specification: JSR-000243 Java(tm) Data Objects ("Specification")

Version: 3.0

Release: 9-April-2010

Copyright 2010 SUN MICROSYSTEMS, INC.

4150 Network Circle, Santa Clara, California 95054, U.S.A

All rights reserved.

LIMITED LICENSE GRANTS

1. License for Evaluation Purposes. Sun hereby grants you a fully-paid, non-exclusive, non-transferable, worldwide, limited license (without the right to sublicense), under Sun's applicable intellectual property rights to view, download, use and reproduce the Specification only for the purpose of internal evaluation. This includes (i) developing applications intended to run on an implementation of the Specification, provided that such applications do not themselves implement any portion(s) of the Specification, and (ii) discussing the Specification with any third party; and (iii) excerpting brief portions of the Specification in oral or written communications which discuss the Specification provided that such excerpts do not in the aggregate constitute a significant portion of the Specification.
2. License for the Distribution of Compliant Implementations. Sun also grants you a perpetual, non-exclusive, non-transferable, worldwide, fully paid-up, royalty free, limited license (without the right to sublicense) under any applicable copyrights or, subject to the provisions of subsection 4 below, patent rights it may have covering the Specification to create and/or distribute an Independent Implementation of the Specification that: (a) fully implements the Specification including all its required interfaces and functionality; (b) does not modify, subset, superset or otherwise extend the Licensor Name Space, or include any public or protected packages, classes, Java interfaces, fields or methods within the Licensor Name Space other than those required/authorized by the Specification or Specifications being implemented; and (c) passes the Technology Compatibility Kit (including satisfying the requirements of the applicable TCK Users Guide) for such Specification ("Compliant Implementation"). In addition, the foregoing license is expressly conditioned on your not acting outside its scope. No license is granted hereunder for any other purpose (including, for example, modifying the Specification, other than to the extent of your fair use rights, or distributing the Specification to third parties). Also, no right, title, or interest in or to any trademarks, service marks, or trade names of Sun or Sun's licensors, Sun or the Sun's licensors is granted hereunder. Java, and Java-related logos, marks and names are trademarks or registered trademarks of Sun Microsystems, Inc. in the U.S. and other countries.

3. Pass-through Conditions. You need not include limitations (a)-(c) from the previous paragraph or any other particular "pass through" requirements in any license You grant concerning the use of your Independent Implementation or products derived from it. However, except with respect to Independent Implementations (and products derived from them) that satisfy limitations (a)-(c) from the previous paragraph, You may neither: (a) grant or otherwise pass through to your licensees any licenses under Sun's applicable intellectual property rights; nor (b) authorize your licensees to make any claims concerning their implementation's compliance with the Spec in question.

4. Reciprocity Concerning Patent Licenses.

a. With respect to any patent claims covered by the license granted under subparagraph 2 above that would be infringed by all technically feasible implementations of the Specification, such license is conditioned upon your offering on fair, reasonable and non-discriminatory terms, to any party seeking it from You, a perpetual, non-exclusive, non-transferable, worldwide license under Your patent rights which are or would be infringed by all technically feasible implementations of the Specification to develop, distribute and use a Compliant Implementation.

b With respect to any patent claims owned by Sun and covered by the license granted under subparagraph 2, whether or not their infringement can be avoided in a technically feasible manner when implementing the Specification, such license shall terminate with respect to such claims if You initiate a claim against Sun that it has, in the course of performing its responsibilities as the Sun, induced any other entity to infringe Your patent rights.

c Also with respect to any patent claims owned by Sun and covered by the license granted under subparagraph, where the infringement of such claims can be avoided in a technically feasible manner when implementing the Specification such license, with respect to such claims, shall terminate if You initiate a claim against Sun that its making, having made, using, offering to sell, selling or importing a Compliant Implementation infringes Your patent rights.

5. Definitions. For the purposes of this Agreement: "Independent Implementation" shall mean an implementation of the Specification that neither derives from any of Sun's source code or binary code materials nor, except with an appropriate and separate license from Sun, includes any of Sun's source code or binary code materials; "Licensor Name Space" shall mean the public class or interface declarations whose names begin with "java", "javax", "com.sun" or their equivalents in any subsequent naming convention adopted by Sun through the Java Community Process, or any recognized successors or replacements thereof; and "Technology Compatibility Kit" or "TCK" shall mean the test suite and accompanying TCK User's Guide provided by Sun which corresponds to the Specification and that was available either (i) from Sun's 120 days before the first release of Your Independent Implementation that allows its use for commercial purposes, or (ii) more recently than 120 days from such release but

against which You elect to test Your implementation of the Specification.

This Agreement will terminate immediately without notice from Sun if you breach the Agreement or act outside the scope of the licenses granted above.

DISCLAIMER OF WARRANTIES

THE SPECIFICATION IS PROVIDED "AS IS". SUN MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO, WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, NON-INFRINGEMENT (INCLUDING AS A CONSEQUENCE OF ANY PRACTICE OR IMPLEMENTATION OF THE SPECIFICATION), OR THAT THE CONTENTS OF THE SPECIFICATION ARE SUITABLE FOR ANY PURPOSE. This document does not represent any commitment to release or implement any portion of the Specification in any product. In addition, the Specification could include technical inaccuracies or typographical errors.

LIMITATION OF LIABILITY

TO THE EXTENT NOT PROHIBITED BY LAW, IN NO EVENT WILL SUN OR ITS LICENSORS BE LIABLE FOR ANY DAMAGES, INCLUDING WITHOUT LIMITATION, LOST REVENUE, PROFITS OR DATA, OR FOR SPECIAL, INDIRECT, CONSEQUENTIAL, INCIDENTAL OR PUNITIVE DAMAGES, HOWEVER CAUSED AND REGARDLESS OF THE THEORY OF LIABILITY, ARISING OUT OF OR RELATED IN ANY WAY TO YOUR HAVING, IMPLEMENTING OR OTHERWISE USING USING THE SPECIFICATION, EVEN IF SUN AND/OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You will indemnify, hold harmless, and defend Sun and its licensors from any claims arising or resulting from: (i) your use of the Specification; (ii) the use or distribution of your Java application, applet and/or implementation; and/or (iii) any claims that later versions or releases of any Specification furnished to you are incompatible with the Specification provided to you under this license.

RESTRICTED RIGHTS LEGEND

U.S. Government: If this Specification is being acquired by or on behalf of the U.S. Government or by a U.S. Government prime contractor or subcontractor (at any tier), then the Government's rights in the Software and accompanying documentation shall be only as set forth in this license; this is in accordance with 48 C.F.R. 227.7201 through 227.7202-4 (for Department of Defense (DoD) acquisitions) and with 48 C.F.R. 2.101 and 12.212 (for non-DoD acquisitions).

REPORT

If you provide Sun with any comments or suggestions concerning the Specification

("Feedback"), you hereby: (i) agree that such Feedback is provided on a non-proprietary and non-confidential basis, and (ii) grant Sun a perpetual, non-exclusive, worldwide, fully paid-up, irrevocable license, with the right to sublicense through multiple levels of sublicensees, to incorporate, disclose, and use without limitation the Feedback for any purpose.

GENERAL TERMS

Any action related to this Agreement will be governed by California law and controlling U.S. federal law. The U.N. Convention for the International Sale of Goods and the choice of law rules of any jurisdiction will not apply.

The Specification is subject to U.S. export control laws and may be subject to export or import regulations in other countries. Licensee agrees to comply strictly with all such laws and regulations and acknowledges that it has the responsibility to obtain such licenses to export, re-export or import as may be required after delivery to Licensee.

This Agreement is the parties' entire agreement relating to its subject matter. It supersedes all prior or contemporaneous oral or written communications, proposals, conditions, representations and warranties and prevails over any conflicting or additional terms of any quote, order, acknowledgment, or other communication between the parties relating to its subject matter during the term of this Agreement. No modification to this Agreement will be binding, unless in writing and signed by an authorized representative of each party.

Rev. January, 2006

Acknowledgments

I have come to know Rick Cattell during many shared experiences in the Java database standards arena. Rick is a Distinguished Engineer at Sun Microsystems and has been the database guru and Enterprise Cardinal in the Java “Church” for many years. I am deeply in his debt for his many contributions to JDO, both technical and organizational.

I want to thank the experts on the JDO expert group who contributed ideas, APIs, feedback, and other valuable input to the standard, especially Heiko Bobzin, Constantine Plotnikov, Luca Garulli, Philip Conroy, Steve Johnson, Michael Birk, Michael Rowley, Gordan Vosicki, and Martin McClure.

I want to recognize Michael Bouschen, David Jordan, David Ezzio, Dave Bristor, and Jeff Norton for their careful review of JDO for consistency, readability, and usability. Without their contributions, JDO would not have been possible.

Since the publication of JDO 1.0, many people have contributed time, energy, and ideas to the JDO effort. I want to recognize these significant contributors: Robin Roos, Abe White, David Jordan, Michael Bouschen, Michael Watzek, Wes Biggs, Geoff Hendry, Christian Romberg, David Tinker, Patrick Linskey, Bernhard Sporkmann, David Ezzio, Dion Almaer, Dirk Bartels, Dirk Theune, Eric Samson, Gordan Vosicki, Keiron McCammon, Matthew Adams, Oliver Kamps, Rod Johnson, Erik Bengtson, Andy Jefferson, Michelle Caisse, and Joerg von Frantzius.

I want to recognize the major contributors to the maintenance release 2.1, Michael Bouschen, Michelle Caisse, Matthew Adams, Andy Jefferson, Erik Bengtson, and Martin Zaun.

I want to recognize the major contributors to the maintenance release 2.2, Michael Bouschen, Michelle Caisse, Andy Jefferson, Matthew Adams, and Richard Schilling.

I want to recognize the major contributors to the maintenance release 3.0, Michael Bouschen, Michelle Caisse, Andy Jefferson, and Matthew Adams.

Table of Contents

1 Introduction	24
1.1 Overview	24
1.2 Scope	25
1.3 Target Audience	25
1.4 Organization	25
1.5 Document Convention	25
1.6 Terminology Convention	26
2 Overview	27
2.1 Definitions	27
2.1.1 JDO common interfaces.....	27
JDO Instance.....	27
JDO Implementation.....	27
JDO Enhancer.....	27
2.1.2 JDO in a managed environment.....	28
Enterprise Information System (EIS).....	28
EIS Resource.....	29
Resource Manager (RM)	29
Connection	29
Application Component	29
Session Beans	29
Message-driven Beans	29
Entity Beans	29
Helper objects	29
Container.....	29
2.2 Rationale	30
2.3 Goals	31
3 JDO Architecture	33
3.1 Overview	33
3.2 JDO Architecture	34
3.2.1 Two tier usage	34
3.2.2 Application server usage	34
Resource Adapter	34
Pooling	35
Contracts.....	35
4 Roles and Scenarios	37
4.1 Roles	37
4.1.1 Application Developer.....	37
4.1.2 Application Component Provider	37
4.1.3 Application Assembler	37
4.1.4 Deployer	38
4.1.5 System Administrator	38
4.1.6 JDO Vendor	38

4.1.7 Connector Provider	38
4.1.8 Application Server Vendor	38
4.1.9 Container Provider.....	38
4.2 Scenario: Embedded calendar management system	39
4.3 Scenario: Enterprise Calendar Manager	40
5 Life Cycle of JDO Instances	42
5.1 Overview	42
5.2 Goals	43
5.3 Architecture:	43
JDO Instances	43
JDO State Manager.....	44
JDO Managed Fields	44
5.4 JDO Identity	44
Three Types of JDO identity	44
Uniquing	45
Change of identity.....	46
JDO Identity Support	46
5.4.1 Application (primary key) identity	46
Compound Identity	47
5.4.2 Single Field Identity.....	48
5.4.3 Datastore identity.....	49
5.4.4 Nondurable JDO identity.....	49
5.5 Life Cycle States	50
Datastore Transactions	51
5.5.1 Transient (Required)	51
5.5.2 Persistent-new (Required)	51
5.5.3 Persistent-dirty (Required).....	52
5.5.4 Hollow (Required)	52
5.5.5 Persistent-clean (Required)	53
5.5.6 Persistent-deleted (Required).....	53
5.5.7 Persistent-new-deleted (Required).....	53
5.5.8 Detached-clean (Required)	54
5.5.9 Detached-dirty (Required).....	54
5.6 Nontransactional (Optional)	54
5.6.1 Persistent-nontransactional (Optional)	56
5.6.2 Persistent-nontransactional-dirty (Optional)	56
5.7 Transient Transactional (Optional)	57
5.7.1 Transient-clean (Optional).....	57
5.7.2 Transient-dirty (Optional)	58
5.8 Optimistic Transactions (Optional)	58
6 The Persistent Object Model	69
6.1 Overview	69
6.2 Goals	70
6.3 Architecture	70
Persistence-capable.....	70
First Class Objects and Second Class Objects	71

First Class Objects	71
Second Class Objects	71
Arrays	72
Primitives	73
Interfaces.....	73
6.4 Field types of persistence-capable classes	73
6.4.1 Nontransactional non-persistent fields.....	73
6.4.2 Transactional non-persistent fields	73
6.4.3 Persistent fields	73
Precision of fields	73
Primitive types	73
Immutable Object Class types	73
Mutable Object Class types	74
Persistence-capable Class types	74
Object Class type	74
Collection Interface types.....	74
Other Interface types.....	74
Arrays	75
Enums	75
6.4.4 Static and final fields	75
6.4.5 Complex enum types	75
6.5 Inheritance	75
7 PersistenceCapable	77
7.1 Persistence Manager	77
7.2 Make Dirty	78
7.3 JDO Identity	78
7.3.1 Version.....	78
7.4 Status interrogation	78
7.4.1 Dirty.....	79
7.4.2 Transactional	79
7.4.3 Persistent	79
7.4.4 New	79
7.4.5 Deleted.....	79
7.4.6 Detached	79
7.5 New instance	80
7.6 State Manager	80
7.7 Replace Flags	80
7.8 Replace Fields	81
7.9 Provide Fields	81
7.10 Copy Fields	81
7.11 Static Fields	81
7.12 JDO identity handling	81
interface ObjectIdFieldSupplier	83
interface ObjectIdFieldConsumer.....	83
interface ObjectIdFieldManager.....	83
7.13 Detachable	83

8 JDOHelper	85
8.1 Persistence Manager	85
8.2 Make Dirty	86
8.3 JDO Identity	86
8.4 JDO Version	86
8.5 Status interrogation	86
8.5.1 Dirty	86
8.5.2 Transactional	87
8.5.3 Persistent	87
8.5.4 New	87
8.5.5 Deleted	87
8.5.6 Detached	87
8.6 State Interrogation	87
8.6.1 enum ObjectState	88
8.7 PersistenceManagerFactory methods	88
Get by Name with Overrides	88
Get by Properties file or input stream	89
Get by Name	89
Get by Properties map	90
Get by JNDI lookup	90
9 JDOImplHelper	91
9.1 JDOImplHelper access	91
9.2 Metadata access	91
9.3 Persistence-capable instance factory	92
9.4 Registration of PersistenceCapable classes	92
9.4.1 Notification of PersistenceCapable class registrations	92
RegisterClassEvent	93
RegisterClassListener	93
9.5 Security administration	93
9.6 Application identity handling	94
9.7 Persistence-capable class state interrogation	95
10 InstanceCallbacks	96
10.1 jdoPostLoad	96
10.2 jdoPreStore	96
10.3 jdoPreClear	97
10.4 jdoPreDelete	97
10.5 jdoPreDetach and jdoPostDetach	97
10.6 jdoPreAttach and jdoPostAttach	97
11 PersistenceManagerFactory	99
11.1 Interface PersistenceManagerFactory	99
ServerTimeZoneID	100
Transaction Isolation Level	100
Connection	100
Datastore Timeout	101
11.1.1 Construction by Properties	101

11.1.2 Construction by jdoconfig.xml	103
11.1.3 Access via persistence.xml	104
11.1.4 jdoconfig.xml	104
11.2 ConnectionFactory	105
11.3 PersistenceManager access	105
11.3.1 Access via proxy	106
11.4 Close the PersistenceManagerFactory	106
11.5 Non-configurable Properties	107
11.6 Optional Feature Support	107
11.7 Properties constructors	110
11.8 Second-level cache management	110
Evicting objects from the cache	111
Pinning objects in the cache	111
Unpinning objects in the cache	111
11.9 Registering for life cycle events	111
11.10 Metadata Access	112
11.11 Serialization	112
11.12 OSGi Service Discovery	113
From the user perspective	113
From the implementation perspective	113
Examples	113
12 PersistenceManager	115
12.1 Overview	115
12.2 Goals	115
12.3 Architecture: JDO PersistenceManager	115
12.4 Threading	116
12.5 Class Loaders	116
12.6 Interface PersistenceManager	117
State Transitions for persistent instances at close	117
Null management	117
12.6.1 Cache management	118
Evict instances	118
Retrieve instances	119
12.6.2 Transaction factory interface	120
12.6.3 Query factory interface	120
12.6.4 Extent Management	120
Extents of interfaces	121
12.6.5 JDO Identity management	121
Getting Multiple Persistent Instances	123
Getting an Object by Class and Key	123
12.6.6 Persistent instance factory	123
12.6.7 JDO Instance life cycle management	124
Make instances persistent	124
Delete persistent instances	125
Make instances transient	126
Make instances transactional	126

Make instances nontransactional	127
12.6.8 Detaching and attaching instances	127
Committing the transaction with DetachAllOnCommit	127
Attaching Detached Instances with CopyOnAttach	128
Serializing Persistent Instances	128
Explicit detach	128
Behavior of Detached Instances	129
12.7 Fetch Plan	130
12.7.1 Fetch Groups	131
12.7.2 MaxFetchDepth	132
12.7.3 Root instances	132
12.7.4 Recursion-depth	132
12.7.5 The FetchPlan interface	133
12.7.6 Defining fetch groups	135
12.7.7 Defining Fetch Groups Dynamically	137
Persistence Manager Factory Scoped Fetch Groups	137
Persistence Manager Scoped Fetch Groups	137
Interface FetchGroup	138
12.8 Flushing instances	139
12.9 Transaction completion	140
12.10 Multithreaded Synchronization	140
12.11 User associated objects	140
12.12 PersistenceManagerFactory	141
12.13 ObjectId class management	141
12.14 Sequence	141
12.15 Life-cycle callbacks	142
InstanceLifecycleEvent	145
12.16 Access to internal datastore connection	146
SQL Portability	147
12.17 Server Date	147
12.18 Serialization	147
13 Transactions and Connections	148
13.1 Overview	148
13.2 Goals	148
13.3 Architecture: PersistenceManager, Transactions, and Connections	148
Connection Management Scenarios	149
Native Connection Management	149
Non-native Connection Management	149
Optimistic Transactions	150
13.4 Interface Transaction	150
13.4.1 PersistenceManager	150
13.4.2 Transaction options	151
Nontransactional access to persistent values	151
Optimistic concurrency control	151
Retain values at transaction commit	151
Restore values at transaction rollback	152

Transaction Isolation Level	152
Serialize Access to Instances Read from the Datastore (SerializeRead)	152
13.4.3 Synchronization	152
13.4.4 Transaction demarcation	154
Non-managed environment	154
Managed environment	154
13.4.5 RollbackOnly	155
13.5 Optimistic transaction management	155
14 Query	157
14.1 Overview	157
14.2 Goals	157
14.3 Architecture: Query	158
14.4 Namespaces in queries	159
Keywords	159
14.5 Query Factory in PersistenceManager interface	160
14.6 Query Interface	162
Persistence Manager	162
Fetch Plan	162
Query element binding	162
Query options	164
Query modification	164
Query evaluation	164
Query compilation	164
Serialize Access to Instances Read from the Datastore (SerializeRead)	164
14.6.1 Query execution	165
Query Timeout	166
Query Cancel	166
14.6.2 Filter specification	167
Methods	170
Subqueries	171
Non-correlated subqueries	171
Correlated subqueries	171
14.6.3 Parameter declaration	172
Implicit parameter declaration	173
14.6.4 Import statements	173
14.6.5 Variable declaration	173
Implicit variable declaration	173
14.6.6 Ordering statement	174
14.6.7 Closing Query results	174
14.6.8 Limiting the Cardinality of the Query Result	175
14.6.9 Specifying the Result of a Query (Projections, Aggregates)	175
Distinct results	175
Named Result Expressions	177
Aggregate Types	177
Primitive Types	177
Null Results	177

Default Result	177
Projected Second Class Result	177
14.6.10 Grouping Aggregate Results	177
14.6.11 Specifying Uniqueness of the Query Result	178
Default Unique setting	178
14.6.12 Specifying the Class of the Result	178
Result Class Requirements	178
14.6.13 Single-string Query element binding	179
14.7 SQL Queries	180
14.7.1 Mapping Columns of SQL Queries to User-specified Result Classes	182
14.8 Deletion by Query	182
14.9 Extensions	183
14.10 Examples:	183
14.10.1 Basic query	184
14.10.2 Basic query with ordering	184
14.10.3 Parameter passing	184
14.10.4 Navigation through single-valued field	184
14.10.5 Navigation through multi-valued field	185
14.10.6 Membership in a collection	185
14.10.7 Projection of a Single Field	185
14.10.8 Projection of Multiple Fields and Expressions	185
14.10.9 Projection of Multiple Fields and Expressions into a Constructed instance	186
14.10.10 Aggregation of a single Field	186
14.10.11 Aggregation of Multiple Fields and Expressions	187
14.10.12 Aggregation of Multiple fields with Grouping	187
14.10.13 Selection of a Single Instance	187
14.10.14 Selection of a Single Field	188
14.10.15 Projection of “this” to User-defined Result Class with Matching Field	188
14.10.16 Projection of “this” to User-defined Result Class with Matching Method	188
14.10.17 Projection of variables	189
14.10.18 Non-correlated subquery	189
14.10.19 Correlated subquery	190
14.10.20 Deleting Multiple Instances	190
15 Object-Relational Mapping	192
Mapping Overview	192
Mapping Strategies	192
15.1 Column Elements	193
Mapping enums	193
15.1.1 Mapping single-valued fields to columns	193
15.2 Join Condition	194
15.2.1 Secondary Table mapping	194
15.2.2 Map using join table	196
15.3 Relationship Mapping	197
Mapping Strategies	198
15.3.1 Many-to-One using foreign key	198
15.3.2 One-to-Many using foreign key	199

15.3.3 Many-to-One and One-to-Many using mapped-by	200
15.3.4 Many-to-One and One-to-Many using compound foreign key	201
15.3.5 Many-to-One and One-to-Many using Map<Department, String>.....	202
15.3.6 Many-to-One and One-to-Many using Map<String, Employee>	203
15.4 Embedding	204
15.4.1 Mapping relationships using embedded, referenced, and join table	204
15.5 Foreign Key Constraints	205
Delete Action, Update Action.....	206
15.5.1 Many-to-One with foreign key constraint	206
15.6 Indexes	207
Unique Constraints	208
15.6.1 Single-field and Compound Indexes	208
15.7 Inheritance	209
15.8 Versioning	209
15.8.1 Inheritance with superclass-table and version	210
15.8.2 Inheritance with new-table and version	211
15.8.3 Inheritance with subclass-table	212
16 Enterprise Java Beans	213
16.1 Session Beans	213
16.1.1 Stateless Session Bean with Container Managed Transactions.....	214
16.1.2 Stateful Session Bean with Container Managed Transactions	214
16.1.3 Stateless Session Bean with Bean Managed Transactions	214
16.1.4 Stateful Session Bean with Bean Managed Transactions	215
16.2 Entity Beans	215
17 JDO Exceptions	216
17.1 JDOException	216
17.1.1 JDOFatalException	217
17.1.2 JDOCANRETRYException	217
17.1.3 JDOUnsupportedOptionException	217
17.1.4 JDOUserException	217
17.1.5 JDOFatalUserException	218
17.1.6 JDOFatalInternalException	218
17.1.7 JDODataStoreException	218
17.1.8 JDOFatalDataStoreException	218
17.1.9 JDOObjectNotFoundException	218
17.1.10 JDOOptimisticVerificationException	218
17.1.11 JDODetachedFieldAccessException	219
17.1.12 JDOUserCallbackException	219
18 XML Metadata	220
Mapping to Relational Databases	221
18.1 ELEMENT jdo	222
18.2 ELEMENT package	222
18.3 ELEMENT interface	222
18.4 ELEMENT column	223
18.5 ELEMENT class	225

18.5.1 ELEMENT datastore-identity	227
18.5.2 ELEMENT version	227
18.6 ELEMENT primary-key	228
18.7 ELEMENT join	228
18.8 ELEMENT inheritance	229
18.9 ELEMENT discriminator	229
18.10 ELEMENT implements	229
18.11 ELEMENT foreign-key	229
18.11.1 ATTRIBUTE update-action	230
18.11.2 ATTRIBUTE delete-action	230
18.11.3 ATTRIBUTE deferred	230
18.11.4 ATTRIBUTE name	230
18.12 ELEMENT unique	230
18.13 ELEMENT index	230
18.14 ELEMENT property	230
18.15 ELEMENT field	231
Default persistence-modifier	231
Embedded	232
Column Mapping	233
Foreign key	234
18.15.1 ELEMENT collection	234
18.15.2 ELEMENT map	235
18.15.3 ELEMENT array	236
18.15.4 ELEMENT embedded	236
18.15.5 ELEMENT key	236
18.15.6 ELEMENT value	237
18.15.7 ELEMENT element	237
18.15.8 ELEMENT order	237
18.16 ELEMENT query	237
18.17 ELEMENT sequence	238
18.18 ELEMENT extension	238
18.19 ELEMENT orm	238
18.20 ELEMENT jdoquery	239
18.21 The jdo Schema Descriptor	239
18.22 The orm Schema Descriptor	243
18.23 The jdoquery Schema Descriptor	247
18.24 Example XML file	248
19 Annotations and Metadata API	250
Java Persistence API Annotations	251
Overrides	251
19.1 Metadata Annotations	251
19.1.1 Cacheable Annotation	251
19.1.2 Column Annotation	251
19.1.3 Columns Annotation	252
19.1.4 DatastoreIdentity Annotation	252
19.1.5 Discriminator Annotation	253

19.1.6 DiscriminatorStrategy Enum	254
19.1.7 Element Annotation	254
19.1.8 Embedded Annotation	256
19.1.9 EmbeddedOnly Annotation	256
19.1.10 Extension Annotation	257
19.1.11 Extensions Annotation	257
19.1.12 FetchGroup Annotation	257
19.1.13 FetchGroups Annotation	258
19.1.14 FetchPlan Annotation	258
19.1.15 FetchPlans Annotation	258
19.1.16 ForeignKey Annotation	259
19.1.17 ForeignKeyAction Enum	259
19.1.18 ForeignKeys Annotation	260
19.1.19 IdGeneratorStrategy Enum	260
19.1.20 IdentityType Enum	260
19.1.21 Index Annotation	260
19.1.22 Indices Annotation	261
19.1.23 Inheritance Annotation	261
19.1.24 InheritanceStrategy Enum	261
19.1.25 Join Annotation	262
19.1.26 Joins Annotation	263
19.1.27 Key Annotation	263
19.1.28 NotPersistent Annotation	265
19.1.29 NullValue Enum	265
19.1.30 Order Annotation	265
19.1.31 PersistenceAware Annotation	266
19.1.32 PersistenceCapable Annotation	266
19.1.33 PersistenceModifier Enum	267
19.1.34 Persistent Annotation	267
19.1.35 PrimaryKey Annotation	270
19.1.36 Queries Annotation	271
19.1.37 Query Annotation	271
19.1.38 Sequence Annotation	272
19.1.39 SequenceStrategy Enum	272
19.1.40 Serialized Annotation	272
19.1.41 Transactional Annotation	272
19.1.42 Unique Annotation	273
19.1.43 Uniques Annotation	273
19.1.44 Value Annotation	273
19.1.45 Version Annotation	275
19.1.46 VersionStrategy Enum	276
19.2 Metadata API	279
19.2.1 Metadata	279
19.2.2 JDO Metadata	280
19.2.3 Package Metadata	283
19.2.4 Component Metadata	286

19.2.5 Class Metadata	294
19.2.6 Interface Metadata	295
19.2.7 Field Metadata	295
19.2.8 Property Metadata	295
19.2.9 Query Metadata	296
20 Java Persistence API (JSRs 220, 317) Alignment	299
20.1 JDOEntityManagerFactory	299
20.2 JDOEntityManager	299
21 Extent	300
21.1 Overview	300
21.2 Goals	300
21.3 Interface Extent	301
22 Portability Guidelines	303
22.1 Optional Features	303
22.1.1 Optimistic Transactions	303
22.1.2 Nontransactional Read	303
22.1.3 Nontransactional Write	303
22.1.4 Transient Transactional	303
22.1.5 RetainValues	303
22.1.6 IgnoreCache	303
22.2 Object Model	303
22.3 JDO Identity	304
22.4 PersistenceManager	304
22.5 Query	304
22.6 XML metadata	305
22.7 Life cycle	305
22.8 JDOHelper	305
22.9 Transaction	305
22.10 Binary Compatibility	305
23 JDO Reference Enhancer	306
23.1 Overview	306
23.2 Goals	306
23.3 Standard Enhancement	307
23.3.1 Enhancer Main	308
23.4 Enhancement: Architecture	309
23.5 Inheritance	312
23.6 Field Numbering	312
23.7 Serialization	313
23.8 Cloning	314
23.9 Introspection (Java core reflection)	314
23.10 Field Modifiers	314
23.10.1 Non-persistent	315
23.10.2 Transactional non-persistent	315
23.10.3 Persistent	315
23.10.4 PrimaryKey	316

23.10.5 Embedded	316
23.10.6 Null-value	316
23.11 Treatment of standard Java field modifiers	316
23.11.1 Static	316
23.11.2 Final	316
23.11.3 Private	316
23.11.4 Public, Protected	317
23.12 Fetch Groups	317
23.13 jdoFlags Definition	317
23.14 Exceptions	318
23.15 Modified field access	318
23.16 Generated fields in least-derived PersistenceCapable class	319
23.17 Generated fields in all PersistenceCapable classes	319
Generated static initializer	319
23.18 Generated methods in least-derived PersistenceCapable class	319
23.19 Generated methods in PersistenceCapable root classes	321
23.20 Generated method in least-derived Detachable classes	322
23.21 Generated methods in all PersistenceCapable classes	322
23.22 Note that there is no modification of a user's readObject. During the execution of readObject, a new transient instance is created. This instance might be made persistent later, but while it is being constructed by serialization, it remains transient.Example class: Employee ..	325
23.22.1 Generated fields	325
23.22.2 Generated static initializer	325
23.22.3 Generated interrogatives	326
23.22.4 Generated jdoReplaceStateManager	326
23.22.5 Generated jdoReplaceFlags	327
23.22.6 Generated jdoNewInstance helpers	327
23.22.7 Generated jdoGetManagedFieldCount	327
23.22.8 Generated jdoGetXXX methods (one per persistent field)	328
23.22.9 Generated jdoSetXXX methods (one per persistent field)	328
23.22.10 Generated jdoReplaceField and jdoReplaceFields	329
23.22.11 Generated jdoProvideField and jdoProvideFields	330
23.22.12 Generated jdoCopyField and jdoCopyFields methods	330
23.22.13 Generated writeObject method	331
23.22.14 Generated jdoPreSerialize method	331
23.22.15 Generated jdoNewObjectIdInstance	332
23.22.16 Generated jdoCopyKeyFieldsToObjectId	332
23.22.17 Generated jdoCopyKeyFieldsFromObjectId	332
23.22.18 Generated Detachable methods	332
24 Interface StateManager	333
24.1 Overview	333
Clone support	333
24.2 StateManager Management	333
24.3 PersistenceManager Management	334
24.4 Dirty management	334
24.5 State queries	334

24.6 JDO Identity	335
24.7 Serialization support	335
24.8 Field Management	335
24.8.1 User-requested value of a field	336
24.8.2 User-requested modification of a field	336
24.8.3 StateManager-requested value of a field	337
24.8.4 StateManager-requested modification of a field	337
24.9 Detached instance support	338
25 JDOPermission	339
26 JDOQL BNF	341
26.1 Single-String JDOQL	341
26.2 Filter Specification	342
26.3 Subqueries	343
26.4 Parameter Declaration	344
26.5 Variable Declaration	344
26.6 Import Declaration	345
26.7 Ordering Specification	345
26.8 Result Specification	345
26.9 Grouping Specification	346
26.10 Types	346
26.11 Literals	347
26.12 Names	347
26.13 Keywords	348
27 Items Deferred to the Next Release	349
27.1 Nested Transactions	349
27.2 Savepoint, Undosavepoint	349
27.3 Inter-PersistenceManager References	349
27.4 Enhancer Invocation API	349
27.5 Prefetch API	349
27.6 BLOB/CLOB datatype support	349
27.7 Managed (inverse) relationship support	350
27.8 Case-Insensitive Query	350
27.9 String conversion in Query	350
27.10 Read-only fields	350
27.11 Enumeration pattern	350
27.12 Non-static inner classes	351
27.13 Projections in query	351
27.14 LogWriter support	351
27.15 New Exceptions	351
27.16 Distributed object support	351
27.17 Object-Relational Mapping	351
28 JDO 1.0.1 Metadata	352
28.1 ELEMENT jdo	353
28.2 ELEMENT package	353
28.3 ELEMENT class	353

28.4 ELEMENT field	354
Default persistence-modifier	354
28.4.1 ELEMENT collection	355
28.4.2 ELEMENT map	355
28.4.3 ELEMENT array	356
28.5 ELEMENT extension	356
28.6 The Document Type Descriptor	356
28.7 Example XML file	357
Appendix A: References	358
Appendix B: Design Decisions	359
B.1 Enhancer	359
Appendix C: Revision History	360
C.1 Changes since Draft 0.1	360
C.1 Changes since Draft 0.2	360
C.1 Changes since Draft 0.3	360
C.1 Changes since Draft 0.4	360
C.1 Changes since Draft 0.5	361
C.1 Changes since Draft 0.6 (Participant Review Draft)	362
C.1 Changes since Draft 0.7	362
C.1 Changes since Draft 0.8	362
C.1 Changes since Draft 0.9	363
C.1 Changes since draft 0.91	364
C.1 Changes since draft 0.92	365
C.1 Changes since draft 0.93	365
C.1 Changes since draft 0.94	366
C.1 Changes since draft 0.95 (Proposed Final Draft)	366
C.1 Changes since draft 0.96	367
C.1 Changes since draft 0.97	368
C.1 Changes since Approved Draft	368
C.1 Changes since 1.0.1	371
C.1 Changes since Proposed Final Draft	372
C.1 Changes since 2.0	373
C.1 Changes since 2.2	376
Appendix D: XML Schema for jdoconfig.xml	378
Appendix E: XML Schema for jdo.xml	381
Appendix F: XML Schema for orm.xml	403
Appendix G: XML Schema for jdoquery.xml	418
Index 420	

List of Tables

Which Enhancement Interface is Used	28
State Transitions	59
State interrogation	79
Query Operators	168
Query Methods	170
Shape of Result (C is the candidate class)	179
Shape of Result of SQL Query	181
Default jdbc-type	224
Annotation correspondence to xml metadata	276
Field access mediation	318
Java SE 5 Signature Changes	375

List of Figures

Figure 1: Standard plug-and-play between application programs and EISes using JDO .	31
Figure 2: Overview of non-managed JDO architecture	33
Figure 3: Contracts between application server and native JDO resource adapter.	36
Figure 4: Contracts between application server and layered JDO implementation	36
Figure 5: Scenario: Embedded calendar manager	39
Figure 6: Scenario: Enterprise Calendar Manager	41
Figure 7: Life Cycle: New Persistent Instances	64
Figure 8: Life Cycle: Transactional Access	64
Figure 9: Life Cycle: Datastore Transactions	64
Figure 10: Life Cycle: Optimistic Transactions	65
Figure 11: Life Cycle: Access Outside Transactions	65
Figure 12: Life Cycle: Transient TransactionalLife Cycle: Transient Transactional1	65
Figure 13: Life Cycle: Detached.	66
Figure 14: JDO Instance State Transitions	67
Figure 15: Instantiated persistent objects	69
Figure 16: Transactions and Connections.	150

1 Introduction

Java is a language that defines a runtime environment in which user-defined classes execute. The instances of these user-defined classes might represent real world data. The data might be stored in databases, file systems, or mainframe transaction processing systems. These data sources are collectively referred to as Enterprise Information Systems (EIS). Additionally, small footprint environments often require a way to manage persistent data in local storage.

The data access techniques are different for each type of data source, and accessing the data presents a challenge to application developers, who currently need to use a different Application Programming Interface (API) for each type of data source.

This means that application developers need to learn at least two different languages to develop business logic for these data sources: the Java programming language; and the specialized data access language required by the data source.

Currently, aside from JDO, there are four Java standards for storing Java data persistently: serialization, JDBC, Enterprise JavaBeans, and Java Persistence API. Serialization preserves relationships among a graph of Java objects, but does not support sharing among multiple users. JDBC requires the user to explicitly manage the values of fields and map them into relational database tables. Enterprise JavaBeans require a container in which to run. Java Persistence API can run either in a container or in a Java SE VM.

Developers can be more productive if they focus on creating Java classes that implement business logic, and use native Java classes to represent data from the data sources. Mapping between the Java classes and the data source, if necessary, can be done by an EIS domain expert.

JDO defines interfaces and classes to be used by application programmers when using classes whose instances are to be stored in persistent storage (persistence-capable classes), and specifies the contracts between suppliers of persistence-capable classes and the run-time environment (which is part of the JDO Implementation).

The supplier of the JDO Implementation is hereinafter called the JDO vendor.

1.1 Overview

There are two major objectives of the JDO architecture: first, to provide application programmers a transparent Java-centric view of persistent information, including enterprise data and locally stored data; and second, to enable pluggable implementations of data-stores into application servers.

The Java Data Objects architecture defines a standard API to data contained in local storage systems and heterogeneous enterprise information systems, such as ERP, mainframe transaction processing and database systems. The architecture also refers to the Connector architecture [see Appendix A reference 4] which defines a set of portable, scalable, secure, and transactional mechanisms for the integration of EIS with an application server.

This architecture enables a local storage expert, an enterprise information system (EIS) vendor, or an EIS domain expert to provide a standard data view (JDO Implementation) for the local data or EIS.

1.2 Scope

The JDO architecture defines a standard set of contracts between an application programmer and an JDO vendor. These contracts focus on the view of the Java instances of persistence-capable classes.

JDO uses the Connector Architecture [see Appendix A reference 4] to specify the contract between the JDO vendor and an application server. These contracts focus on the important aspects of integration with heterogeneous enterprise information systems: instance management, connection management, and transaction management.

To provide transparent storage of local data, the JDO architecture does not require the Connector Architecture in non-managed (non-application server) environments.

1.3 Target Audience

The target audience for this specification includes:

- application developers
- JDO vendors
- enterprise information system (EIS) vendors and EIS Connector providers
- container providers
- enterprise system integrators
- enterprise tool vendors

*JDO defines two types of interfaces: the **JDO API**, of primary interest to application developers (the JDO instance life cycle) and the **JDO SPI**, of primary interest to container providers and JDO vendors. An italicized notice may appear at the end of a section, directing readers interested only in the API side to skip to the next API-side section.*

1.4 Organization

This document describes the rationale and goals for a standard architecture for specifying the interface between an application developer and a local file system or EIS datastore. It then elaborates the JDO architecture and its relationship to the Connector architecture.

The document next describes two typical JDO scenarios, one managed (application server) and the other non-managed (local file storage). This chapter explains key roles and responsibilities involved in the development and deployment of portable Java applications that require persistent storage.

The document then details the prescriptive aspects of the architecture. It starts with the JDO instance, which is the application programmer-visible part of the system. It then details the JDO PersistenceManager, which is the primary interface between a persistence-aware application, focusing on the contracts between the application developer and JDO implementation provider. Finally, the contracts for connection and transaction management between the JDO vendor and application server vendor are defined.

1.5 Document Convention

A Palatino font is used for describing the JDO architecture.

A courier font is used for code fragments.

1.6 Terminology Convention

“Must” is used where the specified component is required to implement some interface or action to be compliant with the specification.

“Might” is used where there is an implementation choice whether or how to implement a method or function.

“Should” is used to describe objectives of the specification and recommended application programming usage. If the recommended usage is not followed by applications, behavior is non-portable, unexpected, or unspecified.

“Should” is also used where there is a recommended choice for possibly different implementation actions. If the recommended usage is not followed by implementations, inefficiencies might result.

2 Overview

This chapter introduces key concepts that are required for an understanding of the JDO architecture. It lays down a reference framework to facilitate a formal specification of the JDO architecture in the subsequent chapters of this document.

2.1 Definitions

2.1.1 JDO common interfaces

JDO Instance

A JDO instance is a Java programming language instance of a Java class that implements the application functions, and represents data in a local file system or enterprise datastore. Without limitation, the data might come from a single datastore entity, or from a collection of entities. For example, an entity might be a single object from an object database, a single row of a relational database, the result of a relational database query consisting of several rows, a merging of data from several tables in a relational database, or the result of executing a data retrieval API from an ERP system.

The objective of JDO is that most user-written classes, including both entity-type classes and utility-type classes, might be persistence capable. The limitations are that the persistent state of the class must be represented entirely by the state of its Java fields. Thus, system-type classes such as `System`, `Thread`, `Socket`, `File`, and the like cannot be JDO persistence-capable, but common user-defined classes can be.

JDO Implementation

A JDO implementation is a collection of classes that implement the JDO contracts. The JDO implementation might be provided by an EIS vendor or by a third party vendor, collectively known as JDO vendor. The third party might provide an implementation that is optimized for a particular application domain, or might be a general purpose tool (such as a relational mapping tool, embedded object database, or enterprise object database).

The primary interface to the application is `PersistenceManager`, with interfaces `Query` and `Transaction` playing supporting roles for application control of the execution environment.

JDO Enhancer

To use persistence-capable classes with binary-compatible JDO implementations, the classes must implement the `PersistenceCapable` contract, which includes implementing the `javax.jdo.spi.PersistenceCapable` contract, as well as adding other methods including static registration methods. This contract enables management of classes including transparent loading and storing of the fields of their persistent instances. A JDO enhancer, or byte code enhancer, is a program that modifies the byte codes of application-component Java class files to implement this interface.

The JDO reference implementation (reference enhancement) contains an approach for the enhancement of Java class files to allow for enhanced class files to be shared among several coresident JDO implementations.

There are alternative approaches to byte code enhancement for having the classes implement the PersistenceCapable contract. These include preprocessing or code generation. If one of these alternatives is used instead of byte code enhancement, the PersistenceCapable contract is implemented explicitly.

A JDO implementation is free to extend the Reference Enhancement contract with implementation-specific methods and fields that might be used by its runtime environment.

Binary Compatibility

A JDO implementation may optionally choose to support binary compatibility with other JDO implementations by supporting the PersistenceCapable contract for persistence-capable classes. If it does, then enhanced classes produced by another implementation or by the reference enhancer must be supported according to the following requirements.

- classes enhanced by the reference enhancer must be usable by any JDO compliant implementation that supports BinaryCompatibility;
- classes enhanced by a JDO compliant implementation must be usable by the reference implementation; and
- classes enhanced by a JDO compliant implementation must be usable by any other JDO compliant implementation that supports BinaryCompatibility.

The following table determines which interface is used by a JDO implementation based on the en-

Table 1: Which Enhancement Interface is Used

	Reference Runtime	Vendor A Runtime	Vendor B Runtime
Reference Enhancer	Reference Enhancement	Reference Enhancement	Reference Enhancement
Vendor A Enhancer	Reference Enhancement	Vendor A Enhancement	Reference Enhancement
Vendor B Enhancer	Reference Enhancement	Reference Enhancement	Vendor B Enhancement

hancement of the persistence-capable class. For example, if Vendor A runtime detects that the class was enhanced by its own enhancement, then the runtime will use its enhancement contract. Otherwise, it will use the Reference Enhancement contract.

Readers primarily interested in JDO as a local persistence mechanism can ignore the following section, as it details architectural features not relevant to local environments. Skip to 2.2 – Rationale.

2.1.2 JDO in a managed environment

This discussion provides a bridge to the Connector architecture, which JDO uses for transaction and connection management in application server environments.

Enterprise Information System (EIS)

An EIS provides the information infrastructure for an enterprise. An EIS offers a set of services to its clients. These services are exposed to clients as local and/or remote interfaces. Examples of EIS include:

- relational database system;
- object database system;
- ERP system; and
- mainframe transaction processing system.

EIS Resource

An EIS resource provides EIS-specific functionality to its clients. Examples are:

- a record or set of records in a database system;
- a business object in an ERP system; and
- a transaction program in a transaction processing system

Resource Manager (RM)

A resource manager manages a set of shared resources. A client requests access to a resource manager to use its managed resources. A transactional resource manager can participate in transactions that are externally controlled and coordinated by a transaction manager.

Connection

A connection provides connectivity to a resource manager. It enables an application client to connect to a resource manager, perform transactions, and access services provided by that resource manager. A connection can be either transactional or non-transactional. Examples include a database connection and a SAP R/3 connection.

Application Component

An application component can be a server-side component, such as an EJB, JSP, or servlet, that is deployed, managed and executed on an application server. It can be a component executed on the web-client tier but made available to the web-client by an application server, such as a Java applet, or DHTML page. It might also be an embedded component executed in a small footprint device using flash memory for persistent storage.

Session Beans

Session objects are EJB application components that execute on behalf of a single client, might be transaction aware, might update data in an underlying datastore, and do not directly represent data in the datastore.

Message-driven Beans

Message-driven beans are EJB application components that execute on behalf of a single client in response to an incoming message, might be transaction aware, might update data in an underlying datastore, and do not directly represent data in the datastore.

Entity Beans

Entity objects are EJB application components that provide an object view of transactional data in an underlying datastore, allow shared access from multiple users, including session objects and remote clients, and directly represent data in the datastore.

Helper objects

Helper objects are application components that provide an object view of data in an underlying datastore, allow transactionally consistent view of data in multiple transactions, are usable by local session and entity beans, but do not have a remote interface.

Container

A container is a part of an application server that provides deployment and runtime support for application components. It provides a federated view of the underlying application server services for the application components. For more details on different types of standard containers, refer to Enterprise JavaBeans (EJB) [see Appendix A reference 1], Java Server Pages (JSP), and Servlets specifications.

2.2 Rationale

The JDO architecture offers a Java solution to the problem of presenting a consistent view of data from the large number of application programs and enterprise information systems already in existence. By using the JDO architecture, it is not necessary for application component vendors to customize their products for each type of datastore.

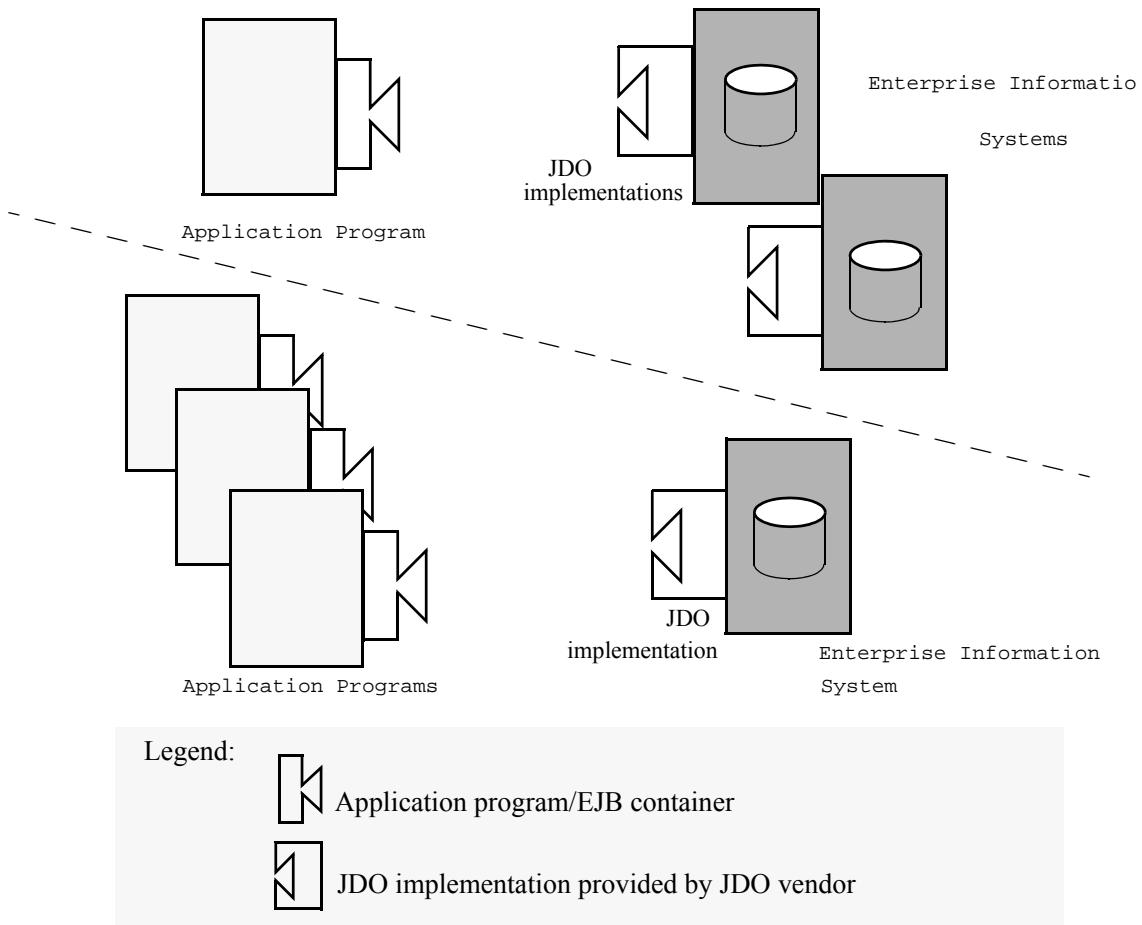
This architecture enables an EIS vendor to provide a standard data access interface for its EIS. The JDO implementation is plugged into an application server and provides underlying infrastructure for integration between the EIS and application components.

Similarly, a third party vendor can provide a standard data access interface for locally managed data such as would be found in an embedded device.

An application component vendor extends its system only once to support the JDO architecture and then exploits multiple data sources. Likewise, an EIS vendor provides one standard JDO implementation and it has the capability to work with any application component that uses the JDO architecture.

The Figure 1.0 on page 31 shows that an application component can plug into multiple JDO implementations. Similarly, multiple JDO implementations for different EISes can plug into an application component. This standard plug-and-play is made possible through the JDO architecture.

Figure 1.0 Standard plug-and-play between application programs and EISes using JDO



2.3 Goals

The JDO architecture has been designed with the following goals:

- The JDO architecture provides a transparent interface for application component and helper class developers to store data without learning a new data access language for each type of persistent data storage.
- The JDO architecture simplifies the development of scalable, secure and transactional JDO implementations for a wide range of EISes — ERP systems, database systems, mainframe-based transaction processing systems.
- The JDO architecture is implementable for a wide range of heterogeneous local file systems and EISes. The intent is that there will be various implementation choices for different EIS—each choice based on possibly application-specific characteristics and mechanisms of a mapping to an underlying EIS.
- The JDO architecture is suitable for a wide range of uses from embedded small footprint systems to large scale enterprise application servers. This architecture provides for exploitation of critical performance features from the underlying EIS, such as query evaluation and relationship management.

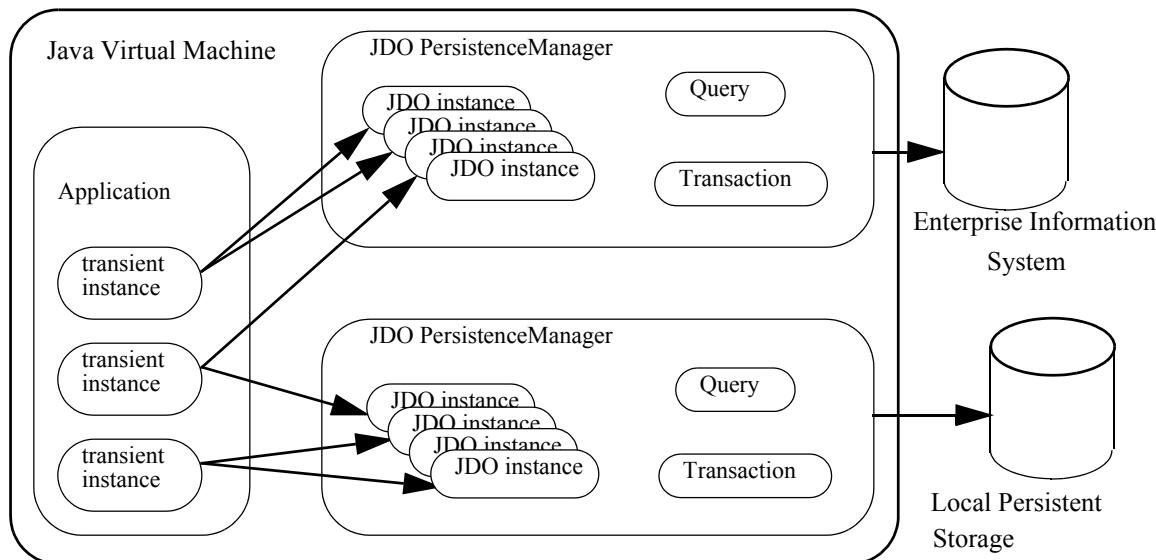
- The JDO architecture uses the J2EE Connector Architecture to make it applicable to all J2EE platform compliant application servers from multiple vendors.
- The JDO architecture makes it easy for application component developers to use the Java programming model to model the application domain and transparently retrieve and store data from various EIS systems.
- The JDO architecture defines contracts and responsibilities for various roles that provide pieces for standard connectivity to an EIS. This enables a standard JDO implementation from a EIS or third party vendor to be pluggable across multiple application servers.
- The connector architecture also enables an application programmer in a non-managed application environment to directly use the JDO implementation to access the underlying file system or EIS. This is in addition to a managed access to an EIS with the JDO implementation deployed in the middle-tier application server. In the former case, application programmers will not rely on the services offered by a middle-tier application server for security, transaction, and connection management, but will be responsible for managing these system-level aspects by using the EIS connector.

3 JDO Architecture

3.1 Overview

Multiple JDO implementations - possibly multiple implementations per type of EIS or local storage - are pluggable into an application server or usable directly in a two tier or embedded architecture. This enables application components, deployed either on a middle-tier application server or on a client-tier, to access the underlying datastores using a consistent Java-centric view of data. The JDO implementation provides the necessary mapping from Java objects into the special data types and relationships of the underlying datastore.

Figure 2.0 Overview of non-managed JDO architecture



In a non-managed environment, the JDO implementation hides the EIS specific issues such as data type mapping, relationship mapping, and data retrieval and storage. The application component sees only the Java view of the data organized into classes with relationships and collections presented as native Java constructs.

Managed environments additionally provide transparency for the application components' use of system-level mechanisms - distributed transactions, security, and connection management, by hiding the contracts between the application server and JDO implementations.

With both managed and non-managed environments, an application component developer focuses on the development of business and presentation logic for the application components without getting involved in the issues related to connectivity with a specific EIS.

3.2 JDO Architecture

3.2.1 Two tier usage

For simple two tier usage, JDO exposes to the application component two primary interfaces: `javax.jdo.PersistenceManager`, from which services are requested; and `javax.jdo.JDOHelper`, which provides the bootstrap and management view of user-defined persistence-capable classes.

The `PersistenceManager` interface provides services such as query management, transaction management, and life cycle management for instances of persistence-capable classes.

The `JDOHelper` class provides services such as bootstrap methods to acquire an instance of `PersistenceManagerFactory` and life cycle state interrogation for instances of persistence-capable classes.

Readers primarily interested in JDO as a local persistence mechanism can ignore the following sections. Skip to 4 – Roles and Scenarios.

3.2.2 Application server usage

For application server usage, the JDO architecture uses the J2EE Connector architecture, which defines a standard set of system-level contracts between the application server and EIS connectors. These system-level contracts are implemented in a resource adapter from the EIS side.

The JDO persistence manager is a caching manager as defined by the J2EE Connector architecture, that might use either its own (native) resource adapter or a third party resource adapter. If the JDO `PersistenceManager` has its own resource adapter, then implementations of the system-level contracts specified in the J2EE Connector architecture must be provided by the JDO vendor. These contracts include `ManagedConnectionFactory`, `XAResource`, and `LocalTransaction` interfaces.

The JDO `Transaction` must implement the `Synchronization` interface so that transaction completion events can cause flushing of state through the underlying connector to the EIS.

The application components are unable to distinguish between JDO implementations that use native resource adapters and JDO implementations that use third party resource adapters. However, the deployer will need to understand that there are two configurable components: the JDO `PersistenceManager` and its underlying resource adapter.

For convenience, the `PersistenceManagerFactory` provides the interface necessary to configure the underlying resource adapter.

Resource Adapter

A resource adapter provided by the JDO vendor is called a native resource adapter, and the interface is specific to the JDO vendor. It is a system-level software driver that is used by an application server or an application client to connect to a resource manager.

The resource adapter plugs into a container (provided by the application server). The application components deployed on the container then use the client API exposed by `javax.jdo.PersistenceManager` to access the JDO `PersistenceManager`. The JDO implementation in turn uses the underlying resource adapter interface specific to the datastore. The resource adapter and application server collaborate to provide the underlying mechanisms - transactions, security and connection pooling - for connectivity to the EIS.

The resource adapter is located within the same VM as the JDO implementation using it. Examples of JDO native resource adapters are:

- Object/Relational (O/R) products that use their own native drivers to connect to object relational databases
- Object Database (OODBMS) products that store Java objects directly in object databases

Examples of non-native resource adapter implementations are:

- O/R mapping products that use JDBC drivers to connect to relational databases
- Hierarchical mapping products that use mainframe connectivity tools to connect to hierarchical transactional systems

Pooling

There are two levels of pooling in the JDO architecture. JDO PersistenceManagers might be pooled, and the underlying connections to the datastores might be independently pooled.

Pooling of the connections is governed by the Connector Architecture contracts. Pooling of PersistenceManagers is an optional feature of the JDO Implementation, and is not standardized for two-tier applications. For managed environments, PersistenceManager pooling is required to maintain correct transaction associations with PersistenceManagers.

For example, a JDO PersistenceManager instance might be bound to a session running a long duration optimistic transaction. This instance cannot be used by any other user for the duration of the optimistic transaction.

During the execution of a business method associated with the session, a connection might be required to fetch data from the datastore. The PersistenceManager will request a connection from the connection pool to satisfy the request. Upon termination of the business method, the connection is returned to the pool but the PersistenceManager remains bound to the session.

After completion of the optimistic transaction, the PersistenceManager instance might be returned to the pool and reused for a subsequent transaction.

Contracts

JDO specifies the application level contract between the application components and the JDO PersistenceManager.

The J2EE Connector architecture specifies the standard contracts between application servers and an EIS connector used by a JDO implementation. These contracts are required for a JDO implementation to be used in an application server environment. The Connector architecture defines important aspects of integration: connection management, transaction management, and security.

The connection management contracts are implemented by the EIS resource adapter (which might include a JDO native resource adapter).

The transaction management contract is between the transaction manager (logically distinct from the application server) and the connection manager. It supports distributed transactions across multiple application servers and heterogeneous data management programs.

The security contract is required for secure access by the JDO connection to the underlying datastore.

Figure 3.0 Contracts between application server and native JDO resource adapter

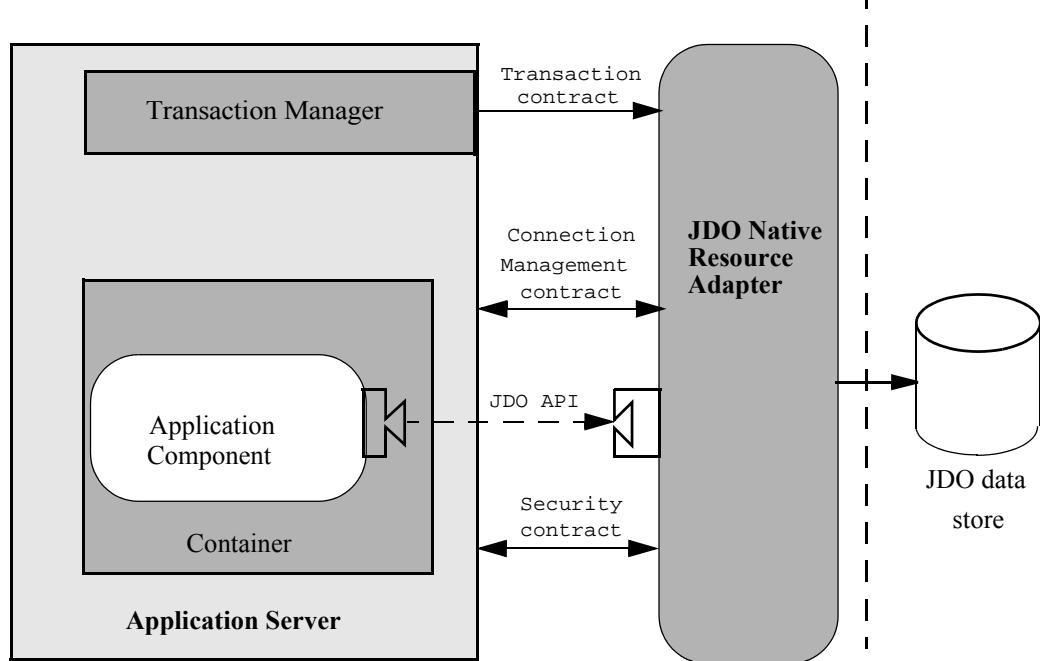
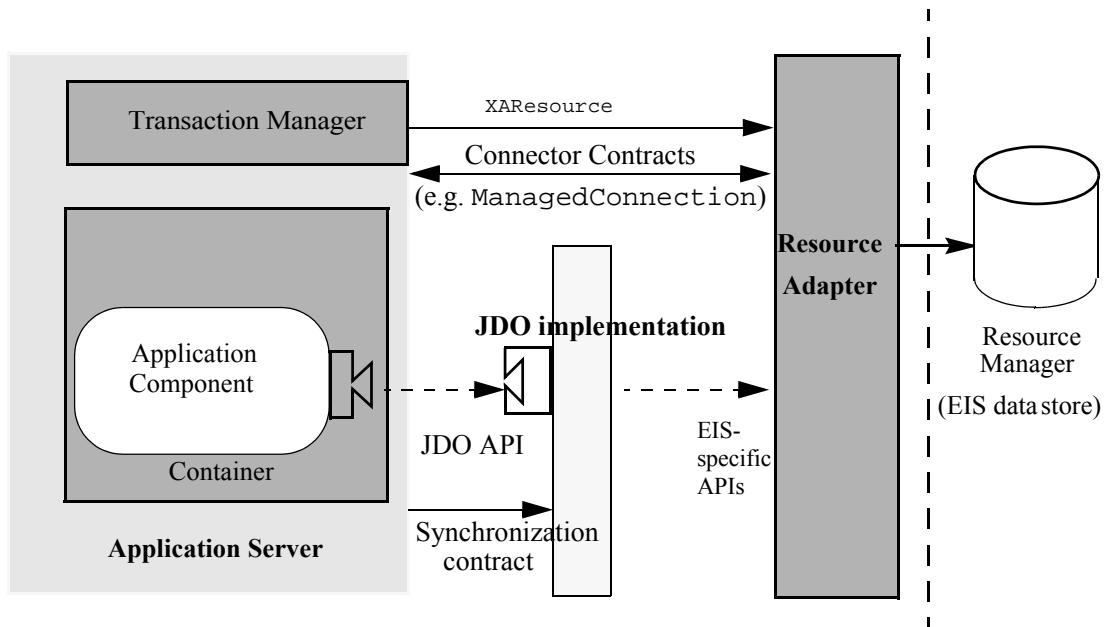


Figure 4.0 Contracts between application server and layered JDO implementation



The above diagram illustrates the relationship between a JDO implementation provided by a third party vendor and an EIS-provided resource adapter.

4 Roles and Scenarios

4.1 Roles

This chapter describes roles required for the development and deployment of applications built using the JDO architecture. The goal is to identify the nature of the work specific to each role so that the contracts specific to each role can be implemented on each side of the contracts.

The detailed contracts are specified in other chapters of this specification. The specific intent here is to identify the primary users and implementors of these contracts.

4.1.1 Application Developer

The application developer writes software to the **JDO API**. The JDO application developer does not have to be an expert in the technology related to a specific datastore.

4.1.2 Application Component Provider

The application component provider produces an application library that implements application functionality through Java classes with business methods that store data persistently in one or more EISes through the JDO API.

There are two types of application components that interact with JDO. JDO-transparent application components, typically helper classes, are those that use JDO to have their state stored in a transactional datastore, and directly access other components by references of their fields. Thus, they do not need to use JDO APIs directly.

JDO-aware application components (message-driven beans and session beans) use services of JDO by directly accessing its API. These components use JDO query facilities to retrieve collections of JDO instances from the datastore, make specific instances persistent in a particular datastore, delete specific persistent instances from the datastore, interrogate the cached state of JDO instances, or explicitly manage the cache of the JDO `PersistenceManager`. These application components are non-transparent users of JDO.

Session beans that use helper JDO classes interact directly with `PersistenceManager` and `JDOHelper`. They can use the life cycle methods and query factory methods, while ignoring the transaction demarcation methods if they use container-managed transactions.

The output of the application component provider is a set of jar files containing application components.

4.1.3 Application Assembler

The application assembler is a domain expert who assembles application components from multiple sources including in-house developers and application library vendors. The application assembler can combine different types of application components, for example EJBs, servlets, or JSPs, into a single end-user-visible application.

The input of the application assembler is one or more jar files, produced by application component providers. The output is one or more jar files with deployment specific descriptions.

4.1.4 Deployer

The deployer is responsible for configuring assembled components into specific operational environments. The deployer resolves all external references from components to other components or to the operational system.

For example, the deployer will bind application components in specific operating environments to datastores in those environments, and will resolve references from one application component to another. This typically involves using container-provided tools.

The deployer must understand, and be able to define, security roles, transactions, and connection pooling protocols for multiple datastores, application components, and containers.

4.1.5 System Administrator

The system administrator manages the configuration and administration of multiple containers, resource adapters and EISs that combine into an operational system.

Readers primarily interested in developing applications with the JDO API can ignore the following sections. Skip to 4.2 – Scenario: Embedded calendar management system.

4.1.6 JDO Vendor

The JDO vendor is an expert in the technology related to a specific datastore and is responsible for providing a **JDO SPI** implementation for that specific datastore. Since this role is highly datastore specific, a datastore vendor will often provide the standard JDO implementation.

A vendor can also provide a JDO implementation and associated set of application development tools through a loose coupling with a specific third party datastore. Such providers specialize in writing connectors and related tools for a specific EIS or might provide a more general tool for a large number of datastores.

The JDO vendor requires that the EIS vendor has implemented the J2EE Connector architecture and the role of the JDO implementation is that of a synchronization adapter to the connector architecture.

Readers primarily interested in JDO as a local persistence mechanism can ignore the following section. Skip to 4.2 – Scenario: Embedded calendar management system.

4.1.7 Connector Provider

The connector provider is typically the vendor of the EIS or datastore, and is responsible for supplying a library of interface implementations that satisfy the resource adapter interface.

In the JDO architecture, the Connector is a separate component, supplied by either the JDO vendor or by an EIS vendor or third party.

4.1.8 Application Server Vendor

An application server vendor [see Appendix A reference 1], provides an implementation of a J2EE compliant application server that provides support for component-based enterprise applications. A typical application server vendor is an OS vendor, middleware vendor, or database vendor.

The role of application server vendor will typically be the same as that of the container provider.

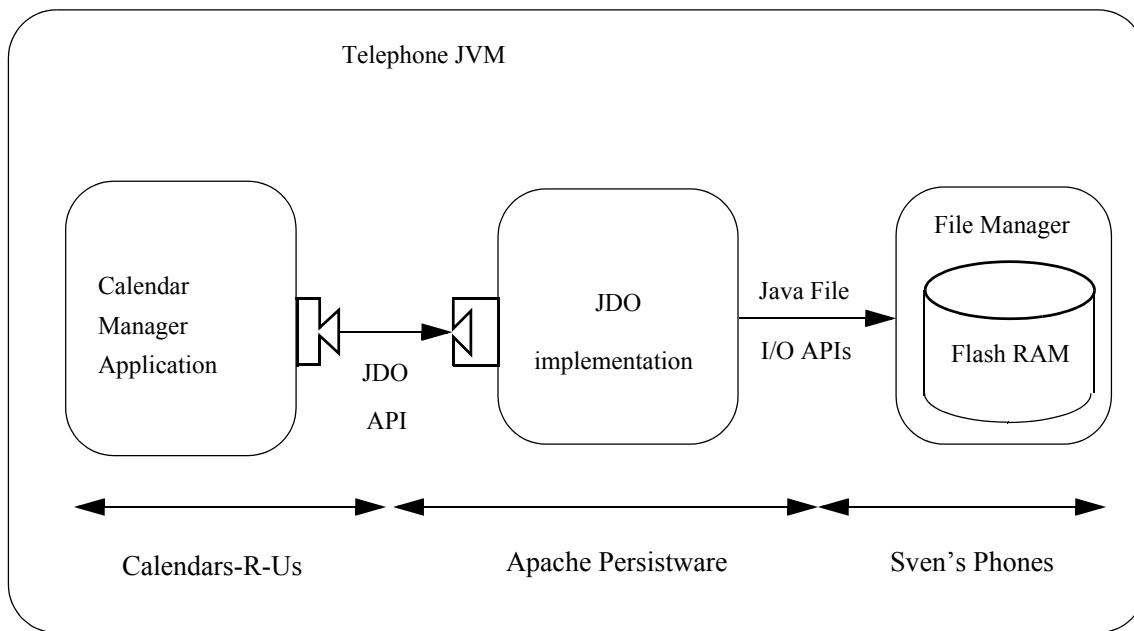
4.1.9 Container Provider

For bean-managed persistence, the container provides deployed application components with transaction and security management, distribution of clients, scalable management of resources and other services that are generally required as part of a managed server platform.

4.2 Scenario: Embedded calendar management system

This section describes a scenario to illustrate the use of JDO architecture in an embedded mobile device such as a personal information manager (PIM) or telephone.

Figure 5.0 Scenario: Embedded calendar manager



Sven's Phones is a manufacturer of high function telephones for the traveling businessperson. They have implemented a Java operating environment that provides persistence via a Java file I/O subsystem that writes to flash RAM.

Apache Persistware is a supplier of JDO software that has a small footprint and as such, is especially suited for embedded devices such as personal digital assistants and telephones. They use Java file I/O to store JDO instances persistently.

Calendars-R-Us is a supplier of appointment and calendar software that is written for several operating environments, from high function telephones to desktop workstations and enterprise application servers.

Calendars-R-Us uses the JDO API directly to manage calendar appointments on behalf of the user. The calendar application needs to insert, delete, and change calendar appointments based on the user's keypad input. It uses Java application domain classes: Appointment, Contact, Note, Reminder, Location, and TelephoneNumber. It employs JDK library classes: Time, Date, ArrayList, and Calendar.

Calendars-R-Us previously used Java file I/O APIs directly, but ran into several difficulties. The most efficient storage for some environments was an indexed file system, which was required only for management of thousands of entries. However, when they ported the application to the telephone, the indexed file system was too resource-intensive, and had to be abandoned.

They then wrote a data access manager for sequential files, but found that it burned out the flash RAM due to too much rewriting of data. They concluded that they needed to use the services of another software provider who specialized in persistence for flash RAM in embedded devices.

Apache Persistware developed a file access manager based on the Berkeley File System and successfully sold it to a range of Java customers from embedded devices to workstations. The interface was proprietary, which meant that every new sale was a challenge, because customers were loath to invest resources in learning a different interface for each environment they wanted to support. After all, Java was portable. Why wasn't file access?

Sven's Phones was a successful supplier of telephones to the mobile professional, but found themselves constrained by a lack of software developers. They wanted to offer a platform on which specially tailored software from multiple vendors could operate, and take advantage of external developers to write software for their telephones.

The solution to all of these issues was to separate the software into components that could be tailored by the domain expert for each component.

Sven's phones implemented the Java runtime environment for their phones, and wrote an efficient sequential file I/O manager that implemented the Java file I/O interface. This interface was used by Apache Persistware to build a JDO implementation, including a JDO instance handler and a JDO query manager.

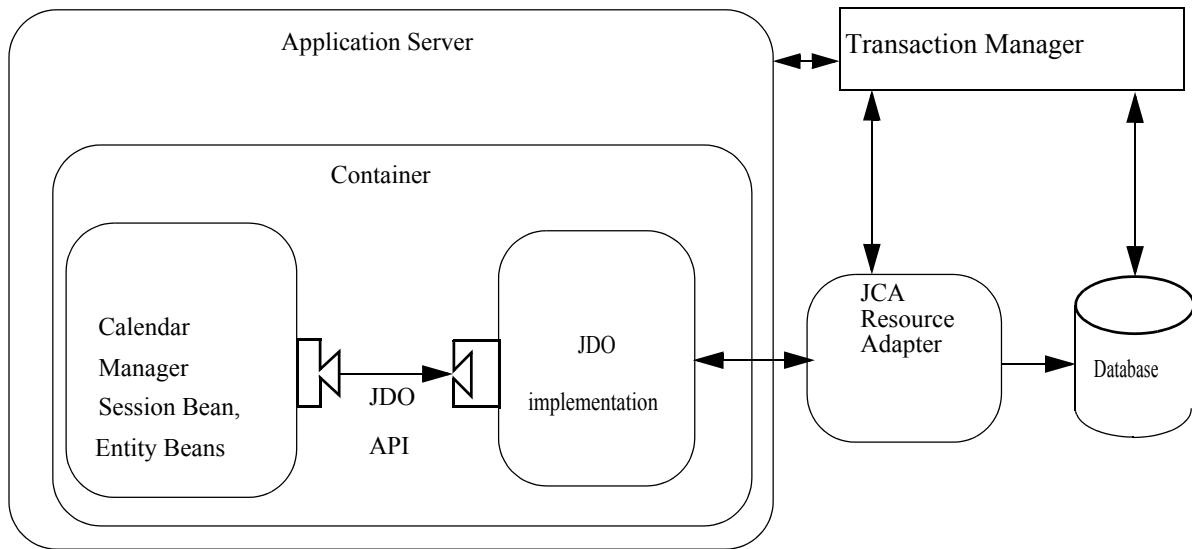
Using the JDO interface, Calendars-R-Us rewrote just the query part of their software. The application classes did not have to be changed. Only the persistence interface that queried for specific instances needed to be modified.

Readers primarily interested in JDO as a local persistence mechanism can ignore the following section. Skip to 5 – Life Cycle of JDO Instances.

4.3 Scenario: Enterprise Calendar Manager

Calendars-R-Us also supports workstations and enterprise mainframes with their calendar software, and they use the same interface for persistence in all environments. For enterprise environments, they simply need to use a different JDO implementation supplied by a different vendor to achieve persistence for their calendar objects.

Figure 6.0 Scenario: Enterprise Calendar Manager



In this scenario, the JDO implementation is provided by a vendor that maps Java objects to relational databases. The implementation uses a JCA Resource Adapter to connect to the datastore.

The JDO PersistenceManager is a caching manager, as defined by the Connector architecture, and it is configured to use a JCA Resource Adapter. The PersistenceManager instance might be cached when used with a Session Bean, and might be serially reused for multiple session beans.

Multiple JDO PersistenceManager instances might serially reuse connections from the same pool of JDBC drivers. Therefore, resource sharing is accomplished while maintaining state for each session.

5 Life Cycle of JDO Instances

This chapter specifies the life cycle for persistence capable class instances, hereinafter “JDO instances”. The classes include behavior as specified by the class (bean) developer, and for binary compatible implementations, additional behavior as provided by the reference enhancer or JDO vendor’s deployment tool. The enhancement of the classes allows application developers to treat JDO instances as if they were normal instances, with automatic fetching of persistent state from the JDO implementation.

5.1 Overview

JDO instances might be transient, detached, or persistent. That is, they might represent the persistent state of data contained in a transactional datastore. If a JDO instance is transient (and not transactional), then the instance behaves exactly like an ordinary instance of the persistence capable class.

If a JDO instance is persistent, its behavior is linked to the transactional datastore with which it is associated. The JDO implementation automatically tracks changes made to the values in the instance, and automatically refreshes values from the datastore and saves values into the datastore as required to preserve transactional integrity of the data. Persistent instances stored in the datastore retain their class and the state of their persistent fields. Changing the class of a persistent instance is not supported explicitly by the JDO API. However, it might be possible for an instance to change class based on external (outside the JDO environment) modifications to the datastore.

If a JDO instance is detached, its behavior is very similar to that of a transient instance, with a few significant exceptions. A detached instance does not necessarily have all of its persistent fields loaded from the data store, and any attempt to access unloaded fields, whether for read or write, is denied. A detached instance maintains its persistent identity and the identity can be obtained by an observer. A detached instance allows changes to be made to loaded fields, and tracks those changes while detached. Detached instances never observe transaction boundaries.

During the life of a JDO instance, it transitions among various states until it is finally garbage collected by the JVM. During its life, the state transitions are governed by the behaviors executed on it directly as well as behaviors executed on the JDO PersistenceManager by both the application and by the execution environment (including the TransactionManager).

During the life cycle, instances at times might be inconsistent with the datastore as of the beginning of the transaction. If instances are inconsistent, the notation for that instance in JDO is “dirty”. Instances made newly persistent, deleted, or modified in the transaction are dirty. Detached instances might be dirty.

At times, the JDO implementation might store the state of persistent instances in the datastore. This process is called “flushing”, and it does not affect the “dirty” state of the instances.

Under application control, transient JDO instances might observe transaction boundaries, in which the state of the instances is either preserved (on commit) or restored (on rollback). Transient instances that observe transaction boundaries are called transient transactional instances. Support for transient transactional instances is a JDO option; that is, a JDO compliant implementation is not required to implement the APIs that cause the state transitions associated with transient transactional instances.

Under application control, persistent JDO instances might not observe transaction boundaries. These instances are called persistent-nontransactional instances, and the life cycle of these instances is not affected by transaction boundaries. Support for nontransactional instances is a JDO option.

In a binary-compatible implementation, if a JDO instance is persistent or transactional, it contains a non-null reference to a JDO `StateManager` instance which is responsible for managing the JDO instance state changes and for interfacing with the JDO `PersistenceManager`.

5.2 Goals

The JDO instance life cycle has the following goals:

- The fact of persistence should be transparent to both JDO instance developer and application component developer
- JDO instances should be able to be used efficiently in a variety of environments, including managed (application server) and non-managed (two-tier) cases
- Several JDO `PersistenceManagers` might be coresident and might share the same persistence capable classes (although a JDO instance can be associated with only one `PersistenceManager` at a time)

5.3 Architecture:

JDO Instances

For transient JDO instances, there is no supporting infrastructure required. That is, transient instances will never make calls to methods to the persistence infrastructure. There is no requirement to instantiate objects outside the application domain. In a binary-compatible implementation, there is no difference in behavior between transient instances of enhanced classes and transient instances of the same non-enhanced classes, with some exceptions:

- additional methods and fields added by the enhancement process are visible to Java core reflection,
- timing of method execution is different because of added byte codes,
- extra methods for registration of metadata are executed at class load time.

Persistent JDO instances execute in an environment that contains an instance of the JDO `PersistenceManager` responsible for its persistent behavior. In a binary-compatible implementation, the JDO instance contains a reference to an instance of the JDO `StateManager` responsible for the state transitions of the instance as well as for managing the contents of the fields of the instance. The `PersistenceManager` and the `StateManager` might be implemented by the same instance, but their interfaces are distinct.

The contract between the persistence capable class and other application components extends the contract between the associated non-persistence capable class and application components. For both binary-compatible and non-binary-compatible implementations, these contract extensions support interrogation of the life cycle state of the instances and are intended for use by management parts of the system.

Persistent instances might be constructed by the application and made persistent; or might be constructed by the JDO `PersistenceManager` in response to a query or navigation from a persistent instance or via the `newInstance` method. If the JDO `PersistenceManager` constructs the instance, the class of the instance might be a derived class of the class of the original instance, and will respond true to `instanceof` the class of the original. Thus, applications must not rely on tests of the actual class of persistent instances, but must instead use the `instanceof` test.

JDO State Manager

In a binary-compatible implementation, persistent and transactional JDO instances contain a reference to a JDO `StateManager` instance to which all of the JDO interrogatives are delegated. The associated JDO `StateManager` instance maintains the state changes of the JDO instance and interfaces with the JDO `PersistenceManager` to manage the values of the datastore.

JDO Managed Fields

Only some fields are of interest to the persistence infrastructure: fields whose values are stored in the datastore are called persistent; fields that participate in transactions (their values may be restored during rollback) are called transactional; fields of either type are called managed.

5.4 JDO Identity

Java defines two concepts for determining if two instances are the same instance (identity), or represent the same data (equality). JDO extends these concepts to determine if two in-memory instances represent the same stored object.

Java object identity is entirely managed by the Java Virtual Machine. Instances are identical if and only if they occupy the same storage location within the JVM. The Java VM implements object identity via the `==` operator. This can be used by JDO implementations to determine whether two instances are identical (have the same location) in the VM.

Java object equality is determined by the class. Distinct instances are equal if they represent the same data, such as the same value for an `Integer`, or same set of bits for a `BitSet`.

The application implements `hashCode` and `equals`, to create the application's vision of equality of instances, typically based on values of fields in the instances. The JDO implementation must not use the application's `hashCode` and `equals` methods from the persistence-capable classes except as needed to implement the Collections Framework in package `java.util`. The JDO implementation must use the application's `hashCode` and `equals` methods from the application-provided object id classes.

The interaction between Java object identity and equality is an important one for JDO developers. Java object equality is an application specific concept, and JDO implementations must not change the application's semantic of equality. Still, JDO implementations must manage the cache of JDO instances such that there is only one JDO instance associated with each JDO `PersistenceManager` representing the persistent state of each corresponding datastore object. Therefore, JDO defines object identity differently from both the Java VM object identity and from the application equality.

Applications should implement `equals` for persistence-capable classes differently from `Object`'s default `equals` implementation, which simply uses the Java VM object identity. This is because the JVM object identity of a persistent instance cannot be guaranteed between `PersistenceManagers` and across space and time, except in very specific cases noted below.

Additionally, if persistence instances are stored in the datastore and are queried using the `==` query operator, or are referred to by a persistent collection that enforces equality (`Set`, `Map`) then the implementation of `equals` should exactly match the JDO implementation of equality, using the primary key or `ObjectId` as the key. This policy is not enforced, but if it is not correctly implemented, semantics of standard collections and JDO collections may differ.

To avoid confusion with Java object identity, this document refers to the JDO concept as JDO identity. The JDO implementation is responsible for the implementation of JDO identity based on the user's declaration of the identity type of each persistence-capable class.

Three Types of JDO identity

JDO defines three types of JDO identity:

- Application identity - JDO identity managed by the application and enforced by the datastore; JDO identity is often called the primary key
- Datastore identity - JDO identity managed by the datastore without being tied to any field values of a JDO instance
- Nondurable identity - JDO identity managed by the implementation to guarantee uniqueness in the JVM but not in the datastore

The type of JDO identity used is a property of a JDO persistence-capable class and is fixed at class loading time.

The representation of JDO identity in the JVM is via a JDO object id. Every persistent instance (Java instance representing a persistent object) has a corresponding object id. There might be an instance in the JVM representing the object id, or not. The object id JVM instance corresponding to a persistent instance might be acquired by the application at run time and used later to obtain a reference to the same datastore object, and it might be saved to and retrieved from durable storage (by serialization or other technique).

The class representing the object id for datastore and nondurable identity classes is defined by the JDO implementation. The implementation might choose to use any class that satisfies the requirements for the specific type of JDO identity for a class. It might choose the same class for several different JDO classes, or might use a different class for each JDO class.

The class representing the object id for application identity classes is defined by the application in the metadata, and might be provided by the application or by a JDO vendor tool.

The application-visible representation of the JDO identity is an instance that is completely under the control of the application. The object id instances used as parameters or returned by methods in the JDO interface (`getObjectId`, `getTransactionalObjectId`, and `getObjectById`) will never be saved internally; rather, they are copies of the internal representation or used to find instances of the internal representation.

Therefore, the object returned by any call to `getObjectId` might be modified by the user, but that modification does not affect the identity of the object that was originally referred. That is, the call to `getObjectId` returns only a copy of the object identity used internally by the implementation.

It is a requirement that the instance returned by a call to `getObjectById(Object)` of different `PersistenceManager` instances returned by the same `PersistenceManagerFactory` represent the same persistent object, but with different Java object identity (specifically, all instances returned by `getObjectId` from the instances must return `true` to `equals` comparisons with all others).

Further, any instances returned by any calls to `getObjectById(Object)` with the same object id instance to the same `PersistenceManager` instance must be identical (assuming the instances were not garbage collected between calls).

The JDO identity of transient instances is not defined. Attempts to get the object id for a transient instance will return `null`.

Uniquing

JDO identity of persistent instances is managed by the implementation. For a durable JDO identity (datastore or application), there is only one persistent instance associated with a specific datastore object per `PersistenceManager` instance, regardless of how the persistent instance was put into the cache:

- `PersistenceManager.getObjectById(Object oid, boolean validate);`
- query via a `Query` instance associated with the `PersistenceManager` instance;

- navigation from a persistent instance associated with the PersistenceManager instance;
- `PersistenceManager.makePersistent(Object pc);`

Change of identity

Change of identity is supported only for application identity, and is an optional feature of a JDO implementation. An application attempt to change the identity of an instance (by writing a primary key field) where the implementation does not support this optional feature results in `JDOUnsupportedOptionException` being thrown. The exception might be thrown immediately or upon flush or transaction commit.

NOTE: Application developers should take into account that changing primary key values changes the identity of the instance in the datastore. In production environments where audit trails of changes are kept, change of the identity of datastore instances might cause loss of audit trail integrity, as the historical record of changes does not reflect the current identity in the datastore.

JDO instances using application identity may change their identity during a transaction if the application changes a primary key field. In this case, there is a new JDO Identity associated with the JDO instance immediately upon completion of the statement that changes a primary key field. If a JDO instance is already associated with the new JDO Identity, then a `JDOUserException` is thrown. The exception might be thrown immediately or upon flush or transaction commit.

Upon successful commit of the transaction, the existing datastore instance will have been updated with the changed values of the primary key fields.

JDO Identity Support

A JDO implementation is required to support either or both of application (primary key) identity or datastore identity, and may optionally support nondurable identity.

5.4.1 Application (primary key) identity

This is the JDO identity type used for datastores in which the value(s) in the instance determine the identity of the object in the datastore. Thus, JDO identity is managed by the application. The class provided by the application that implements the JDO object id has all of the characteristics of an RMI remote object, making it possible to use the JDO object id class as the EJB primary key class. Specifically:

- the `ObjectId` class must be public;
- the `ObjectId` class must implement `Serializable`;
- the `ObjectId` class must have a public no-arg constructor, which might be the default constructor;
- the field types of all non-static fields in the `ObjectId` class must be serializable, and for portability should be primitive, `String`, `Date`, `Byte`, `Short`, `Integer`, `Long`, `Float`, `Double`, `BigDecimal`, or `BigInteger` types; JDO implementations are required to support these types and might support other reference types;
- all serializable non-static fields in the `ObjectId` class must be public;
- the names of the non-static fields in the `ObjectId` class must include the names of the primary key fields in the JDO class, and the types of the corresponding fields must be identical;

- the `equals()` and `hashCode()` methods of the `ObjectId` class must use the value(s) of all the fields corresponding to the primary key fields in the JDO class;
- if the `ObjectId` class is an inner class, it must be `static`;
- the `ObjectId` class must override the `toString()` method defined in `Object`, and return a `String` that can be used as the parameter of a constructor;
- the `ObjectId` class must provide a constructor taking either a `String` alone or a `Class` and `String` that returns an instance that compares equal to an instance that returned that `String` by the `toString()` method.

These restrictions allow the application to construct an instance of the primary key class providing values only for the primary key fields, or alternatively providing only the result of `toString()` from an existing instance. The JDO implementation is permitted to extend the primary key class to use additional fields, not provided by the application, to further identify the instance in the datastore. Thus, the JDO object id instance returned by an implementation might be a subclass of the user-defined primary key class. Any JDO implementation must be able to use the JDO object id instance from any other JDO implementation.

A primary key identity is associated with a specific set of fields. The fields associated with the primary key are a property of the persistence-capable class, and cannot be changed after the class is enhanced for use at runtime. When a transient instance is made persistent, the implementation uses the values of the fields associated with the primary key to construct the JDO identity.

A primary key instance must have none of its primary key fields set to null when used to find a persistent instance. The persistence manager will throw `JDOUserException` if the primary key instance contains any null values when the key instance is the parameter of `getObjectById`.

Persistence-capable classes that use application identity have special considerations for inheritance. To be portable, the key class must be the same for all classes in the inheritance hierarchy derived from the least-derived (topmost) concrete persistence-capable class in the hierarchy.

Compound Identity

Compound identity is a special case of application identity. References to other persistence-capable classes can be defined as key fields. In this case, the object id class contains a field that is of the type of the object id of the relationship field.

For example, two classes have a one-many relationship, and on the reference side of the relationship, the field is a key field. On the other side of the relationship, there is a Collection or other multi-valued type.

```
class Order {  
    long orderId;  
    Set<OrderItem> items;  
}  
class OrderId {  
    long orderId; // matches orderId field name and type  
}  
class OrderItem {  
    Order order;  
    long item;  
}  
class OrderItemId {  
    OrderId order; // matches order field name and OrderId type  
    long item; // matches item field name and type  
}
```

5.4.2 Single Field Identity

A common case of application identity uses exactly one persistent field in the class to represent identity. In this case, the application can use a standard JDO class instead of creating a new user-defined class for the purpose.

A JDO implementation that supports application identity must also support single field identity.

```
package javax.jdo.identity;
public abstract class SingleFieldIdentity
    implements Externalizable, Comparable {
    protected SingleFieldIdentity(Class pcClass);
    public Class getTargetClass();
    public String getTargetClassName();
    public Object getKeyAsObject();
}

public class ByteIdentity
    extends SingleFieldIdentity {
    public byte getKey();
    public ByteIdentity(Class pcClass, byte key);
    public ByteIdentity(Class pcClass, Byte key);
    public ByteIdentity(Class pcClass, String key);
}

public class CharIdentity
    extends SingleFieldIdentity {
    public char getKey();
    public CharIdentity(Class pcClass, char key);
    public CharIdentity(Class pcClass, Character key);
    public CharIdentity(Class pcClass, String key);
}

public class ShortIdentity
    extends SingleFieldIdentity {
    public short getKey();
    public ShortIdentity(Class pcClass, short key);
    public ShortIdentity(Class pcClass, Short key);
    public ShortIdentity(Class pcClass, String key);
}

public class IntIdentity
    extends SingleFieldIdentity {
    public int getKey();
    public IntIdentity(Class pcClass, int key);
    public IntIdentity(Class pcClass, Integer key);
    public IntIdentity(Class pcClass, String key);
}

public class LongIdentity
    extends SingleFieldIdentity {
    public long getKey();
    public LongIdentity(Class pcClass, long key);
    public LongIdentity(Class pcClass, Long key);
    public LongIdentity(Class pcClass, String key);
}

public class StringIdentity
    extends SingleFieldIdentity {
    public String getKey();
    public StringIdentity(Class pcClass, String key);
}
```

```
public class ObjectIdentity
    extends SingleFieldIdentity {
    public Object getKey();
    public ObjectIdentity(Class pcClass, Object key);
}
```

The constructors that take reference types throw `JDONullIdentityException` if the second argument is null. Valid key values are never null.

Constructors of primitive identity types that take `String` parameters convert the parameter to the proper type using the static `parseXXX` method of the corresponding wrapper class.

Instances of `SingleFieldIdentity` classes are immutable. When serialized, the name of the target class is serialized. When deserialized, the name of the target class is restored, but not the target class. The deserialized instance will return `null` to `getTargetClass`. All instances will return the “binary” name of the target class (the result of `Class.getName()`).

The `SingleFieldIdentity` classes adhere to all of the requirements for application object id classes, with the exception of field names. That is, there are no public fields visible to the application.

The `SingleFieldIdentity` classes implement the `Comparable` interface. They can thus be used as elements in ordered Sets and keys in ordered Maps. The order is an absolute ordering. In the specific case of `ObjectIdentity`, the ordering is based first upon the name of the target class and second upon the value of the key. If the key does not implement `Comparable`, then the `compareTo` method in `ObjectIdentity` will throw `ClassCastException`.

5.4.3 Datastore identity

This is the JDO identity type used for datastores in which the identity of the data in the datastore does not depend on the values in the instance. The implementation guarantees uniqueness for all instances.

A JDO implementation might choose one of the primitive wrapper classes as the `ObjectId` class (e.g. `Short`, `Integer`, `Long`, or `String`), or might choose an implementation-specific class. Implementation-specific classes used as JDO `ObjectId` have the following characteristics:

- the `ObjectId` class must be public;
- the `ObjectId` class must implement `Serializable`;
- the `ObjectId` class must have a public no-arg constructor, which might be the default constructor;
- all serializable fields in the `ObjectId` class must be public;
- the field types of all non-static fields in the `ObjectId` class must be serializable;
- the `ObjectId` class must override the `toString()` method defined in `Object`, and return a `String` that can be used as the parameter of the `PersistenceManager` method `newObjectIdInstance(Class cls, String key)`;

Note that, unlike application identity, datastore identity `ObjectId` classes are **not** required to support equality with `ObjectId` classes from other JDO implementations. Further, the application cannot change the JDO identity of an instance of a class using datastore identity.

5.4.4 Nondurable JDO identity

The primary usage for nondurable JDO identity is for log files, history files, and other similar files, where performance is a primary concern, and there is no need for the overhead associated with managing a durable identity for each datastore instance. Objects are typically inserted into datastores

with transactional semantics, but are not accessed by key. They may have references to instances elsewhere in the datastore, but often have no keys or indexes themselves. They might be accessed by other attributes, and might be deleted in bulk.

Multiple objects in the datastore might have exactly the same values, yet an application program might want to treat the objects individually. For example, the application must be able to count the persistent instances to determine the number of datastore objects with the same values. Also, the application might change a single field of an instance with duplicate objects in the datastore, and the expected result in the datastore is that exactly one instance has its field changed. If multiple instances in memory are modified, then instances in the datastore are modified corresponding one-to-one with the modified instances in memory. Similarly, if the application deletes some number of multiple duplicate objects, the same number of the objects in the datastore must be deleted.

As another example, if a datastore instance using nondurable identity is loaded twice into the VM by the same `PersistenceManager`, then two separate instances are instantiated, with two different JDO identities, even though all of the values in the instances are the same. It is permissible to update or delete only one of the instances. At commit time, if only one instance was updated or deleted, then the changes made to that instance are reflected in the datastore by changing the single datastore instance. If both instances were changed, then the transaction will fail at commit, with a `JDOUserException` because the changes must be applied to different datastore instances. Because the JDO identity is not visible in the datastore, there are special behaviors with regard to nondurable JDO identity:

- the `ObjectId` is not valid after making the associated instance hollow, and attempts to retrieve it will throw a `JDOUserException`;
- the `ObjectId` cannot be used in a different instance of `PersistenceManager` from the one that issued it, and attempts to use it even indirectly (e.g. `getObjectById` with a persistence-capable object as the parameter) will throw a `JDOUserException`;
- the persistent instance might transition to persistent-nontransactional or hollow but cannot transition to any other state afterward;
- attempts to access the instance in the hollow state will throw a `JDOUserException`;
- the results of a query in the datastore will always return instances that are not already in the Java VM, so multiple queries that find the same objects in the datastore will return additional JDO instances with the same values and different JDO identities;
- `makePersistent` will succeed even though another instance already has the same values for all persistent fields.

For JDO identity that is not managed by the datastore, the class that implements JDO `ObjectId` has the following characteristics:

- the `ObjectId` class must be public;
- the `ObjectId` class must have a public constructor, which might be the default constructor or a no-arg constructor;
- all fields in the `ObjectId` class must be public;
- the field types of all fields in the `ObjectId` class must be serializable.

5.5 Life Cycle States

There are many states defined by this specification. Some states are required, and others states are optional. If an implementation does not support certain operations, then these optional states are not reachable.

Datastore Transactions

The following descriptions apply to datastore transactions with retainValues=false. Optimistic transaction and retainValues=true state transitions are covered later in this chapter.

5.5.1 Transient (Required)

JDO instances created by using a developer-written or compiler-generated constructor that do not involve the persistence environment behave exactly like instances of the unenhanced class.

There is no JDO identity associated with a transient instance.

There is no intermediation to support fetching or storing values for fields. There is no support for demarcation of transaction boundaries. Indeed, there is no transactional behavior of these instances, unless they are referenced by transactional instances at commit time.

When a persistent instance is committed to the datastore, instances referenced by persistent fields of the flushed instance become persistent. This behavior propagates to all instances in the closure of instances through persistent fields. This behavior is called persistence by reachability.

No methods of transient instances throw exceptions except those defined by the class developer.

A transient instance transitions to persistent-new if it is the parameter of makePersistent, or if it is referenced by a persistent field of a persistent instance when that instance is committed or made persistent.

5.5.2 Persistent-new (Required)

JDO instances that are newly persistent in the current transaction are persistent-new. This is the state of an instance that has been requested by the application component to become persistent, by using one of the PersistenceManager makePersistent methods on the instance.

During the transition from transient to persistent-new

- the associated PersistenceManager becomes responsible to implement state interrogation and further state transitions.
- if the transaction flag restoreValues is true, the values of persistent and transactional non-persistent fields are saved for use during rollback.
- the values of persistent fields of mutable SCO types (e.g. java.util.Date, java.util.HashSet, etc.) are replaced with JDO implementation-specific copies of the field values that track changes and are owned by the persistent instance.
- a JDO identity is assigned to the instance by the JDO implementation. This identity uniquely identifies the instance inside the PersistenceManager and might uniquely identify the instance in the datastore. A copy of the JDO identity will be returned by the PersistenceManager method getObjectId(Object).
- instances reachable from this instance by fields of persistence-capable types and collections of persistence-capable types become provisionally persistent and transition from transient to persistent-new. If the instances made provisionally persistent are still reachable at commit time, they become persistent. This effect is recursive, effectively making the transitive closure of transient instances provisionally persistent.

A persistent-new instance transitions to persistent-new-deleted if it is the parameter of deletePersistent.

A persistent-new instance transitions to hollow when it is flushed to the datastore during commit when retainValues is false. This transition is not visible during beforeCompletion, and is visible during afterCompletion. During beforeCompletion, the user-defined jdoPreStore method is called if the class implements InstanceCallbacks.

A persistent-new instance transitions to transient at rollback. The instance loses its JDO Identity and its association with the `PersistenceManager`. If `restoreValues` is false, the values of managed fields in the instance are left as they were at the time rollback was called. If `restoreValues` is true, the values of managed fields in the instance are restored to the values as they were at the time `makePersistent` was called.

5.5.3 Persistent-dirty (Required)

JDO instances that represent persistent data that was changed in the current transaction are persistent-dirty.

A persistent-dirty instance transitions to persistent-deleted if it is the parameter of `deletePersistent`.

Persistent-dirty instances transition to hollow during commit when `retainValues` is false or during rollback when `restoreValues` is false. During `beforeCompletion`, the user-defined `jdoPreStore` method is called if the class implements `StoreCallback`.

If an application modifies a managed field, but the new value is equal to the old value, then it is an implementation choice whether the JDO instance is modified or not. If no modification to any managed field was made by the application, then the implementation must not mark the instance as dirty. If a modification was made to any managed field that changes the value of the field, then the implementation must mark the instance as dirty.

Since changes to array-type fields cannot be tracked by JDO, setting the value of an array-type managed field marks the field as dirty, even if the new value is identical to the old value. This special case is required to allow the user to mark an array-type field as dirty without having to call the `JDOHelper` method `makeDirty`.

5.5.4 Hollow (Required)

JDO instances that represent specific persistent data in the datastore but whose values are not in the JDO instance are hollow. The hollow state provides for the guarantee of uniqueness for persistent instances between transactions.

This is permitted to be the state of instances committed from a previous transaction, acquired by the method `getObjectById`, returned by iterating an `Extent`, returned in the result of a query execution, or navigating a persistent field reference. However, the JDO implementation may choose to return instances in a different state reachable from hollow.

A JDO implementation is permitted to effect a legal state transition of a hollow instance at any time, as if a field were read. Therefore, the hollow state might not be visible to the application.

During the commit of the transaction in which a dirty persistent instance has had its values changed (including a new persistent instance), the underlying datastore is changed to have the transactionally consistent values from the JDO instance, and the instance transitions to hollow.

Requests by the application for an instance with the same JDO identity (query, navigation, or lookup by `ObjectId`), in a subsequent transaction using the same `PersistenceManager` instance, will return the identical Java instance, assuming it has not been garbage collected. If the application does not hold a strong reference to a hollow instance, the instance might be garbage collected, as the `PersistenceManager` must not hold a strong reference to any hollow instance.

The hollow JDO instance maintains its JDO identity and its association with the JDO `PersistenceManager`. If the instance is of a class using application identity, the hollow instance maintains its primary key fields.

A hollow instance transitions to persistent-deleted if it is the parameter of `deletePersistent`.

A hollow instance transitions to persistent-dirty if a change is made to any managed field. It transitions to persistent-clean if a read access is made to any persistent field other than one of the primary key fields.

A hollow instance transitions to detached if the transaction associated with its persistence manager is committed while the `DetachAllOnCommit` property is true.

The behavior of persistent instances at close of the corresponding `PersistenceManager` is not further defined in this specification.

5.5.5 Persistent-clean (Required)

JDO instances that represent specific transactional persistent data in the datastore, and whose values have not been changed in the current transaction, are persistent-clean. This is the state of an instance whose values have been requested in the current datastore transaction, and whose values have not been changed by the current transaction.

A persistent-clean instance transitions to persistent-dirty if a change is made to any managed field.

A persistent-clean instance transitions to persistent-deleted if it is the parameter of `deletePersistent`. A persistent-clean instance transitions to persistent-nontransactional if it is the parameter of `makeNontransactional`.

A persistent-clean instance transitions to hollow at commit when `retainValues` is false; or rollback when `restoreValues` is false. It retains its identity and its association with the `PersistenceManager`.

5.5.6 Persistent-deleted (Required)

JDO instances that represent specific persistent data in the datastore, and that have been deleted in the current transaction, are persistent-deleted.

Read access to primary key fields is permitted. Any other access to persistent fields is not supported and might throw a `JDOUserException`.

Before the transition to persistent-deleted, the user-written `jdoPreDelete` is called if the persistence-capable class implements `InstanceCallbacks`.

A persistent-deleted instance transitions to transient at commit. During the transition, its persistent fields are written with their Java default values, and the instance loses its JDO Identity and its association with the `PersistenceManager`.

A persistent-deleted instance transitions to hollow at rollback when `restoreValues` is false. The instance retains its JDO Identity and its association with the `PersistenceManager`.

5.5.7 Persistent-new-deleted (Required)

JDO instances that represent instances that have been newly made persistent and deleted in the current transaction are persistent-new-deleted.

Read access to primary key fields is permitted. Any other access to persistent fields is not supported and might throw a `JDOUserException`.

Before the transition to persistent-new-deleted, the user-written `jdoPreDelete` is called if the persistence-capable class implements `InstanceCallbacks`.

A persistent-new-deleted instance transitions to transient at commit. During the transition, its persistent fields are written with their Java default values, and the instance loses its JDO Identity and its association with the `PersistenceManager`.

A persistent-new-deleted instance transitions to transient at rollback. The instance loses its JDO Identity and its association with the `PersistenceManager`.

If `RestoreValues` is `true`, the values of managed fields in the instance are restored to their state as of the call to `makePersistent`. If `RestoreValues` is `false`, the values of managed fields in the instance are left as they were at the time rollback was called.

5.5.8 Detached-clean (Required)

JDO instances that have been detached from their persistence manager and have not been modified are detached-clean. Detachment is done by one of three ways:

- the instance or an instance containing a reference to the instance is serialized; in this case, the serialized instance is detached
- the transaction of the persistence manager managing the instance is committed and the `DetachAllOnCommit` property is `true`; in this case the persistent instance itself is detached (there is no copy)
- the instance is explicitly detached from the persistence manager via one of the `detachCopy` or `detachCopyAll` methods; in this case the copy is detached.

Detached-clean instances transition to detached-dirty if a loaded field is modified. Attempts to change their state via any of the persistence manager methods except for `makePersistent` and `deletePersistent` throw `JDOUserException`.

`Evict`, `refresh`, `retrieve`, `makeTransient`, `makeTransactional`, and `makeNontransactional` throw `JDOUserException` if a parameter instance is in the detached-clean or detached-dirty state.

A detachable class is not serialization-compatible with the corresponding unenhanced class.

Detached-clean instances transition to persistent-nontransactional or persistent-clean (depending on the `Optimistic` setting) if they are parameters to `makePersistent` when `CopyOnAttach` is `false`.

Detached instances are further described in section 12.6.8.

5.5.9 Detached-dirty (Required)

JDO instances that have been removed from their persistence manager and have fields marked as modified are detached-dirty.

Fields are marked as modified if a field of the detached instance is explicitly modified by the application.

Detached-dirty instances do not change their life cycle state unless `CopyOnAttach` is `false`. When `CopyOnAttach` is `false`, detached-dirty instances transition to persistent-dirty during `makePersistent`.

`Evict`, `refresh`, `retrieve`, `makeTransient`, `makeTransactional`, and `makeNontransactional` throw `JDOUserException` if a parameter instance is in the detached-clean or detached-dirty state.

5.6 Nontransactional (Optional)

Management of nontransactional instances is an optional feature of a JDO implementation. Usage is primarily for slowly changing data or for optimistic transaction management, as the values in non-transactional instances are not guaranteed to be transactionally consistent.

The use of this feature is governed by the `PersistenceManager` options `NontransactionalRead`, `NontransactionalWrite`, `Optimistic`, and `RetainValues`. An implementation might support any or all of these options. For example, an implementation might support only `NontransactionalRead`. For options that are not supported, the value of the unsupported property is `false` and it may not be changed.

If a PersistenceManager does not support this optional feature, an operation that would result in an instance transitioning to the persistent-nontransactional state or a request to set the NontransactionalRead, NontransactionalWrite, Optimistic, or RetainValues option to true, throws a JDOUnsupportedOptionException.

NontransactionalRead, NontransactionalWrite, Optimistic, and RetainValues are independent options. A JDO implementation must not automatically change the values of these properties as a side effect of the user changing other properties.

With NontransactionalRead set to true:

- Navigation and queries are valid outside a transaction. It is a JDO implementation decision whether the instances returned are in the hollow or persistent-nontransactional state.
- When a managed, non-key field of a hollow instance is read outside a transaction, the instance transitions to persistent-nontransactional.
- If a persistent-clean instance is the parameter of makeNontransactional, the instance transitions to persistent-nontransactional.

With NontransactionalWrite set to true:

- Modification of persistent-nontransactional instances is permitted outside a transaction. The changes might participate in a subsequent transaction.
- This is an incompatible change from the behavior in JDO 1.0. Compatibility is only supported if a subsequent transaction is not begun after making changes to persistent instances in the cache.

With RetainValues set to true:

- At commit, persistent-clean, persistent-new, and persistent-dirty instances transition to persistent-nontransactional. Fields defined in the XML metadata as containing mutable second-class types are examined to ensure that they contain instances that track changes made to them and are owned by the instance. If not, they are replaced with new second class object instances that track changes, constructed from the contents of the second class object instance. These include `java.util.Date`, and `Collection` and `Map` types. NOTE: This process is not required to be recursive, although an implementation might choose to recursively convert the closure of the collection to become second class objects. JDO requires conversion only of the affected persistence-capable instance's fields.

With RestoreValues set to true:

- If the JDO implementation does not support persistent-nontransactional instances, at rollback persistent-deleted, persistent-clean and persistent-dirty instances transition to hollow.
- If the JDO implementation supports persistent-nontransactional instances, at rollback persistent-deleted, persistent-clean and persistent-dirty instances transition to persistent-nontransactional. The state of each managed field in persistent-deleted and persistent-dirty instances is restored:
 - fields of primitive types (`int`, `float`, etc.), wrapper types (`Integer`, `Float`, etc.), immutable types (`Locale`, etc.), and references to persistence-capable types are restored to their values as of the beginning of the transaction and the fields are marked as loaded.
 - fields of mutable types (`Date`, `Collection`, array-type, etc.) are set to `null` and the fields are marked as not loaded.

5.6.1 Persistent-nontransactional (Optional)

NOTE: The following discussion applies only to datastore transactions. See section 5.8 for a discussion on how optimistic transactions change this behavior.

JDO instances that represent specific persistent data in the datastore, whose values are currently loaded but not transactionally consistent, are persistent-nontransactional. There is a JDO Identity associated with these instances, and transactional instances can be obtained from the object ids.

The persistent-nontransactional state allows persistent instances to be managed as a shadow cache of instances that are updated asynchronously.

As long as a transaction is not in progress:

- if `NontransactionalRead` is `true`, persistent field values might be retrieved from the datastore by the `PersistenceManager`;
- if `NontransactionalWrite` is `true`, the application might make changes to the persistent field values in the instance. These changes might be committed in a subsequent transaction.

A persistent-nontransactional instance transitions to persistent-clean if it is the parameter of a `makeTransactional` method executed when a transaction is in progress. The state of the instance in memory is discarded (cleared) and the state is loaded from the datastore.

A persistent-nontransactional instance transitions to persistent-clean if any managed field is accessed when a datastore transaction is in progress. The state of the instance in memory is discarded and the state is loaded from the datastore.

A persistent-nontransactional instance transitions to persistent-dirty if any managed field is written when a transaction is in progress. The state of the instance in memory is saved for use during rollback, and the state is loaded from the datastore. Then the change is applied.

A persistent-nontransactional instance transitions to persistent-deleted if it is the parameter of `deletePersistent`. The state of the instance in memory is saved for use during rollback.

A persistent-nontransactional instance transitions to detached if a transaction is committed while the `DetachAllOnCommit` property is true.

A persistent-nontransactional instance transitions to persistent-nontransactional-dirty if a change is made outside a transaction while the `NontransactionalWrite` property is true.

If the application does not hold a strong reference to a persistent-nontransactional instance, the instance might be garbage collected. The `PersistenceManager` must not hold a strong reference to any persistent-nontransactional instance.

The behavior of persistent instances at close of the corresponding `PersistenceManager` is not further defined in this specification.

5.6.2 Persistent-nontransactional-dirty (Optional)

JDO instances that represent specific persistent data in the datastore, whose values may be currently loaded but not transactionally consistent, and have been modified since the last commit, are persistent-nontransactional-dirty. There is a JDO Identity associated with these instances, and non-transactional instances can be obtained from the object ids.

The persistent-nontransactional-dirty state allows applications to operate on nontransactional instances in the cache and make changes to the instances without having a transaction active. At some future point, the application can begin a transaction and incorporate the changes into the transactional state. Committing the transaction makes the changes made outside the transaction durable.

A persistent-nontransactional-dirty instance transitions to hollow if it is the parameter of evict or evictAll. This allows the application to remove instances from the set of instances whose state is to be committed to the datastore.

If a datastore transaction is begun, no state change occurs immediately, and commit will write the changes to the datastore with no checking as to the current state of the instances in the datastore. That is, the changes made outside the transaction together with any changes made inside the transaction will overwrite the current state of the datastore. The persistent-nontransactional-dirty instances will transition according to the RetainValues flag. With the RetainValues flag set to true, persistent-nontransactional-dirty instances will transition to persistent-nontransactional. With the RetainValues flag set to false, persistent-nontransactional-dirty instances will transition to hollow.

If a datastore transaction is begun, no state change occurs immediately, and rollback will not write any changes to the datastore. The persistent-nontransactional-dirty instances will transition according to the RestoreValues flag. With the RestoreValues flag set to true, persistent-nontransactional-dirty instances will make no state transition, but the fields will be restored to their values as of the beginning of the transaction, and any changes made within the transaction will be discarded. With the RestoreValues flag set to false, persistent-nontransactional-dirty instances will transition to hollow.

If an optimistic transaction is begun, no state change occurs immediately, and commit will write the changes to the datastore after checking as to the current state of the instances in the datastore. The changes made outside the transaction together with any changes made inside the transaction will update the current state of the datastore if the version checking is successful. The persistent-nontransactional-dirty instances will transition according to the RetainValues flag. With the RetainValues flag set to true, persistent-nontransactional-dirty instances will transition to persistent-nontransactional. With the RetainValues flag set to false, persistent-nontransactional-dirty instances will transition to hollow.

If an optimistic transaction is begun, no state change occurs immediately, and rollback will not write any changes to the datastore. The persistent-nontransactional-dirty instances will transition according to the RestoreValues flag. With the RestoreValues flag set to true, persistent-nontransactional-dirty instances will make no state transition, but the fields will be restored to their values as of the beginning of the transaction, and any changes made within the transaction will be discarded. With the RestoreValues flag set to false, persistent-nontransactional-dirty instances will transition to hollow.

The behavior of persistent instances at close of the corresponding PersistenceManager is not further defined in this specification.

5.7 Transient Transactional (Optional)

Management of transient transactional instances is an optional feature of a JDO implementation. The following sections describe the additional states and state changes when using transient transactional behavior.

A transient instance transitions to transient-clean if it is the parameter of makeTransactional.

5.7.1 Transient-clean (Optional)

JDO instances that represent transient transactional instances whose values have not been changed in the current transaction are transient-clean. This state is not reachable if the JDO PersistenceManager does not implement the optional feature javax.jdo.option.TransientTransactional.

Changes made outside a transaction are allowed without a state change. A transient-clean instance transitions to transient-dirty if any managed field is changed in a transaction. During the transition, values of managed fields are saved by the PersistenceManager for use during rollback. This behavior is not dependent on the setting of the RestoreValues flag.

A transient-clean instance transitions to transient if it is the parameter of makeNontransactional.

5.7.2 Transient-dirty (Optional)

JDO instances that represent transient transactional instances whose values have been changed in the current transaction are transient-dirty. This state is not reachable if the JDO PersistenceManager does not implement the optional feature javax.jdo.option.TransientTransactional.

A transient-dirty instance transitions to transient-clean at commit. The values of managed fields saved (for rollback processing) at the time the transition was made from transient-clean to transient-dirty are discarded. None of the values of fields in the instance are modified as a result of commit.

A transient-dirty instance transitions to transient-clean at rollback. The values of managed fields saved at the time the transition was made from transient-clean to transient-dirty are restored. This behavior is not dependent on the setting of the RestoreValues flag.

A transient-dirty instance transitions to persistent-new at makePersistent. The values of managed fields saved at the time the transition was made from transient-clean to transient-dirty are used as the before image for the purposes of rollback.

5.8 Optimistic Transactions (Optional)

Optimistic transaction management is an optional feature of a JDO implementation.

The Optimistic flag set to true changes the state transitions of persistent instances:

- If a persistent field other than one of the primary key fields is read, a hollow instance transitions to persistent-nontransactional instead of persistent-clean. Subsequent reads of these fields do not cause a transition from persistent-nontransactional.
- A persistent-nontransactional instance transitions to persistent-deleted if it is a parameter of deletePersistent. The state of the managed fields of the instance in memory is saved for use during rollback, and for verification during commit. The values in fields of the instance in memory are unchanged. If fresh values need to be loaded from the datastore, then the user should first call refresh on the instance.
- A persistent-nontransactional instance transitions to persistent-clean if it is a parameter of a makeTransactional method executed when an optimistic transaction is in progress. The values in managed fields of the instance in memory are unchanged. If fresh values need to be loaded from the datastore, then the user should first call refresh on the instance.
- A persistent-nontransactional instance transitions to persistent-dirty if a managed field is modified when an optimistic transaction is in progress. If RestoreValues is true, a before image is saved before the state transition. This is used for restoring field values during rollback. Depending on the implementation the before image of the instance in memory might be saved for verification during commit. The values in fields of the instance in memory are unchanged before the update is applied. If fresh values need to be loaded from the datastore, then the user should first call refresh on the instance.

Table 2: State Transitions

method \ current state	Transient	P-new	P-clean	P-dirty	Hollow
makePersistent	P-new	unchanged	unchanged	unchanged	unchanged
deletePersistent	error	P-new-del	P-del	P-del	P-del
makeTransactional	T-clean	unchanged	unchanged	unchanged	P-clean
makeNontransactional	error	error	P-nontrans	error	unchanged
makeTransient	unchanged	error	Transient	error	Transient
commit retainValues=false	unchanged	Hollow	Hollow	Hollow	unchanged
commit retainValues=true	unchanged	P-nontrans	P-nontrans	P-nontrans	unchanged
commit DetachAllOnCommit true	unchanged	detached-clean	detached-clean	detached-clean	detached-clean
rollback restoreValues=false	unchanged	Transient	Hollow	Hollow	unchanged
rollback restoreValues=true	unchanged	Transient	P-nontrans	P-nontrans	unchanged
refresh with active Datastore transaction	unchanged	unchanged	unchanged	P-clean	unchanged
refresh with active Optimistic transaction	unchanged	unchanged	unchanged	P-nontrans	unchanged
evict	n/a	unchanged	Hollow	unchanged	unchanged
read field outside transaction	unchanged	impossible	impossible	impossible	P-nontrans
read field with active Optimistic transaction	unchanged	unchanged	unchanged	unchanged	P-nontrans
read field with active Datastore transaction	unchanged	unchanged	unchanged	unchanged	P-clean
write field or makeDirty outside transaction	unchanged	impossible	impossible	impossible	P-nontrans
write field or makeDirty with active transaction	unchanged	unchanged	P-dirty	unchanged	P-dirty

Table 2: State Transitions

method \ current state	Transient	P-new	P-clean	P-dirty	Hollow
retrieve outside or with active Optimistic transaction	unchanged	unchanged	unchanged	unchanged	P-nontrans
retrieve with active Datastore transaction	unchanged	unchanged	unchanged	unchanged	P-clean
detachCopy outside transaction with NontransactionalRead true	error	impossible	impossible	impossible	parameter: P-nontrans returned: detached-clean
detachCopy outside transaction with NontransactionalRead false	error	impossible	impossible	impossible	error
detachCopy with active Optimistic transaction	parameter: P-new returned: detached-clean	parameter: unchanged returned: detached-clean	parameter: unchanged returned: detached-clean	parameter: unchanged returned: detached-clean	parameter: P-nontrans returned: detached-clean
detachCopy with active Datastore transaction	parameter: P-new returned: detached-clean	parameter: unchanged returned: detached-clean	parameter: unchanged returned: detached-clean	parameter: unchanged returned: detached-clean	parameter: P-clean returned: detached-clean

method \ current state	T-clean	T-dirty	P-new-del	P-del	P-nontrans
makePersistent	P-new	P-new	unchanged	unchanged	unchanged
deletePersistent	error	error	unchanged	unchanged	P-del
makeTransactional	unchanged	unchanged	unchanged	unchanged	P-clean
makeNontransactional	Transient	error	error	error	unchanged
makeTransient	unchanged	unchanged	error	error	Transient
commit retainValues=false	unchanged	T-clean	Transient	Transient	unchanged
commit retainValues=true	unchanged	T-clean	Transient	Transient	unchanged

method \ current state	T-clean	T-dirty	P-new-del	P-del	P-nontrans
commit transaction with DetachAllOnCommit true	unchanged	T-clean	Transient	Transient	detached-clean
rollback restoreValues=false	unchanged	T-clean	Transient	Hollow	unchanged
rollback restoreValues=true	unchanged	T-clean	Transient	P-nontrans	unchanged
refresh	unchanged	unchanged	unchanged	unchanged	unchanged
evict	unchanged	unchanged	unchanged	unchanged	Hollow
read field outside transaction	unchanged	impossible	impossible	impossible	unchanged
read field with Optimistic transaction	unchanged	unchanged	error	error	unchanged
read field with active Datastore transaction	unchanged	unchanged	error	error	P-clean
write field or makeDirty outside transaction	unchanged	impossible	impossible	impossible	P-nontrans-dirty
write field or makeDirty with active transaction	T-dirty	unchanged	error	error	P-dirty
retrieve outside or with active Optimistic transaction	unchanged	unchanged	unchanged	unchanged	unchanged
retrieve with active Datastore transaction	unchanged	unchanged	unchanged	unchanged	P-clean
detachCopy outside transaction with NontransactionalRead true	error	impossible	impossible	impossible	parameter: unchanged returned: detached-clean
detachCopy outside transaction with NontransactionalRead false	error	impossible	impossible	impossible	error

method \ current state	T-clean	T-dirty	P-new-del	P-del	P-nontrans
detachCopy with active optimistic transaction	parameter: P-new returned: detached-clean	parameter: P-new returned: detached-clean	error	error	parameter: unchanged returned: detached-clean
detachCopy with active datastore transaction	parameter: P-new returned: detached-clean	parameter: P-new returned: detached-clean	error	error	parameter: P-clean returned: detached-clean

method \ current state	P-nontrans-dirty	detached-clean	detached-dirty
makePersistent with active Optimistic transaction and CopyOnAttach false	unchanged	P-nontrans	P-dirty
makePersistent with active Datastore transaction and CopyOnAttach false	unchanged	P-clean	P-dirty
makePersistent with CopyOnAttach false and instance with the same oid already in the cache	unchanged	error	error
makePersistent with active Optimistic transaction and CopyOnAttach true	unchanged	parameter: unchanged returned: P-nontrans	parameter: unchanged returned: P-dirty
makePersistent with active Datastore transaction and CopyOnAttach true	unchanged	parameter: unchanged returned: P-clean	parameter: unchanged returned: P-dirty
deletePersistent	error	unchanged	unchanged
makeTransactional	unchanged	error	error

method \ current state	P-nontrans-dirty	detached-clean	detached-dirty
makeNontransactional	error	error	error
makeTransient	error	error	error
commit with retainValues=false	hollow	unchanged	unchanged
commit with retainValues=true	P-nontrans	unchanged	unchanged
rollback	unchanged	unchanged	unchanged
refresh	unchanged	error	error
evict	hollow	error	error
read field	unchanged	unchanged	unchanged
write field or makeDirty	unchanged	detached-dirty	unchanged
retrieve	unchanged	error	error
commit transaction with DetachAllOnCommit true	detached	unchanged	unchanged
detachCopy outside transaction with NontransactionalRead true	parameter: unchanged returned: unspecified	parameter: unchanged returned: detached-clean	parameter: unchanged returned: unspecified
detachCopy outside transaction with NontransactionalRead false	error	error	error
detachCopy with active transaction	impossible	parameter: unchanged returned: detached-clean	parameter: unchanged returned: detached-clean

- error: a `JDOUserException` is thrown; the state does not change
- unchanged: no state change takes place; no exception is thrown due to the state change
- n/a: not applicable; if this instance is an explicit parameter of the method, a `JDOUserException` is thrown; if this instance is an implicit parameter, it is ignored.
- impossible: the state cannot occur in this scenario

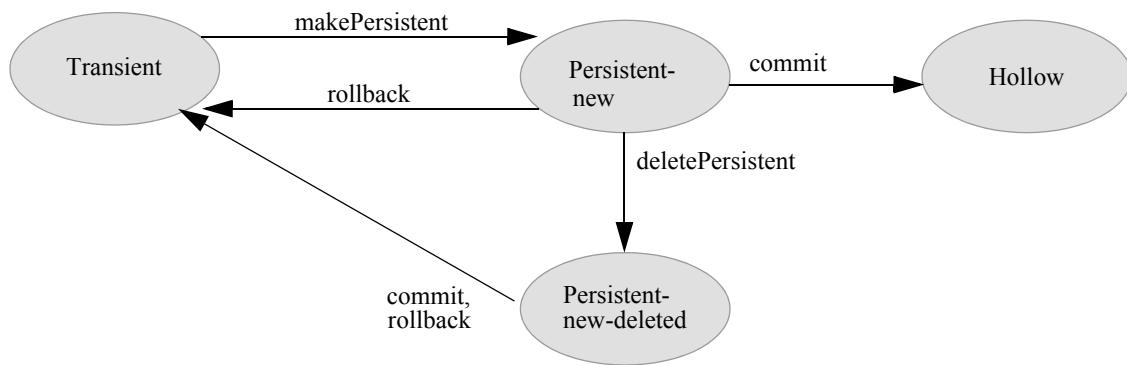
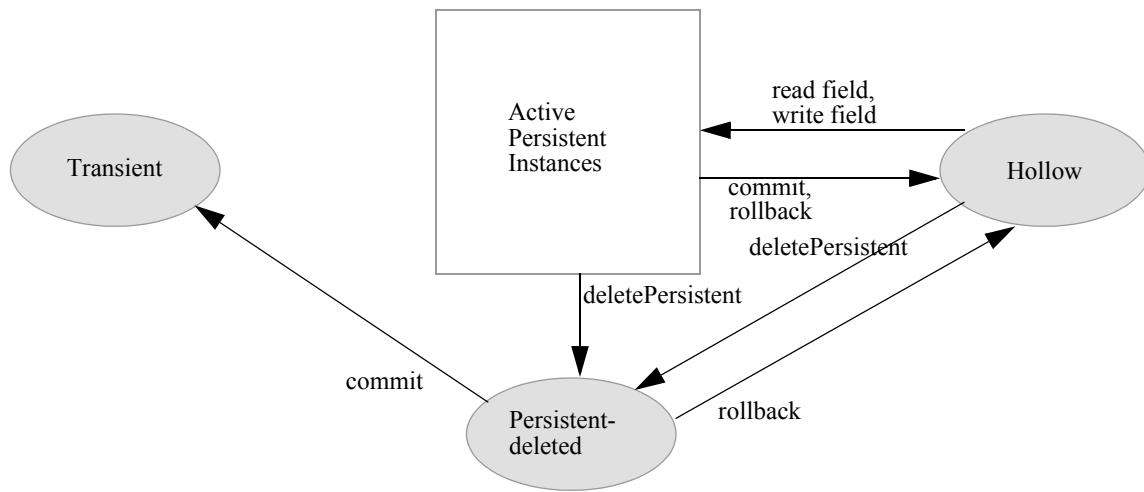
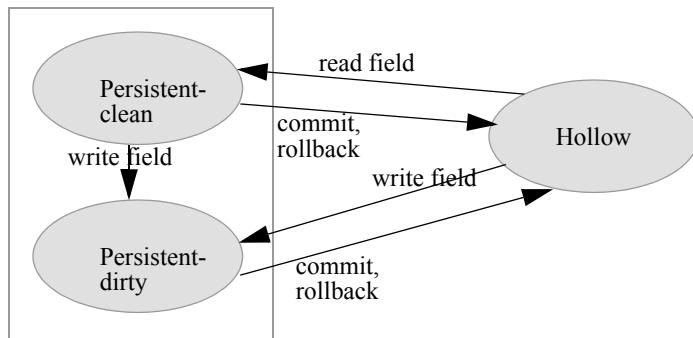
Figure 7.0 Life Cycle: New Persistent Instances**Figure 8.0** Life Cycle: Transactional Access**Figure 9.0** Life Cycle: Datastore Transactions

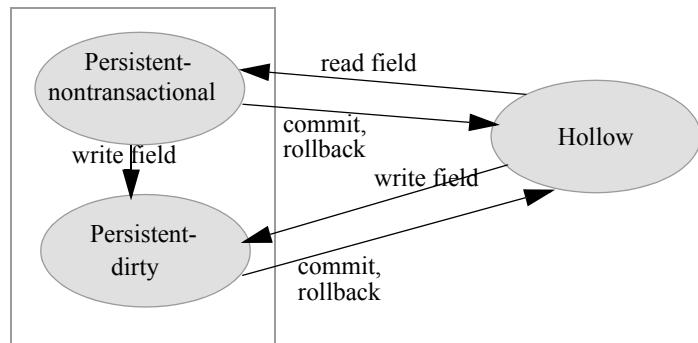
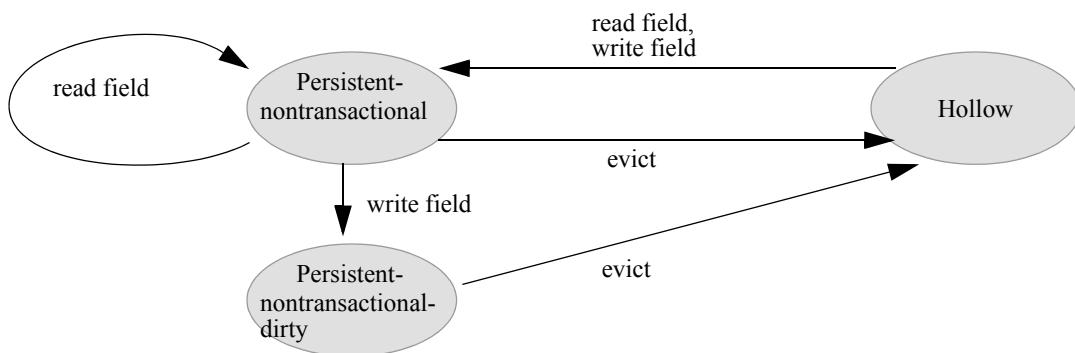
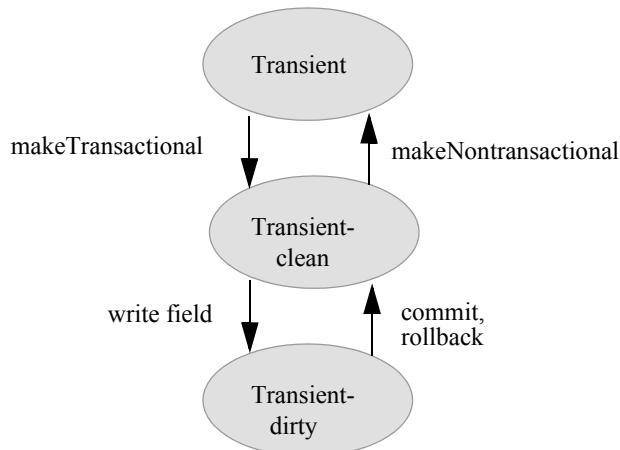
Figure 10.0 Life Cycle: Optimistic Transactions**Figure 11.0** Life Cycle: Access Outside Transactions**Figure 12.0** Life Cycle: Transient Transactional

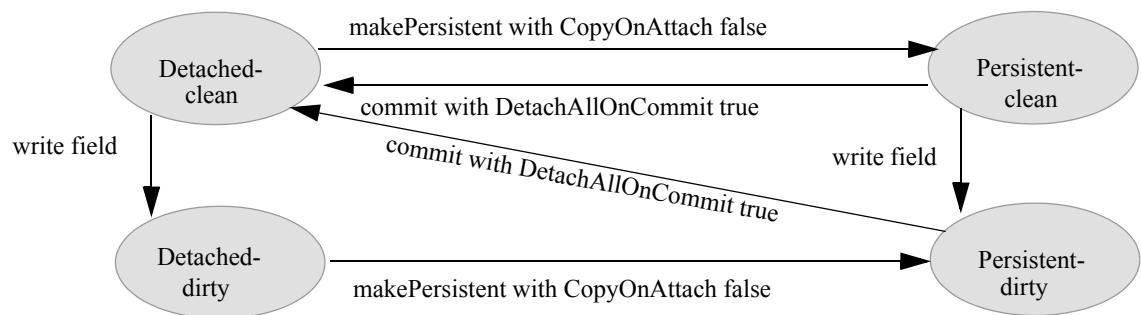
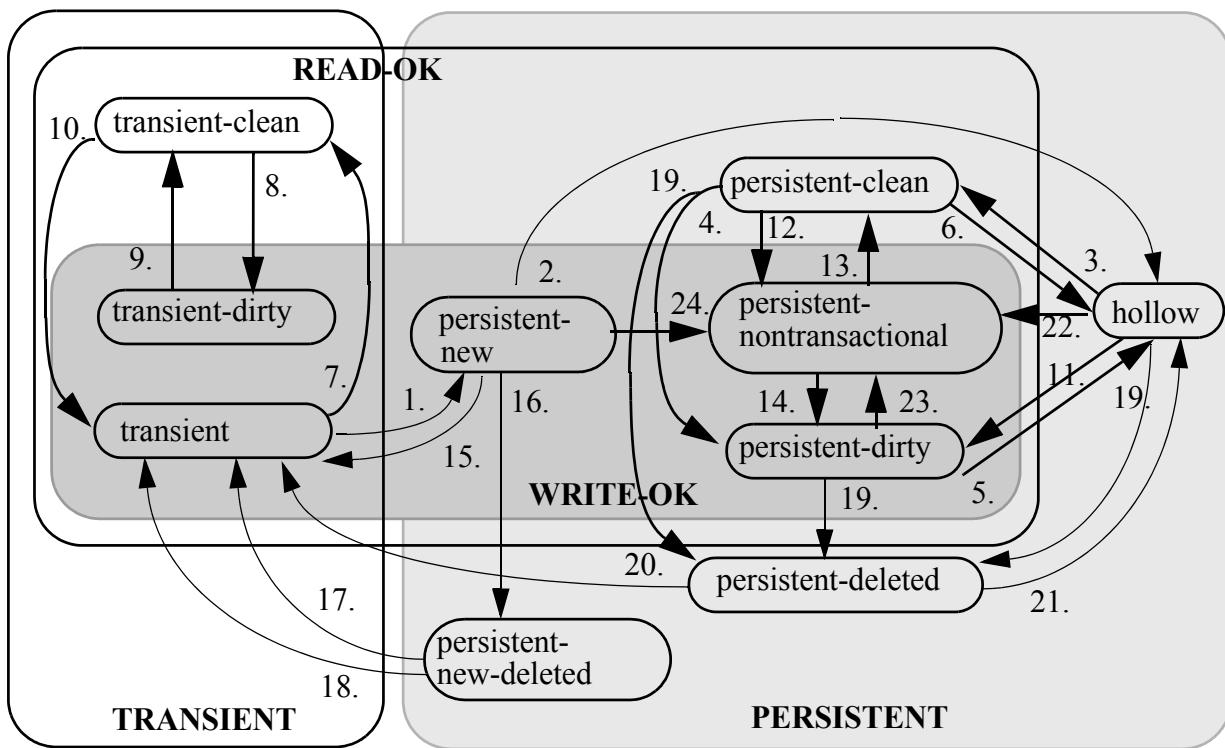
Figure 13.0 Life Cycle: Detached

Figure 14.0 JDO Instance State Transitions

NOTE: Not all possible state transitions are shown in this diagram.

1. A transient instance transitions to persistent-new when the instance is the parameter of a `makePersistent` method.
2. A persistent-new instance transitions to hollow when the transaction in which it was made persistent commits.
3. A hollow instance transitions to persistent-clean when a field is read.
4. A persistent-clean instance transitions to persistent-dirty when a field is written.
5. A persistent-dirty instance transitions to hollow at commit or rollback.
6. A persistent-clean instance transitions to hollow at commit or rollback.
7. A transient instance transitions to transient-clean when it is the parameter of a `makeTransactional` method.
8. A transient-clean instance transitions to transient-dirty when a field is written.
9. A transient-dirty instance transitions to transient-clean at commit or rollback.
10. A transient-clean instance transitions to transient when it is the parameter of a `makeNontransactional` method.
11. A hollow instance transitions to persistent-dirty when a field is written.

12. A persistent-clean instance transitions to persistent-nontransactional at commit when `RetainValues` is set to `true`, at rollback when `RestoreValues` is set to `true`, or when it is the parameter of a `makeNontransactional` method.
13. A persistent-nontransactional instance transitions to persistent-clean when it is the parameter of a `makeTransactional` method.
14. A persistent-nontransactional instance transitions to persistent-dirty when a field is written in a transaction.
15. A persistent-new instance transitions to transient on rollback.
16. A persistent-new instance transitions to persistent-new-deleted when it is the parameter of `deletePersistent`.
17. A persistent-new-deleted instance transitions to transient on rollback. The values of the fields are restored as of the `makePersistent` method.
18. A persistent-new-deleted instance transitions to transient on commit. No changes are made to the values.
19. A hollow, persistent-clean, or persistent-dirty instance transitions to persistent-deleted when it is the parameter of `deletePersistent`.
20. A persistent-deleted instance transitions to transient when the transaction in which it was deleted commits.
21. A persistent-deleted instance transitions to hollow when the transaction in which it was deleted rolls back.
22. A hollow instance transitions to persistent-nontransactional when the `NontransactionalRead` option is set to `true`, a field is read, and there is either an optimistic transaction or no transaction active.
23. A persistent-dirty instance transitions to persistent-nontransactional at commit when `RetainValues` is set to `true` or at rollback when `RestoreValues` is set to `true`.
24. A persistent-new instance transitions to persistent-nontransactional at commit when `RetainValues` is set to `true`.

6 The Persistent Object Model

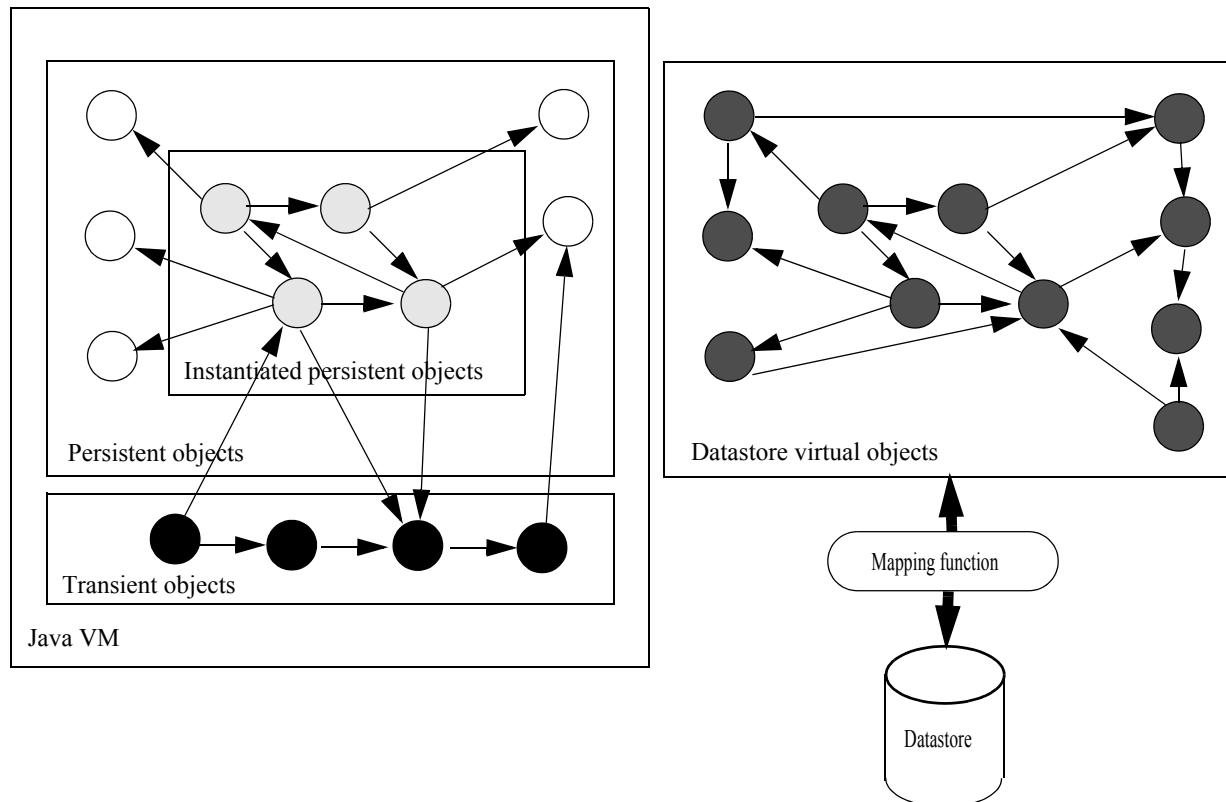
This chapter specifies the object model for persistence capable classes. To the extent possible, the object model is the same as the Java object model. Differences between the Java object model and the JDO object model are highlighted.

6.1 Overview

The Java execution environment supports different kinds of classes that are of interest to the developer. The classes that model the application and business domain are the primary focus of JDO. In a typical application, application classes are highly interconnected, and the graph of instances of those classes includes the entire contents of the datastore.

Applications typically deal with a small number of persistent instances at a time, and it is the function of JDO to allow the illusion that the application can access the entire graph of connected instances, while in reality only small subset of instances needs to be instantiated in the JVM. This concept is called transparent data access, transparent persistence, or simply transparency.

Figure 15.0 Instantiated persistent objects



Within a JVM, there may be multiple independent units of work that must be isolated from each other. This isolation imposes requirements on JDO to permit the instantiation of the same datastore object into multiple Java instances. The connected graph of Java instances is only a subset of the entire contents of the datastore. Whenever a reference is followed from one persistent instance to another, the JDO implementation transparently instantiates the required instance into the JVM.

The storage of objects in datastores might be quite different from the storage of objects in the JVM. Therefore, there is a mapping between the Java instances and the objects in the datastore. This mapping is performed by the JDO implementation, using metadata that is available at runtime. The metadata is generated by a JDO vendor-supplied tool, in cooperation with the deployer of the system. The mapping is not standardized by JDO except in the case of relational databases, for which a subset of mapping functionality is standard. The standard part of the mapping is specified in Chapter 15.

JDO instances are stored in the datastore and retrieved, possibly field by field, from the datastore at specific points in their life cycle. The class developer might use callbacks at certain points to make a JDO instance ready for execution in the JVM, or make a JDO instance ready to be removed from the JVM. While executing in the JVM, a JDO instance might be connected to other instances, both persistent and transient.

There is no restriction on the types of non-persistent fields of persistence-capable classes. These fields behave exactly as defined by the Java language. Persistent fields of persistence-capable classes have restrictions in JDO, based on the characteristics of the types of the fields in the class definition.

6.2 Goals

The JDO Object Model has the following objectives:

- All field types supported by the Java language, including primitive types, reference types and interface types should be supported by JDO instances.
- All class and field modifiers supported by the Java language including private, public, protected, static, transient, abstract, final, synchronized, and volatile, should be supported by JDO instances. There are some known issues with final and static fields; therefore implementations are not required to support making final or static fields persistent.
- All user-defined classes should be allowed to be persistence-capable.
- Some system-defined classes (especially those for modeling state) should be persistence-capable.

6.3 Architecture

In Java, variables (including fields of classes) have types. Types are either primitive types or reference types. Reference types are either classes or interfaces. Arrays are treated as classes.

An object is an instance of a specific class, determined when the instance is constructed. Instances may be assigned to variables if they are assignment compatible with the variable type.

Persistence-capable

The JDO Object Model distinguishes between two kinds of classes: those that are marked as persistence-capable and those that aren't. A user-defined class can be persistence-capable unless its state depends on the state of inaccessible or remote objects (e.g. it extends `java.net.SocketImpl` or uses JNI (native calls) to implement `java.net.SocketOptions`). A non-static inner class

cannot be persistence-capable because the state of its instances depends on the state of their enclosing instances.

Except for system-defined classes specially addressed by the JDO specification, system-defined classes (those defined in `java.lang`, `java.io`, `java.util`, `java.net`, etc.) are not persistence-capable, nor is a system-defined class allowed to be the type of a persistent field.

First Class Objects and Second Class Objects

A First Class Object (FCO) is an instance of a persistence-capable class that has a JDO Identity, can be stored in a datastore, and can be independently deleted and queried. A Second Class Object (SCO) has no JDO Identity of its own and is stored in the datastore only as part of a First Class Object. In some JDO implementations, some SCO instances are actually artifacts that have no literal datastore representation at all, but are used only to represent relationships. For example, a Collection of instances of a persistence-capable class might not be stored in the datastore, but created when needed to represent the relationship in memory. At commit time, the memory artifact is discarded and the relationship is represented entirely by datastore relationships.

First Class Objects

FCOs support unquiqing; whenever an FCO is instantiated into memory, there is guaranteed to be only one instance representing that FCO managed by the same `PersistenceManager` instance. They are passed as arguments by reference.

An FCO can be shared among multiple FCOs, and if an FCO is changed (and the change is committed to the datastore), then the changes are visible to all other FCOs that refer to it.

Second Class Objects

Second Class Objects are either instances of immutable system classes (`java.lang.Integer`, `java.lang.String`, etc.), JDO implementation subclasses of mutable system classes that implement the functionality of their system class (`java.util.Date`, `java.util.HashSet`, etc.), or persistence-capable classes.

Second Class Objects of mutable system classes and persistence-capable classes track changes made to them, and notify their owning FCO that they have changed. The change is reflected as a change to the owning FCO (e.g. the owning instance might change state from persistent-clean to persistent-dirty). They are stored in the datastore only as part of a FCO. They do not support unquiqing, and the Java object identity of the values of the persistent fields containing them is lost when the owning FCO is flushed to the datastore. They are passed as arguments by reference.

SCO fields must be explicitly or by default identified in the metadata as embedded. If a field, or an element of a collection or a map key or value is identified as embedded (embedded-element, embedded-key, or embedded-value) then any instances so identified in the collection or map are treated as SCO during commit. That is, the value is stored with the owning FCO and the value loses its own identity if it had one.

SCO fields of persistence-capable types are identified as embedded. The behavior of embedded persistence-capable types is intended to mirror the behavior of system types, but this is not standard, and portable applications must not depend on this behavior.

It is possible for an application to assign the same instance of a mutable SCO class to multiple FCO embedded fields, but this non-portable behavior is strongly discouraged for the following reason: if the assignment is done to persistent-new, persistent-clean, or persistent-dirty instances, then at the time that the FCOs are committed to the datastore, the Java object identity of the owned SCOS might change, because each FCO might have its own unshared SCO. If the assignment is done before `makePersistent` is called to make the FCOs persistent, the embedded fields are immediately replaced by copies, and no sharing takes place.

When an FCO is instantiated in the JVM by a JDO implementation, and an embedded field of a mutable type is accessed, the JDO implementation assigns to these fields a new instance that tracks changes made to itself, and notifies the owning FCO of the change. Similarly, when an FCO is made persistent, either by being the parameter of makePersistent or makePersistentAll or by being reachable from a parameter of makePersistent or makePersistentAll at the time of the execution of the makePersistent or makePersistentAll method call, the JDO implementation replaces the field values of mutable SCO types with instances of JDO implementation subclasses of the mutable system types.

Therefore, the application cannot assume that it knows the actual class of instances assigned to SCO fields, although it is guaranteed that the actual class is assignment compatible with the type.

There are few differences visible to the application between a field mapped to an FCO and an SCO. One difference is in sharing. If an FCO1 is assigned to a persistent field in FCO2 and FCO3, then any changes at any time to instance FCO1 will be visible from FCO2 and FCO3.

If an SCO1 is assigned to a persistent field in persistent instances FCO1 and FCO2, then any changes to SCO1 will be visible from instances FCO1 and FCO2 only until FCO1 and FCO2 are committed. After commit, instance SCO1 might not be referenced by either FCO1 or FCO2, and any changes made to SCO1 might not be reflected in either FCO1 or FCO2.

Another difference is in visibility of SCO instances by queries. SCO instances are not added to Extents. If the SCO instance is of a persistence-capable type, it is not visible to queries of the Extent of the persistence-capable class. Furthermore, the field values of SCO instances of persistence-capable types might not be visible to queries at all.

Sharing of immutable SCO fields is supported in that it is good practice to assign the same immutable instance to multiple SCO fields. But the field values should not be compared using Java identity, but only by Java equality. This is the same good practice used with non-persistent instances.

Arrays

Arrays are system-defined classes that do not necessarily have any JDO Identity of their own, and support by a JDO implementation is optional. If an implementation supports them, they might be stored in the datastore as part of an FCO. They do not support unquoting, and the Java object identity of the values of the persistent fields containing them is lost when the owning FCO is flushed to the datastore. They are passed as arguments by reference.

Tracking changes to Arrays is not required to be done by a JDO implementation. If an Array owned by an FCO is changed, then the changes might not be flushed to the datastore. Portable applications must not require that these changes be tracked. In order for changes to arrays to be tracked, the application must explicitly notify the owning FCO of the change to the Array by calling the makeDirty method of the `JDOHelper` class, or by replacing the field value with its current value.

Since changes to array-type fields cannot be tracked by JDO, setting the value of an array-type managed field marks the field as dirty, even if the new value is identical to the old value. This special case is required to allow the user to mark an array-type field as dirty without having to call the `JDOHelper` method `makeDirty`.

Furthermore, an implementation is permitted, but not required to, track changes to Arrays passed as references outside the body of methods of the owning class. There is a method defined on class `JDOHelper` that allows the application to mark the field containing such an Array to be modified so its changes can be tracked. Portable applications must not require that these changes be tracked automatically. When a reference to the Array is returned as a result of a method call, a portable application first marks the Array field as dirty.

It is possible for an application to assign the same instance of an Array to multiple FCOs, but after the FCO is flushed to the datastore, the Java object identity of the Array might change.

When an FCO is instantiated in the JVM, the JDO implementation assigns to fields with an Array type a new instance with a different Java object identity from the instance stored.

Therefore, the application cannot assume that it knows the identity of instances assigned to Array fields, although it is guaranteed that the actual value is the same as the value stored.

Primitives

Primitives are types defined in the Java language and comprise `boolean`, `byte`, `short`, `int`, `long`, `char`, `float`, and `double`. They might be stored in the datastore only as part of an FCO. They have no Java identity and no datastore identity of their own. They are passed as arguments by value.

Interfaces

Interfaces are types whose values may be instances of any class that declare that they implement that interface.

6.4 Field types of persistence-capable classes

6.4.1 Nontransactional non-persistent fields

There are no restrictions on the types of nontransactional non-persistent fields. These fields are managed entirely by the application, not by the JDO implementation. Their state is not preserved by the JDO implementation, although they might be modified during execution of user-written callbacks defined in interface `InstanceCallbacks` at specific points in the life cycle, or any time during the instance's existence in the JVM.

6.4.2 Transactional non-persistent fields

There are no restrictions on the types of transactional non-persistent fields. These fields are partly managed by the JDO implementation. Their state is preserved and restored by the JDO implementation during certain state transitions.

6.4.3 Persistent fields

Precision of fields

JDO implementations may not represent Java types precisely in the datastore, because not all datastores are able to natively represent all Java types. Some type mapping may be required. The precision of the mapping is a quality of service issue with the JDO implementation and the particular datastore.

The mapping precision restriction applies to the range of values that can be faithfully stored and retrieved, the precision of the values, and the scale of `BigDecimal` values.

Primitive types

JDO implementations must support fields of any of the primitive types

- `boolean`, `byte`, `short`, `int`, `long`, `char`, `float`, and `double`.

Primitive values are stored in the datastore associated with their owning FCO. They have no JDO Identity.

Immutable Object Class types

JDO implementations must support fields that reference instances of immutable object classes, and may choose to support these instances as SCOs or FCOs:

- package `java.lang`: `Boolean`, `Character`, `Byte`, `Short`, `Integer`, `Long`, `Float`, `Double`, and `String`;

- package `java.util`: `Locale`, `Currency`.
- package `java.math`: `BigDecimal`, `BigInteger`.

Portable JDO applications must not depend on SCO or FCO unquing behavior, nor on the storage mechanism in the datastore, of values of fields of immutable classes. Portable applications may use the same instance of these classes as field values in any persistence-capable class instance.

The scale of `BigDecimal` values is not guaranteed to be preserved by implementations. For example, saving a persistent field with value `BigDecimal("1.2300")` might be returned as value `BigDecimal("1.23")`.

Mutable Object Class types

JDO implementations must support fields that reference instances of the following mutable object classes, and may choose to support these instances as SCOs or FCOs:

- package `java.util`: `Date`, `HashSet`, `HashMap`, `Hashtable`, `LinkedHashMap`, `LinkedHashSet`.

JDO implementations may optionally support fields that reference instances of the following mutable object classes, and may choose to support these instances as SCOs or FCOs:

- package `java.util`: `ArrayList`, `LinkedList`, `TreeMap`, `TreeSet`, and `Vector`.

Because the treatment of these fields may be as SCO, the behavior of these mutable object classes when used in a persistent instance is not identical to their behavior in a transient instance.

Portable JDO applications must not depend on whether instances of these classes referenced by fields are treated as SCOs or FCOs.

Persistence-capable Class types

JDO implementations must support references to FCO instances of persistence-capable classes and are permitted, but not required, to support references to SCO instances of persistence-capable classes.

Portable JDO applications must not depend on whether these fields are treated as SCOs or FCOs.

Object Class type

JDO implementations must support fields of `Object` class type as FCOs. The implementation is permitted, but is not required, to allow any class to be assigned to the field. If an implementation restricts instances to be assigned to the field, a `ClassCastException` must be thrown at the time of any incorrect assignment.

Portable JDO applications must not depend on whether these fields are treated as SCOs or FCOs.

Collection Interface types

JDO implementations must support fields of interface types, and may choose to support them as SCOs or FCOs: package `java.util`: `Collection`, `Map`, `Set`, and `List`. `Collection`, `Map`, and `Set` are required; `List` is optional.

Portable JDO applications must not depend on whether these fields are treated as SCOs or FCOs.

Other Interface types

JDO implementations must support fields of interface types other than `Collection` interface types as FCOs. The implementation is permitted, but is not required, to allow any class that implements the interface to be assigned to the field. If an implementation further restricts instances that can be assigned to the field, a `ClassCastException` must be thrown at the time of any incorrect assignment.

Portable JDO applications must treat these fields as FCOs.

Arrays

JDO implementations may optionally support fields of array types, and may choose to support them as SCOs or FCOs. If Arrays are supported by JDO implementations, they are permitted, but not required, to track changes made to Arrays that are fields of persistence capable classes in the methods of the classes. They need not track changes made to Arrays that are passed by reference as arguments to methods, including methods of persistence-capable classes.

Portable JDO applications must not depend on whether these fields are treated as SCOs or FCOs.

Enums

JDO implementations that support Java 5 must support fields of enum types and collections of as enum types identified above and optionally arrays of enum types. If arrays are supported, arrays of enums must be supported.

Portable JDO applications must not depend on whether these fields are treated as SCOs or FCOs.

6.4.4 Static and final fields

Static fields pose a challenge for implementations. Since they are singletons typically initialized when the class is loaded, there is no convenient time to load the values from the database. Therefore, in portable applications, static fields are not persistent.

Final fields pose a challenge for implementations. While it is possible to modify the values of static fields, it can only be done via reflection and there are synchronization issues. Therefore, in portable applications, final fields are not persistent.

6.4.5 Complex enum types

Complex enum types are enums that contain fields that might change during execution instead of being initialized during class initialization. While it is possible to manage these singleton instances' persistent state, there are issues with the transaction isolation of the instances and with the ownership of the instances by a persistence manager. Therefore, dynamically changing fields of enum types are not persistent.

6.5 Inheritance

A class might be persistence-capable even if its superclass is not persistence-capable. This allows users to extend classes that were not designed to be persistence-capable. If a class is persistence-capable, then its subclasses might or might not be persistence-capable themselves.

Further, subclasses of such classes that are not persistence-capable might be persistence-capable. That is, it is possible for some classes in the inheritance hierarchy to be persistence-capable and some not persistence-capable.

The expression "obj instanceof PersistenceCapable" can be true (because of a persistence-capable superclass) when in fact the class of obj is not persistence-capable. Thus, it is not possible for an application to examine a class to determine whether an instance of that class is allowed to be persistent.

Fields identified in the XML metadata as persistent or transactional in persistence-capable classes must be fields declared in that Java class definition. That is, inherited fields cannot be named in the XML metadata.

Fields identified as persistent in persistence-capable classes will be persistent in subclasses; fields identified as transactional in persistence-capable classes will be transactional in subclasses; and fields identified as non-persistent in persistence-capable classes will be non-persistent in subclasses.

Of course, a class might define a new field with the same name as the field declared in the superclass, and might define it with a different persistence-modifier from the inherited field. But Java treats the declared field as a different field from the inherited field, so there is no conflict.

All persistence-capable classes must have a no-arg constructor. This constructor might be a private constructor, as it is only used from within the `jdoNewInstance` methods. The constructor might be the default no-arg constructor created by the compiler when the source code does not define any constructors.

The identity type of the least-derived persistence-capable class defines the identity type for all persistence-capable classes that extend it.

Persistence-capable classes that use application identity have special considerations for inheritance: Key fields may be declared only in abstract superclasses and least-derived concrete classes in inheritance hierarchies. Key fields declared in these classes must also be declared in the corresponding objectid classes, and the objectid classes must form an inheritance hierarchy corresponding to the inheritance hierarchy of the persistence-capable classes. A persistence-capable class can only have one concrete objectid class anywhere in its inheritance hierarchy.

For example, if an abstract class `Component` declares a key field `masterId`, the objectid class `ComponentKey` must also declare a field of the same type and name. If `ComponentKey` is concrete, then no subclass is allowed to define an objectid class.

If `ComponentKey` is abstract, an instance of a concrete subclass of `ComponentKey` must be used to find a persistent instance. A concrete class `Part` that extends `Component` must declare a concrete objectid class (for example, `PartKey`) that extends `ComponentKey`. There might be no key fields declared in `Part` or `PartKey`. Persistence-capable subclasses of `Part` must not have an objectid class.

Another concrete class `Assembly` that extends `Component` must declare a concrete objectid class (for example, `AssemblyKey`) that extends `ComponentKey`. If there is a key field, it must be declared in both `Assembly` and `AssemblyKey`. Persistence-capable subclasses of `Assembly` must not have an objectid class.

There might be other abstract classes or non-persistence-capable classes in the inheritance hierarchy between `Component` and `Part`, or between `Component` and `Assembly`. These classes are ignored for the purposes of objectid classes and key fields.

Readers primarily interested in developing applications with the JDO API can ignore the following chapter. Skip to 8 – `JDOHelper`.

7 PersistenceCapable

For JDO implementations that support the BinaryCompatibility rules, every instance that is managed by a JDO PersistenceManager must be of a class that implements the public PersistenceCapable interface. This interface defines methods that allow the implementation to manage the instances. It also defines methods that allow a JDO aware application to examine the runtime state of instances, for example to discover whether the instance is transient, persistent, transactional, dirty, etc., and to discover its associated PersistenceManager if it has one.

The JDO Reference Enhancer modifies the class to implement PersistenceCapable prior to loading the class into the runtime environment. The enhancer additionally adds code to implement the methods defined by PersistenceCapable. Other enhancers can be used for specific binary-compatible JDO implementations.

The PersistenceCapable interface is designed to avoid name conflicts in the scope of user-defined classes. All of its declared method names are prefixed with “jdo”.

Class implementors may explicitly declare that the class implements PersistenceCapable. If this is done, the implementor must implement the PersistenceCapable contract, and the enhancer will ignore the class instead of enhancing it.

The recommended (and only portable) approach for applications to interrogate the state of persistence-capable instances is to use the class JDOHelper, which provides static methods that delegate to the instance if it implements PersistenceCapable, and if not, attempts to find the JDO implementation responsible for the instance, and if unable to do so, returns the values that would have been returned by a transient instance.

Classes that are to be detached from the persistence manager further implement the Detachable interface. This interface is used to establish the fields loaded before detachment and to query the instance if it is presented for attachment later.

The persistence modifier, identity type, identity class, key fields, persistent fields, and detachability of the class are fixed at enhancement time, or when the class is loaded, whichever occurs first.

*NOTE: This interface is not intended to be used by application programmers.
It is for use only by implementations. Applications should use the methods
defined in class JDOHelper instead of these methods.*

```
package javax.jdo.spi;  
public interface PersistenceCapable {
```

7.1 Persistence Manager

```
PersistenceManager jdoGetPersistenceManager();
```

This method returns the associated PersistenceManager or null if the instance is transient.

7.2 Make Dirty

```
void jdoMakeDirty (String fieldName); void jdoMakeDirty (int fieldNumber);
```

These methods mark the specified field dirty so that its values will be modified in the datastore when the transaction in which the instance is modified is committed. The `fieldName` is the name of the field to be marked as dirty, optionally including the fully qualified package name and class name of the field. This method returns with no effect if the instance is not detached or managed by a `StateManager`. This method has the same effect on the life cycle state of the instance as changing a managed field would. The `fieldNumber` parameter is the internal field number assigned during class enhancement.

If the instance is detached and the field has not been loaded, `JDODetachedFieldAccessException` is thrown.

If the same name is used for multiple fields (a class declares a field of the same name as a field in one of its superclasses) then the unqualified name refers to the most-derived class in which the field is declared to be persistent. The qualified name (`className.fieldName`) should always be used to identify the field to avoid ambiguity with subclass-defined fields.

The rationale for this is that a method in a superclass might call this method, and specify the name of the field that is hidden by a subclass. The `StateManager` has no way of knowing which class called this method, and therefore assumes the Java rule regarding field names.

It is always safe to explicitly name the class and field referred to in the parameter to the method. The `StateManager` will resolve the scope of the name in the class named in the parameter.

For example, if class C inherits class B which inherits class A, and field X is declared in classes A and C, a method declared in class B may refer to the field in the method as “B.X” and it will refer to the field declared in class A. Field X is not declared in B; however, in the scope of class B, X refers to A.X.

7.3 JDO Identity

```
Object jdoGetObjectId();
```

This method returns the JDO identity of the instance. If the instance is transient, `null` is returned. If the identity is being changed in a transaction, this method returns the identity as of the beginning of the transaction. If the instance is detached, this method returns the identity as of the time of detachment.

```
Object jdoGetTransactionalObjectId();
```

This method returns the JDO identity of the instance. If the instance is transient, `null` is returned. If the identity is being changed in a transaction, this method returns the current identity in the transaction. If the instance is detached, this method returns the identity as of the time of detachment.

7.3.1 Version

```
Object jdoGetVersion();
```

This method returns the version of the instance.

7.4 Status interrogation

The status interrogation methods return a boolean that represents the state of the instance:

7.4.1 Dirty

```
boolean jdoIsDirty();
```

Instances whose state has been changed in the current transaction return `true`. Instances whose state has not been changed in the current transaction return `false` to a call to `jdoIsDirty`. If the instance is transient or detached, `false` is returned.

7.4.2 Transactional

```
boolean jdoIsTransactional();
```

Instances whose state is associated with the current transaction return `true`. Instances whose state has not been changed in the current transaction return `false` to a call to `jdoIsTransactional`. If the instance is transient or detached, `false` is returned.

7.4.3 Persistent

```
boolean jdoIsPersistent();
```

Instances that represent persistent objects in the datastore return `true`. Instances that do not represent persistent objects in the datastore return `false` to a call to `jdoIsPersistent`. If the instance is transient or detached, `false` is returned.

7.4.4 New

```
boolean jdoIsNew();
```

Instances that have been made persistent in the current transaction return `true`. Instances that have not been made persistent in the current transaction return `false` to a call to `jdoIsNew`. If the instance is transient or detached, `false` is returned.

7.4.5 Deleted

```
boolean jdoIsDeleted();
```

Instances that have been deleted in the current transaction return `true`. Instances that have not been deleted in the current transaction return `false` to a call to `jdoIsDeleted`. If the instance is transient or detached, `false` is returned.

7.4.6 Detached

```
boolean jdoIsDetached();
```

Table 3: State interrogation

	Persistent	Transactional	Dirty	New	Deleted	Detached
Transient						
Transient-clean		✓				
Transient-dirty		✓	✓			
Persistent-new	✓	✓	✓	✓		
Persistent-nontransactional	✓					
Persistent-nontransactional-dirty	✓		✓			

Table 3: State interrogation

	Persistent	Transactional	Dirty	New	Deleted	Detached
Persistent-clean	✓	✓				
Persistent-dirty	✓	✓	✓			
Hollow	✓					
Persistent-deleted	✓	✓	✓		✓	
Persistent-new-deleted	✓	✓	✓	✓	✓	
Detached-clean						✓
Detached-dirty			✓			✓

Instances that have been detached return `true`.

7.5 New instance

```
PersistenceCapable jdoNewInstance(StateManager sm);
```

This method creates a new instance of the class of the instance. It is intended to be used as a performance optimization compared to constructing a new instance by reflection using the constructor. It is intended to be used only by JDO implementations, not by applications. If the class is abstract, `JDOFatalInternalException` is thrown.

```
PersistenceCapable jdoNewInstance(StateManager sm, Object oid);
```

This method creates a new instance of the class of the instance, and copies key field values from the `oid` parameter instance. It is intended to be used as a performance optimization compared to constructing a new instance by reflection using the constructor, and copying values from the `oid` instance by reflection. It is intended to be used only by JDO implementations for classes that use application identity, not by applications. If the class is abstract, `null` is returned.

7.6 State Manager

```
void jdoReplaceStateManager (StateManager sm)
    throws SecurityException;
```

This method sets the `jdoStateManager` field to the parameter. This method is normally used by the `StateManager` during the process of making an instance persistent, transactional, or transient. The caller of this method must have `JDOPermission("setStateManager")` for the instance, otherwise `SecurityException` is thrown.

7.7 Replace Flags

```
void jdoReplaceFlags ( );
```

This method tells the instance to call the owning `StateManager`'s `replacingFlags` method to get a new value for the `jdoFlags` field.

7.8 Replace Fields

```
void jdoReplaceField (int fieldNumber);
```

This method gets a new value from the StateManager for the field specified in the parameter. The field number must refer to a field declared in this class or in a superclass.

```
void jdoReplaceFields (int[] fieldNumbers);
```

This method iterates over the array of field numbers and calls `jdoReplaceField` for each one.

7.9 Provide Fields

```
void jdoProvideField (int fieldNumber);
```

This method provides the value of the specified field to the StateManager. The field number must refer to a field declared in this class or in a superclass.

```
void jdoProvideFields (int[] fieldNumbers);
```

This method iterates over the array of field numbers and calls `jdoProvideField` for each one.

7.10 Copy Fields

```
void jdoCopyFields (Object other, int[] fieldNumbers);
```

```
void jdoCopyField (Object other, int fieldNumber);
```

These methods copy fields from another instance of the same class. These methods can be invoked only when both `this` and `other` are managed by the same StateManager.

7.11 Static Fields

The following fields define the permitted values for the `jdoFlags` field.

```
public static final byte READ_WRITE_OK = 0;
public static final byte READ_OK = -1;
public static final byte LOAD_REQUIRED = 1;
```

The following fields define the flags for the `jdoFieldFlags` elements.

```
public static final byte CHECK_READ = 1;
public static final byte MEDIATE_READ = 2;
public static final byte CHECK_WRITE = 4;
public static final byte MEDIATE_WRITE = 8;
public static final byte SERIALIZABLE = 16;
```

7.12 JDO identity handling

```
public Object jdoNewObjectIdInstance();
```

This method creates a new instance of the class used for JDO identity. It is intended only for application identity. If the class has been enhanced for datastore identity, or if the class is abstract, `null` is returned.

For classes using single field identity, this method must be called on an instance of a persistence-capable class with its primary key field initialized (not null), or a `JDONullIdentityException` is thrown.

The instance returned is initialized with the value(s) of the primary key field(s) of the instance on which the method is called.

```
public Object jdoNewObjectInstanceId(Object key);
```

This method creates a new instance of the class used for JDO identity, using the appropriate constructor of the object id class. It is intended only for application identity, including single field identity. If the class has been enhanced for datastore identity, or if the class is abstract, `null` is returned. The identity instance returned has no relationship with the values of the primary key fields of the persistence-capable instance on which the method is called.

For single field identity, there is specific behavior required for parameters of these types:

- `ObjectFieldSupplier`: the field value is fetched and used to construct the single field identity instance.
- `Number` or `Character`: the parameter `key` must be an instance of the key type or, for primitive key types, the wrapper of the key type; the key is passed as a parameter to the single field identity constructor.
- `String`: the `String` is parsed to a value of the appropriate type and the value is used to construct the single field identity instance. For `ObjectIdentity`, the `String` is decomposed into two parts using ":" as a delimiter. The first part is the class name; the second is the `String` representation of the value of the class.
- `Object`: for `ObjectIdentity`, the key type must be assignable from the parameter `key`.

```
public void jdoCopyKeyFieldsToObjectId(Object oid);
```

This method copies all key fields from this instance to the parameter. The parameter must be an instance of the JDO identity class, or `ClassCastException` is thrown. If the class uses single field identity, this method always throws `JDOFatalInternalException`.
`jdoCopyKeyFieldsToObjectId (PersistenceCapable pc, Object oid)` copies all key fields from the first parameter to the second parameter. The first parameter of `jdoCopyKeyFieldsToObjectId (PersistenceCapable pc, Object oid)` must be of the same class as this instance, or a `ClassCastException` is thrown. The second parameter of `jdoCopyKeyFieldsToObjectId (PersistenceCapable pc, Object oid)` must be an instance of the JDO identity class, or a `ClassCastException` is thrown.

```
public void jdoCopyKeyFieldsToObjectId(ObjectFieldSupplier fs, Object oid);
```

This method copies fields from the field manager instance to the second parameter instance. Each key field in the `ObjectId` class matching a key field in the `PersistenceCapable` class is set by the execution of this method. For each key field, the method of the `ObjectFieldSupplier` is called for the corresponding type of field. The second parameter must be an instance of the JDO identity class. If the parameter is not of the correct type, then `ClassCastException` is thrown. If the class uses single field identity, this method always throws `JDOFatalInternalException`.

```
public void jdoCopyKeyFieldsFromObjectId(ObjectFieldConsumer fc, Object oid);
```

This method copies fields to the field manager instance from the second parameter instance. Each key field in the `ObjectId` class matching a key field in the `PersistenceCapable` class is retrieved by the execution of this method. For each key field, the method of the `ObjectField-`

`Consumer` is called for the corresponding type of field. The second parameter must be an instance of the JDO identity class. If the parameter is not of the correct type, then `ClassCastException` is thrown.

interface ObjectIdFieldSupplier

```
boolean fetchBooleanField (int fieldNumber);
byte fetchByteField (int fieldNumber);
char fetchCharField (int fieldNumber);
short fetchShortField (int fieldNumber);
int fetchIntField (int fieldNumber);
long fetchLongField (int fieldNumber);
float fetchFloatField (int fieldNumber);
double fetchDoubleField (int fieldNumber);
String fetchStringField (int fieldNumber);
Object fetchObjectField (int fieldNumber);
```

These methods all fetch one field from the field manager. The returned value is stored in the object id instance. The generated code in the `PersistenceCapable` class calls a method in the field manager for each key field in the object id. The field number is the same as in the persistence capable class for the corresponding key field.

interface ObjectIdFieldConsumer

```
void storeBooleanField (int fieldNumber, boolean value);
void storeByteField (int fieldNumber, byte value);
void storeCharField (int fieldNumber, char value);
void storeShortField (int fieldNumber, short value);
void storeIntField (int fieldNumber, int value);
void storeLongField (int fieldNumber, long value);
void storeFloatField (int fieldNumber, float value);
void storeDoubleField (int fieldNumber, double value);
void storeStringField (int fieldNumber, String value);
void storeObjectField (int fieldNumber, Object value);
```

These methods all store one field to the field manager. The value is retrieved from the object id instance. The generated code in the `PersistenceCapable` class calls a method in the field manager for each key field in the object id. The field number is the same as in the persistence capable class for the corresponding key field.

interface ObjectIdFieldManager

This interface is a convenience interface that extends both `ObjectIdFieldSupplier` and `ObjectIdFieldConsumer`.

7.13 Detachable

This interface contains the method used by the `StateManager` to manage the detached state in a detached instance. This interface is not intended to be used by application programs.

The detached state is stored as a field in each instance of `Detachable`. The field is serialized so as to maintain the state of the instance while detached. While detached, only the `BitSet` of modified fields will be modified. The structure is as follows.

```
Object[] jdoDetachedState;
jdoDetachedState[0]: the Object Id of the instance
jdoDetachedState[1]: the Version of the instance
jdoDetachedState[2]: a BitSet of loaded fields
jdoDetachedState[3]: a BitSet of modified fields
package javax.jdo.spi;
public interface Detachable {
    void jdoReplaceDetachedState();
}
```

This method calls the `StateManager` with the current detached state instance as a parameter and replaces the current detached state instance with the value provided by the `StateManager`.

8 JDOHelper

JDOHelper is a class with static methods that is intended for use by persistence-aware classes. It contains methods that allow interrogation of the persistent state of an instance of a persistence-capable class.

Each method delegates to the instance, if it implements PersistenceCapable. Otherwise, it delegates to any JDO implementations registered with JDOImplHelper via the StateInterrogation interface.

If no registered implementation recognizes the instance, then

- if the method returns a value of reference type, it returns null;
- if the method returns a value of boolean type, it returns false;

if the method returns void, there is no effect. If no registered implementation recognizes the instance, then

- if the method returns a value of reference type, it returns null;
- if the method returns a value of boolean type, it returns false;

if the method returns void, there is no effect. If no registered implementation recognizes the instance, then

- if the method returns a value of reference type, it returns null;
- if the method returns a value of boolean type, it returns false;
- if the method returns void, there is no effect.

```
package javax.jdo;
class JDOHelper {
    /* Some applications might prefer to use an instance
     * method instead of static methods.
    */
    public JDOHelper();
```

The instance returned by the constructor is thread safe. It can be used from any number of threads without concern for synchronization.

8.1 Persistence Manager

```
static PersistenceManager getPersistenceManager (Object pc);
```

This method returns the associated PersistenceManager. It returns null if the instance is transient or null or if its class is not persistence-capable.

See also PersistenceCapable.jdoGetPersistenceManager().

8.2 Make Dirty

```
static void makeDirty (Object pc, String fieldName);
```

This method marks the specified field dirty so that its values will be modified in the datastore when the instance is flushed. The `fieldName` is the name of the field to be marked as dirty, optionally including the fully qualified package name and class name of the field. This method has no effect if the instance is transient or `null`, or if its class is not persistence-capable; or `fieldName` is not a managed field. If the instance is not transient and the field is not managed, a `JDOUserException` is thrown by `makeDirty`.

See also `PersistenceCapable.jdoMakeDirty(String fieldName)`.

8.3 JDO Identity

```
static Object getObjectId (Object pc);
```

This method returns the JDO identity of the instance for persistent and detached instances. It returns `null` if the instance is transient or `null` or if its class is not persistence-capable. If the identity is being changed in a transaction, this method returns the identity as of the beginning of the transaction.

See also `PersistenceCapable.jdoGetObjectId()` and `PersistenceManager.getObjectId(Object pc)`.

```
static Object[] getObjectIds (Object[] pcs);
```

```
static Collection getObjectIds (Collection pcs);
```

These methods return the JDO identities of the parameter instances. For each instance in the parameter, the `getObjectId` method is called. They return one identity instance for each persistence-capable instance in the parameter. The order of iteration of the returned `Collection` exactly matches the order of iteration of the parameter `Collection`.

```
static Object getTransactionalObjectId (Object pc);
```

This method returns the JDO identity of the instance. It returns `null` if the instance is transient or `null` or does not implement `PersistenceCapable`. If the identity is being changed in a transaction, this method returns the current identity in the transaction.

See also `PersistenceCapable.jdoGetTransactionalObjectId()` and `PersistenceManager.getTransactionalObjectId(Object pc)`.

8.4 JDO Version

```
static Object getVersion (Object pc);
```

This method returns the JDO version of the instance for persistent and detached instances. It returns `null` if the instance is transient or `null` or if its class is not persistence-capable.

8.5 Status interrogation

The status interrogation methods return a boolean that represents the state of the instance:

8.5.1 Dirty

```
static boolean isDirty (Object pc);
```

Instances whose state has been changed in the current transaction return `true`. If the object parameter is not `null` and implements `PersistenceCapable`, `JDOHelper.isDirty` delegates to

the parameter instance and instances whose state has not been changed in the current transaction return `false`. It returns `false` if the instance is transient or `null` or if its class is not persistence-capable.

See also `PersistenceCapable.jdoIsDirty()`;

8.5.2 Transactional

```
static boolean isTransactional (Object pc);
```

Instances whose state is associated with the current transaction return `true`. If the object parameter is not null, not transient, and implements `PersistenceCapable`, `isTransactional` delegates to the parameter instance and instances whose state is not associated with the current transaction return `false`. It returns `false` if the instance is transient or `null` or if its class is not persistence-capable.

See also `PersistenceCapable.jdoIsTransactional()`.

8.5.3 Persistent

```
static boolean isPersistent (Object pc);
```

Instances that represent persistent objects in the datastore return `true`. If the object parameter is not null, not transient, and implements `PersistenceCapable`, `isPersistent` delegates to the parameter instance and instances that do not represent persistent objects in the data store return `false`. It returns `false` if the instance is transient or `null` or if its class is not persistence-capable.

See also `PersistenceCapable.jdoIsPersistent()`;

8.5.4 New

```
static boolean isNew (Object pc);
```

Instances that have been made persistent in the current transaction return `true`. If the object parameter is not null, not transient, and implements `PersistenceCapable`, `isNew` delegates to the parameter instance and instances that have not been made persistent in the current transaction return `false`. It returns `false` if the instance is transient or `null` or if its class is not persistence-capable.

See also `PersistenceCapable.jdoIsNew()`;

8.5.5 Deleted

```
static boolean isDeleted (Object pc);
```

Instances that have been deleted in the current transaction return `true`. If the object parameter is not null, not transient, and implements `PersistenceCapable`, `isDeleted` delegates to the parameter instance and instances that have not been deleted in the current transaction return `false`. It returns `false` if the instance is transient or `null` or if its class is not persistence-capable.

See also `PersistenceCapable.jdoIsDeleted()`;

8.5.6 Detached

```
static boolean isDetached (Object pc);
```

Instances that have been detached return `true`. The method returns `false` if the instance is transient or `null` or if its class is not detachable.

See also `PersistenceCapable.jdoIsDetached()`;

8.6 State Interrogation

```
public static ObjectState getObjectState(Object pc);
```

This method returns an enum representing the life cycle state of the parameter instance. The enum has an overloaded `toString` method that returns the life cycle state as discussed in section 5.5. If the parameter instance is null, the returned `ObjectState` is null.

8.6.1 enum ObjectState

```
public enum ObjectState {  
    TRANSIENT("transient"),  
    TRANSIENT_CLEAN("transient-clean"),  
    TRANSIENT_DIRTY("transient-dirty"),  
    PERSISTENT_NEW("persistent-new"),  
    HOLLOW_PERSISTENT_NONTRANSACTIONAL("hollow/persistent-nontransactional"),  
    PERSISTENT_NONTRANSACTIONAL_DIRTY("persistent-nontransactional-dirty"),  
    PERSISTENT_CLEAN("persistent-clean"),  
    PERSISTENT_DIRTY("persistent-dirty"),  
    PERSISTENT_DELETED("persistent-deleted"),  
    PERSISTENT_NEW_DELETED("persistent-new-deleted"),  
    DETACHED_CLEAN("detached-clean"),  
    DETACHED_DIRTY("detached-dirty");  
}
```

8.7 PersistenceManagerFactory methods

The methods in this section provide for bootstrapping the `PersistenceManagerFactory` by configuration according to the properties documented in Section 11.1. Users have a choice of configuration techniques:

- The application provides a Map of properties used to construct a `PersistenceManagerFactory`
- The application provides a name (the name of a resource in standard Java Properties format, the name of a named `PersistenceManagerFactory` from `jdoconfig.xml`, or the name of a JPA persistence unit), used to construct a `PersistenceManagerFactory`
- The application provides a Map of override properties and a name, used to construct a `PersistenceManagerFactory`
- The application provides an `InputStream` in standard Java Properties format whose contents define the properties for the `PersistenceManagerFactory`
- The application provides a `File` whose contents are in standard Java Properties format which define the properties for the `PersistenceManagerFactory`
- The application provides a JNDI name and context in which the name is defined
- The application provides a resource named `META-INF/jdoconfig.xml` and optionally `META-INF/services/javax.jdo.PersistenceManagerFactory` which contain configuration information
- The application provides a resource named `META-INF/persistence.xml` and optionally `META-INF/services/javax.persistence.EntityManagerFactory` which contain configuration information

Get by Name with Overrides

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (Map overrides, String name, ClassLoader loader);
```

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (Map overrides, String name);
```

These methods resolve the name parameter, taking the name as a resource name, the name of a PersistenceManagerFactory from jdoconfig.xml, or a Persistence Unit name from persistence.xml and delegate to the static factory method `getPersistenceManagerFactory (Map overrides, Map props)`. The name is trimmed of leading and trailing white space before being used.

Get by Properties file or input stream

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (File propsFile);  
  
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (File propsFile, ClassLoader loader);  
  
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (InputStream stream);  
  
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (InputStream stream, ClassLoader loader);
```

These methods use the parameter(s) passed as arguments to construct a `Properties` instance, and then delegate to the `JDOHelper` method `getPersistenceManagerFactory` that takes a `Map` parameter.

Get by Name

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (String name);  
  
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (String name, ClassLoader loader);  
  
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
        (String name, ClassLoader propsLoader,  
            ClassLoader pmfLoader);
```

These methods use either the `propsLoader` (if specified), the `loader`, or the current thread's context class loader to attempt to resolve the name to a `Properties` instance, and delegate to the static factory method `getPersistenceManagerFactory (Map props)`. The name is trimmed of leading and trailing white space before being used.

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory();
```

This method delegates to the method taking a `String` with the parameter set to the empty `String`. The default `PersistenceManagerFactory` from `jdoconfig.xml` is obtained.

Get by Properties map

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
(Map props); This method delegates to the corresponding method with a class loader parameter,  
using the calling thread's current ContextClassLoader as the class loader.  
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
(Map props, ClassLoader loader);
```

The standard key values for the properties are found in Section 11.1.

The returned `PersistenceManagerFactory` is not configurable (the `setXXX` methods will throw an exception). JDO implementations might manage a map of instantiated `PersistenceManagerFactory` instances based on specified property key values, and return a previously instantiated `PersistenceManagerFactory` instance. In this case, the properties of the returned instance must exactly match the requested properties.

Get by JNDI lookup

```
public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
(String jndiLocation, Context context);  
@deprecated public static  
    PersistenceManagerFactory getPersistenceManagerFactory  
(String jndiLocation, Context context, ClassLoader loader);
```

These methods look up the `PersistenceManagerFactory` using the naming context and name supplied. The implementation's factory method is not called. The behavior of this method depends on the implementation of the context and its interaction with the saved `PersistenceManagerFactory` object. As with the other factory methods, the returned `PersistenceManagerFactory` is not configurable.

9 JDOImplHelper

This class is a public helper class for use by JDO implementations. It contains a registry of metadata by class. Use of the methods in this class avoids the use of reflection at runtime. PersistenceCapable classes register metadata with this class during class initialization.

*NOTE: This interface is not intended to be used by application programmers.
It is for use only by implementations.*

```
package javax.jdo.spi;  
public class JDOImplHelper {
```

9.1 JDOImplHelper access

```
public static JDOImplHelper getInstance()  
    throws SecurityException;
```

This method returns an instance of the `JDOImplHelper` class if the caller is authorized for `JDOPermission("getMetadata")`, and throws `SecurityException` if not authorized. This instance gives access to all of the other methods, except for `registerClass`, which is static and does not need any authorization.

9.2 Metadata access

```
public String[] getFieldNames (Class pcClass);
```

This method returns the names of persistent and transactional fields of the parameter class. If the class does not implement `PersistenceCapable`, or if it has not been enhanced correctly to register its metadata, a `JDOFatalUserException` is thrown.

Otherwise, the names of fields that are either persistent or transactional are returned, in order. The order of names in the returned array are the same as the field numbering. Relative field 0 refers to the first field in the array. The length of the array is the number of persistent and transactional fields in the class.

```
public Class[] getFieldTypes (Class pcClass);
```

This method returns the types of persistent and transactional fields of the parameter class. If the parameter does not implement `PersistenceCapable`, or if it has not been enhanced correctly to register its metadata, a `JDOFatalUserException` is thrown.

Otherwise, the types of fields that are either persistent or transactional are returned, in order. The order of types in the returned array is the same as the field numbering. Relative field 0 refers to the first field in the array. The length of the array is the number of persistent and transactional fields in the class.

```
public byte[] getFieldFlags (Class pcClass);
```

This method returns the field flags of persistent and transactional fields of the parameter class. If the parameter does not implement PersistenceCapable, or if it has not been enhanced correctly to register its metadata, a JDOFatalUserException is thrown.

Otherwise, the types of fields that are either persistent or transactional are returned, in order. The order of types in the returned array is the same as the field numbering. Relative field 0 refers to the first field in the array. The length of the array is the number of persistent and transactional fields in the class.

```
public Class getPersistenceCapableSuperclass (Class pcClass);
```

This method returns the PersistenceCapable superclass of the parameter class, or null if there is none.

9.3 Persistence-capable instance factory

```
public PersistenceCapable newInstance (Class pcClass,  
    StateManager sm);  
public PersistenceCapable newInstance (Class pcClass, StateManager  
    sm, Object oid);
```

If the class does not implement PersistenceCapable, or if it has not been enhanced correctly to register its metadata, a JDOFatalUserException is thrown. If the class is abstract, a JD OFatalInternalException is thrown.

Otherwise, a new instance of the class is constructed and initialized with the parameter StateManager. The new instance has its jdoFlags set to LOAD_REQUIRED but has no defined state. The behavior of the instance is determined by the owning StateManager.

The second form of the method returns a new instance of PersistenceCapable that has had its key fields initialized by the ObjectId parameter instance. If the class has been enhanced for datastore identity, then the oid parameter is ignored.

See also PersistenceCapable.jdoNewInstance(StateManager sm) and PersistenceCapable.jdoNewInstance (StateManager sm, Object oid).

9.4 Registration of PersistenceCapable classes

```
public static void registerClass  
(Class pcClass, String[] fieldNames,  
    Class[] fieldTypes,  
    byte[] fieldFlags,  
    Class persistenceCapableSuperclass,  
    PersistenceCapable pcInstance);
```

This method registers a PersistenceCapable class so that the other methods can return the correct information. The registration must be done in a static initializer for the persistence-capable class.

```
public static Collection getRegisteredClasses();
```

This method returns a collection of classes that have been registered.

9.4.1 Notification of PersistenceCapable class registrations

```
addRegisterClassListener(RegisterClassListener rcl);
```

This method registers a RegisterClassListener to be notified upon new PersistenceCapable Class registrations. A RegisterClassEvent instance is generated for each class registered already plus classes registered in future, which is sent to each registered listener. The same event instance might be sent to multiple listeners.

```
removeRegisterClassListener(RegisterClassListener rcl);
```

This method removes a RegisterClassEvent from the list to be notified upon new PersistenceCapable Class registrations.

RegisterClassEvent

```
public class RegisterClassEvent extends java.util.EventObject {  
    An instance of this class is generated for each class that registers itself, and is sent to each registered listener.  
  
    public Class getRegisteredClass();  
    Returns the newly registered Class.  
  
    public String[] getFieldNames();  
    Returns the field names of the newly registered Class.  
  
    public Class[] getFieldTypes();  
    Returns the field types of the newly registered Class.  
  
    public byte[] getFieldFlags();  
    Returns the field flags of the newly registered Class.  
  
    public Class getPersistenceCapableSuperclass();  
    Returns the PersistenceCapable superclass of the newly registered Class.  
}
```

RegisterClassListener

```
public interface RegisterClassListener extends  
    java.util.EventListener {
```

This interface must be implemented by classes that register as listeners to be notified of registrations of PersistenceCapable classes.

```
    void registerClass (RegisterClassEvent rce);
```

This method is called for each PersistenceCapable class that registers itself.

```
}
```

// interface RegisterClassListener

9.5 Security administration

```
public static void registerAuthorizedStateManagerClass  
(Class smClass) throws SecurityException;
```

This method manages the list of classes authorized to execute replaceStateManager. During execution of this method, the security manager, if present, is called to validate that the caller is authorized for JDOPermission("setStateManager"). If successful, the parameter class is added to the list of authorized StateManager classes.

This method provides for a fast security check during makePersistent. An implementation of StateManager should register itself with the JDOImplHelper to take advantage of this fast check.

```
public static void registerAuthorizedStateManagerClasses  
(Collection smClasses) throws SecurityException;
```

This method manages the list of classes authorized to execute replaceStateManager. During execution of this method, the security manager, if present, is called to validate that the caller is authorized for JDOPermission("setStateManager"). If successful, all parameter classes are added to the list of authorized StateManager classes.

```
public static void checkAuthorizedStateManagerClass (Class  
smClass) throws SecurityException;
```

This method is used internally but might be used by an implementation. If the parameter instance is a class in the list of authorized StateManager classes, then this method returns silently. If not, then the security manager, if present, is called to validate that the caller is authorized for JDOPermission("setStateManager"). If successful, the method returns silently. If not, a SecurityException is thrown.

```
public static void checkAuthorizedStateManager (StateManager sm)  
throws SecurityException;
```

This method is called by enhanced persistence-capable class method replaceStateManager. If the parameter instance is of a class in the list of authorized StateManager classes, then this method returns silently. If not, then the security manager, if present, is called to validate that the caller is authorized for JDOPermission("setStateManager"). If successful, the method returns silently. If not, a SecurityException is thrown.

9.6 Application identity handling

```
public Object newObjectIdInstance(Class pcClass);
```

This method creates a new instance of the ObjectId class for the PersistenceCapable class. If the class uses datastore identity, then null is returned. If the class is abstract, a JDOFatalInternalException is thrown.

```
public Object newObjectIdInstance(Class pcClass, Object key);
```

This method creates a new instance of the ObjectId class for the PersistenceCapable class, using the appropriate constructor of the object id class. If the class uses datastore identity, then null is returned. If the class is abstract, a JDOFatalInternalException is thrown.

```
public Object newObjectIdInstance(PersistenceCapable pc);
```

This method returns an instance of the ObjectId class for the parameter PersistenceCapable instance. If the class of the instance uses an immutable ObjectId class, then the oid instance associated with the persistent instance might be returned. If the class of the instance uses datastore identity, then null is returned.

```
public void copyKeyFieldsToObjectId (Class pcClass,  
PersistenceCapable.ObjectIdFieldSupplier fs, Object oid);
```

This method copies key fields from the field manager to the ObjectId instance oid. This is intended for use by the implementation to copy fields from a datastore-specific representation to the ObjectId. If the class is abstract, a JDOFatalInternalException is thrown.

```
public void copyKeyFieldsFromObjectId (Class pcClass, Persistence-  
Capable.ObjectIdFieldConsumer fc, Object oid);
```

This method copies key fields to the field manager from the ObjectId instance oid. This is intended for use by the implementation to copy fields to a datastore-specific representation from the ObjectId. If the class is abstract, a JDOFatalInternalException is thrown.

This method allows the implementation to register a DateFormat for use when constructing SingleFieldIdentity instances of type ObjectIdentity that use java.util.Date as the key field. The default in case the implementation does not register a DateFormat is DateFormat.getDateInstance(). If this cannot be obtained, the default is DateFormat.getInstance(). For example,

```
SimpleDateFormat usDateFormat = new SimpleDateFormat
    ("MMM dd, yyyy hh:mm:ss a", Locale.US);
helper.registerDateFormat(usDateFormat);
Object oid = new ObjectIdentity(Object.class,
    "java.util.Date:Jan 01, 1970 00:00:00 AM");
```

9.7 Persistence-capable class state interrogation

For JDO implementations that do not support BinaryCompatibility, an instance of StateInterrogation must be registered with JDOImplHelper to handle JDOHelper methods for instances that do not implement PersistenceCapable.

The StateInterrogation interface is implemented by a JDO implementation class to take responsibility for determining the life cycle state and object identity, and for marking fields dirty.

```
package javax.jdo.spi;
public interface StateInterrogation {
    Boolean isPersistent(Object pc);
    Boolean isTransactional(Object pc);
    Boolean isDirty(Object pc);
    Boolean isNew(Object pc);
    Boolean isDeleted(Object pc);
    Boolean isDetached(Object pc);
    PersistenceManager getPersistenceManager(Object pc);
    Object getObjectId(Object pc);
    Object getTransactionalObjectId(Object pc);
    boolean makeDirty(Object pc, String fieldName);
    Object getVersion(Object pc);
}
```

For methods returning Boolean, PersistenceManager, and Object, if the StateInterrogation instance does not recognize the parameter instance, null is returned, and the next registered StateInterrogation instance is called.

For makeDirty, if the StateInterrogation instance does not recognize the parameter instance, false is returned, and the next registered StateInterrogation instance is called.

```
public void addStateInterrogation(StateInterrogation si);
```

This method of JDOImplHelper registers an instance of StateInterrogation for delegation of life cycle state queries made on JDOHelper.

```
public void removeStateInterrogation(StateInterrogation si);
```

This method of JDOImplHelper removes an instance of StateInterrogation, so it is no longer called by JDOHelper for life cycle state queries.

10 InstanceCallbacks

Instance callbacks provide a mechanism for instances to take some action on specific JDO instance life cycle events. For example, classes that include non-persistent fields might use callbacks to correctly populate the values in these fields. Classes that affect the runtime environment might use callbacks to register and deregister themselves with other objects. This interface defines the methods executed by the `StateManager` for these life cycle events.

These methods will be called only on instances for which the class implements the corresponding callback interface. For backward compatibility, `InstanceCallbacks` is redefined as follows:

```
package javax.jdo;
public interface InstanceCallbacks extends
    javax.jdo.listener.LoadCallback,
    javax.jdo.listener.StoreCallback,
    javax.jdo.listener.ClearCallback,
    javax.jdo.listener.DeleteCallback {
}
```

10.1 jdoPostLoad

```
package javax.jdo.listener;
public interface LoadCallback {
    void jdoPostLoad();
}
```

This method is called after values have been loaded from the `StateManager` into the instance, if an active fetch group has been defined with the post-load attribute set to true. Non-persistent fields whose value depends on values of loaded fields should be initialized in this method. This method is not modified by the enhancer. Only fields that are loaded by an active fetch group should be accessed by this method, as other fields are not guaranteed to be initialized. This method might register the instance with other objects in the runtime environment.

The context in which this call is made does not allow access to other persistent JDO instances.

10.2 jdoPreStore

```
package javax.jdo.listener;
public interface StoreCallback {
    void jdoPreStore();
}
```

This method is called before the values are stored from the instance to the datastore. This happens during `beforeCompletion` and `flush` for persistent-new and persistent-dirty instances of persistence-capable classes that implement `StoreCallback`. Datastore fields that might have been affected by modified non-persistent fields should be updated in this method. This method is modified by the enhancer so that changes to persistent fields will be reflected in the datastore.

The context in which this call is made allows access to the PersistenceManager and other persistent JDO instances.

This method is not called for deleted instances.

10.3 jdoPreClear

```
package javax.jdo.listener;
public interface ClearCallback {
    void jdoPreClear();
}
```

This method is called before the implementation clears the values in the instance to their Java default values. This happens during an application call to evict, and in afterCompletion for commit with RetainValues false and rollback with RestoreValues false. The method is called during any state transition to hollow. Non-persistent, non-transactional fields should be cleared in this method. Associations between this instance and others in the runtime environment should be cleared. This method is not modified by the enhancer, so access to fields is not mediated.

10.4 jdoPreDelete

```
package javax.jdo.listener;
public interface DeleteCallback {
    void jdoPreDelete();
}
```

This method is called during the execution of deletePersistent before the state transition to persistent-deleted or persistent-new-deleted. Access to field values within this call are valid. Access to field values after this call are disallowed. This method is modified by the enhancer so that fields referenced can be used in the business logic of the method.

To implement a containment aggregate, the user could implement this method to delete contained persistent instances.

10.5 jdoPreDetach and jdoPostDetach

```
package javax.jdo.listener;
public interface DetachCallback {
    void jdoPreDetach();
}
```

This method is called during the execution of detachCopy on the persistent instance before the copy is made.

```
public void jdoPostDetach(Object detached);
```

This method is called during the execution of detachCopy on the detached instance after the copy is made. The parameter is the corresponding persistent instance.

```
}
```

10.6 jdoPreAttach and jdoPostAttach

```
package javax.jdo.listener;
```

```
public interface AttachCallback {
```

```
    void jdoPreAttach();
```

This method is called during the execution of `makePersistent` on the detached instance before the copy is made.

```
    public void jdoPostAttach(Object attached);
```

This method is called during the execution of `makePersistent` on the persistent instance after the copy is made. The parameter is the corresponding detached instance.

```
}
```

11 PersistenceManagerFactory

This chapter details the `PersistenceManagerFactory`, which is responsible for creating `PersistenceManager` instances for application use.

```
package javax.jdo;
public interface PersistenceManagerFactory {
```

11.1 Interface PersistenceManagerFactory

A JDO vendor must provide a class that implements `PersistenceManagerFactory` and is permitted to provide a `PersistenceManager` constructor[s].

A non-managed JDO application might choose to use a `PersistenceManager` constructor (JDO vendor specific) or use a `PersistenceManagerFactory` (provided by the JDO vendor). A portable JDO application must use the `PersistenceManagerFactory`.

In a managed environment, the JDO `PersistenceManager` instance is typically acquired by a two step process: the application uses JNDI lookup to retrieve an environment-named object, which is then cast to `javax.jdo.PersistenceManagerFactory`; and then calls one of the factory's `getPersistenceManager` methods. Alternatively, one of the `JDOHelper` methods can be used to acquire a `PersistenceManagerFactory`.

In a non-managed environment, the JDO `PersistenceManager` instance is acquired by lookup as above; by constructing a `PersistenceManager`; or by constructing a `PersistenceManagerFactory`, configuring the factory, and then calling the factory's `getPersistenceManager` method. These constructors are not part of the JDO standard. However, the following is recommended to support portable applications.

The `PersistenceManagerFactory` implementation class must implement a no-args constructor. This allows the standard Java 6 service discovery implementation to create a factory instance upon which the `getPersistenceManager` methods can be invoked.

Configuring the `PersistenceManagerFactory` follows the Java Beans pattern. Supported properties have a `get` method and a `set` method.

The following properties, if set in the `PersistenceManagerFactory`, are the default settings of all `PersistenceManager` instances created by the factory:

- `Optimistic`: the transaction mode that specifies `concurrencyControlRetainValues`: the transaction mode that specifies the treatment of persistent instances after `commitRestoreValues`: the transaction mode that specifies the treatment of persistent instances after rollback
- `IgnoreCache`: the query mode that specifies whether cached instances are considered when evaluating the filter `expressionNontransactionalRead`: the `PersistenceManager` mode that allows instances to be read outside a `transactionNontransactionalWrite`: the `PersistenceManager` mode that allows instances to be written outside a `transactionMultithreaded`: the `PersistenceManager` mode that indicates that the application will invoke methods or access fields of managed instances from multiple threads.

`TransactionIsolationLevel`: the `Transaction` mode that indicates that the implementation should use a specific isolation level when using connections.`DetachAllOnCommit`: the `PersistenceManager` mode that indicates that instances will be detached when the transaction commits.

- `CopyOnAttach`: the `PersistenceManager` mode that indicates that detached instances will be copied and not transitioned during `makePersistent`. The default is true due to backward compatibility.

The following properties can only be set in the `PersistenceManagerFactory`:

`Mapping`: the name of the mapping model for object-to-datastore mapping
`Catalog`: the name of the catalog for object-to-relational mapping
`Schema`: the name of the schema for object-to-relational mapping

`PersistenceUnitName`: the name of the Persistence Unit corresponding to the `PersistenceManagerFactory`

`TransactionType`: the type of transaction management used by this `PersistenceManagerFactory`; allowable values are `JTA` and `RESOURCE_LOCAL`, corresponding to the definitions of these terms in the JSR-220 specification.

`ServerTimeZoneID`: the time zone ID of the server to which this `PersistenceManagerFactory` is connected, for use with the `PersistenceManager` method `getServerDate`

- `ReadOnly`: the datastore is not able to be written by the jdo implementation, and if an attempt is made to write (via `commit` or `flush`) then `JDOReadOnlyException` is thrown. Implementations may eagerly throw an exception if an instance is modified or deleted, or an instance is made persistent.

ServerTimeZoneID

If `ServerTimeZoneID` is specified, the value must correspond to a valid time zone ID as returned by `TimeZone.getAvailableIDs()`. The implementation uses the `ServerTimeZoneID` to implement the `getServerDate` method. If `ServerTimeZoneID` is not specified, the implementation might use proprietary methods to determine the time zone in which the server is located. If `ServerTimeZoneID` is not specified, and the implementation cannot or does not use proprietary methods to determine the server time zone, then the default time zone ID of the Java VM is used.

Transaction Isolation Level

If the transaction isolation level is specified, the implementation will set the actual isolation level to be no less than requested, or `JDOUnsupportedOptionException` is thrown during freezing of the configuration (after the first use of `getPersistenceManager()` or during construction via properties, `jdoconfig.xml`, or `persistence.xml`).

Connection

The following properties are for convenience, if there is no connection pooling or other need for a connection factory:

- `ConnectionUserName`: the name of the user establishing the connection
- `ConnectionPassword`: the password for the user
- `ConnectionURL`: the URL for the data source
- `ConnectionDriverName`: the class name of the driver

For a portable application, if any other connection properties are required, then a connection factory must be configured.

The following properties are for use when a connection factory is used, and override the connection properties specified in `ConnectionURL`, `ConnectionUserName`, or `ConnectionPassword`.

- `ConnectionFactory`: the connection factory from which datastore connections are obtained
- `ConnectionFactoryName`: the name of the connection factory from which datastore connections are obtained. This name is looked up with JNDI to locate the connection factory.

If multiple connection properties are set, then they are evaluated in order:

- if `ConnectionFactory` is specified (not null), all other properties are ignored;
- else if `ConnectionFactoryName` is specified (not null), all other properties are ignored.

For the application server environment, connection factories always return connections that are enlisted in the thread's current transaction context. To use optimistic transactions in this environment requires a connection factory that returns connections that are not enlisted in the current transaction context. For this purpose, the following two properties are used:

- `ConnectionFactory2`: the connection factory from which nontransactional datastore connections are obtained
- `ConnectionFactory2Name`: the name of the connection factory from which nontransactional datastore connections are obtained. This name is looked up with JNDI to locate the connection factory.

Datastore Timeout

Some datastore operations can exceed the expected or desired time to execute, due to conditions that might not be influenced by the application directly. In order to allow the application to gracefully recover from these conditions, the application can specify timeouts to be applied separately to read and write datastore operations.

- `DatastoreReadTimeoutMillis`: the number of milliseconds allowed for read operations to complete. Read operations include retrieving instances from the datastore, loading fields, and executing queries that do not change the datastore.
- `DatastoreWriteTimeoutMillis`: the number of milliseconds allowed for write operations to complete. Write operations include flushing changes and deleting instances by query.

Timeouts can be specified at three locations: the `PersistenceManagerFactory`, the `PersistenceManager`, and the `Query`. Timeouts specified at the `PersistenceManagerFactory` are the defaults for timeouts of the `PersistenceManager`. Timeouts specified at the `PersistenceManager` are the defaults for `Query`. Timeouts specified at the `Query` apply only to that specific query.

If a timeout is specified, the implementation will use the supplied value as a timeout for operations where the underlying datastore supports it. The timeouts are in milliseconds. If it is not specified then there is no timeout.

11.1.1 Construction by Properties

An implementation must provide two methods to construct a `PersistenceManagerFactory` by a `Map` instance. One static method is called by the `JDOHelper` method `getPersistenceManagerFactory (Map props)`. The other static method is called by `JDOHelper` method `getPersistenceManagerFactory (Map overrides, String name)`.

```
static PersistenceManagerFactory getPersistenceManagerFactory (Map  
props);  
  
static PersistenceManagerFactory getPersistenceManagerFactory (Map  
overrides, Map props);
```

The `overrides` entries consist of JDO vendor-specific properties and standard property names. The `props` entries consist of: `"javax.jdo.PersistenceManagerFactoryClass"`, whose value is the name of the implementation class; any JDO vendor-specific properties; and the following standard property names, which correspond to the properties as documented in this chapter.

- `"javax.jdo.option.Optimistic"`
- `"javax.jdo.option.RetainValues"`
- `"javax.jdo.option.RestoreValues"`
- `"javax.jdo.option.IgnoreCache"`
- `"javax.jdo.option.NontransactionalRead"`
- `"javax.jdo.option.NontransactionalWrite"`
- `"javax.jdo.option.Multithreaded"`
- `"javax.jdo.option.DetachAllOnCommit"`
- `"javax.jdo.option.CopyOnAttach"`
- `"javax.jdo.option.ConnectionUserName"`
- `"javax.jdo.option.ConnectionPassword"`
- `"javax.jdo.option.ConnectionURL"`
- `"javax.jdo.option.ConnectionDriverName"`
- `"javax.jdo.option.ConnectionFactoryName"`
- `"javax.jdo.option.ConnectionFactory2Name"`
- `"javax.jdo.option.Mapping"`
- `"javax.jdo.mapping.Catalog"`
- `"javax.jdo.mapping.Schema"`
- `"javax.jdo.option.TransactionType"`
- `"javax.jdo.option.ServerTimeZoneID"`
- `"javax.jdo.option.ReadOnly"`
- `"javax.jdo.option.DatastoreReadTimeoutMillis"`
- `"javax.jdo.option.DatastoreWriteTimeoutMillis"`

The following two properties are only used in the `props`, not in the `overrides`.

- `"javax.jdo.option.Name"`
- `"javax.jdo.option.PersistenceUnitName"`

The property `"javax.jdo.PersistenceManagerFactoryClass"` is the fully qualified class name of the `PersistenceManagerFactory.Properties` whose key begins with the prefix `"javax.jdo.listener.InstanceLifecycleListener."` have special treatment. The part of the key following the prefix is used as the class name of a class that implements `javax.jdo.listener.InstanceLifecycleListener`. The implementation first attempts to get an instance via the static method `getInstance()` that returns an instance that implements the `javax.jdo.listener.InstanceLifecycleListener`. If this is unsuccessful, an in-

stance of this class is constructed via a no-args constructor. The value of the key is a comma-separated list of classes to which the instantiated listener is registered to listen.

Similarly, properties whose key begins with the prefix "javax.jdo.datastore.DataStoreCache." have special treatment. The part of the key following the prefix is used as the class name of a class that implements javax.jdo.datastore.DataStoreCache. The implementation first attempts to get an instance via the static method `getInstance()` that returns an instance that implements the javax.jdo.datastore.DataStoreCache. If this is unsuccessful, an instance of this class is constructed via a no-args constructor. The implementation registers it as the cache for the PersistenceManagerFactory.

The String type properties are taken without change from the value of the corresponding keys. Boolean type properties treat the String value as representing true if the value of the String compares equal, ignoring case, to "true", and false if the value of the String is anything else.

Any property not recognized by the implementation must be silently ignored. Any standard property corresponding to an optional feature not supported by the implementation must throw `JDOUnsupportedOptionException`.

The Mapping property specifies the object-data store mapping to be used by the implementation. The property is used to construct the names of resource files containing metadata. For more information on the use of this property, see Chapters 15 and 18.

Default values for properties not specified in the props parameter are provided by the implementation. A portable application must specify all values for properties needed by the application.

There are properties that are provided by the JDOHelper methods in the following cases.

- If the user uses the methods `getPersistenceManagerFactory(File file)` or `getPersistenceManagerFactory(File file, ClassLoader loader)` then the Map instance passed to the static method will contain a property with a key of "javax.jdo.spi.PropertiesFileName", and a value equal to the result of calling `getAbsolutePath()` on the file parameter. Absence of this property means that neither of these methods was used.
- If the user uses the methods `getPersistenceManagerFactory(String resourceName)` or `getPersistenceManagerFactory(String resourceName, ClassLoader loader)` and the properties instance was loaded from a resource, then the Properties instance passed to the static method will contain a property with a key of "javax.jdo.spi.PropertiesResourceName", and a value equal to the name of the resource. Absence of this property means that neither of these methods was used.
- If the user uses the method `getPersistenceManagerFactory(String resourceName)` and the properties instance was created from `jdoconfig.xml`, then the Properties instance passed to the static method will contain a property with a key of "javax.jdo.Name", and a value equal to the name of the persistence manager factory in the `jdoconfig.xml` file.

11.1.2 Construction by `jdoconfig.xml`

Users can access a PersistenceManagerFactory by creating a `jdoconfig.xml` file and making it available on the class path as `META-INF/jdoconfig.xml`. The format of the `jdoconfig.xml` file is described fully in Appendix D. Any number of `META-INF/jdoconfig.xml` files can be used. The element `persistence-manager-factory` configures the named PersistenceManagerFactory.

Each attribute and sub-element in the `persistence-manager-factory` corresponds to a property already discussed above.

If the user uses the JDOHelper methods `getPersistenceManagerFactory (String resourceName)` or `getPersistenceManagerFactory (String resourceName, ClassLoader loader)` then a `Properties` instance is created from the contents of the `jdoconfig.xml` element that contains `resourceName` as the value of the element or property called "javax.jdo.option.Name". This `Properties` instance is passed to the static `PersistenceManagerFactory` method `getPersistenceManagerFactory (Map props)`.

11.1.3 Access via persistence.xml

Users can access a `PersistenceManagerFactory` by referring to an existing `persistence.xml` file that contains the configuration information for a `PersistenceManagerFactory`. If a `PersistenceManagerFactory` definition includes the property `PersistenceUnitName`, then the `PersistenceManagerFactory` will use the named `PersistenceUnitName` for configuration properties. Properties specified by the `Properties` override the properties specified by the `PersistenceUnitName`.

11.1.4 jdoconfig.xml

The `jdoconfig.xml` file can be described by the non-normative DTD:

```
<!DOCTYPE jdoconfig
  PUBLIC "-//Sun Microsystems, Inc.//DTD Java Data Objects Configuration 2.3//EN"
  "http://java.sun.com/dtd/jdoconfig_2_3.dtd">
-->
<!ELEMENT jdoconfig (persistence-manager-factory+)>

<!ELEMENT persistence-manager-factory (property*, instance-lifecycle-listener*)>
<!ATTLIST persistence-manager-factory class CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory name CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory persistence-unit-name CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory optimistic (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory readonly (true|false) CDATA 'false'>
<!ATTLIST persistence-manager-factory retain-values (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory restore-values (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory ignore-cache (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory nontransactional-read (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory nontransactional-write (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory multithreaded (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory transaction-isolation-level CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory connection-driver-name CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory connection-user-name CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory connection-password CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory connection-url CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory connection-factory-name CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory connection-factory2-name CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory mapping CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory detach-all-on-commit (true|false) CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory server-time-zone-id CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory datastore-read-timeout-millis CDATA #IMPLIED>
<!ATTLIST persistence-manager-factory datastore-write-timeout-millis CDATA #IMPLIED>

<!ELEMENT property EMPTY>
<!ATTLIST property name CDATA #REQUIRED>
<!ATTLIST property value CDATA #IMPLIED>

<!ELEMENT instance-lifecycle-listener EMPTY>
<!ATTLIST instance-lifecycle-listener listener CDATA #REQUIRED>
<!ATTLIST instance-lifecycle-listener classes CDATA #IMPLIED>
```

11.2 ConnectionFactory

For implementations that layer on top of standard `Connector` implementations, the configuration will typically support all of the associated `ConnectionFactory` properties.

When used in a managed environment, the `ConnectionFactory` will be obtained from a `ManagedConnectionFactory`, which is then responsible for implementing the resource adapter interactions with the container.

The following properties of the `ConnectionFactory` should be used if the data source has a corresponding concept:

- `URL`: the URL for the data source
- `UserName`: the name of the user establishing the connection
- `Password`: the password for the user
- `DriverName`: the driver name for the connection
- `ServerName`: name of the server for the data source
- `PortNumber`: port number for establishing connection to the data source
- `MaxPool`: the maximum number of connections in the connection pool
- `MinPool`: the minimum number of connections in the connection pool
- `MsWait`: the number of milliseconds to wait for an available connection from the connection pool before throwing a `JDODataStoreException`
- `LogWriter`: the `PrintWriter` to which messages should be sent
- `LoginTimeout`: the number of seconds to wait for a new connection to be established to the data source

In addition to these properties, the `PersistenceManagerFactory` implementation class can support properties specific to the data source or to the `PersistenceManager`.

Aside from vendor-specific configuration APIs, there are these required methods for `PersistenceManagerFactory`:

11.3 PersistenceManager access

```
PersistenceManager getPersistenceManager();
PersistenceManager getPersistenceManager(String userid, String
password);
```

Returns a `PersistenceManager` instance with the configured properties. The instance might have come from a pool of instances. The default values for option settings are reset to the value specified in the `PersistenceManagerFactory` before returning the instance. This method will never return the same instance as was returned by a previous invocation of the method. Note that this implies that pooled implementations must use proxies and not return the identical pooled instance.

After the first use of `getPersistenceManager`, none of the `set` methods will succeed. The settings of operational parameters might be modified dynamically during runtime via a vendor-specific interface.

If the method with the `userid` and `password` is used to acquire the `PersistenceManager`, then all accesses to the connection factory during the life of the `PersistenceManager` will use the `userid` and `password` to get connections. If `PersistenceManager` instances are pooled, then

only PersistenceManager instances with the same userid and password will be used to satisfy the request.

11.3.1 Access via proxy

```
PersistenceManager getPersistenceManagerProxy();
```

Returns a PersistenceManager instance that is thread-safe, for use in web and application servers and outside servers. The instance returned can be used in a servlet init method to initialize a static variable in a web server application. Similarly, it can be used in a session bean to initialize a static variable in an application server application.

If this method is used with a PersistenceManagerFactory that is configured with Transaction-Type JTA, the proxy returned will dynamically delegate to a PersistenceManager. The close method on the proxy has no effect.

- If there is a PersistenceManager currently associated with the thread's transaction, the method in the proxy delegates to the corresponding method in the PersistenceManager currently associated with the thread's transaction.
- If there is no PersistenceManager currently associated with the thread's transaction, a PersistenceManager is created and associated with the thread's transaction.
- If there is no transaction currently associated with the calling thread, a new PersistenceManager is created with no transaction association, and no possibility of beginning a transaction (in this case, the begin method on the Transaction instance throws JDOUserException). Persistent instances returned as a result of queries can be used to navigate via nontransactional access, regardless of whether a transaction is subsequently associated with the thread. The PersistenceManager returned from methods `Query.getPersistenceManager`, `JDOHelper.getPersistenceManager`, and `PersistenceCapable.getPersistenceManager` return the actual PersistenceManager to which the proxy delegated the original method.

If this method is used with a PersistenceManagerFactory that is configured with Transaction-Type RESOURCE_LOCAL, the proxy returned will dynamically delegate to the PersistenceManager currently associated with an implementation-defined thread-local variable. The thread-local variable is inherited by any threads created by the thread that currently has a PersistenceManager associated with it. The close method on the proxy clears the thread local variable to null, and a subsequent invocation on the proxy will create a new PersistenceManager.

11.4 Close the PersistenceManagerFactory

During operation of JDO, resources might be acquired on behalf of a PersistenceManagerFactory, e.g. connection pools, persistence manager pools, compiled queries, cached metadata, etc. If a PersistenceManagerFactory is no longer needed, these resources should be returned to the system. The close method disables the PersistenceManagerFactory and allows cleanup of resources.

Premature close of a PersistenceManagerFactory has a significant impact on the operation of the system. Therefore, a security check is performed to check that the caller has the proper permission. The security check is for JDOPermission("closePersistenceManagerFactory"). If the security check fails, the close method throws SecurityException.

```
void close();
```

Close this PersistenceManagerFactory. Check for JDOPermission("closePersistenceManagerFactory") and if not authorized, throw SecurityException.

If the authorization check succeeds, check to see that all PersistenceManager instances obtained from this PersistenceManagerFactory have no active transactions. If any PersistenceManager instances have an active transaction, throw a JDOUserException, with one nested JDOUserException for each PersistenceManager with an active Transaction.

If there are no active transactions, then close all PersistenceManager instances obtained from this PersistenceManagerFactory and mark this PersistenceManagerFactory as closed. After close completes, disallow all methods except close, isClosed, and get methods except for getPersistenceManager. If any disallowed method is called after close, then JDOUserException is thrown.boolean isClosed();

Return true if this PersistenceManagerFactory is closed; and false otherwise.

11.5 Non-configurable Properties

The JDO vendor might store certain non-configurable properties and make those properties available to the application via a `Properties` instance. This method retrieves the `Properties` instance.

```
Properties getProperties();
```

The application is not prevented from modifying the instance.

Each key and value is a `String`. The keys defined for standard JDO implementations are:

- `VendorName`: The name of the JDO vendor.
- `VersionNumber`: The version number string.

Other properties are vendor-specific.

11.6 Optional Feature Support

```
Collection<String> supportedOptions();
```

The JDO implementation might optionally support certain features, and will report the features that are supported. The supported query languages are included in the returned `Collection`.

This method returns a `Collection` of `String`, each `String` instance representing an optional feature of the implementation or a supported query language. The following are the values of the `String` for each optional feature in the JDO specification:

```
javax.jdo.option.TransientTransactional
```

The JDO implementation supports the transient transactional life cycle states.

```
javax.jdo.option.NontransactionalRead
```

The JDO implementation supports reading and querying outside a transaction.

```
javax.jdo.option.NontransactionalWrite
```

The JDO implementation supports the persistent-nontransactional-dirty life cycle state.

```
javax.jdo.option.RetainValues
```

The JDO implementation supports retaining values of persistent instances after commit.

```
javax.jdo.option.Optimistic
```

The JDO implementation supports the optimistic transaction semantics.

```
javax.jdo.option.ApplicationIdentity
```

The JDO implementation supports application identity for persistent classes.

`javax.jdo.option.DatastoreIdentity`

The JDO implementation supports datastore identity for persistent classes.

`javax.jdo.option.NonDurableIdentity`

The JDO implementation supports nondurable identity for persistent classes

`javax.jdo.option.ArrayList`

The JDO implementation supports persistent field types of ArrayList.

`javax.jdo.option.LinkedList`

The JDO implementation supports persistent field types of LinkedList.

`javax.jdo.option.TreeMap`

The JDO implementation supports persistent field types of TreeMap.

`javax.jdo.option.TreeSet`

The JDO implementation supports persistent field types of TreeSet.

`javax.jdo.option.Vector`

The JDO implementation supports persistent field types of Vector.

`javax.jdo.option.List`

The JDO implementation supports persistent field types of List. This is now a requirement but the option is for compatibility with JDO 1.0 where this support was optional.

`javax.jdo.option.Array`

The JDO implementation supports persistent field types of array.

`javax.jdo.option.NullCollection`

The JDO implementation allows null collections to be stored. Most relational implementations do not distinguish between empty and null collections, and this option will not be set for those implementations.

`javax.jdo.option.ChangeApplicationIdentity`

The JDO implementation supports changing of the application identity of instances.

`javax.jdo.option.BinaryCompatibility`

The JDO implementation supports the binary compatibility contract.

`javax.jdo.option.GetDataStoreConnection`

The JDO implementation supports use of a direct datastore connection.

`javax.jdo.option.GetJDBCConnection`

The JDO implementation supports use of a direct datastore connection that implements the java.sql.Connection interface.

`javax.jdo.option.TransactionIsolationLevel.read-committed`

The datastore supports the read-committed isolation level.

`javax.jdo.option.TransactionIsolationLevel.read-uncommitted`

The datastore supports the read-uncommitted isolation level.

`javax.jdo.option.TransactionIsolationLevel.repeatable-read`

The datastore supports the repeatable-read isolation level.

`javax.jdo.option.TransactionIsolationLevel.serializable`

The datastore supports the serializable isolation level.

`javax.jdo.option.TransactionIsolationLevel.snapshot`

The datastore supports the snapshot isolation level.

`javax.jdo.query.SQL`

The JDO implementation supports SQL for queries executed via the `javax.jdo.Query` interface.

`javax.jdo.option.UnconstrainedQueryVariables`

The JDO implementation supports JDOQL queries that contain a variable without a contains clause to constrain the variable.

`javax.jdo.option.version.DateTime`

The JDO implementation supports use of a the date-time strategy for version checking.

`javax.jdo.option.version.StateImage`

The JDO implementation supports use of the state-image strategy for version checking.

`javax.jdo.option.PreDirtyEvent`

The JDO implementation supports event notifications of changes made to persistent instances before the instance is made dirty.

`javax.jdo.option.mapping.HeterogeneousObjectType`

The JDO implementation supports mapping a persistent field of type Object to multiple types. There is no standard way to map this support.

`javax.jdo.option.mapping.HeterogeneousInterfaceType`

The JDO implementation supports mapping a persistent field of a persistent interface type to multiple types. There is no standard way to map this support.

`javax.jdo.option.mapping.JoinedTablePerClass`

The JDO implementation supports mapping persistent class inheritance hierarchies to tables in which each class, including abstract classes, is mapped to a table; and each table mapped to a subclass defines a primary key that has a foreign key relationship to the primary key of the table mapped by the superclass.

`javax.jdo.option.mapping.JoinedTablePerConcreteClass`

The JDO implementation supports mapping persistent class inheritance hierarchies to tables in which each concrete class (excluding abstract classes) is mapped to a table; and each table mapped to a subclass defines a primary key that has a foreign key relationship to the primary key of the table mapped by the superclass.

`javax.jdo.option.mapping.NonJoinedTablePerConcreteClass`

The JDO implementation supports mapping persistent class inheritance hierarchies to tables in which each concrete class (excluding abstract classes) is mapped to a table; and there is not necessarily any foreign key relationship among the mapped tables.

`javax.jdo.option.mapping.RelationSubclassTable`

The JDO implementation supports mapping persistent fields containing relationships to classes in an inheritance relationship that use subclass-table as the field mapping strategy.

`javax.jdo.option.QueryCancel`

The JDO implementation supports canceling a running query. The underlying datastore must also support canceling a running query. The cancel support in the datastore must at least free the client thread executing the query. The server cancel behavior is not specified.

`javax.jdo.option.DatastoreTimeout`

The JDO implementation supports datastore timeouts. The underlying datastore must also support datastore timeouts. The server timeout behavior is not specified.

The standard JDO query must be returned as the `String`:

```
javax.jdo.query.JDOQL
```

Other query languages are represented by a `String` not defined in this specification.

11.7 Properties constructors

The following methods are used by `JDOHelper` to construct an instance of `PersistenceManagerFactory` based on user-specified property overrides and the name of a resource.

```
public static PersistenceManagerFactory  
    getPersistenceManagerFactory (Map props);
```

This static method must be defined on the class that implements `PersistenceManagerFactory`. It returns an instance of `PersistenceManagerFactory` based on the properties in the parameter.

The method is used by `JDOHelper` to construct an instance of `PersistenceManagerFactory` based on user-specified properties.

```
public static PersistenceManagerFactory  
    getPersistenceManagerFactory (Map overrides, Map props);
```

This static method is a method defined in the `PersistenceManagerFactory` interface, and must be defined on the class that implements `PersistenceManagerFactory`. It returns an instance of `PersistenceManagerFactory` based on the properties in the parameters. Properties in `overrides` must be kept separate from properties in `props` for the purpose of serialization.

JDO implementations are permitted to define key values of their own. Any key values not recognized by the implementation must be ignored. Key values that are recognized but not supported by an implementation must result in a `JDOFatalUserException` thrown by the method.

The returned `PersistenceManagerFactory` is not configurable (the `setXXX` methods will throw an exception). JDO implementations might manage a map of instantiated `PersistenceManagerFactory` instances based on specified property key values, and return a previously instantiated `PersistenceManagerFactory` instance. In this case, the properties of the returned instance must exactly match the requested properties.

11.8 Second-level cache management

Most JDO implementations allow instances to be cached in a second-level cache, and allow direct management of the cache by knowledgeable applications. The second-level cache is typically a single VM cache and is used for persistent instances associated with a single `PersistenceManagerFactory`. For the purpose of standardizing this behavior, the `DataStoreCache` interface is used.

To obtain a reference to the cache manager, the `getDataStoreCache()` method of `PersistenceManagerFactory` is used.

```
DataStoreCache getDataStoreCache();
```

If there is no second-level cache, the returned instance silently does nothing.

```
package javax.jdo.datastore;  
public interface DataStoreCache {
```

Evicting objects from the cache

```
void evict(Object oid);
void evictAll();
void evictAll(Object... oids);
void evictAll(Collection oids);
void evictAll(Class pcClass, boolean subclasses);
```

The evict methods are hints to the implementation that the instances referred to by the object ids are stale and should be evicted from the cache. Evicting an instance does not unpin it.

Pinning objects in the cache

```
void pin(Object oid);
void pinAll(Collection oids);
void pinAll(Object... oids);
void pinAll(Class pcClass, boolean subclasses);
```

The pin methods are hints to the implementation that the instances referred to by the object ids should be pinned in the cache (not subject to algorithm-based eviction, but subject to explicit eviction). There is no requirement that an instance be in the cache in order to pin or unpin it. The pinAll method with the Class parameter automatically pins all instances of that class, including those instances already in the cache and future instances of the class. When a class is pinned, pin and unpin methods on instances of the pinned class are ignored.

Unpinning objects in the cache

```
void unpin(Object oid);
void unpinAll(Collection oids);
void unpinAll(Object... oids);
void unpinAll(Class pcClass, boolean subclasses);
```

The unpin methods are hints to the implementation that the instances referred to by the object ids should be unpinned (subject to eviction based on algorithm). There is no requirement that an instance be in the cache in order to pin or unpin it. The unpinAll method with the Class parameter automatically unpins all instances of that class, including those instances already in the cache and future instances of the class. When a class is pinned, pin and unpin methods on instances of the pinned class are ignored.

```
}
```

11.9 Registering for life cycle events

```
void addInstanceLifecycleListener (InstanceLifecycleListener
listener, Class[] classes);
```

This PersistenceManagerFactory method adds the listener to the list of instance lifecycle event listeners set as the initial listeners for each PersistenceManager created by this PersistenceManagerFactory. The classes parameter identifies all of the classes of interest. If the classes parameter is specified as null, events for all persistent classes and interfaces are generated. If the listener is already registered for life cycle events, the classes are added to the set of classes being listened to. If the classes specified have persistence-capable subclasses, all such subclasses are registered implicitly.

The listener will be called for each event for which it implements the corresponding listener interface.

```
void removeInstanceLifecycleListener (InstanceLifecycleListener  
listener);
```

This PersistenceManagerFactory method removes the listener from the list of event listeners set as the initial listeners for each PersistenceManager created by this PersistenceManagerFactory.

The addInstanceLifecycleListener and removeInstanceLifecycleListener methods are considered to be configuration methods and can only be called when the PersistenceManagerFactory is configurable (before the first getPersistenceManager is called).

11.10 Metadata Access

Metadata can be specified via annotations, xml, or API. These methods provide access to metadata managed by the PersistenceManagerFactory.

```
ComponentMetadata getMetadata(String className);
```

Return the class or interface metadata object for the specified class or interface, if there is metadata defined for that class or interface. If the parameter is null, null is returned. If the parameter does not reference a class or interface whose metadata is available, null is returned.

```
void registerMetadata(JDOMetadata metadata);
```

Register metadata with this PersistenceManagerFactory. Metadata can be created using the newMetadata method.

```
JDOMetadata newMetadata();
```

Return a new JDO metadata object that can be subsequently modified and registered with this PersistenceManagerFactory.

11.11 Serialization

Serialization of a persistence manager factory allows an application to preserve a reference to the factory via calling `writeObject` on it and having its state preserved by writing it to a stream in an external form. Later, the state can be read from a stream and a functionally equivalent instance of the factory can be restored.

When serializing the state of a persistence manager factory, the properties used to create the factory must be serialized. Some of the properties might depend on the context of the Java VM, and so are not able to be serialized. These properties may include the registered life cycle listener instances, class loaders, and any other values that are not serializable.

If the persistence manager factory was created via the `getPersistenceManagerFactory(Map props)` method, then the serializable properties in `props` must be written to the stream and upon restoration, used to construct or locate the persistence manager factory in the new context.

If the persistence manager factory was created via the `javax.persistence.Persistence.createEntityManagerFactory(Map overrides, String name)` method, then the persistence manager factory must write the overrides and the name to the stream and use these parameters in the new context to read the `persistence.xml` in the new context, use the overrides, and reconstruct the persistence manager factory.

If the persistence manager factory was created via the `getPersistenceManagerFactory(Map overrides, Map props)` method, then the serializable properties in the `overrides` must be written to the stream and upon restoration, used to establish overrides for the

persistence manager factory in the new context. The treatment of the `props` parameter depends on the existence of certain entries:

- If the property `javax.jdo.spi.PropertiesFileName` is a key in the `props`, then the value of this key and the overrides must be written to the stream and used in the new context to recreate the persistence manager factory from the file name.
- If the property `javax.jdo.Name` is a key in the `props`, then the value of this key and the overrides must be written to the stream and used in the new context to recreate the persistence manager factory from `jdoconfig.xml`.

11.12 OSGi Service Discovery

The objective of OSGi when used with JDO is to provide fewer development-time dependencies on specific JDO vendors. Without runtime discovery, the implementation class name is required to be put into persistence manager factory properties.

Typical usage is an application deployed in production which uses a JDO implementation A that is not performing well. To fix the issue the user decides to replace the implementation with a different vendor. Without runtime discovery, the procedure consists of replacing the JDO vendor jar in the classpath and updating the persistence manager factory properties to refer to the new vendor persistence manager factory class.

With runtime service discovery, this procedure would be simplified to replacing only the JDO vendor jar. The new vendor would be found dynamically.

From the user perspective

There is a small change needed to deployment to use service discovery. As before, the application uses `JDOHelper.getPersistenceManagerFactory` using properties or configuration name. However there is no need to set the property `javax.jdo.PersistenceManagerFactoryClass` if there is only one JDO vendor jar in the classpath.

From the implementation perspective

In the JDO implementation jar file, add the file `META-INF/services/javax.jdo.PersistenceManagerFactory`, which contains a single line with the fully qualified class name of the `PersistenceManagerFactory` implementation.

The `JDOHelper.getPersistenceManagerFactory(String)` will do the service discovery, by using the standard jar spec.

This service discovery is most likely to be used in Java SE environments.

Examples

An OSGi application is usually split into several jars, something like:

```
mycomponent1.jar (OSGi bundle)
mycomponent2.jar (OSGi bundle)
mycomponent3.jar (OSGi bundle)
```

Each OSGi bundle is loaded by a different classloader, with the java runtime classloader the parent for the bundle classloaders.

Each component can include libraries inside, for instance JDO.

```
mycomponent1.jar (OSGi bundle)
  - jdo.jar
  - Person.class (PersistenceCapable)
  - Company.class (PersistenceCapable)
mycomponent2.jar (OSGi bundle)
```

```
mycomponent3.jar (OSGi bundle)
```

Only mycomponent1 currently uses the persistence-capable classes. But if mycomponent3 now needs to read Company instances, you will also need the persistence-capable classes and jdo.jar in the classpath for mycomponent3. You might decide to duplicate the classes in both OSGi bundles:

```
mycomponent1.jar (OSGi bundle)
  - jdo.jar
  - Person.class (PersistenceCapable)
  - Company.class (PersistenceCapable)
mycomponent2.jar (OSGi bundle)
mycomponent3.jar (OSGi bundle)
  - jdo.jar
  - Person.class (PersistenceCapable)
  - Company.class (PersistenceCapable)
```

But actually this will fail with `ClassCastException` at runtime, since Person of mycomponent1 is not the same class, and instances cannot be cast to Person of mycomponent3. The solution is to reorganize the dependencies:

```
mycomponent1.jar (OSGi bundle) - depends on mydomainclasses.jar and jdo.jar OSGi
bundles
mycomponent2.jar (OSGi bundle)
mycomponent3.jar (OSGi bundle) - depends on mydomainclasses.jar and jdo.jar OSGi
bundles
jdo.jar (OSGi bundle)
  - jdo.jar
mydomainclasses.jar (OSGi bundle) - depends on jdo.jar
  - Person.class (PersistenceCapable)
  - Company.class (PersistenceCapable)
```

This fixes the issue of `ClassCastException` since both components depend on classes loaded by the same class loader.

The jdo vendor implementation can be put anywhere, unless you also want to share instances of the JDO vendor classes at runtime between OSGi bundles. The best choice is this:

```
mycomponent1.jar (OSGi bundle) - depends on mydomainclasses.jar, jdo.jar and
VENDOR_X.jar OSGi bundles
mycomponent2.jar (OSGi bundle)
mycomponent3.jar (OSGi bundle) - depends on mydomainclasses.jar, jdo.jar and
VENDOR_X.jar OSGi bundles
jdo.jar (OSGi bundle)
  - jdo.jar
mydomainclasses.jar (OSGi bundle) - depends on jdo.jar
  - Person.class (PersistenceCapable)
  - Company.class (PersistenceCapable)
VENDOR_X.jar (OSGi bundle)
```

12 PersistenceManager

This chapter specifies the JDO PersistenceManager and its relationship to the application components, JDO instances, and J2EE Connector.

12.1 Overview

The JDO PersistenceManager is the primary interface for JDO-aware application components. It is the factory for the Query interface and contains methods for managing the life cycle of persistent instances.

The JDO PersistenceManager interface is architected to support a variety of environments and data sources, from small footprint embedded systems to large enterprise application servers. It might be a layer on top of a standard Connector implementation such as JDBC or JMS, or itself include connection management and distributed transaction support.

J2EE Connector support is optional . If it is not supported by a JDO implementation, then a constructor for the JDO PersistenceManager or PersistenceManagerFactory is required. The details of the construction of the PersistenceManager or PersistenceManagerFactory are not specified by JDO.

12.2 Goals

The architecture of the PersistenceManager has the following goals:

- No changes to application programs to change to a different vendor's PersistenceManager if the application is written to conform to the portability guidelines
- Application to non-managed and managed environments with no code changes

12.3 Architecture: JDO PersistenceManager

The JDO PersistenceManager instance is visible only to certain application components: those that explicitly manage the life cycle of JDO instances; and those that query for JDO instances. The JDO PersistenceManager is not required to be used by JDO instances.

There are three primary environments in which the JDO PersistenceManager is architected to work:

- non-managed (non-application server), minimum function, single transaction, single JDO PersistenceManager where compactness is the primary metric;
- non-managed but where extended features are desired, such as multiple PersistenceManager instances to support multiple data sources, XA coordinated transactions, or nested transactions; and
- managed, where the full range of capabilities of an application server is required.

Support for these three environments is accomplished by implementing transaction completion APIs on a companion JDO Transaction instance, which contains transaction policy options and local transaction support.

12.4 Threading

It is a requirement for all JDO implementations to be thread-safe. That is, the behavior of the implementation must be predictable in the presence of multiple application threads. Operations implemented by the `PersistenceManager` directly or indirectly via access or modification of persistent or transactional fields of persistence-capable classes must be treated as if they were serialized. The implementation is free to serialize internal data structures and thus order multi-threaded operations in any way it chooses. The only application-visible behavior is that operations might block indefinitely (but not infinitely) while other operations complete.

Since synchronizing the `PersistenceManager` is a relatively expensive operation, and not needed in many applications, the application must specify whether multiple threads might access the same `PersistenceManager` or instances managed by the `PersistenceManager` (persistent or transactional instances of persistence-capable classes; instances of `Transaction` or `Query`; query results, etc.).

If applications depend on serializing operations, then the applications must implement the appropriate synchronizing behavior, using instances visible to the application. This includes some instances of the JDO implementation (e.g. `PersistenceManager`, `Query`, etc.) and instances of persistence-capable classes.

The implementation must not use user-visible instances (instances of `PersistenceManagerFactory`, `PersistenceManager`, `Transaction`, `Query`, etc.) as synchronization objects, with one exception. The implementation must synchronize instances of persistence-capable classes during state transitions that replace the `StateManager`. This is to avoid race conditions where the application attempts to make the same instance persistent in multiple `PersistenceManager`s.

12.5 Class Loaders

JDO requires access to class instances in several situations where the class instance is not provided explicitly. In these cases, the only information available to the implementation is the name of the class.

To resolve class names to class instances, JDO implementations will use `Class.forName (String name, boolean initialize, ClassLoader loader)` with up to three loaders. The `initialize` parameter can be either true or false depending on the implementation.

These loaders will be used in this order:

1. The loader that loaded the class or instance referred to in the API that caused this class to be loaded.
 - In case of query, this is the loader of the candidate class, or the loader of the object passed to the `newQuery` method.
 - In case of navigation from a persistent instance, this is the loader of the class of the instance.
 - In the case of `getExtent` with subclasses, this is the loader of the candidate class.
 - In the case of `getObjectById`, this is the loader of the object id instance.
 - Other cases do not have an explicit loader.
2. The loader returned in the current context by `Thread.getContextClassLoader()`.

3. The loader returned by `Thread.getContextClassLoader()` at the time the application calls `PersistenceManagerFactory.getPersistenceManager()`. This loader is saved with the `PersistenceManager` and cleared when the `PersistenceManager` is closed.

12.6 Interface PersistenceManager

A JDO `PersistenceManager` instance supports any number of JDO instances at a time. It is responsible for managing the identity of its associated JDO instances. A JDO instance is associated with either zero or one JDO `PersistenceManager`. It will be zero if and only if the JDO instance is in the transient or detached state. As soon as a transient instance is made persistent or transactional, it will be associated with exactly one JDO `PersistenceManager`. Detached instances are never associated with a `PersistenceManager`.

A JDO `PersistenceManager` instance supports one transaction at a time, and uses one connection to the underlying data source at a time. The JDO `PersistenceManager` instance might use multiple transactions serially, and might use multiple connections serially.

Therefore, to support multiple concurrent connection-oriented data sources in an application, multiple JDO `PersistenceManager` instances are required.

In this interface, for implementations that support BinaryCompatibility, JDO instances passed as parameters and returned as values must implement `PersistenceCapable`. The interface defines these formal parameters as `Object` because binary compatibility is optional.

```
package javax.jdo;
public interface PersistenceManager {
    boolean isClosed();
    void close();
```

The `isClosed` method returns `false` upon construction of the `PersistenceManager` instance, or upon retrieval of a `PersistenceManager` from a pool. It returns `true` only after the `close` method completes successfully. After being closed, the `PersistenceManager` instance might be returned to the pool or garbage collected, at the choice of the JDO implementation. Before being used again to satisfy a `getPersistenceManager` request, the options will be reset to their default values as specified in the `PersistenceManagerFactory`.

In a non-managed environment, if the current transaction is active, `close` throws `JDOUserException`.

After `close` completes, all methods on the `PersistenceManager` instance except `isClosed()`, `close()`, and `get` methods throw a `JDOFatalUserException`.

State Transitions for persistent instances at close

The behavior of persistent instances at close of the corresponding `PersistenceManager` is not further defined in this specification.

Null management

In the APIs that follow, `Object[]` and `Collection` are permitted parameter types. As these may contain nulls, the following rules apply.

Null arguments to APIs that take an `Object` parameter cause the API to have no effect. Null arguments to APIs that take `Object[]` or `Collection` will cause the API to throw `NullPointerException`. Non-null `Object[]` or `Collection` arguments that contain null elements will have the documented behavior for non-null elements, and the null elements will be ignored.

12.6.1 Cache management

Normally, cache management is automatic and transparent. When instances are queried, navigated to, or modified, instantiation of instances and their fields and garbage collection of unreferenced instances occurs without any explicit control. When the transaction in which persistent instances are created, deleted, or modified completes, eviction is automatically done by the transaction completion mechanisms. Therefore, eviction is not normally required to be done explicitly. However, if the application chooses to become more involved in the management of the cache, several methods are available.

The non-parameter version of these methods applies the operation to each appropriate JDO instance in the cache. For evictAll, these are all persistent-clean instances; for refreshAll, all transactional instances.

Evict instances

```
void evict (Object pc);
void evictAll ();
void evictAll (Object... pcs);
void evictAll (Collection pcs);
void evictAll (Class pcClass, boolean subclasses);
```

Eviction is a hint to the PersistenceManager that the application no longer needs the parameter instances in the cache. Eviction allows the parameter instances to be subsequently garbage collected. Evicted instances will not have their values retained after transaction completion, regardless of the settings of the retainValues or restoreValues flags.

If evictAll with no parameters is called, then all persistent-clean instances are evicted (they transition to hollow). If users wish to automatically evict transactional instances at transaction commit time, then they should set RetainValues to false. Similarly, to automatically evict transactional instances at transaction rollback time, then they should set RestoreValues to false.

If the parameter instance is detached, then JDOUserException is thrown.

For each persistent-clean and persistent-nontransactional instance that the JDO PersistenceManager evicts, it:

- calls the jdoPreClear method on each instance, if the class of the instance implements InstanceCallbacks
- clears persistent fields on each instance (sets the value of the field to its Java default value);
- changes the state of instances to hollow.

```
Refresh instances
void refresh (Object pc);
void refreshAll ();
void refreshAll (Object... pcs);
void refreshAll (Collection pcs);
void refreshAll (JDOException ex);
```

The refresh and refreshAll methods update the values in the parameter instance[s] from the data in the datastore. The intended use is for optimistic transactions where the state of the JDO instance is not guaranteed to reflect the state in the datastore, and for datastore transactions to undo the changes to a specific set of instances instead of rolling back the entire transaction. This method

can be used to minimize the occurrence of commit failures due to mismatch between the state of cached instances and the state of data in the datastore.

When called with a transaction active, the `refreshAll` method with no parameters causes all transactional instances to be refreshed. If a transaction is not in progress, then this call has no effect.

If there is a fetch plan in effect, then the fetch plan affects the results of this method. All modified fields and all fields in the current fetch plan are unloaded and then fields in the current fetch plan are fetched from the datastore.

Note that this method will cause loss of changes made to affected instances by the application due to refreshing the contents from the datastore.

When used with the `JDOException` parameter, the `JDO PersistenceManager` refreshes all instances in the exception, including instances in nested exceptions, that failed verification. Updated and unchanged instances that failed verification are reloaded from the datastore. Datastore instances corresponding to new instances that failed due to duplicate key are loaded from the datastore.

If the parameter instance is detached, then `JDOUserException` is thrown.

The `JDO PersistenceManager`:

- loads persistent values from the datastore into the instance;
- calls the `jdoPostLoad` method on each persistent instance, if the class of the instance implements `InstanceCallbacks`; and
- changes the state of persistent-dirty instances to persistent-clean in a datastore transaction; or persistent-nontransactional in an optimistic transaction.

Retrieve instances

```
void retrieve(Object pc);
void retrieve(Object pc, boolean useFetchPlan);
void retrieveAll(Collection pcs);
void retrieveAll(Collection pcs, boolean useFetchPlan);
void retrieveAll(Object... pcs);
void retrieveAll(Object[] pcs, boolean useFetchPlan);
void retrieveAll(boolean useFetchPlan, Object... pcs);
```

These methods request the `PersistenceManager` to load persistent fields into the parameter instances. Subsequent to this call, the application might call `makeTransient` on the parameter instances, and the fields can no longer be touched by the `PersistenceManager`. The `PersistenceManager` might also retrieve related instances according to the current fetch plan or a vendor-specific pre-read policy (not specified by JDO).

If the `useFetchPlan` parameter is false, or the method without the `useFetchPlan` parameter is invoked, all fields must be loaded from the datastore.

If the `useFetchPlan` parameter is true, and the fetch plan has not been modified from its default setting (see 12.7.5), then this is a hint to the implementation that only the fields in the current fetch group need to be retrieved. A compliant implementation is permitted to retrieve all fields regardless of the setting of this parameter. After the call with the `useFetchPlan` parameter true, all fields in the current fetch group must have been fetched, but other fields might be fetched lazily by the implementation.

If the `useFetchPlan` parameter is true, and the fetch plan has been changed, then only the fields specified by the fetch plan are loaded.

If the parameter instance or instances are detached, then `JDOUserException` is thrown.

The method `retrieveAll(Object[] pcs, boolean useFetchPlan)` is deprecated in favor of `retrieveAll(boolean useFetchPlan, Object... pcs)`.

The JDO PersistenceManager:

- loads persistent values from the datastore into the instance;
- for hollow instances, changes the state to persistent-clean in a datastore transaction; or persistent-nontransactional in an optimistic transaction;
- if the class of the instance implements `LoadCallback` calls `jdoPostLoad`;
- calls `postLoad` for all `LifecycleListener` instances that are registered for load callbacks for the class of the loaded instances.

12.6.2 Transaction factory interface

```
Transaction currentTransaction();
```

The `currentTransaction` method returns the `Transaction` instance associated with the `PersistenceManager`. The identical `Transaction` instance will be returned by all `currentTransaction` calls to the same `PersistenceManager` until `close`. Note that multiple transactions can be begun and completed (serially) with this same instance.

Even if the `Transaction` instance returned cannot be used for transaction completion (due to external transaction management), it still can be used to set flags.

12.6.3 Query factory interface

The query factory methods are detailed in the Query chapter .

```
void setIgnoreCache (boolean flag);  
boolean getIgnoreCache ();
```

These methods get and set the value of the `IgnoreCache` option for all `Query` instances created by this `PersistenceManager` [see Query options]. The `IgnoreCache` option if set to `true`, is a hint to the query engine that the user expects queries to be optimized to return approximate results by ignoring changed values in the cache.

The `IgnoreCache` option also affects the iterator obtained from `Extent` instances obtained from this `PersistenceManager`.

The `IgnoreCache` option is preserved for query instances constructed from other query instances.

```
void setDatastoreReadTimeoutMillis(Integer milliseconds);  
Integer getDatastoreReadTimeoutMillis();
```

These methods set and get the datastore read timeout value in milliseconds. The value might have been set in the `PersistenceManagerFactory` via API or properties. Setting the value to `null` will use the value specified in `PersistenceManagerFactory`. Setting the timeout to a non-null value will override the value specified in `PersistenceManagerFactory`.

```
void setDatastoreWriteTimeoutMillis(Integer milliseconds);  
Integer getDatastoreWriteTimeoutMillis();
```

These methods set and get the datastore write timeout value in milliseconds. The value might have been set in the `PersistenceManagerFactory` via API or properties. Setting the value to `null` will use the value specified in `PersistenceManagerFactory`. Setting the timeout to a non-null value will override the value specified in `PersistenceManagerFactory`.

12.6.4 Extent Management

Extents are collections of datastore objects managed by the datastore, not by explicit user operations on collections. Extent capability is a boolean property of persistence capable classes and interfaces.

If an instance of a class or interface that has a managed extent is made persistent via reachability, the instance is put into the extent implicitly. If an instance of a class that implements an interface that has a managed extent is made persistent, then that instance is put into the interface's extent.

```
Extent getExtent (Class persistenceCapable, boolean subclasses);  
Extent getExtent (Class persistenceCapable);
```

The `getExtent` method returns an `Extent` that contains all of the instances in the parameter class or interface, and if the `subclasses` flag is `true`, all of the instances of the parameter class and its subclasses. The method with no `subclasses` parameter is treated as equivalent to `getExtent (persistenceCapable, true)`.

If the metadata does not indicate via the `requires-extent` attribute in the class or interface element that an extent is managed for the parameter class or interface, then `JDOUserException` is thrown. The extent might not include instances of those subclasses for which the metadata indicates that an extent is not managed for the subclass.

This method can be called whether or not a transaction is active, regardless of whether `NontransactionalRead` is supported. If `NontransactionalRead` is not supported, then the iterator method will throw a `JDOUnsupportedOptionException` if called outside a transaction.

It might be a common usage to iterate over the contents of the `Extent`, and the `Extent` should be implemented in such a way as to avoid out-of-memory conditions on iteration.

The primary use for the `Extent` returned as a result of this method is as a candidate collection parameter to a `Query` instance. For this usage, the elements in the `Extent` typically will not be instantiated in the Java VM; it is used only to identify the prospective datastore instances.

Extents of interfaces

If the `Class` parameter of the `getExtent` method is an interface, then the interface must be identified in the metadata as having its extent managed.

12.6.5 JDO Identity management

```
Object getObjectById (Object oid);
```

The `getObjectById` method attempts to find an instance in the cache with the specified JDO identity. This method behaves exactly as the method `getObjectById (Object oid, boolean validate)` with the `validate` flag set to `true`.

```
Object getObjectById (Object oid, boolean validate);
```

The `getObjectById` method attempts to find an instance in the cache with the specified JDO identity. The `oid` parameter object might have been returned by an earlier call to `getObjectId` or `getTransactionalObjectId`, or might have been constructed by the application.

If the `PersistenceManager` is unable to resolve the `oid` parameter to an `ObjectID` instance, then it throws a `JDOUserException`. This might occur if the implementation does not support application identity, and the parameter is an instance of an object identity class.

If the `validate` flag is `false`, the user asserts that the instance exists and the object id represents the exact class of the persistent instance (specifically not an abstract class, a subclass, or an interface):

- If the object id represents an interface or abstract class, `JDOUserException` is thrown.
- If there is already an instance in the cache with the same JDO identity as the `oid` parameter, then this method returns it. There is no change made to the state of the returned instance.
- If there is not an instance already in the cache with the same JDO identity as the `oid` parameter, then this method creates an instance with the specified JDO identity and returns it.

- If there is no transaction in progress, the returned instance will be hollow or persistent-nontransactional, at the choice of the implementation.
- If there is a transaction in progress, the returned instance will be hollow, persistent-nontransactional, or persistent-clean, at the choice of the implementation.
- The implementation must not access the datastore to determine the exact class. If the class is not the exact class, then an exception must be thrown subsequently if any field other than the identity field is accessed.
- If the instance does not exist in the datastore, then this method will not fail. But a subsequent access of the fields of the instance will throw a `JDOObjectNotFoundException` if the instance does not exist at that time. Further, if a relationship is established to this instance, and the instance does not exist when the instance is flushed to the datastore, then the transaction in which the association was made will fail.

If the `validate` flag is `true`:

- If there is already a transactional instance in the cache with the same jdo identity as the oid parameter, then this method returns it. There is no change made to the state of the returned instance.
- If there is an instance already in the cache with the same jdo identity as the oid parameter, the instance is not transactional, and the instance does not exist in the datastore, then a `JDOObjectNotFoundException` is thrown.
- If there is not an instance already in the cache with the same jdo identity as the oid parameter, then this method creates an instance with the specified jdo identity, verifies that it exists in the datastore, and returns it. The class in the object id might be the exact class or an abstract or concrete superclass of the actual instance. If the instance does not exist in the datastore, then a `JDOObjectNotFoundException` is thrown. If the fetch plan has been changed from its original value, the fetch plan governs which fields are fetched from the datastore and which related objects are also fetched with them.
 - If there is no transaction in progress, the returned instance will be hollow or persistent-nontransactional, at the choice of the implementation.
 - If there is a datastore transaction in progress, the returned instance will be persistent-clean.
 - If there is an optimistic transaction in progress, the returned instance will be persistent-nontransactional.

`Object getObjectId (Object pc);`

The `getObjectId` method returns an `ObjectId` instance that represents the object identity of the specified JDO instance. The identity is guaranteed to be unique only in the context of the JDO `PersistenceManager` that created the identity, and only for two types of JDO Identity: those that are managed by the application, and those that are managed by the datastore.

If the object identity is being changed in the transaction, by the application modifying one or more of the application key fields, then this method returns the identity as of the beginning of the transaction. The value returned by `getObjectId` will be different following `afterCompletion` processing for successful transactions.

Within a transaction, the `ObjectId` returned will compare equal to the `ObjectId` returned by only one among all JDO instances associated with the `PersistenceManager` regardless of the type of `ObjectId`.

The `ObjectId` does not necessarily contain any internal state of the instance, nor is it necessarily an instance of the class used to manage identity internally. Therefore, if the application makes a change to the `ObjectId` instance returned by this method, there is no effect on the instance from which the `ObjectId` was obtained.

The `getObjectById` method can be used between instances of `PersistenceManager` of different JDO vendors only for instances of persistence capable classes using application-managed (primary key) JDO identity. If it is used for instances of classes using datastore identity, the method might succeed, but there are no guarantees that the parameter and return instances are related in any way.

If the parameter `pc` is not persistent, or is `null`, then `null` is returned.

```
Object getTransactionalObjectId (Object pc);
```

If the object identity is being changed in the transaction, by the application modifying one or more of the application key fields, then this method returns the current identity in the transaction. If there is no transaction in progress, or if none of the key fields is being modified, then this method has the same behavior as `getObjectId`.

To get an instance in a `PersistenceManager` with the same identity as an instance from a different `PersistenceManager`, use the following: `aPersistenceManager.getObjectById(JDOHelper.getObjectId(pc), validate)`. The `validate` parameter has a value of true or false depending on your application requirements.

Getting Multiple Persistent Instances

```
Collection getObjectsById (Collection oids);
Object[] getObjectsById (Object... oids);
Collection getObjectsById (Collection oids, boolean validate);
Object[] getObjectsById (Object[] oids, boolean validate);
Object[] getObjectsById (boolean validate, Object... oids);
```

The `getObjectsById` method attempts to find instances in the cache with the specified JDO identities. The elements of the `oids` parameter object might have been returned by earlier calls to `getObjectId` or `getTransactionalObjectId`, or might have been constructed by the application.

If a method with no `validate` parameter is used, the method behaves exactly as the corresponding method with the `validate` flag set to true.

If the `Object[]` or `Object...` form of the method is used, the returned objects correspond by position with the object ids in the `oids` parameter. If the `Collection` form of the method is used, the iterator over the returned `Collection` returns instances in the same order as the `oids` returned by an iterator over the parameter `Collection`. The cardinality of the return value is the same as the cardinality of the `oids` parameter.

The method `getObjectsById (Object[] oids, boolean validate)` is deprecated in favor of `getObjectsById (boolean validate, Object... oids)`.

Getting an Object by Class and Key

```
<T> T getObjectById (Class<T> cls, Object key);
```

The `getObjectById` method attempts to find an instance in the cache with the derived JDO identity. The `key` parameter is either the string representation of the object id, or is an object representation of a single field identity key.

This is a convenience method that exactly matches the behavior of calling

```
pm.getObjectById (pm.newObjectIDInstance (cls, key), true).
```

12.6.6 Persistent instance factory

The following method is used to create an instance of a persistence-capable interface, or of a concrete or abstract class.

```
<T> T newInstance(Class<T> persistenceCapable);
```

The parameter must be one of the following:

- an abstract class that is declared in the metadata as persistence-capable, in which all abstract methods are persistent properties, or
- an interface that is declared in the metadata as persistence-capable, in which all methods are persistent properties, or
- a concrete class that is declared in the metadata as persistence-capable. In this case, the concrete class must declare a public no-args constructor.

If the parameter does not satisfy the above requirements, `JDOUserException` is thrown. The returned instance is transient, and is an “instanceof” the parameter. Applications might use the instance via the get and set property methods and change its life cycle state exactly as if it were an instance of a persistence-capable class.

In order for the `newInstance` method to be used, the parameter interface must be completely mapped. For relational implementations, the interface must be mapped to a table and all persistent properties must be mapped to columns. Additionally, interfaces that are the targets of all relationships from persistent properties must also be mapped. Otherwise, `JDOUserException` is thrown by the `newInstance` method.

For interfaces and classes that use a `SingleFieldIdentity` as the object-id class, if the returned instance is subsequently made persistent, the target class stored in the object-id instance is the parameter of the `newInstance` method that created it.

12.6.7 JDO Instance life cycle management

The following methods take either a single instance or multiple instances as parameters.

If a collection or array of instances is passed to any of the methods in this section, and one or more of the instances fail to complete the required operation, then all instances will be attempted, and a `JDOUserException` will be thrown which contains a nested exception array, each exception of which contains one of the failing instances. The succeeding instances will transition to the specified life cycle state, and the failing instances will remain in their current state.

Make instances persistent

```
<T> T makePersistent (T pc);
<T> T[ ] makePersistentAll (T... pcs);
<T> T makePersistentAll (Collection<T> pcs);
```

These methods make transient instances persistent and apply detached instance changes to the cache. They must be called in the context of an active transaction, or a `JDOUserException` is thrown. For a transient instance, they will assign an object identity to the instance and transition it to persistent-new. Any transient instances reachable from this instance via persistent fields of this instance will become provisionally persistent, transitively. That is, they behave as persistent-new instances (return `true` to `isPersistent`, `isNew`, and `isDirty`). But at commit time, the reachability algorithm is run again, and instances made provisionally persistent that are not currently reachable from persistent instances will revert to transient. For a detached instance with the `CopyOnAttach` property `true`, they locate or create a persistent instance with the same JDO identity as the detached instance, and merge the persistent state of the detached instance into the persistent instance. Only the state of persistent fields is merged. If non-persistent state needs to be copied, the application should use the `jdoPostAttach` callback or the `postAttach` lifecycle event listener. Any references to the detached instances from instances in the closure of the parameter instances are modified to refer to the corresponding persistent instance instead of to the detached instance. If the `CopyOnAttach` property is `false`, then the instance itself is transitioned to persistent-clean

for datastore transactions or persistent-nontransactional for optimistic transactions. If there already is an instance in the cache with the same identity, `JDOUserException` is thrown.

During application of changes of the detached state, if the JDO implementation can determine that there were no changes made during detachment, then the implementation is not required to mark the corresponding instance dirty. If it cannot determine if changes were made, then it must mark the instance dirty.

No consistency checking is done during `makePersistent` of detached instances. If consistency checking is required by the application, then `flush` or `checkConsistency` should be called after attaching the instances.

These methods have no effect on parameter persistent instances already managed by this `PersistenceManager`. They will throw a `JDOUserException` if the parameter instance is managed by a different `PersistenceManager`.

If an instance is of a class whose identity type (`application`, `datastore`, or `none`) is not supported by the JDO implementation, then a `JDOUserException` will be thrown for that instance. The return value for instances in the transient or persistent states is the same as the parameter value. With `CopyOnAttach true`, the return value for detached instances is the persistent instance corresponding to the detached instance; with `CopyOnAttach false`, the return value for detached instances is the instance itself.

The return values for `makePersistentAll` methods correspond by position to the parameter instances.

Delete persistent instances

```
void deletePersistent (Object pc);
void deletePersistentAll (Object... pcs);
void deletePersistentAll (Collection pcs);
```

These methods delete persistent instances from the datastore. They must be called in the context of an active transaction, or a `JDOUserException` is thrown. The representation in the datastore will be deleted when this instance is flushed to the datastore (via `commit` or `evict`).

Note that this behavior is not exactly the inverse of `makePersistent`, due to the transitive nature of `makePersistent`. The implementation might delete dependent datastore objects depending on implementation-specific policy options that are not covered by the JDO specification. However, if a field is marked as containing a dependent reference, the dependent instance is deleted as well.

These methods have no effect on parameter instances already deleted in the transaction or on embedded instances. Embedded instances are deleted when their owning instance is deleted.

Deleting instances involved in relationships have special handling. See “Relationship Mapping” on page 197. for details.

Portable applications should use this method to delete instances from the datastore, and not depend on any reachability algorithm to automatically delete instances.

If the parameter instance of `deletePersistent()` is a detached instance, the method applies to the associated persistent instance. Similarly, if any of the parameter instances of `deletePersistentAll()` is a detached instance, the method applies to the associated persistent instances. If the class of any instance to be deleted implements `DeleteCallback`, or if there are any `InstanceLifecycleListeners` registered for deletion callbacks of instances of any detached objects’ class, then the parameter persistent instances of those classes are instantiated, the callback is executed, and/or the listeners are called with the event, as described in section 12.15.

These methods will throw a `JDOUserException` if the parameter instance is managed by a different `PersistenceManager`. These methods will throw a `JDOUserException` if the parameter instance is transient.

Make instances transient

```
void makeTransient (Object pc);
void makeTransientAll (Object... pcs);
void makeTransientAll (Collection pcs);
```

These methods make persistent instances transient, so they are no longer associated with the `PersistenceManager` instance. They do not affect the persistent state in the datastore. They can be used as part of a sequence of operations to move a persistent instance to another `PersistenceManager`. The instance transitions to transient, and it loses its JDO identity. If the instance has state (persistent-nontransactional or persistent-clean) the state in the cache is preserved unchanged. If the instance is dirty, a `JDOUserException` is thrown.

The effect of these methods is immediate and not subject to rollback. Field values in the instances are not modified. To avoid having the instances become persistent by reachability at commit, the application should update all persistent instances containing references to the parameter instances to avoid referring to them, or make the referring instances transient.

If the parameter instance or instances are detached, then `JDOUserException` is thrown.

These methods will be ignored if the instance is transient.

```
void makeTransient (Object pc, boolean useFetchPlan);
void makeTransientAll (Object[] pcs, boolean useFetchPlan);
void makeTransientAll (boolean useFetchPlan, Object... pcs);
void makeTransientAll (Collection pcs, boolean useFetchPlan);
```

If the `useFetchPlan` parameter is false, these methods behave exactly as the corresponding `makeTransient` methods.

If the `useFetchPlan` parameter is true, the current `FetchPlan`, including `MaxFetchDepth`, `DETACH_LOAD_FIELDS`, and `DETACH_UNLOAD_FIELDS`, is applied to the `pc` or `pcs` parameter instance(s) to load fields and instances from the datastore. The `DetachmentRoots` is not affected. After the fetch plan is used to load instances, the entire graph of instances reachable via loaded fields of the parameter instances is made transient. Transient fields are not modified by the method.

If the parameter instance or instances are detached, then `JDOUserException` is thrown.

The method `makeTransientAll (Object[] pcs, boolean useFetchPlan)` is deprecated in favor of `makeTransientAll (boolean useFetchPlan, Object... pcs)`.

Make instances transactional

```
void makeTransactional (Object pc);
void makeTransactionalAll (Object... pcs);
void makeTransactionalAll (Collection pcs);
```

These methods make transient instances transactional and cause a state transition to transient-clean. After the method completes, the instance observes transaction boundaries. If the transaction in which this instance is made transactional commits, then the transient instance retains its values. If the transaction is rolled back, then the transient instance takes its values as of the call to `makeTransactional` if the call was made within the current transaction; or the beginning of the transaction, if the call was made prior to the beginning of the current transaction.

If the implementation does not support `TransientTransactional`, and the parameter instance is transient, then `JDOUnsupportedOptionException` is thrown.

If the parameter instance or instances are detached, then `JDOUserException` is thrown.

These methods are also used to mark a nontransactional persistent instance as being part of the read-consistency set of the transaction. In this case, the call must be made in the context of an active transaction, or a `JDOUserException` is thrown.

The effect of these methods is immediate and not subject to rollback.

Make instances nontransactional

```
void makeNontransactional (Object pc);
void makeNontransactionalAll (Object[] pcs);
void makeNontransactionalAll (Collection pcs);
```

These methods make transient-clean instances nontransactional and cause a state transition to transient. After the method completes, the instance does not observe transaction boundaries.

These methods make persistent-clean instances nontransactional and cause a state transition to persistent-nontransactional.

If the parameter instance or instances are detached, then `JDOUserException` is thrown.

If this method is called with a dirty parameter instance, a `JDOUserException` is thrown.

The effect of these methods is immediate and not subject to rollback.

12.6.8 Detaching and attaching instances

These methods provide a way for an application to identify persistent instances, obtain copies of these persistent instances, modify the detached instances either in the same JVM or in a different JVM, apply the changes to the same or different `PersistenceManager`, and commit the changes.

There are three ways to cause the creation of detached instances:

- explicitly via methods defined on `PersistenceManager`;
- implicitly by committing the transaction while the `DetachAllOnCommit` flag is true;
- or implicitly by serializing persistent instances.

NOTE: serializing for storage using the `serialized`, `serialized-element`, `serialized-key`, or `serialized-value` metadata attributes does not create a detached instance.

Attaching detached instances (in order to commit changes made while detached) is done explicitly via the `makePersistent` method.

Committing the transaction with `DetachAllOnCommit`

```
boolean getDetachAllOnCommit ( );
```

The value of the `DetachAllOnCommit` flag is returned.

```
void setDetachAllOnCommit(boolean flag);
```

The value of the `DetachAllOnCommit` flag is set to the parameter value. The flag takes effect during the next commit after being called. This method is allowed at any time except during transaction completion (`beforeCompletion` and `afterCompletion`).

In JDO 1.0, the behavior of persistent instances after closing the associated `PersistenceManager` is undefined. JDO 2 defines a new property called `DetachAllOnCommit` which changes this behavior. With this flag set to false, the state of persistent instances in the cache after commit is defined by the `retainValues` flag.

With this flag set to `true`, during `beforeCompletion` all cached instances are prepared for detachment according to the fetch plan in effect at commit. Loading fields and unloading fields required by the fetch plan is done after calling the user's `beforeCompletion` callback. During `afterCompletion`, before calling the user's `afterCompletion` callback, all detachable persistent instances in the cache transition to detached; non-detachable persistent instances transition to transient; and detachable instances can be serialized as detached instances. Transient transactional instances are unaffected by this flag.

Attaching Detached Instances with `CopyOnAttach`

```
boolean getCopyOnAttach();
```

The value of the `CopyOnAttach` flag is returned.

```
void setCopyOnAttach(boolean flag);
```

The value of the `CopyOnAttach` flag is set to the parameter value. The flag takes effect during the next `makePersistent` method.

In JDO 2.0, `makePersistent` resulted in a deep copy of the parameter detached instances. The detached instances themselves never made a state transition. With JDO 2.1, this behavior is the same if the `CopyOnAttach` flag is `true`. But with `CopyOnAttach` flag set to `false`, detached instances transition from detached to persistent. This change potentially improves usability and performance:

- The overhead of making a copy of the detached instance is removed;
- Transient state of detached instances is preserved, without requiring implementation of a `JDOPostAttach` callback or `postAttach` lifecycle listener;
- In conjunction with `DetachAllOnCommit`, the same instances can be used for multiple round trips using different persistence managers

For example, consider a web application where a detached instance is stored in the session. During several interactions with the remote user, the instance can be dirtied during an incoming request. With `CopyOnAttach true`, the application would need to replace the detached instance each time a request came in. But with `CopyOnAttach false`, the application can simply use the detached instance directly, needing only to call `makePersistent` on the detached instances when a new persistence manager is obtained, and setting `DetachAllOnCommit` to `true`.

Note that for backward compatibility, the user must explicitly set `CopyOnAttach` to `false` to obtain the new behavior. This can be done either in the persistence manager or in the persistence manager factory.

Serializing Persistent Instances

The JDO 1.0 specification requires that serialized instances be made ready for serialization by instantiating all serializable persistent fields before calling `writeObject`. For binary-compatible implementations, this is done by the enhancer adding a call to the `StateManager` prior to invoking the user's `writeObject` method. The behavior is the same in JDO 2.0, with the additional requirement that restored detachable serialized instances are treated as detached instances.

Explicit detach

```
<T> T detachCopy(T pc);
<T> Collection<T> detachCopyAll(Collection<T> pcs);
<T> T[ ] detachCopyAll(T... pcs);
```

This method makes detached copies of the parameter instances and returns the copies as the result of the method. The order of instances in the parameter `Collection`'s iteration corresponds to the order of corresponding instances in the returned `Collection`'s iteration. Only persistent fields are

copied by the JDO implementation. If transient fields need to be copied, the application should implement the `jdoPreDetach` callback or the `preDetach` lifecycle event listener.

If a `detachCopy` method is called with an active transaction, the parameter `Collection` of instances is first made persistent, and the reachability algorithm is run on the instances. This ensures that the closure of all of the instances in the parameter `Collection` is persistent.

If a `detachCopy` method is called outside an active transaction, the reachability algorithm will not be run; if any transient instances are either in the parameter list or reachable via persistent fields of the closure of the parameter list, a `JDOUserException` is thrown for each persistent instance containing such fields. If any detached instances are in the parameter list or reachable from detached or persistent instances in the closure of the parameter list, the corresponding persistent instance is obtained.

If a `detachCopy` method is called outside an active transaction, the `NontransactionalRead` property must be true or `JDOUserException` is thrown.

For each instance in the parameter `Collection`, a corresponding detached copy is returned. Each field in the persistent instance is handled based on its type and whether the field is contained in the fetch group for the persistence-capable class. If there are duplicates in the parameter `Collection`, the corresponding detached copy is used for each such duplicate.

Instances in the persistent-new and persistent-dirty state are updated with their current object identity and version (as if they had been flushed to the datastore prior to copying their state). This ensures that the object identity and version (if any) is properly set prior to creating the copy. The transaction in which the flush is performed is assumed to commit; if the transaction rolls back, then the detached instances become invalid (they no longer refer to the correct version of the datastore instances). This situation will be detected at the subsequent attempt to commit or flush a transaction after attaching the detached instances.

If instances in a deleted state (either persistent-deleted or persistent-new-deleted) are attempted to be detached, a `JDOUserException` is thrown with nested `JDOUserExceptions`, one for each such instance.

Instances to be detached that are not of a `Detachable` class are detached as transient instances.

The `FetchPlan` in effect in the `PersistenceManager` at the time of detachment determines the fields to be fetched in the closure of the persistent instances. If the default fetch plan is active, instances are detached in their current state. If the user has changed the fetch plan, then each instance to be detached will have the fetch plan applied to it, including detachment options. The `DETACH_LOAD_FIELDS` causes the fields in the fetch plan to be loaded before the instances are detached. The `DETACH_UNLOAD_FIELDS` causes loaded fields that are not in the fetch plan to be unloaded before detachment.

Fields in the `FetchPlan` of primitive and wrapper types are set to their values from the datastore. Fields of references to persistence-capable types are set to the detached copy corresponding to the persistent instance. Fields of Collections and Maps are set to detached SCO instances containing references to detached copies corresponding to persistent instances in the datastore.

The result of the `detachCopyAll` method is a `Collection` or array of detached instances whose closure contains copies of detached instances. Among the closure of detached instances there are no references to persistent instances; all such references from the persistent instances have been replaced by the corresponding detached instance.

There might or might not be a transaction active when the `detachCopy` method is called.

Behavior of Detached Instances

While detached, any field access to a field that was not loaded throws `JDODetachedFieldAccessException`.

While detached, each detached instance has a persistent identity that can be obtained via the static `JDOHelper` method `getObjectId(Object pc)`. The version of detached instances can be obtained by the static `JDOHelper` method `getVersion(Object pc)`.

While detached, identity fields of application-identity classes might be modified by the application. These fields are marked as modified by the detached instance, but the object id of the detached instance does not change. Upon attachment, the change will be rejected if the jdo implementation does not support application identity change. See `PersistenceManagerFactory` property `javax.jdo.option.ChangeApplicationIdentity`.

Changes made to embedded instances of mutable types including persistence-capable types are tracked by the detached instance if they are replaced or modified. Changes are reflected by marking the detached instance's field as modified.

To apply changes made to instances while detached, use the `makePersistent` method with the detached instance as parameter.

12.7 Fetch Plan

A fetch plan defines rules for instantiating the loaded state for an object graph. It specifies fields to be loaded for all of the instances in the graph. Using fetch plans, users can control the field fetching behavior of many JDO APIs. A fetch plan can be associated with a `PersistenceManager` and, independently, with a `Query` and with an `Extent`.

A fetch plan also defines rules for creating the detached object graph for the detach APIs and for automatic detachment at commit with `DetachAllOnCommit` set to true.

A fetch plan consists of a number of fetch groups that are combined additively for each affected class; a fetch size that governs the number of instances of multi-valued fields retrieved by queries; a recursion-depth per field that governs the recursion depth of the object graph fetched for that field; a maximum fetch depth that governs the depth of the object graph fetched starting with the root objects; and flags that govern the behavior of detachment.

The default fetch plan contains exactly one fetch group, "default". It has a fetch size of 0, and detachment option `DETACH_LOAD_FIELDS`. The default fetch plan is in effect when the `PersistenceManager` is first acquired from the `PersistenceManagerFactory`.

With the default fetch plan in effect, the behavior of JDO 2 is very similar to the behavior of JDO 1. That is, when instances are loaded into memory in response to queries or navigation, fields in the default fetch group are loaded, and the `jdoPostLoad` callback is executed the first time an instance is fetched from the datastore. The implementation is allowed to load additional fields, as in JDO 1. Upon detachment, fields that have been loaded into the detached instances are preserved, regardless of whether they were loaded automatically by the implementation or loaded in response to application access; and fields that have not been loaded are marked in the detached instances as not loaded.

This behavior is sufficient for the most basic use case for detachment, where the detached instances are simply "data transfer objects" containing primitive fields. The detached instances can be modified in place or serialized and sent to another tier to be changed and sent back. Upon being received back, the instances can be attached and if there are no version conflicts, the changes can be applied to the datastore.

The most common use case for fetch groups is to restrict the fields loaded for an instance to the primitive values and avoid loading related instances for queries. For more control over the default behavior, the "default" fetch group can simply be redefined for specific classes. For example, a `String` field that contains a typically large document can be defined as not part of the default fetch group, and the field will be loaded only when accessed by the application. Similarly, an `Order` field

associated with OrderLine might be defined as part of the default fetch group of OrderLine, and queries on OrderLine will always load the corresponding Order instance as well. This can easily improve the performance of applications that always need the Order whenever OrderLine instances are loaded.

For explicit detachment, the parameters of the detach method are each treated as roots for the purpose of determining the detached object graph. The fetch plan is applied to each of the roots as if no other roots were also being detached. The roots and their corresponding object graphs are combined and the resulting object graph is detached in its entirety.

12.7.1 Fetch Groups

Fetch groups are used to identify the list of fields and their associated field recursion-depth for each class for which the fetch plan is applied.

Fetch groups are identified by name and apply to one or more classes. Names have global scope so the same fetch group name can be used for any number of classes. This makes it possible to specify fetch groups per PersistenceManager instead of per extent. This greatly simplifies the use of fetch groups in an application.

The default fetch group (named "default") for each class is created by the JDO implementation according to the rules in the JDO 1.0.1 specification. That is, it includes all fields that by default belong to the default fetch group (i.e. single-valued fields), and causes the jdoPostLoad method to be called the first time fields are loaded. The default fetch group may also be defined by the user in the metadata like any other fetch group, in order to make use of JDO 2 features.

The implementation must also define another fetch group named "all" for each class. The "all" group contains all fields in the class, but can be redefined by the user, for example to add recursion-depth to certain fields, or to exclude some fields from being loaded.

If a fetch plan other than the default fetch plan is active for a PersistenceManager, the behavior of several APIs changes:

- For `detachCopy` the JDO implementation must ensure that the graph specified by the active fetch groups is copied, based on the `DETACH_LOAD_FIELDS` and `DETACH_UNLOAD_FIELDS` flags.
- For `refresh`, after clearing fields in the instances, the JDO implementation uses the fetch plan to determine which fields to load from the datastore.
- For `retrieve` with `useFetchPlan` true, the implementation uses the fetch plan to determine which fields are loaded from the datastore. With `useFetchPlan` false, the implementation reverts to JDO 1 behavior, which loads all fields from the datastore; in this case, no related instances are loaded.
- When executing a query the JDO implementation loads the fields as specified in the fetch plan associated with the `Query` instance.
- When the application dereferences an unloaded field, the JDO implementation uses the current fetch plan and the load-fetch-group of the field to create the fetch strategy for the field. The specific behavior depends on whether the unloaded field is a relation to another persistence-capable class.
 - for non-relation fields, the current fetch plan is applied to the field's owning instance, and the fields in the field's load-fetch-group, plus the field itself are added to the list of fields.
 - for relation fields, the fields in the owning instance are fetched as immediately above, and additionally the instances referred by the field are loaded using the current fetch plan plus the field's load-fetch-group.

```
FetchPlan getFetchPlan();
```

This method retrieves the fetch plan associated with the `PersistenceManager`. It always returns the identical instance for the same `PersistenceManager`.

FetchGroups may be defined statically (in metadata) or dynamically (while the program is running).

12.7.2 MaxFetchDepth

When relationship fields are included in the active fetch plan, it may be possible to retrieve the entire contents of the datastore, which might not be the desired effect. To avoid this behavior, and to allow the application to control the amount of data retrieved from the datastore, the `MaxFetchDepth` property of the fetch plan is used. The `MaxFetchDepth` is the depth of references (fields of relationship types) to instantiate, starting with the root instances.

Setting `MaxFetchDepth` to 1 limits the instances retrieved to the root instances and instances directly reachable from the root instances through a field in the fetch plan for the root class(es). Setting `MaxFetchDepth` to 0 has no meaning, and `JDOUserException` will be thrown. Setting `MaxFetchDepth` to -1 does not limit the instances retrieved via relationship fields in the fetch plan. Caution should be exercised to avoid retrieving more instances than desired.

For example, assume the class `Employee` defines field `dept` of type `Department`, and class `Department` defines field `comp` of type `Company`. When a query for `Employee` is executed, with a fetch plan that includes `Employee.dept` and `Department.comp` and with `MaxFetchDepth` set to 1, the Departments referenced by Employees returned from the query are instantiated, but the `Company` field is not instantiated. With the `MaxFetchDepth` set to 2, Departments and their corresponding Companies are instantiated for the `Employee` instances returned by the query.

12.7.3 Root instances

Root instances are parameter instances for `retrieve`, `detachCopy`, and `refresh`; and result instances for queries. Root instances for `DetachAllOnCommit` are defined explicitly by the user via the `FetchPlan` property `DetachmentRoots` or `DetachmentRootClasses`. If not set explicitly, the detachment roots consist of the union of all root instances of methods executed since the last commit or rollback.

Once set explicitly, the detachment roots will not be changed until commit, at which time the detachment roots will be set to the empty collection.

Detachment roots and root classes are ignored for all `FetchPlans` except those associated directly with the `PersistenceManager`. Detachment root classes are never changed by the JDO implementation; they are completely controlled by the user. Detachment root classes is an empty `Class[]` when the `PersistenceManager` is first acquired from the `PersistenceManagerFactory`.

12.7.4 Recursion-depth

For object models with bidirectional relationships or self-referencing relationships, it is useful to limit the depth of the object graph retrieved through these relationships recursively. The recursion-depth attribute of the field element is used for this purpose. The recursion-depth for a relationship field specifies the number of times an instance of the same class, subclass, or superclass can be fetched via traversing this field.

A value of negative 1 (or any negative value) means that the recursion-depth is not limited by traversing this field. If a field is defined in multiple fetch groups, the recursion-depth is the largest of the values specified, treating any negative number as a very large positive number. If not specified in any fetch group or in the base field definition, the default is 1. A value of 0 means that this field is not traversed at all, effectively removing the field from the fetch group.

For example, assume a class `Directory` with a field `parent` of type `Directory` and a field `children` of type `Set<Directory>`, and assume the recursion-depth of the `parent` field is

set to negative 1 and the recursion-depth of the children field is set to 2. When a query for a Directory is executed, all parents of the selected Directory instances will be retrieved, and all of the parents' parents until a parent is found with a null parent. Additionally, all children of the selected Directory will be retrieved and all children of the children of the selected Directory.

12.7.5 The FetchPlan interface

Fetch groups are activated using methods on the interface FetchPlan. PersistenceManager, Extent, and Query have getFetchPlan() methods. When a Query or Extent is created from a persistence manager, its fetch plan is initialized to the same settings as that of the persistence manager. Subsequent modifications of the Query or Extent fetch plan are localized (not reflected in the fetch plan of the persistence manager). Similarly, subsequent modifications of the fetch plan of the persistence manager are not reflected in any existing Query or Extent.

Mutating FetchPlan methods return the fetch plan instance to allow method chaining.

```
package javax.jdo;
public interface FetchPlan {
    String DEFAULT = "default";
    String ALL = "all";
    int FETCH_SIZE_GREEDY = -1;
    int FETCH_SIZE_OPTIMAL = 0;
    int DETACH_LOAD_FIELDS = 1;
    int DETACH_UNLOAD_FIELDS = 2;
    /** Add the fetchgroup to the set of active fetch groups. Duplicate names will be
     * removed.*/
    FetchPlan addGroup(String fetchGroupName);
    /** Remove the fetch group from the set active fetch groups. */
    FetchPlan removeGroup(String fetchGroupName);
    /** Remove all active groups, including the default fetch group. */
    FetchPlan clearGroups();
    /** Return an immutable copy of the names of all currently active fetch groups. */
    Set getGroups();
    /** Set a Collection of group names to replace the current groups. Duplicate names
     * will be removed.*/
    FetchPlan setGroups(Collection fetchGroupNames);
    /** Set an array of group names to replace the current groups. Duplicate names will
     * be removed.*/
    FetchPlan setGroups(String... fetchGroupNames);
    /** Set a single group to replace the current groups. */
    FetchPlan setGroup(String fetchGroupName);
    /** Set the roots for DetachAllOnCommit */
    FetchPlan setDetachmentRoots(Collection roots);
    /** Get the roots for DetachAllOnCommit */
    Collection getDetachmentRoots();
    /** Set the roots for DetachAllOnCommit */
    FetchPlan setDetachmentRootClasses(Class... rootClasses);
    /** Get the roots for DetachAllOnCommit */
    Class[] getDetachmentRootClasses();
    /** Set the maximum fetch depth. */
    FetchPlan setMaxFetchDepth(int fetchDepth);
    /** Get the maximum fetch depth. */
    int getMaxFetchDepth();
    /** Set the fetch size for large result set support. */
    FetchPlan setFetchSize(int fetchSize);
    /** Return the fetch size; 0 if not set; -1 for greedy fetching. */
    int getFetchSize();
    /** Set detachment options */
    FetchPlan setDetachmentOptions(int options);
    /** Return the detachment options */
    int getDetachmentOptions();
```

```
int getDetachmentOptions();
```

The `getGroups` method returns a collection of names. After a call to `clearGroups` this method returns an empty collection. It is legal to remove the default fetch group explicitly via `pm.getFetchPlan().removeGroup("default")`, or to use `setGroups()` with a collection that does not contain "default". This makes it possible to have only a given fetch group active without the default fetch group. If no fetch groups are active then a collection with no elements is returned. In this case, loading an instance might not result in loading the default fetch group fields and the `jdoPostLoad` method will only be called if there is an active fetch group that declares `post-load="true"`.

The fetch size allows users to explicitly control the number of instances retrieved from queries. A positive value is the number of result instances to be fetched. A value of `FETCH_SIZE_GREEDY` indicates that all results should be obtained immediately. A value of `FETCH_SIZE_OPTIMAL` indicates that the JDO implementation should try to optimize the fetching of results.

Note that the graph and fields specified by a FetchPlan is strictly the union of all the active fetch groups not based on any complicated set mathematics. So, if a field `f1` is in fetch groups A and B, and both A and B are added to the FetchPlan, and subsequently B is removed from the active fetch groups and the instance is loaded, then the field `f1` will be loaded, because it is in fetch group A.

Examples:

```
pm = pmf.getPersistenceManager();
FetchPlan fp = pm.getFetchPlan();

fp.addGroup("detail").addGroup("list");
// prints [default, detail, list]
System.out.println(fp.getGroups());
// refreshes fields in any of default+detail+list
pm.refresh(anInstance);

fp.clearGroups();
// prints []
System.out.println(fp.getGroups());
pm.refresh(anInstance); // doesn't do anything

fp.addGroup("list");
// prints [list]
System.out.println(fp.getGroups());
// refreshes fields in list only
pm.refresh(anInstance);
```

When an instance is loaded using `getObjectById`, a Query is executed, or an Extent is iterated, the implementation may choose to use the active fetch groups to prefetch data. If an instance being loaded does not have a fetch group with the same name as any of the active groups, and the semantics of the method allow returning a hollow instance, then it may be loaded as hollow. If it has more than one of the active groups then the union of fields in all active groups is used.

Instances loaded through field navigation behave in the same way as for `getObjectById` except that an additional fetch group may be specified for the field in the metadata using the new "load-fetch-group" attribute. If present the load-fetch-group is considered active just for the loading of the field. This can be used to load several fields together when one of them is touched. The field touched is loaded even if it is not in the load-fetch-group.

For the refresh and retrieve methods, the implementation must ensure that only the graph specified by the active fetch groups is refreshed or retrieved; i.e. these operations will recursively refresh or retrieve the instances and fields in the graph covered by the active fetch groups. The refreshed or

retrieved graph must not contain extra instances but extra fields may be refreshed for an instance in the graph.

12.7.6 Defining fetch groups

Fetch groups are defined in the metadata for a class or interface, or dynamically with methods on `PersistenceManager` and `PersistenceManagerFactory`.

```
<!ELEMENT fetch-group (extension*,(fetch-group|field|property)*,extension*)>
```

```
<!ATTLIST fetch-group name CDATA #REQUIRED>
<!ATTLIST fetch-group post-load (true|false) #IMPLIED>
<!ATTLIST field recursion-depth CDATA #IMPLIED>
<!ATTLIST property recursion-depth CDATA #IMPLIED>
```

The `post-load` attribute on the `fetch-group` element indicates whether the `jdoPostLoad` callback will be made when the fetch group is loaded. It defaults to false, for all fetch groups except the default fetch group, on which it defaults to true. The callback will be called if any field of an instance is loaded when any fetch group is active that contains the `post-load` attribute set to true.

The `name` attribute on a field or property element contained within a `fetch-group` element is the name of a member (field or property) in the enclosing type (class or interface), or a dot-separated expression identifying a member reachable from the type by navigating a reference, a collection, or a map. For maps of persistence-capable types "`#key`" or "`#value`" may be appended to the name of the map member to navigate the key or value respectively (e.g. to include a member of the key type or value type in the fetch group).

For collection and arrays of persistence-capable types, "`#element`" may be appended to the name of the member to navigate the element. This is optional; if omitted for collections and arrays, `#element` is assumed.

Recursive fetch group references are controlled by the `recursion-depth` attribute on a contained `field` or `property` element of a `fetch-group`. A `recursion-depth` of negative 1 (or any negative number) will fetch the whole graph of instances reachable from this member. A value of 0 means that this member is not traversed at all, effectively removing the member from the fetch group. The default is 1, meaning that only the instance directly reachable from this member is fetched.

A contained `fetch-group` element indicates that the named group is to be included in the group being defined. Nested fetch group elements are limited to only the `name` attribute and no contained elements. That is, it is not permitted to nest entire fetch group definitions. If there are two definitions for a reference, collection or map member (due to fetch groups including other fetch groups) then the union of the fetch groups involved is used. If one or more depths have been specified then the largest depth is used unless one of the depths has not been specified (unlimited overrides other depth specifications).

```
public class Person {
    private String name;
    private Address address;
    private Set children;
}

public class Address {
    private String street;
    private String city;
    private Country country;
```

```
}

public class Country {
    private String code;
    private String name;
}

<class name="Person" ...>
...
<!-- name + address + country code -->
<fetch-group name="detail">
    <fetch-group name="default"/>
    <field name="address"/>
    <field name="address.country.code"/>
</fetch-group>

<!-- name + address + country code + same for children -->
<fetch-group name="detail+children">
    <fetch-group name="detail"/>
    <field name="children"/>
</fetch-group>

<!-- name + address + country code + names of children -->
<fetch-group name="detail+children-names">
    <fetch-group name="detail"/>
    <field name="children#element.name"/>
</fetch-group>

<!-- name + address + country code + list fg of children -->
<fetch-group name="detail+children-list">
    <fetch-group name="detail"/>
    <field name="children" fetch-group="list"/>
</fetch-group>

</class>
```

Here is a map example:

```
public class Node {
    private String name;
    private Map edges; // Node -> EdgeWeight
}

public class EdgeWeight {
    private int weight;
}

<class name="Node" ...>
...
<fetch-group name="neighbour-weights">
    <field name="edges#key.name"/>
    <field name="edges#value"/>
</fetch-group>
<fetch-group name="neighbours">
    <field name="edges"/>
</fetch-group>
<fetch-group name="whole-graph">
    <field name="edges" recursion-depth="-1"/>
</fetch-group>
</class>
```

12.7.7 Defining Fetch Groups Dynamically

Fetch groups can be defined dynamically. Two distinct use-cases are supported:

- fetch groups that are local to a `PersistenceManager` and affect only operations on the specific `PersistenceManager`; these are called persistence manager scope;
- fetch groups that are global to a `PersistenceManagerFactory` and affect operations on all `PersistenceManagers` associated with the `PersistenceManagerFactory`; these are called persistence manager factory scope.

Persistence Manager Factory Scoped Fetch Groups

To support persistence manager factory scoped fetch groups, a factory method is defined on `PersistenceManagerFactory`:

```
FetchGroup getFetchGroup(Class cls, String groupName);
```

This method returns a `FetchGroup` instance that represents the named fetch group associated with the persistence-capable type `cls`. If there is already an active fetch group with the same class and name, a modifiable copy of the fetch group is returned. If there is not an active fetch group with the same class and name, a new modifiable fetch group instance is returned. The returned fetch group is not active, and any changes made to it will have no immediate effect.

The fetch group instance can be modified by adding and removing members, adding and removing groups of members of specific categories, and setting the recursion-depth of members. In order to make the fetch group instances active, use the method defined on `PersistenceManagerFactory`:

```
void addFetchGroups(FetchGroup... groups);
```

This method updates the active fetch groups in the `PersistenceManagerFactory`. The `PersistenceManagerFactory` maintains a set of active fetch groups. Equality of fetch groups is determined by a combination of the persistent type and fetch group name. Parameter fetch groups that are not already active are made active. Parameter fetch groups that have an equal active fetch group replace the corresponding fetch group.

Fetch groups can be removed from the active set by calling another method on `PersistenceManagerFactory`:

```
void removeFetchGroups(FetchGroup... groups);
```

This method updates the active fetch groups in the `PersistenceManagerFactory`. Active fetch groups that match a parameter fetch group are removed from the persistence manager factory scope.

Persistence Manager Scoped Fetch Groups

To support persistence manager scoped fetch groups, a factory method is defined on `PersistenceManager`:

```
FetchGroup getFetchGroup(Class cls, String groupName);
```

This method returns a `FetchGroup` instance that represents the named fetch group associated with the persistence-capable type `cls`. If there is already a modifiable fetch group of the same type and name in persistence manager scope, that instance is returned. If not, a new modifiable fetch group is created.

The fetch group instance can be modified by adding and removing members, adding and removing groups of members of specific categories, and setting the recursion-depth of members. The returned `FetchGroup` is immediately made active so changes to its state will affect operations of the `PersistenceManager` from which it was obtained. For example, if the fetch plan includes the fetch

group extended, getting and modifying a fetch group whose class is `Employee` and group name is extended will affect `PersistenceManager` operations involving the `Employee` class.

Interface FetchGroup

```
public interface FetchGroup {
```

To facilitate modifying fetch groups, categories of members are defined:

- `default`: the default category contains only the default fetch group members.
- `relationship`: the relationship category contains all relationship type fields, including embedded relationships
- `multivalued`: the multivalued category includes members of all multi-valued types, including `Collection`, `array`, and `Map` types of basic and relationship types
- `basic`: the basic category includes members of all primitive and immutable object class types as defined in section 6.4 of the specification, including `String`, `Locale`, `Currency`, `BigDecimal`, and `BigInteger`; as well as `Date` and its jdbc subtypes; and `Enum` types
- `all`: the all category includes all members

```
public static final String DEFAULT = "default";
public static final String RELATIONSHIP = "relationship";
public static final String MULTIVALUED = "multivalued";
public static final String BASIC = "basic";
```

```
public static final String ALL = "all";
int hashCode();
```

The hash code should combine both the class and fetch group name. The hash codes for two equal instances (fetch group instances representing the same persistent type and the same fetch group name) must be identical.

```
boolean equals(Object other);
```

The `equals` method must compare the class for identity and the fetch group name for equality.

```
String getName();
```

Get the name of this `FetchGroup`. The name is set only in the factory method.

```
Class getType();
```

Get the persistent type (class or interface) of this `FetchGroup`. The persistent type is set only in the factory method.

```
boolean getPostLoad();
```

Get the post-load property of this `FetchGroup`.

```
FetchGroup setPostLoad(boolean postLoad);
```

Set the post-load property of this `FetchGroup`.

```
FetchGroup addMember(String memberName);
```

Add the named member (field or property) to the set of members in this `FetchGroup`. The parameter is the name of a member to add to the `FetchGroup`. `JDOUserException` is thrown if the parameter is not the name of a member of the persistent type.

```
FetchGroup addMembers(String... memberNames);
```

Add the member (field or property) to the set of members in this FetchGroup. Duplicates are ignored. The parameter is an array of names of members to add to the FetchGroup. JDOUserException is thrown if any element of the parameter is not the name of a member.

```
FetchGroup removeMember(String memberName);
```

Remove the member (field or property) from the set of members in this FetchGroup. JDOUserException is thrown if the parameter is not the name of a member of the persistent type.

```
FetchGroup removeMembers(String... memberNames);
```

Remove the member (field or property) from the set of members in this FetchGroup. Duplicates in the parameter list are eliminated before removing them from the membership. JDOUserException is thrown if any element of the parameter is not the name of a member.

```
FetchGroup addCategory(String categoryName);
```

Add the members (fields or properties) of the named category to the set of members in this FetchGroup. This method first resolves the category name to a set of members and then adds the members as if addMembers was called. After this method executes, the category is not remembered.

```
FetchGroup removeCategory(String categoryName);
```

Remove the members (fields or properties) of the named category from the set of members in this FetchGroup. This method first resolves the category name to a set of members and then removes the members as if removeMembers was called. After this method executes, the category is not remembered.

```
FetchGroup setRecursionDepth(String memberName, int recursionDepth);
```

Set the recursion-depth for this member. The default is 1. A value of 0 means don't fetch the member (as if the member were omitted entirely). A value of -1 means fetch all instances reachable via this member.

```
int getRecursionDepth(String memberName);
```

Get the recursion-depth for this member.

```
Set getMembers();
```

Return an immutable Set of String containing the names of all members in the fetch group. The Set is a copy of the currently defined members and will not change based on subsequent changes to the membership in the FetchGroup.

```
FetchGroup setUnmodifiable();
```

Make this FetchGroup unmodifiable. If already unmodifiable, this method has no effect.

```
boolean isUnmodifiable();
```

Return whether this FetchGroup is unmodifiable. If so, methods that would modify the fetch group throw JDOUserException.

```
}
```

12.8 Flushing instances

```
void flush();
```

This method flushes all dirty, new, and deleted instances to the datastore. It has no effect if a transaction is not active.

If a datastore transaction is active, this method synchronizes the cache with the datastore and reports any exceptions.

If an optimistic transaction is active, this method obtains a datastore connection and synchronizes the cache with the datastore using this connection. The connection obtained by this method is held until the end of the transaction.

```
void checkConsistency();
```

This method validates the cache with the datastore. It has no effect if a transaction is not active.

If a datastore transaction is active, this method verifies the consistency of instances in the cache against the datastore. An implementation might flush instances as if flush() were called, but it is not required to do so.

If an optimistic transaction is active, this method obtains a datastore connection and verifies the consistency of the instances in the cache against the datastore. If any inconsistencies are detected, a JDOOptimisticVerificationException is thrown. This exception contains a nested JDOOptimisticVerificationException for each object that failed the consistency check. No datastore resources acquired during the execution of this method are held beyond the scope of this method.

12.9 Transaction completion

Transaction completion management is delegated to the associated `Transaction` instance .

12.10 Multithreaded Synchronization

The application might require the `PersistenceManager` to synchronize internally to avoid corruption of data structures due to multiple application threads. This synchronization is not required when the flag `Multithreaded` is set to `false`.

```
void setMultithreaded (boolean flag);  
boolean getMultithreaded();
```

NOTE: When the `Multithreaded` flag is set to `true`, there is a synchronization issue with `jdoFlags` values `READ_OK` and `READ_WRITE_OK`. Due to out-of-order memory writes, there is a chance that a value for a field in the default fetch group might be incorrect (stale) when accessed by a thread that has not synchronized with the thread that set the `jdoFlags` value. Therefore, it is recommended that a JDO implementation not use `READ_OK` or `READ_WRITE_OK` for `jdoFlags` if `Multithreaded` is set to `true`.

The application may choose to perform its own synchronization, and indicate this to the implementation by setting the `Multithreaded` flag to `false`. In this case, the JDO implementation is not required to implement any additional synchronizations, although it is permitted to do so.

12.11 User associated objects

The application might manage `PersistenceManager` instances by using an associated object for bookkeeping purposes. These methods allow the user to manage the associated object.

```
void setUserObject (Object o);  
Object getUserObject ();
```

The parameter is not inspected or used in any way by the JDO implementation. For applications where multiple users need to access their own user objects, the following methods allow user objects to be stored and retrieved by key. The values are not examined by the `PersistenceManager`.

There are no restrictions on values. Keys must not be null. For proper behavior, the keys must be immutable (e.g. `java.lang.String`, `java.lang.Integer`, etc.) or the keys' identity (to the extent that it

modifies the behavior of equals and hashCode methods) must not change while a user object is associated with the key. This behavior is not enforced by the PersistenceManager.

```
Object putUserObject(Object key, Object value);
```

This method models the put method of Map. The current value associated with the key is returned and replaced by the parameter value. If the parameter value is null, the implementation may remove the entry from the table of managed key/value pairs.

```
Object removeUserObject(Object key);
```

This method models the remove method of Map. The current value associated with the key is returned and removed.

```
Object getUserObject(Object key);
```

This method models the get method of Map. The current value associated with the key is returned. If the key is not found in the table, null is returned.

12.12 PersistenceManagerFactory

The application might need to get the PersistenceManagerFactory that created this PersistenceManager. If the PersistenceManager was created using a constructor, then this call returns null.

```
PersistenceManagerFactory getPersistenceManagerFactory();
```

This method returns the PersistenceManagerFactory that created this PersistenceManager.

12.13 ObjectId class management

In order for the application to construct instances of the ObjectId class, there is a method that returns the ObjectId class given the persistence capable class.

```
Class getObjectIdClass (Class pcClass);
```

This method returns the class of the object id for the given class. This method returns the class specified by the application for persistence capable classes that use application (primary key) JDO identity. It returns the implementation-defined class for persistence-capable classes that use datastore identity. If the parameter class is not persistence-capable, or the parameter is null, null is returned. If the object-id class defined in the metadata for the parameter class is abstract then null is returned.

If the implementation does not support application identity, and the class is defined in the jdo metadata to use application identity, then null is returned.

```
Object newObjectIdInstance (Class pcClass, Object key);
```

This method returns an object id instance corresponding to the pcClass and key arguments. A String argument might have been the result of executing `toString` on an object id instance. The key argument is the value of the key field for single field identity.

This method is portable for datastore identity and application identity.

12.14 Sequence

The JDO metadata defines named sequence value object generators, or simply, sequences. A sequence implements the javax.jdo.datastore.Sequence interface.

The behavior of the sequence with regard to transactions and rolling over maximum values is specified in the metadata.

Note that there is no portable way for a user-defined sequence to implement the Sequence interface. In particular, the getName method might not return the name of the sequence, and the transactional behavior of the sequence as specified by the user in metadata might not be implemented. A future version of the specification might add a sequence factory spi to enable portable user-defined sequences.

The PersistenceManager provides a method to retrieve a Sequence by name.

```
Sequence getSequence(String name);
```

If the named sequence does not exist, JDOUserException is thrown.

The name is the scoped name of the sequence , which uses the standard Java package naming. For example, a sequence might be named “com.acme.hr.EmployeeSequence”.

```
package javax.jdo.datastore;  
public interface Sequence {
```

```
    String getName();
```

This method returns the fully qualified name of the Sequence.

```
    Object next();
```

This method returns the next sequence value object. The sequence might be protected by transactional semantics, in which case the sequence value object will be reused if the transaction in which the sequence value object was obtained rolls back.

```
    void allocate(int additional);
```

This method is a hint to the implementation that the application needs the additional number of sequence value objects in short order. There is no externally visible behavior of this method. It is used to potentially improve the efficiency of the algorithm of obtaining additional sequence value objects.

```
    Object current();
```

This method returns the current sequence value object if it is available. It is intended to return a sequence value object previously used. The implementation might choose to return null for all cases or for any cases where a current sequence value object is not available.

```
    long nextValue();
```

This method returns the next sequence value as a long if it is available and able to be converted to a number. It is equivalent to ((Long)next()).longValue().

```
    long currentValue();
```

This method returns the current sequence value as a long if it is available and able to be converted to a number. It is equivalent to ((Long)current()).longValue().

```
}
```

12.15 Life-cycle callbacks

In order to minimize the impact on domain classes, the instance callbacks can be defined to use a life-cycle listener pattern instead of having the domain class implement the callback interface(s).

```
package javax.jdo.listener;  
public interface InstanceLifecycleListener {  
}  
public interface CreateLifecycleListener  
extends InstanceLifecycleListener {
```

```
void postCreate(InstanceLifecycleEvent event);
}
```

This method is called whenever a persistent instance is created, during makePersistent. It is called after the instance transitions to persistent-new.

```
package javax.jdo.listener;
public interface LoadLifecycleListener
    extends InstanceLifecycleListener {
void postLoad(InstanceLifecycleEvent event);
}
```

This method is called whenever a persistent instance is loaded. It is called after the jdoPostLoad method is invoked on the instance.

```
package javax.jdo.listener;
public interface StoreLifecycleListener
    extends InstanceLifecycleListener {
void preStore(InstanceLifecycleEvent event);
}
```

This method is called whenever a persistent instance is stored, for example during flush or commit. It is called before the jdoPreStore method is invoked on the instance. An object identity for a persistent-new instance might not have been assigned to the instance when this callback is invoked.

```
void postStore(InstanceLifecycleEvent event);
}
```

This method is called whenever a persistent instance is stored, for example during flush or commit. It is called after the jdoPreStore method is invoked on the instance. An object identity for a persistent-new instance must have been assigned to the instance when this callback is invoked.

```
package javax.jdo.listener;
public interface ClearLifecycleListener
    extends InstanceLifecycleListener {
void preClear(InstanceLifecycleEvent event);
}
```

This method is called whenever a persistent instance is cleared, for example during afterCompletion. It is called before the jdoPreClear method is invoked on the instance.

```
void postClear(InstanceLifecycleEvent event);
```

This method is called whenever a persistent instance is cleared, for example during afterCompletion. It is called after the jdoPreClear method is invoked on the instance and the fields have been cleared by the JDO implementation.

```
package javax.jdo.listener;
public interface DeleteLifecycleListener
    extends InstanceLifecycleListener {
void preDelete(InstanceLifecycleEvent event);
}
```

This method is called whenever a persistent instance is deleted, during deletePersistent. It is called before the state transition and before the jdoPreDelete method is invoked on the instance.

```
void postDelete(InstanceLifecycleEvent event);
```

```
}
```

This method is called whenever a persistent instance is deleted, during deletePersistent. It is called after the jdoPreDelete method is invoked on the instance and after the state transition.

```
package javax.jdo.listener;  
public interface DirtyLifecycleListener  
    extends InstanceLifecycleListener {  
    void preDirty(InstanceLifecycleEvent event);  
}
```

This method is called whenever a persistent clean instance is first made dirty, during an operation that modifies the value of a persistent or transactional field. It is called before the field value is changed. During this method, the instance responds false to isDirty. During this method, fields in the source instance and others might be changed, but this method will only be invoked once until the instance is no longer dirty.

```
void postDirty(InstanceLifecycleEvent event);  
}
```

This method is called whenever a persistent clean instance is first made dirty, during an operation that modifies the value of a persistent or transactional field. It is called after the field value was changed. During this method, the instance responds true to isDirty. During this method, fields in the source instance and others might be changed, but this method will only be invoked once until the instance is no longer dirty.

```
package javax.jdo.listener;  
public interface DetachLifecycleListener  
    extends InstanceLifecycleListener {  
    void preDetach(InstanceLifecycleEvent event);  
}
```

This method is called before a persistent instance is copied for detachment. It is called before the jdoPreDetach callback.

```
void postDetach(InstanceLifecycleEvent event);  
}
```

This method is called whenever a persistent instance is copied for detachment. The source instance is the detached copy; the target instance is the persistent instance. It is called after the jdoPostDetach callback on the detached copy.

```
package javax.jdo.listener;  
public interface AttachLifecycleListener  
    extends InstanceLifecycleListener {  
    void preAttach(InstanceLifecycleEvent event);  
}
```

This method is called before a detached instance is attached, via the makePersistent method. The source instance is the detached instance. This method is called before the corresponding jdoPreAttach on the detached instance.

```
void postAttach(InstanceLifecycleEvent event);  
}
```

This method is called after a detached instance is attached. The source instance is the corresponding persistent instance in the cache; the target instance is the detached instance. This method is called after the corresponding jdoPostAttach on the persistent instance.

InstanceLifecycleEvent

This class is provided as part of the javax.jdo.listener package.

Note that although InstanceLifecycleEvent inherits Serializable interface from EventObject, it is not intended to be Serializable. Appropriate serialization methods are implemented to throw NotSerializableException.

```
package javax.jdo.listener;
public class InstanceLifecycleEvent
    extends java.util.EventObject {
    static final int CREATE = 0;
    static final int LOAD = 1;
    static final int STORE = 2;
    static final int CLEAR = 3;
    static final int DELETE = 4;
    static final int DIRTY = 5;
    static final int DETACH = 6;
    static final int ATTACH = 7;
    int getEventType();
```

This method returns the event type that triggered the event.

```
InstanceLifecycleEvent(int type, Object source);
```

This constructor creates an instance with the type, and source object.

```
InstanceLifecycleEvent(int type, Object source, Object target);
```

This constructor creates an instance with the type, source, and target objects.

```
Object getSource();
```

This method returns the object for which the event was triggered. This method is inherited from the EventObject class.

```
Object getTarget();
```

This method returns the “other” object associated with the event. Specifically, the target object is the detached instance in the case of postAttach, and the persistent instance in the case of postDetach. The target must be null for all other cases.

```
Object getPersistentInstance();
```

This method returns the persistent instance for which the event was triggered. This method is a convenience method that returns the source or target depending on the event.

```
Object getDetachedInstance();
```

This method returns the detached instance for which the event was triggered. This method is a convenience method that returns the source or target depending on the event.

```
}
```

```
void addInstanceLifecycleListener (InstanceLifecycleListener
    listener, Class... classes);
```

This PersistenceManager method adds the listener to the list of lifecycle event listeners. The classes parameter identifies all of the classes of interest. If the classes parameter is specified as null, events for all persistent classes and interfaces are generated. If the classes specified have persistence-capable subclasses, all such subclasses are registered implicitly.

The listener will be called for each event for which it implements the corresponding listener interface.

```
void removeInstanceLifecycleListener (InstanceLifecycleListener  
listener);
```

This PersistenceManager method removes the listener from the list of event listeners.

12.16 Access to internal datastore connection

In order for the application to perform some datastore-specific functions, such as to execute a query that is not directly supported by JDO, applications might need access to the datastore connection used by the JDO implementation. This method returns a wrapped connection that can be cast to the appropriate datastore connection and used by the application.

The capability to get the datastore connection is indicated by the optional feature string javax.jdo.option.GetDataStoreConnection.

```
package javax.jdo.datastore;  
public interface JDOConnection {  
    Object getNativeConnection();  
    void close();  
}  
JDOConnection getDataStoreConnection();
```

If this method is called while a JDO transaction is active, it is equivalent to calling `getDataStoreConnection(true)`. If this method is called outside an active JDO transaction, it is equivalent to calling `getDataStoreConnection(false)`.

```
JDOConnection getDataStoreConnection(boolean enlist);
```

With the enlist parameter false, the native connection returned by `getNativeConnection` will not be enlisted in any native transaction.

With the enlist parameter true, and there is no active JDO transaction, a `JDOUserException` is thrown. With the enlist parameter true, with an active JDO transaction, the native connection returned by `getNativeConnection` will be enlisted in the native transaction being used by the JDO transaction. There is always a native transaction in the case of a JDO datastore transaction. If there is an active optimistic JDO transaction, and a native transaction has not yet begun, a native transaction is begun before returning the `JDOConnection`.

An enlisted `JDOConnection` must be returned to the JDO implementation by the application by calling its `close` method, prior to calling any JDO method or performing any action on any persistent instance that might require the JDO implementation to use a connection. If the object has not been returned and the JDO implementation needs a connection, a `JDOUserException` is thrown. The object is returned to the JDO implementation by calling the `close` method on the object.

For JDOR implementations

- the `JDOConnection` obtained by `getDataStoreConnection` implements `java.sql.Connection`.

- The application returns a JDBC Connection to the JDO implementation by calling its `close()` method.

SQL Portability

For portability, a JDBC-based JDO implementation will return an instance that implements `java.sql.Connection`. The instance will throw an exception for any of the following method calls: `commit`, `getMetaData`, `releaseSavepoint`, `rollback`, `setAutoCommit`, `setCatalog`, `setHoldability`, `setReadOnly`, `setSavepoint`, `setTransactionIsolation`, and `setTypeMap`.

12.17 Server Date

```
java.util.Date getServerDate();
```

Return a Date instance corresponding to the UTC Date as seen by the server.

Time skew is a phenomenon in which machines connected together in client/server configurations might have clocks that are not perfectly synchronized, and the time as seen by different clients might differ. In order for the application to avoid time skew, this method can be used to acquire a Date instance corresponding to the UTC Date as seen by the server. Clients using this method can order their operations according to a single time source.

The underlying implementation should return instances of `java.sql.Timestamp` for data-stores that support nanosecond-precision of date-time values.

Implementations use the setting of the server time zone to prepare a Date instance that represents UTC time on the server. See “`ServerTimeZoneID`” on page 100.

12.18 Serialization

Serializing or externalizing a persistence manager is an optional feature of a jdo implementation. An implementation of `PersistenceManager` (including `PersistenceManager` proxy) is declared as implementing `Serializable` or `Externalizable`, and the corresponding `PersistenceManagerFactory` is also declared as implementing `Serializable` or `Externalizable`, or neither is. In this section, serialization refers to both serialization and externalization.

Serializing a persistence manager works in conjunction with serializing other state, independent of the persistence manager. A persistence manager whose `writeObject` or `writeExternal` method is called must therefore not assume that it is the root object of serialization.

When serialized, a persistence manager must write out its own state as well as the state of each of its managed instances. It must write a reference to its corresponding persistence manager factory sufficient to locate or create it when restored. It must write the life cycle state of all instances that have not been garbage collected. It must write the before image of dirty instances in order to restore these instances later.

Serialization must only be done when there is no datastore transaction enlisted. That is, a datastore transaction must not be active; and if an optimistic transaction is active, `flush` must not have been called. If either of these conditions exists, `JDOUserException` is thrown.

13 Transactions and Connections

This chapter describes the interactions among JDO instances, JDO Persistence Managers, datastore transactions, and datastore connections.

13.1 Overview

Operations on persistent JDO instances at the user's choice might be performed in the context of a transaction. That is, the view of data in the datastore is transactionally consistent, according to the standard definition of ACID transactions:

- atomic --within a transaction, changes to values in JDO instances are all executed or none is executed
- consistent -- changes to values in JDO instances are consistent with changes to other values in the same JDO instance
- isolated -- changes to values in JDO instances are isolated from changes to the same JDO instances in different transactions
- durable -- changes to values in JDO instances survive the end of the VM in which the changes were made

13.2 Goals

The JDO transaction and connection contracts have the following goals.

- JDO implementations might span a range of small, embedded systems to large, enterprise systems
- Transaction management might be entirely hidden from class developers and application components, or might be explicitly exposed to class and application component developers.

13.3 Architecture: PersistenceManager, Transactions, and Connections

An instance of an object supporting the `PersistenceManager` interface represents a single user's view of persistent data, including cached persistent instances across multiple serial datastore transactions.

There is a one-to-one relationship between the `PersistenceManager` and the `Transaction`. The `Transaction` interface is isolated because of separation of concerns. The methods could have been added to the `PersistenceManager` interface.

The `javax.jdo.Transaction` interface provides for management of transaction options and, in the non-managed environment, for transaction completion. It is similar in functionality to `javax.transaction.UserTransaction`. That is, it contains begin, commit, and rollback methods used to delimit transactions.

Connection Management Scenarios

- single connection: In the simplest case, the PersistenceManager directly connects to the datastore and manages transactional data. In this case, there is no reason to expose any Connection properties other than those needed to identify the user and the data source. During transaction processing, the Connection will be used to satisfy data read, write, and transaction completion requests from the PersistenceManager.
- connection pooling: In a slightly more complex situation, the PersistenceManagerFactory creates multiple PersistenceManager instances which use connection pooling to reduce resource consumption. The PersistenceManagers are used in single datastore transactions. In this case, a pooling connection manager is a separate component used by the PersistenceManager instances to effect the pooling of connections. The PersistenceManagerFactory will include a reference to the connection pooling component, either as a JNDI name or as an object reference. The connection pooling component is separately configured, and the PersistenceManagerFactory simply needs to be configured to use it.
- distributed transactions: An even more complex case is where the PersistenceManager instances need to use connections that are involved in distributed transactions. This case requires coordination with a Transaction Manager, and exposure of the XAResource from the datastore Connection. JDO does not specify how the application coordinates transactions among the PersistenceManager and the Transaction Manager.
- managed connections: The last case to consider is the managed environment, where the PersistenceManagerFactory uses a datastore Connection whose transaction completion is managed by the application server. This case requires the datastore Connection to implement the J2EE Connector Architecture and the PersistenceManager to use the architected interfaces to obtain a reference to a Connection.

The interface between the JDO implementation and the Connection component is not specified by JDO. In the non-managed environment, transaction completion is handled by the Connection managed internally by the Transaction. In the managed environment, transaction completion is handled by the XAResource associated with the Connection. In both cases, the PersistenceManager implementation is responsible for setting up the appropriate interface to the Connection infrastructure.

Native Connection Management

If the JDO implementation supplies its own resource adapter implementation, this is termed native connection management. For use in a managed environment, the association between Transaction and Connection must be established using the J2EE Connector Architecture [see Appendix A reference 4]. This is done by the JDO implementation implementing the javax.resource.ManagedConnectionFactory interface.

When used in a non-managed environment, with non-distributed transaction management (local transactions) the application can use the PersistenceManagerFactory. But if distributed transaction management is required, the application needs to supply an implementation of javax.resource.ManagedConnectionFactory interface. This interface provides the infrastructure to enlist the XAResource with the Transaction Manager used in the application.

Non-native Connection Management

If the JDO implementation uses a third party Connection interface, then it can be used in a managed environment only if the third party Connection supports the J2EE Connector Architecture. In this

case, the `PersistenceManagerFactory` property `ConnectionFactory` is used to allow the application server to manage connections.

In the non-managed case, non-distributed transaction management can use the `PersistenceManagerFactory`, as above. But if distributed transaction management is required, the application needs to supply an implementation of `javax.resource.ConnectionManager` interface to be used with the application's implementation of the Connection management.

Optimistic Transactions

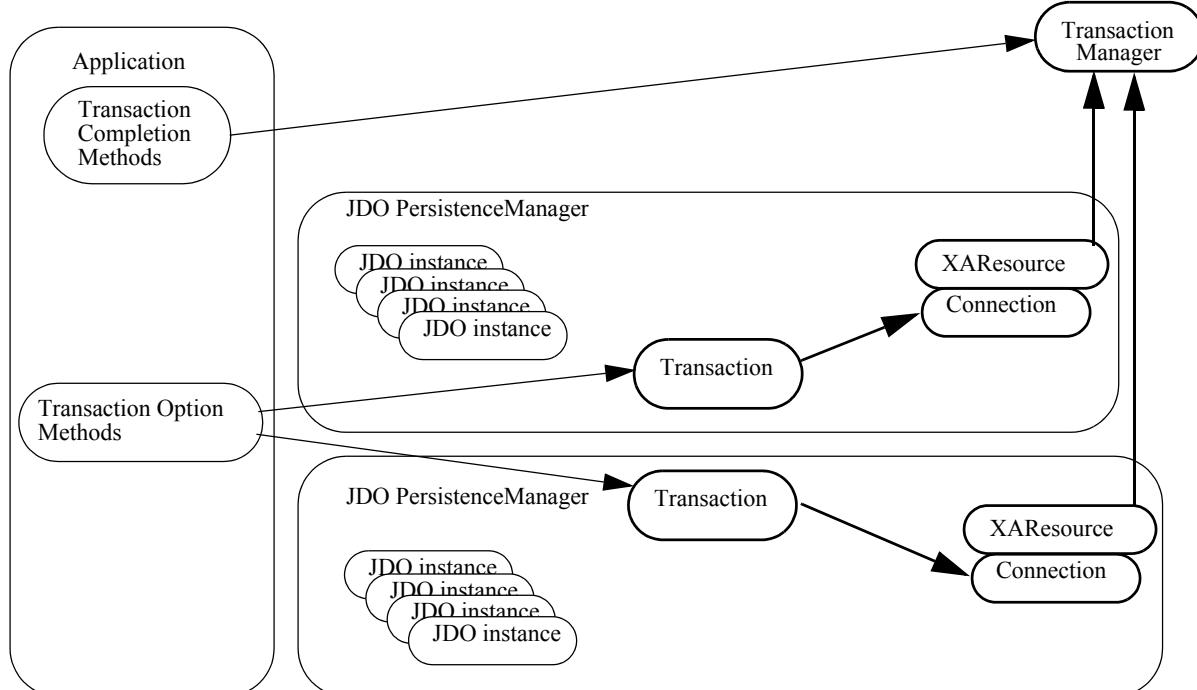
There are two types of transaction management strategies supported by JDO: “datastore transaction management”; and “optimistic transaction management”.

With datastore transaction management, all operations performed by the application on persistent data are done using a datastore transaction. This means that between the first data access until the commit, there is an active datastore transaction.

With optimistic transaction management, operations performed by the application on persistent data outside a transaction or before commit are done using a short local datastore transaction. During flush, a datastore transaction is used for the update operations, verifying that the proposed changes do not conflict with a parallel update by a different transaction.

Optimistic transaction management is specified by the `Optimistic` setting on `Transaction`.

Figure 16.0 Transactions and Connections



13.4 Interface Transaction

```
package javax.jdo;
public interface Transaction {
```

13.4.1 PersistenceManager

```
PersistenceManager getPersistenceManager();
```

This method returns the PersistenceManager associated with this Transaction instance.

```
boolean isActive ();
```

This method tells whether there is an active transaction. The transaction might be either a local transaction or a distributed transaction. If the transaction is local, then a return value of `true` means that the `begin` method was executed and neither `commit` nor `rollback` has been executed. If the transaction is managed by `XAResource` with a `TransactionManager`, then this method indicates whether there is a distributed transaction active.

This method returns `true` after the transaction has been started, until before the `afterCompletion` synchronization method is called. The method returns `false` during `afterCompletion`.

13.4.2 Transaction options

Transaction options are valid for both managed and non-managed environments. Flags are durable until changed explicitly by `set` methods. They are not changed by transaction demarcation methods.

If any of the `set` methods is called during commit or rollback processing (within the `beforeCompletion` synchronization method), a `JDOUserException` is thrown. These methods can be called during `afterCompletion` processing.

If an implementation does not support the option, then an attempt to set the flag to an unsupported value will throw `JDOUnsupportedOptionException`.

Nontransactional access to persistent values

```
boolean getNontransactionalRead ();
void setNontransactionalRead (boolean flag);
```

These methods access the flag that allows persistent instances to be read outside a transaction. If this flag is set to `true`, then queries and read access (including navigation) are allowed without an active transaction. If this flag is set to `false`, then queries and non-primary key field read access (including navigation) outside an active transaction throw a `JDOUserException`.

```
boolean getNontransactionalWrite ();
void setNontransactionalWrite (boolean flag);
```

These methods access the flag that allows non-transactional instances to be written in the cache. If this flag is set to `true`, then updates to non-transactional instances are allowed without an active transaction. If this flag is set to `false`, then updates to non-transactional instances outside an active transaction throw a `JDOUserException`.

Optimistic concurrency control

If this flag is set to `true`, then optimistic concurrency is used for managing transactions.

```
boolean getOptimistic ();
```

The optimistic setting currently active is returned.

```
void setOptimistic (boolean flag);
```

The optimistic setting passed replaces the optimistic setting currently active.

Retain values at transaction commit

If this flag is set to `true`, then eviction of transactional persistent instances does not take place at transaction commit. If this flag is set to false, then eviction of transactional persistent instances takes place at transaction commit.

This flag is only used if the PersistenceManager `DetachAllOnCommit` flag is false.

```
boolean getRetainValues ();
```

The `retainValues` setting currently active is returned.

```
void setRetainValues (boolean flag);
```

The `retainValues` setting passed replaces the `retainValues` setting currently active.

Restore values at transaction rollback

If this flag is set to `true`, then restoration of transactional persistent instances takes place at transaction rollback. If this flag is set to `false`, then eviction of transactional persistent instances takes place at transaction rollback.

```
boolean getRestoreValues ();
```

The `restoreValues` setting currently active is returned.

```
void setRestoreValues (boolean flag);
```

The `restoreValues` setting passed replaces the `restoreValues` setting currently active.

Transaction Isolation Level

This value determines some of the behavior of the implementation with regard to the connection to the underlying datastore.

With datastore transactions, the underlying connection for the transaction will be obtained using the specified isolation level or a higher one if the requested level is not supported. The isolation level cannot be changed while a transaction is in progress. If the specified isolation or higher is not available, `JDOUnsupportedOptionException` is thrown.

With optimistic transactions, for each connection to the datastore, the underlying connection will be obtained using the specified isolation level or a higher one if the requested level is not supported. The isolation level can be changed while a transaction is in progress, and the new level is used for any connections obtained during subsequent operations. If the specified isolation or higher is not available, `JDOUnsupportedOptionException` is thrown.

```
String getIsolationLevel();
```

The `IsolationLevel` setting currently active is returned. This might be a higher isolation level than requested.

```
void setIsolationLevel (String level);
```

The `level` passed replaces the `IsolationLevel` currently active.

Serialize Access to Instances Read from the Datastore (SerializeRead)

This value determines some of the behavior of the implementation with regard to the access to all instances that are subsequently read or queried. With this flag set to `true`, the implementation requests exclusive access to the instances in the datastore to prevent other concurrent accesses until transaction commit. With the flag set to `false`, accesses are not exclusive. With the flag set to `null`, the behavior is determined by the metadata setting of the `serialize-read` property of the persistent class or interface.

```
Boolean getSerializeRead();
```

The `SerializeRead` setting currently active is returned.

```
void setSerializeRead(Boolean flag);
```

The `SerializeRead` setting is replaced by the value of the parameter.

13.4.3 Synchronization

The `Transaction` instance participates in synchronization in two ways: as a supplier of synchronization callbacks, and as a consumer of callbacks. As a supplier of callbacks, a user can register with the `Transaction` instance to be notified at transaction completion. As a consumer of call-

backs, the jdo implementation will need to be notified upon transaction completion in order to flush changes to the datastore. In a managed environment, the implementation should use one of two mechanisms:

- the proprietary interfaces of the managed environment to be notified of externally-initiated transaction completion events;
- the standard `TransactionSynchronizationRegistry` that provides for an interposed synchronization registration.

For this latter purpose, the JDO implementation class might implement `javax.transaction.Synchronization` or might use a delegate to be notified.

Synchronization is supported for both managed and non-managed environments. A `Synchronization` instance registered with the `Transaction` remains registered until changed explicitly by another `setSynchronization`.

Only one `Synchronization` instance can be registered with the `Transaction`. If the application requires more than one instance to receive synchronization callbacks, then the application instance is responsible for managing them, and forwarding callbacks to them.

```
void setSynchronization (javax.transaction.Synchronization sync);
```

The `Synchronization` instance is registered with the `Transaction` for transaction completion notifications. Any `Synchronization` instance already registered will be replaced. If the parameter is `null`, then no instance will be notified. If this method is called during commit processing (within the user's `beforeCompletion` or `afterCompletion` method), a `JDOUserException` is thrown.

The two `Synchronization` methods allow the application control over the environment in which the transaction completion executes (for example, validate the state of the cache before completion) and to control the cache disposition once the transaction completes (for example, to change persistent instances to persistent-nontransactional state).

The `beforeCompletion` method will be called during the behavior specified for the transaction completion method `commit`. The `beforeCompletion` method will not be called before `rollback`.

During transaction completion, the environment calls the jdo implementation's `beforeCompletion` method, which in turn calls the user's `beforeCompletion` method registered by the `setSynchronization` method.

During the user's `beforeCompletion` method, fields in persistent and transactional instances might be changed, persistent instances might be deleted, and instances might be made persistent. These changes will be reflected in the current transaction.

After the user's `beforeCompletion` method completes, the jdo implementation flushes the cache to the datastore. During flush, life cycle methods declared in the persistence-capable classes are called back, as well as methods on instances registered with the `PersistenceManager` via `addInstanceLifecycleListener`.

After transaction completion, the environment calls the jdo implementation's `afterCompletion` method, which performs state transitions of the instances in the cache. During these state transitions, life cycle methods declared in the persistence-capable classes are called back, as well as methods on instances registered with the `PersistenceManager` via `addInstanceLifecycleListener`. Subsequently, the jdo implementation calls the user's `afterCompletion` method registered by the `setSynchronization` method. The parameter for the `afterCompletion(int status)` method will be either `javax.transaction.Status.STATUS_COMMITTED` or `javax.transaction.Status.STATUS_ROLLED_BACK`.

```
javax.transaction.Synchronization getSynchronization ();
```

This method returns the `Synchronization` currently registered.

13.4.4 Transaction demarcation

If multiple parallel transactions are required, then multiple `PersistenceManager` instances must be used. If distributed transactions are required, then the Connector Architecture is used to co-ordinate transactions among the JDO `PersistenceManagers`.

Non-managed environment

In a non-managed environment, with a single JDO `PersistenceManager` per application, there is a `Transaction` instance representing a local transaction associated with the `PersistenceManager` instance.

```
void begin();
void commit();
void rollback();
```

The `begin`, `commit`, and `rollback` methods can be used only in a non-managed environment, or in a managed environment with Bean Managed Transactions. If one of these methods is executed in a managed environment with Container Managed Transactions, a `JDOUserException` is thrown.

If `commit` or `rollback` is called when a transaction is not active, `JDOUserException` is thrown. If `begin` is called when a transaction is active, `JDOUserException` is thrown.

The `commit` method performs the following operations:

- calls the `beforeCompletion` method of the `Synchronization` instance registered with the `Transaction`;
- flushes dirty persistent instances;
- notifies the underlying datastore to commit the transaction;
- transitions persistent instances according to the life cycle specification;
- calls the `afterCompletion` method of the `Synchronization` instance registered with the `Transaction` with the results of the datastore commit operation.

The `rollback` method performs the following operations:

- rolls back changes made in this transaction from the datastore;
- transitions persistent instances according to the life cycle specification;
- calls the `afterCompletion` method of the `Synchronization` instance registered with the `Transaction`.

Managed environment

In a managed environment, there is either a user transaction or a local transaction associated with the `PersistenceManager` instance when executing method calls on JDO instances or on the `PersistenceManager`. Which of the two types of transactions is active is a policy issue for the managed environment.

If datastore transaction management is being used with the `PersistenceManager` instance, and a Connection to the datastore is required during execution of the `PersistenceManager` or JDO instance method, then the `PersistenceManager` will dynamically acquire a Connection. The call to acquire the Connection will be made with the calling thread in the appropriate transactional context, and the Connection acquired will be in the proper datastore transaction.

If optimistic transaction management is being used with the `PersistenceManager` instance, and a Connection to the datastore is required during execution of an instance method or a non-com-

pletion `PersistenceManager` method, then the `PersistenceManager` will use a local transaction Connection.

13.4.5 RollbackOnly

At times, a component needs to mark a transaction as failed even though that component is not authorized to complete the transaction. In order to mark the transaction as unsuccessful, and to determine if a transaction has been so marked, two methods are used:

```
void setRollbackOnly();
boolean getRollbackOnly();
```

Either the user application or the JDO implementation may call `setRollbackOnly`. There is no way for the application to determine explicitly which component called the method.

Once a transaction has been marked for rollback via `setRollbackOnly`, the commit method will always fail with `JDOFatalDataStoreException`. The JDO implementation must not try to make any changes to the database during commit when the transaction has been marked for rollback.

When a transaction is not active, and after a transaction is begun, `getRollbackOnly` will return false. Once `setRollbackOnly` has been called, it will return true until commit or rollback is called.

13.5 Optimistic transaction management

Optimistic transactions are an optional feature of a JDO implementation. They are useful when there are long-running transactions that rarely affect the same instances, and therefore the datastore will exhibit better performance by deferring datastore exclusion on modified instances until commit.

In the following discussion, “transactional datastore context” refers to the transaction context of the underlying datastore, while “transaction”, “datastore transaction”, and “optimistic transaction” refer to the JDO transaction concepts.

With datastore transactions, persistent instances accessed within the scope of an active transaction are guaranteed to be associated with the transactional datastore context. With optimistic transactions, persistent instances accessed within the scope of an active transaction are not associated with the transactional datastore context; the only time any instances are associated with the transactional datastore context is during commit.

With optimistic transactions, instances queried or read from the datastore will not be transactional unless they are modified, deleted, or marked by the application as transactional. At commit time, the JDO implementation:

- establishes a transactional datastore context in which verification, insert, delete, and updates will take place;
- calls the `beforeCompletion` method of the `Synchronization` instance registered with the `Transaction`;
- verifies unmodified instances that have been made transactional, to ensure that the state in the datastore is the same as the instance used in the transaction [this is done using a JDO implementation-specific algorithm];
- verifies modified and deleted instances during flushing to the datastore, to ensure that the state in the datastore is the same as the before image of the instance that was modified or deleted by the transaction [this is done using a JDO implementation-specific algorithm]
- If any instance fails the verification, a `JDOOptimisticVerificationException` is thrown which contains an array of `JDOOptimisticVerificationException`, one for each instance that failed the verification. The optimistic transaction is failed, and

the transaction is rolled back. The definition of “changed instance” is a JDO implementation choice, but it is required that a field that has been changed to different values in different transactions results in one of the transactions failing.

- if verification succeeds, notifies the underlying datastore to commit the transaction;
- transitions persistent instances according to the life cycle specification, based on whether the transaction succeeds and the setting of the RetainValues and RestoreValues flags;
- calls the `afterCompletion` method of the `Synchronization` instance registered with the `Transaction` with the results of the commit operation.

Details of the state transitions of persistent instances in optimistic transactions may be found in section 5.8.

14 Query

This chapter specifies the query contract between an application component and the JDO `PersistenceManager`.

The query facility consists of two parts: the query API, and the query language. This chapter specifies the query language “JDOQL”, and includes conventions for the use of “SQL” as the language for JDO implementations using a relational store.

14.1 Overview

An application component requires access to JDO instances so it can invoke specific behavior on those instances. From a JDO instance, it might navigate to other associated instances, thereby operating on an application-specific closure of instances.

However, getting to the first JDO instance is a bootstrap issue. There are three ways to get an instance from JDO. First, if the users have or can construct a valid `ObjectID`, then they can get an instance via the persistence manager’s `getObjectById` method. Second, users can iterate a class extent by calling `getExtent`. Third, the JDO `Query` interface provides the ability to acquire access to JDO instances from a particular JDO persistence manager based on search criteria specified by the application.

The persistent manager instance is a factory for query instances, and queries are executed in the context of the persistent manager instance.

The actual query execution might be performed by the JDO `PersistenceManager` or might be delegated by the JDO `PersistenceManager` to its datastore. The actual query executed thus might be implemented in a very different language from Java, and might be optimized to take advantage of particular query language implementations.

For this reason, methods in the query filter have semantics possibly different from those in the Java VM.

14.2 Goals

The JDO `Query` interface has the following goals:

- Query language neutrality. The underlying query language might be a relational query language such as SQL; an object database query language such as OQL; or a specialized API to a hierarchical database or mainframe EIS system.
- Optimization to specific query language. The `Query` interface must be capable of optimizations; therefore, the interface must have enough user-specified information to allow for the JDO implementation to exploit data source specific query features.
- Accommodation of multi-tier architectures. Queries might be executed entirely in memory, or might be delegated to a back end query engine. The JDO `Query` interface must provide for both types of query execution strategies.

- Large result set support. Queries might return massive numbers of JDO instances that match the query. The JDO Query architecture must provide for processing the results within the resource constraints of the execution environment.
- Compiled query support. Parsing queries may be resource-intensive, and in many applications can be done during application development or deployment, prior to execution time. The query interface allows for compiling queries and binding run-time parameters to the bound queries for execution.
- Deletion by query. Deleting multiple instances in the datastore can be done efficiently if specified as a query method instead of instantiating all persistent instances and calling the `deletePersistent` method on them.

14.3 Architecture: Query

The JDO `PersistenceManager` instance is a factory for JDO Query instances, which implement the JDO Query interface. Multiple JDO Query instances might be active simultaneously in the same JDO `PersistenceManager` instance. Multiple queries might be executed simultaneously by different threads, but the implementation might choose to execute them serially. In either case, the execution must be thread safe.

There are three required elements in any query:

- the class of the candidate instances. The class is used to scope the names in the query filter. All of the candidate instances are of this class or a subclass of this class. If the class is not explicitly passed to the query, it is obtained from the Extent.
- the collection of candidate JDO instances. The collection of candidate instances is either a `java.util.Collection`, or an Extent of instances in the datastore. Instances that are not of the required class or subclass will be silently ignored. The `Collection` might be a previous query result, allowing for subqueries. If the collection is not explicitly passed to the query, then it is obtained from the class.
- the query filter. The query filter is a Java `boolean` expression that tells whether instances in the candidate collection are to be returned in the result. If not specified, the filter defaults to `true`.

Other elements in queries include:

- parameter declarations. The parameter declaration is a `String` containing one or more query parameter declarations separated with commas. It follows the syntax for formal parameters in the Java language. Each parameter named in the parameter declaration must be bound to a value when the query is executed.
- parameter values to bind to parameters. Values are specified as Java `Objects`, and might include simple wrapper types or more complex object types. The values are passed to the `execute` methods and are not preserved after a query executes.
- variable declarations: Variables might be used in the filter, and these variables must be declared with their type. The variable declaration is a `String` containing one or more variable declarations. Each declaration consists of a type and a variable name, with declarations separated by a semicolon if there are two or more declarations. It is similar to the syntax for local variables in the Java language.
- import statements: Parameters and variables might come from a different class from the candidate class, and the names might need to be declared in an import statement to eliminate ambiguity. Import statements are specified as a `String` with semicolon-separated statements. The syntax is the same as in the Java language import statement.

- ordering specification. The ordering specification includes a list of expressions with the ascending/descending indicator. To be portable, the expression's type must be one of:
 - primitive types except boolean;
 - wrapper types except Boolean;
 - BigDecimal;
 - BigInteger;
 - String;
 - Date.
- result specification. The application might want to get results from a query that are not instances of the candidate class. The results might be fields of persistent instances, instances of classes other than the candidate class, or aggregates of fields.
- grouping specification. Aggregates are most useful when the application can specify the result field by which to group the results.
- uniqueness. The application can specify that the result of a query is unique, and therefore a single value instead of a Collection should be returned from the query.
- result class. The application may have a user-defined class that best represents the results of a query. In this case, the application can specify that instances of this class should be returned.
- limiting the size of the results. The application might want to limit the number of instances returned by the query, and might want to skip over some number of instances that might have been returned previously.
- subqueries. Some aspects of the filter might best be described by a subquery, whose result is used as part of an expression of the outer query. The subquery might use parameters or expressions of the outer query and might range over the extent of a class in the datastore.

The class implementing the `Query` interface must be serializable. The serialized fields include the candidate class, the filter, parameter declarations, variable declarations, imports, ordering specification, uniqueness, result specification, grouping specification, result class, and subqueries. The candidate collection, limits on size, and number of skipped instances are not serialized. If a serialized instance is restored, it loses its association with its former `PersistenceManager`.

14.4 Namespaces in queries

The query namespace is modeled after methods in Java:

- `setClass` corresponds to the class definition
- `declareParameters` corresponds to formal parameters of a method
- `declareVariables` corresponds to local variables of a method
- `setFilter`, `setGrouping`, `setOrdering`, and `setResult` correspond to the method body and do not introduce names to the namespace

There are two namespaces in queries. Type names have their own namespace that is separate from the namespace for fields, variables and parameters.

Keywords

Keywords must not be used as package names, class names, parameter names, or variable names in queries. Keywords are permitted as field names only if they are on the right side of the “.” in field access expressions as defined in the Java Language Specification second edition, section 15.11. Keywords include the Java language keywords and the JDOQL keywords. Java keywords are as de-

fined in the Java language specification section 3.9, plus the boolean literals true and false, and the null literal. JDOQL keywords are the following:

select, SELECT, unique, UNIQUE, distinct, DISTINCT, avg, AVG, min, MIN, max, MAX, count, COUNT, sum, SUM, as, AS, into, INTO, from, FROM, exclude, EXCLUDE, subclasses, SUBCLASSES, where, WHERE, order, ORDER, by, BY, ascending, ASCENDING, asc, ASC, descending, DESCENDING, desc, DESC, group, GROUP, having, HAVING, parameters, PARAMETERS, variables, VARIABLES, range, RANGE.

The method `setClass` introduces the name of the candidate class in the type namespace. The method `declareImports` introduces the names of the imported class or interface types in the type namespace. When used (e.g. in a parameter declaration, cast expression, etc.) a type name must be the name of the candidate class, the name of a class or interface imported by the parameter to `declareImports`, denote a class or interface from the same package as the candidate class, or must be declared by exactly one type-import-on-demand declaration (“`import <package>.*;`”). It is valid to specify the same import multiple times.

The names of the public types declared in the packages `java.lang` and `javax.jdo` are automatically imported as if the declaration “`import java.lang.*; import javax.jdo.*;`” appeared in `declareImports`. It is a JDOQL-compile time error (reported during compile or execute methods) if a used type name is declared by more than one type-import-on-demand declaration.

The method `setClass` also introduces the names of the candidate class fields.

The method `declareParameters` introduces the names of the parameters. A name in the filter preceded by “`:`” has the same effect. A parameter name hides the name of a candidate class field if equal. Parameter names must be unique.

The method `declareVariables` introduces the names of variables. A name introduced by `declareVariables` hides the name of a candidate class field if equal. Variable names must be unique and must not conflict with parameter names. A name in the filter that is not a parameter name or a field name is implicitly a variable name.

An alias definition in a subquery introduces the alias name into the namespace of the subquery for fields, variables and parameters. In this case, the alias hides any field, variable, or parameter of the same name from the outer query; and the alias can only be used where the keyword `this` would be allowed.

A hidden field may be accessed using the `this` qualifier: `this.fieldName`.

14.5 Query Factory in PersistenceManager interface

The `PersistenceManager` interface contains `Query` factory methods.

`Query newQuery();`

Construct a new empty query instance.

`Query newQuery (Object query);`

Construct a new query instance from another query instance. JDO implementations must support a serialized/restored `Query` instance from the same JDO vendor but a different execution environment, a query instance currently bound to the same `PersistenceManager`, and a query instance currently bound to a `PersistenceManager` from the same JDO vendor. Any of the elements `Class`, `QueryString`, `IgnoreCache` flag, `Result`, `ResultClass`, `Import` declarations, `Variable` declarations, `Parameter` declarations, `Grouping`, and `Ordering` from the parameter `Query` are copied to the new `Query` instance, but a candidate `Collection` or `Extent` element is discarded.

`Query newQuery (String queryString);`

Construct a new query instance using the specified `String` as the single-string representation of the query [see section 14.6.13].

```
Query newQuery (String language, Object query);
```

Construct a new query instance using the specified language and the specified query. The query instance will be of a class defined by the query language. The language parameter for the JDO Query language as herein documented is “`javax.jdo.query.JDOQL`”. In this case, the parameter is a `String` representing the single-string version of the query [see section 14.6.13].

For use with SQL, the language parameter is “`javax.jdo.query.SQL`” and the query parameter is a `String` containing the SQL query [see section 14.7]. Other languages’ parameter is not specified.

```
Query newQuery (Class cls);
```

Construct a new query instance with the candidate class specified.

```
Query newQuery (Extent cln);
```

Construct a new query instance with the candidate `Extent` specified; the candidate class is taken from the `Extent`.

```
Query newQuery (Class cls, Collection cln);
```

Construct a new query instance with the candidate class and candidate `Collection` specified.

```
Query newQuery (Class cls, String queryString);
```

Construct a new query instance with the candidate class and query string specified. The query string parameter might be the filter or the single string representing the query [see section 14.6.13].

```
Query newQuery (Class cls, Collection cln, String queryString);
```

Construct a query instance with the candidate class, the candidate `Collection`, and query string specified. The query string parameter might be the filter or the single string representing the query [see section 14.6.13].

```
Query newQuery (Extent cln, String queryString);
```

Construct a new query instance with the candidate `Extent` and query string specified; the candidate class is taken from the `Extent`. The query string parameter might be the filter or the single string representing the query [see section 14.6.13].

```
Query newNamedQuery (Class cls, String queryName);
```

Construct a new query instance with the given candidate class from a named query. The query name given must be the name of a query defined in metadata. The metadata is searched for the specified name. The extent, including subclasses, is the default for the candidate collection.

If the named query is not found in already-loaded metadata, the query is searched for using an algorithm. Files containing metadata are examined in turn until the query is found. The order is based on the metadata search order for class metadata, but includes files named based on the class name.

The file search order for a query scoped to class `com.sun.nb.Bar` is: `META-INF/package.jdo`, `WEB-INF/package.jdo`, `package.jdo`, `com/package.jdo`, `com/sun/package.jdo`, `com/sun/nb/package.jdo`, `com/sun/nb/Bar.jdo`. Once metadata for the class is found, no more `.jdo` files will be examined for the class.

If the metadata is not found in the above, and there is a property in the `PersistenceManagerFactory` `javax.jdo.option.Mapping=mySQL`, then the following files are searched: `META-INF/package-mySQL.orm`, `WEB-INF/package-mySQL.orm`, `package-mySQL.orm`, `com/package-mySQL.orm`, `com/sun/package-mySQL.orm`, `com/sun/nb/package-mySQL.orm`, `com/sun/nb/Bar-mySQL.orm`. Once mapping metadata for the class is found, no more `.orm` files will be examined for the class.

If metadata is not found in the above, then the following files are searched: META-INF/package.jdoquery, WEB-INF/package.jdoquery, package.jdoquery, com/package.jdoquery, com/sun/package.jdoquery, com/sun/nb/package.jdoquery, com/sun/nb/Bar.jdoquery. Once the query metadata is found, no more .jdoquery files will be examined for the query.

If the metadata for the named query is not found in the above, a JDOUserException is thrown.

NOTE: If no class is provided as a parameter, the metadata must be in one of the top level locations or must have already been processed during loading of metadata for a class or interface whose metadata has been loaded.

This resource name is loaded by one of the three class loaders used to resolve resource names (see Section 12.5). The loaded resource must contain the metadata definition of the query name. The schema for the loaded resource is the same as for the .jdo file.

If the unmodifiable attribute is specified as or defaults to “false”, then the Query instance returned from this method can be modified by the application, just like any other Query instance.

Named queries must be compilable. Attempts to get a named query that cannot be compiled result in JDOUserException.

14.6 Query Interface

```
package javax.jdo;
public interface Query extends Serializable {
    String JDOQL = "javax.jdo.query.JDOQL";
    String SQL = "javax.jdo.query.SQL";
```

Persistence Manager

```
PersistenceManager getPersistenceManager();
```

Return the associated PersistenceManager instance. If this Query instance was restored from a serialized form, then null is returned.

Fetch Plan

```
FetchPlan getFetchPlan();
```

This method retrieves the fetch plan associated with the Query. It always returns the identical instance for the same Query instance. Any change made to the fetch plan affects subsequent query execution. Fetch plan is described in Section 12.7.

Query element binding

The Query interface provides methods to bind required and other elements prior to execution.

All of these methods replace the previously set query element, by the parameter. [The methods are not additive.] For example, if multiple variables are needed in the query, all of them must be specified in the same call to declareVariables.

```
void setClass (Class candidateClass);
```

Bind the candidate class to the query instance.

```
void setCandidates (Collection candidateCollection);
```

Bind the candidate Collection to the query instance. If the user adds or removes elements from the Collection after this call, it is not determined whether the added/removed elements take part in the Query, or whether a NoSuchElementException is thrown during execution of the Query.

For portability, the elements in the collection must be persistent instances associated with the same PersistenceManager as the Query instance. An implementation might support transient instances in the collection. If persistent instances associated with another PersistenceManager are in the collection, JDOUserException is thrown during execute().

If the candidates are not specified explicitly by newQuery, setCandidates(Collection), or setCandidates(Extent), then the candidate extent is the extent of instances of the candidate class in the datastore including subclasses. That is, the candidates are the result of getPersistenceManager().getExtent(candidateClass, true).

```
void setCandidates (Extent candidateExtent);
```

Bind the candidate Extent to the query instance.

```
void setFilter (String filter);
```

Bind the query filter to the query instance.

```
void declareImports (String imports);
```

Bind the import statements to the query instance. All imports must be declared in the same method call, and the imports must be separated by semicolons.

```
void declareVariables (String variables);
```

Bind the variable types and names to the query instance. This method defines the types and names of variables that will be used in the filter but not provided as values by the execute method.

```
void declareParameters (String parameters);
```

Bind the parameter statements to the query instance. This method defines the parameter types and names that will be used by a subsequent execute method.

```
void setOrdering (String ordering);
```

Bind the ordering statements to the query instance.

```
void setResult (String result);
```

Specify the results of the query if not instances of the candidate class.

```
void setGrouping (String grouping);
```

Specify the grouping of results for aggregates.

```
void setUnique (boolean unique);
```

Specify that there is a single result of the query.

```
void setResultClass (Class resultClass);
```

Specify the class to be used to return result instances.

```
setRange (long fromIncl, long toExcl);
```

```
setRange (String fromIncltoExcl);
```

Specify the number of instances to skip over and the maximum number of result instances to return.

```
void addSubquery (Query subquery, String variableDeclaration,
```

```
    String candidateCollectionExpression);
```

```
void addSubquery(String variableDeclaration,
```

```
    Query subquery, String candidateCollectionExpr, String...  
    parameter);
```

```
void addSubquery(String variableDeclaration,
```

```
    Query subquery, String candidateCollectionExpr, String...  
    parameters);
```

```
void addSubquery(String variableDeclaration,
    Query subquery, String candidateCollectionExpr, Map parameters);
These methods specify a subquery to become part of this query.
```

Query options

```
void setIgnoreCache (boolean flag);
boolean getIgnoreCache ();
```

The `IgnoreCache` option, when set to `true`, is a hint to the query engine that the user expects queries to be optimized to return approximate results by ignoring changed values in the cache. This option is useful only for optimistic transactions and allows the datastore to return results that do not take modified cached instances into account. An implementation may choose to ignore the setting of this flag, and always return exact results reflecting current cached values, as if the value of the flag were `false`.

Query modification

```
void setUnmodifiable();
boolean isUnmodifiable();
```

The `Unmodifiable` option, when set, disallows further modification of the query, except for specifying the range, result class, and `ignoreCache` option.

Query evaluation

This discussion covers queries constructed by one of these methods: `newQuery(String singleStringQuery)`; `newNamedQuery(Class candidateClass, String namedQueryName)`; or `newQuery("javax.jdo.query.JDOQL", Object singleStringQuery)`.

- the candidate class cannot be overridden via `setClass` except where there is either an exact match of the name in the JDOQL query and the `setClass` parameter, or where the `FROM` clause is missing from the query string in the `newQuery` method.
- the single string query is first parsed to yield the result, result class, filter, variable list, parameter list, import list, grouping, ordering, and range.
- then, the values specified in APIs `setResult`, `setResultClass`, `setFilter`, `declareVariables`, `declareParameters`, `declareImports`, `setGrouping`, `setOrdering`, and `setRange` override the corresponding settings from the single string query.

Evaluation of implicit parameters and variable declarations is done after applying overrides from APIs.

Query compilation

The `Query` interface provides a method to compile queries for subsequent execution.

```
void compile();
```

This method requires the `Query` instance to validate any elements bound to the query instance and report any inconsistencies by throwing a `JDOUserException`. It is a hint to the `Query` instance to prepare and optimize an execution plan for the query.

Serialize Access to Instances Read from the Datastore (`SerializeRead`)

This value determines some of the behavior of the implementation with regard to the access to all instances that are returned by the query. With this flag set to `true`, the implementation requests exclusive access to the instances in the datastore to prevent other concurrent accesses until transaction commit. With the flag set to `false`, accesses are not exclusive. With the flag set to `null`, the

behavior is determined by the current setting of the Transaction. If the Transaction setting is also null, the behavior is determined by the metadata setting of the `serialize-read` property of the persistent class or interface.

```
Boolean getSerializeRead();
```

The `SerializeRead` setting currently active is returned.

```
void setSerializeRead(Boolean flag);
```

The `SerializeRead` setting is replaced by the value of the parameter.

14.6.1 Query execution

The `Query` interface provides methods that execute the query based on the parameters given. By default, they return an unmodifiable `List` which the user can iterate to get results. The user can specify the class of the result of executing a query. Executing any operation on the `List` that might change it throws `UnsupportedOperationException`. The signature of the `execute` methods specifies that they return an `Object` that must be cast to the proper type by the user.

Any parameters passed to the `execute` methods are used only for this execution, and are not remembered for future execution.

For portability, parameters of persistence-capable types must be persistent or transactional instances. Parameters that are persistent or transactional instances must be associated with the same `PersistenceManager` as the `Query` instance. An implementation might support transient instances of persistence-capable types as parameters, but this behavior is not portable. If a persistent instance associated with another `PersistenceManager` is passed as a parameter, `JDOUserException` is thrown during `execute()`.

Queries may be constructed at any time before the `PersistenceManager` is closed, but may be executed only at certain times. If the `PersistenceManager` that constructed the `Query` is closed, then the `execute` methods throw `JDOFatalUserException`. If the `NontransactionalRead` property is `false`, and a transaction is not active, then the `execute` methods throw `JDOUserException`.

```
Object execute ();
Object execute (Object p1);
Object execute (Object p1, Object p2);
Object execute (Object p1, Object p2, Object p3);
```

The `execute` methods execute the query using the parameters and return the result, which by default is an unmodifiable `List` of instances that satisfy the boolean filter. The result may be a large `List`, which should be iterated or possibly passed to another `Query`. The `size()` method returns `Integer.MAX_VALUE` if the actual size of the result is not known (for example, the `List` represents a cursoried result); if the size of the result equals or exceeds `Integer.MAX_VALUE`; or if the range equals or exceeds `Integer.MAX_VALUE`.

When using an `Extent` to define candidate instances, the contents of the extent are subject to the setting of the `ignoreCache` flag. With `ignoreCache` set to `false`:

- if instances were made persistent in the current transaction, the instances will be considered part of the candidate instances.
- if instances were deleted in the current transaction, the instances will not be considered part of the candidate instances.
- modified instances will be evaluated using their current transactional values.

With `ignoreCache` set to `true`:

- if instances were made persistent in the current transaction, the new instances might not be considered part of the candidate instances.
- if instances were deleted in the current transaction, the instances might or might not be considered part of the candidate instances.
- modified instances might be evaluated using their current transactional values or the values as they exist in the datastore, which might not reflect the current transactional values.

Each parameter of the `execute` method(s) is an `Object` that is either the value of the corresponding parameter or the wrapped value of a primitive parameter. The parameters associate in order with the parameter declarations in the `Query` instance.

```
Object executeWithMap (Map parameters);
```

The `executeWithMap` method is similar to the `execute` method, but takes its parameters from a `Map` instance. The `Map` contains key/value pairs, in which the key is the declared parameter name, and the value is the value to use in the query for that parameter. Unlike `execute`, there is no limit on the number of parameters. If implicit parameters are used, the keys in the map do not include the leading “`:`”.

```
Object executeWithArray (Object... parameters);
```

The `executeWithArray` method is similar to the `execute` method, but takes its parameters from an array instance. The array contains `Objects`, in which the positional `Object` is the value to use in the query for that parameter. Unlike `execute`, there is no limit on the number of parameters.

Query Timeout

Queries may have timeouts associated with them. The timeout values might be set in the `PersistenceManagerFactory`, in the `PersistenceManager`, or in the `Query` instance.

```
Integer getDatastoreReadTimeoutMillis();
```

```
Integer getDatastoreWriteTimeoutMillis();
```

A value of `null` indicates that there is no timeout set for this query. A non-`null` value indicates that the timeout was set by this query, or the value was obtained by the default value set in the `PersistenceManager` or the `PersistenceManagerFactory`. A timeout value of 0 indicates that there is no timeout for this query.

```
void setDatastoreReadTimeoutMillis(Integer timeoutMillis);
```

```
void setDatastoreWriteTimeoutMillis(Integer timeoutMillis);
```

If a non-`null` timeout value is specified, a running query will be interrupted if it exceeds the execution time of the timeout value. The thread executing the query will throw `JDODatastoreException`. Specifying a timeout value of 0 indicates that there is no timeout for this query (a setting of 0 overrides the default specified in the `PersistenceManager` or the `PersistenceManagerFactory`).

If the timeout value is specified as `null`, then the timeout is obtained from the `PersistenceManager` or the `PersistenceManagerFactory`. If there is no timeout specified in any of the `Query`, the `PersistenceManager` or the `PersistenceManagerFactory`, there is no timeout for the query.

Query Cancel

Queries might be canceled by a different thread from the thread currently executing the query. There is no requirement that the `Multithreaded` flag be set in order to invoke the cancel operation from a different thread.

```
void cancelAll();
```

```
void cancel(Thread thread);
```

These methods cancel a running query (or queries). The thread that has its query canceled will throw a `JDOQueryInterruptedException`.

If `cancel` is not supported (most likely due to the underlying implementation not supporting `cancel`) then `JDOUnsupportedOptionException` is thrown to the caller.

14.6.2 Filter specification

The filter specification is a `String` containing a boolean expression that is to be evaluated for each of the instances in the candidate collection. If the filter is not specified, then it defaults to "true", and the input `Collection` is filtered only for class type.

An element of the candidate collection is returned in the result if:

- it is assignment compatible to the candidate `Class` of the `Query`; and
- for all variables there exists a value for which the filter expression evaluates to `true`. The user may denote uniqueness in the filter expression by explicitly declaring an expression (for example, `e1 != e2`). For example, a filter for a `Department` where there exists an `Employee` with more than one dependent and an `Employee` making more than 30,000 might be: `"(emps.contains(e1) & e1.dependents > 1) & (emps.contains(e2) & e2.salary > 30000)"`. The same `Employee` might satisfy both conditions. But if the query required that there be two different `Employees` satisfying the two conditions, an additional expression could be added: `"(emps.contains(e1) & e1.dependents > 1) & (emps.contains(e2) & (e2.salary > 30000 & e1 != e2))"`.

Rules for constructing valid expressions follow the Java language, except for these differences:

- Equality and ordering comparisons between primitives and instances of wrapper classes are valid.
- Equality and ordering comparisons of `Date` fields and `Date` parameters are valid.
- Equality and ordering comparisons of `String` fields and `String` parameters are valid. The comparison is done according to an ordering not specified by JDO. This allows an implementation to order according to a datastore-specified ordering, which might be locale-specific.
- White space (non-printing characters space, tab, carriage return, and line feed) is a separator and is otherwise ignored.
- The assignment operators `=`, `+=`, etc. and pre- and post-increment and -decrement are not supported.
- Methods, including object construction, are not supported, except for `Collection`, `String`, and `Map` methods documented below. Implementations might choose to support non-mutating method calls as non-standard extensions.
- Navigation through a null-valued field, which would throw `NullPointerException`, is treated as if the subexpression returned `false`. Similarly, a failed cast operation, which would throw `ClassCastException`, is treated as if the subexpression returned `false`. Other subexpressions or other values for variables might still qualify the candidate instance for inclusion in the result set.
- Navigation through multi-valued fields (`Collection` types) is specified using a variable declaration and the `Collection.contains(Object o)` method.

- The following literals are supported, as described in the Java Language Specification: `IntegerLiteral`, `FloatingPointLiteral`, `BooleanLiteral`, `CharacterLiteral`, `StringLiteral`, and `NullLiteral`.
- There is no distinction made between `char` literals and `String` literals. Single-character `String` literals can be used wherever `char` literals are permitted. `Char` literals will be widened if used in numerical expressions; or treated as single-character `String` literals if used in `String` expressions.
- `String` literals are allowed to be delimited by single quote marks or double quote marks. This allows `String` literal filters to use single quote marks instead of escaped double quote marks.

Note that comparisons between floating point values are by nature inexact. Therefore, equality comparisons (`==` and `!=`) with floating point values should be used with caution.

Identifiers in the expression are considered to be in the name space of the specified class, with the addition of declared imports, parameters and variables. As in the Java language, `this` is a reserved word, and it refers to the element of the collection being evaluated.

Identifiers that are persistent field names or public final static field names are required to be supported by JDO implementations. Other identifiers might be supported but are not required. Thus, portable queries must not use fields other than persistent or public final static field names in filter expressions.

Navigation through single-valued fields is specified by the Java language syntax of `field_name.field_name.....field_name`.

A JDO implementation is allowed to reorder the filter expression for optimization purposes.

The following are minimum capabilities of the expressions that every implementation must support:

- operators applied to all types where they are defined in the Java language:

Table 4: Query Operators

Operator	Description
<code>==</code>	equal
<code>!=</code>	not equal
<code>></code>	greater than
<code><</code>	less than
<code>>=</code>	greater than or equal
<code><=</code>	less than or equal
<code>&</code>	boolean logical AND (not bitwise)
<code>&&</code>	conditional AND
<code> </code>	boolean logical OR (not bitwise)
<code> </code>	conditional OR
<code>~</code>	integral unary bitwise complement
<code>+</code>	binary addition, unary plus, or <code>String</code> concatenation

Table 4: Query Operators

Operator	Description
-	binary subtraction or unary numeric sign inversion
*	times
/	divide by
!	logical complement
%	modulo operator
instanceof	instanceof operator

- exceptions to the above:
 - String concatenation is supported only for `String + String`, not `String + <primitive>`;
 - parentheses to explicitly mark operator precedence
 - cast operator (class)
- promotion of numeric operands for comparisons and arithmetic operations. The rules for promotion follow the Java rules (see chapter 5.6 Numeric Promotions of the Java language spec) extended by `BigDecimal`, `BigInteger` and numeric wrapper classes:
 - if either operand is of type `BigDecimal`, the other is converted to `BigDecimal`.
 - otherwise, if either operand is of type `BigInteger`, and the other type is a floating point type (`float`, `double`) or one of its wrapper classes (`Float`, `Double`) both operands are converted to `BigDecimal`.
 - otherwise, if either operand is of type `BigInteger`, the other is converted to `BigInteger`.
 - otherwise, if either operand is of type `double`, the other is converted to `double`.
 - otherwise, if either operand is of type `float`, the other is converted to `float`.
 - otherwise, if either operand is of type `long`, the other is converted to `long`.
 - otherwise, both operands are converted to type `int`.
 - operands of numeric wrapper classes are treated as their corresponding primitive types. If one of the operands is of a numeric wrapper class and the other operand is of a primitive numeric type, the rules above apply and the result is of the corresponding numeric wrapper class.
- equality comparison among persistent instances of persistence-capable types use the JDO Identity comparison of the references; this includes containment methods applied to `Collection` and `Map` types. Thus, two objects will compare equal if they have the same JDO Identity.
- comparisons between persistent and non-persistent instances return not equal.
- equality comparison of instances of non-persistence-capable reference types uses the `equals` method of the type; this includes containment methods applied to `Collection` and `Map` types.

- String methods `startsWith` and `endsWith` support wild card queries but not in a portable way. JDO does not define any special semantic to the argument passed to the method; in particular, it does not define any wild card characters. To achieve portable behavior, applications should use `matches(String)`.
- Null-valued fields of Collection types are treated as if they were empty if a method is called on them. In particular, they return `true` to `isEmpty` and return `false` to all `contains` methods. For datastores that support null values for Collection types, it is valid to compare the field to `null`. Datastores that do not support null values for Collection types, will return `false` if the query compares the field to `null`. Datastores that support null values for Collection types should include the option "`javax.jdo.option.NullCollection`" in their list of supported options (`PersistenceManagerFactory.supportedOptions()`).

Methods

The following methods are supported for their specific types, with semantics as defined by the Java language:

Table 5: Query Methods

Method	Description
<code>contains(Object)</code>	applies to Collection types
<code>get(Object)</code>	applies to Map types
<code>containsKey(Object)</code>	applies to Map types
<code>containsValue(Object)</code>	applies to Map types
<code>isEmpty()</code>	applies to Map and Collection types
<code>size()</code>	applies to Map and Collection types
<code>toLowerCase()</code>	applies to String type
<code>toUpperCase()</code>	applies to String type
<code>indexOf(String)</code>	applies to String type; 0-indexing is used
<code>indexOf(String, int)</code>	applies to String type; 0-indexing is used
<code>matches(String)</code>	applies to String type; only the following regular expression patterns are required to be supported and are portable: global "(?i)" for case-insensitive matches; and "." and ".?" for wild card matches. The pattern passed to matches must be a literal or parameter.
<code>substring(int)</code>	applies to String type
<code>substring(int, int)</code>	applies to String type
<code>startsWith(String)</code>	applies to String type
<code>endsWith(String)</code>	applies to String type
<code>Math.abs(numeric)</code>	static method in <code>java.lang.Math</code> , applies to types of float, double, int, and long

Table 5: Query Methods

Method	Description
Math.sqrt(numeric)	static method in java.lang.Math, applies to double type
JDOHelper.getObjectId(Object)	static method in JDOHelper, allows using the object identity of an instance directly in a query.

Subqueries

```
void addSubquery (Query subquery, String variableDeclaration,
    String candidateCollectionExpression);
```

This method adds a subquery to this query. A subquery is composed as a `Query` and subsequently attached to a different `Query` (the outer `Query`) by calling this method. The `String` parameters are trimmed of white space.

The `Query` parameter instance is unmodified as a result of the `addSubquery` or subsequent execution of the outer `Query`. Only some of the parameter query parts are copied for use as the subquery. The parts copied include the candidate class, filter, parameter declarations, variable declarations, imports, ordering specification, uniqueness, result specification, and grouping specification. The association with a `PersistenceManager`, the candidate collection or extent, result class, and range limits are not used.

The `variableDeclaration` parameter is the name of the variable containing the results of the subquery execution. If the same value of `variableDeclaration` is used to add multiple subqueries, the subquery replaces the previous subquery for the same named variable. If the subquery parameter is `null`, the variable is unset, effectively making the variable named in the `variableDeclaration` unbound. If the trimmed value is the empty `String`, or the parameter is `null`, then `JDOUserException` is thrown.

The `candidateCollectionExpression` is the expression from the outer query that represents the candidates over which the subquery is evaluated. If the trimmed value is the empty `String`, or the parameter is `null`, then the candidate collection is the extent of the candidate class.

Non-correlated subqueries

If the subquery has no references to expressions in the outer query the subquery is non-correlated.

For example, to find employees who work more than the average of all employees,

```
Query sub = pm.newQuery(Employee.class);
sub.setResult("avg(this.weeklyhours)");
Query q = pm.newQuery(Employee.class);
q.setFilter("this.weeklyHours > averageWeeklyhours");
q.addSubquery(sub, "double averageWeeklyhours", null);
```

Correlated subqueries

A correlated subquery is a subquery which contains references to expressions in the outer query. If the correlation can be expressed as a restriction of the candidate collection of the subquery, no parameters are needed.

For example, to find employees who work more than the average of their department employees:

```
Query sub = pm.newQuery(Employee.class);
sub.setResult("avg(this.weeklyhours)");
Query q = pm.newQuery(Employee.class);
q.setFilter("this.weeklyhours > averageWeeklyhours");
q.addSubquery(sub, "double averageWeeklyhours", "this.department.employees");
```

If the correlation cannot be expressed as a restriction of the candidate collection, the correlation is expressed as one or more parameters in the subquery which are bound to expressions of the outer query.

```
void addSubquery(String variableDeclaration,
    Query subquery, String candidateCollectionExpr, String
parameter);
void addSubquery(String variableDeclaration,
    Query subquery, String candidateCollectionExpr, String...
parameters);
void addSubquery(String variableDeclaration,
    Query subquery, String candidateCollectionExpr, Map parameters);
```

The `parameters` in the above methods binds parameters in the subquery to expressions in the outer query. `String` parameters are trimmed of white space. The single `String` version of the method binds the named expression to the single parameter in the subquery. The `String[]` version of the method binds the named expressions in turn to parameters in the order in which they are declared in the subquery, or in the order they are found in the filter if not explicitly declared in the subquery. The `Map` version of the method treats the key of each map entry as the name of the parameter in the subquery, with or without the leading “`:`”, and the value as the name of the expression in the outer query. If the trimmed expression is the empty `String` for either the parameter or the value of the `String...`, or for any map key or value, that expression is ignored.

For example, to find employees who work more than the average of the employees in their department having the same manager:

```
Query sub = pm.newQuery(Employee.class);
sub.setResult("avg(this.weeklyhours)");
sub.setFilter("this.manager == :manager");
Query q = pm.newQuery(Employee.class);
q.setFilter("this.weeklyHours > averageWeeklyhours");
q.addSubquery(sub, "double averageWeeklyhours", "this.department.employees",
"this.manager");
```

The parameter in the subquery “`:manager`” is bound to the expression “`this.manager`” in the context of the outer query.

14.6.3 Parameter declaration

The parameter declaration is a `String` containing one or more parameter type declarations separated by commas. This follows the Java syntax for method signatures.

Parameter types for primitive values can be specified as either the primitive types or the corresponding wrapper types. If a parameter type is specified as a primitive, the parameter value passed to `execute()` must not be null or a `JDOUserException` is thrown.

Parameters must all be declared explicitly via `declareParameters` or all be declared implicitly in the filter. Parameters implicitly declared (in the result, filter, ordering, grouping, or range) are identified by prepending a “`:`” to the parameter everywhere it appears. All parameter types can be determined by one of the following techniques:

- the parameter is used as the right hand side or left hand side of a boolean operator (`<`, `<=`, `==`, `>=`, or `>`) and the other side is strongly typed, or

- the parameter is used in a method from Table 5 on page 170 directly as either a parameter or the object on which the method is called, and the type can be determined from the context of the method, or
- the parameter is explicitly cast using the cast operator and the cast is identical everywhere the parameter appears.

Implicit parameter declaration

When parameters are declared implicitly, if the query is string-based, parameters are recognized in the order that they appear in the query string. If the query is API-based, parameters are recognized as if declared explicitly, with the order of their first appearance in the result, filter, grouping, ordering, and range, in that order. This is significant if a positional form of execute or addSubquery is used.

14.6.4 Import statements

The import statements follow the Java syntax for import statements. Import statements are separated by semicolons. Import on demand is supported. Classes in java.lang and javax.jdo are automatically imported.

14.6.5 Variable declaration

The type declarations follow the Java syntax for local variable declarations. Variable declarations are separated by semicolons.

A variable that is not constrained with an explicit contains clause is constrained by the extent of the persistence capable class (including subclasses). If the class does not manage an Extent, then no results will satisfy the query.

If the query result uses a variable, the variable must not be constrained by an extent. Further, each side of an "OR" expression must constrain the variable using a contains clause.

A portable query will constrain all variables with a contains clause in each side of an "OR" expression of the filter where the variable is used. Further, each variable must either be used in the query result or its contains clause must be the left expression of an "AND" expression where the variable is used in the right expression. That is, for each occurrence of an expression in the filter using the variable, there is a contains clause "ANDed" with the expression that constrains the possible values by the elements of a collection.

The semantics of contains is "exists", where the contains clause is used to filter instances. The meaning of the expression "emps.contains(e) && e.salary < param" is "there exists an e in the emps collection such that e.salary is less than param". This is the natural meaning of contains in the Java language, except where the expression is negated. If the variable is used in the result, then it need not be constrained.

If the expression is negated, then "!(emps.contains(e) && e.salary < param)" means "there does not exist an employee e in the collection emps such that e.salary is less than param". Another way of expressing this is "for each employee e in the collection emps, e.salary is greater than or equal to param". If a variable is used in the result, then it must not be used in a negated contains clause.

Implicit variable declaration

The variable declaration is unnecessary if all variables are implicitly declared. All variables must be explicitly declared, or all variables must be implicitly declared.

Names in the filter are treated as parameters if they are explicitly declared via declareParameters or if they begin with ":".

Names are treated as variable names if they are explicitly declared via declareVariables.

Names are treated as field or property names if they are fields or properties of the candidate class.

Names are treated as class names if they exist in the package of the candidate class, have been imported, or if they are in the `java.lang` package. e.g. `Integer`.

Otherwise, names are treated as implicitly defined variable names.

Variables must be typed. Implicitly defined variables are typed according to the following:

- if the variable is the parameter of a `contains` method, the type is the element type of the collection; or
- if the variable is the parameter of a `containsKey` method, the type is the key type of the map; or
- if the variable is the parameter of a `containsValue` method, the type is the value type of the map; or
- if the variable is not constrained by a `contains`, `containsKey`, or `containsValue` method, the variable must be typed by an explicit cast the first time the variable appears in the filter.

14.6.6 Ordering statement

The ordering statement is a `String` containing one or more ordering declarations separated by commas. Each ordering declaration is a Java expression of an orderable type:

- primitives (`boolean` is non-portable);
- wrappers (`Boolean` is non-portable);
- `BigDecimal`;
- `BigInteger`;
- `String`;
- `Date`

followed by one of the following words: “`ascending`”, “`descending`”, “`asc`”, or “`desc`”.

Ordering might be specified including navigation. The name of the field to be used in ordering via navigation through single-valued fields is specified by the Java language syntax of `field_name.field_name....field_name`.

The result of the first (leftmost) expression is used to order the results. If the leftmost expression evaluates the same for two or more elements, then the second expression is used for ordering those elements. If the second expression evaluates the same, then the third expression is used, and so on until the last expression is evaluated. If all of the ordering expressions evaluate the same, then the ordering of those elements is unspecified.

The ordering of instances containing null-valued fields specified by the ordering is not specified. Different JDO implementations might order the instances containing null-valued fields either before or after instances whose fields contain non-null values.

Ordering of boolean fields, if supported by the implementation, is false before true, unless descending is specified. Ordering of null-valued Boolean fields is as above.

14.6.7 Closing Query results

When the application has finished with the query results, it might optionally close the results, allowing the JDO implementation to release resources that might be engaged, such as database cursors or iterators. The following methods allow early release of these resources.

```
void close (Object queryResult);
```

This method closes the result of one `execute(...)` method, and releases resources associated with it. After this method completes, the query result can no longer be used, for example to iterate

the returned elements. Any elements returned previously by iteration of the results remain in their current state. Any iterators acquired from the queryResult will return `false` to `hasNext()` and will throw `NoSuchElementException` to `next()`.

```
void closeAll();
```

This method closes all results of `execute(...)` methods on this `Query` instance, as above. The `Query` instance is still valid and can still be used.

14.6.8 Limiting the Cardinality of the Query Result

The application may want to skip some number of results that may have been previously returned, and additionally may want to limit the number of instances returned from a query. The parameters are modeled after `String.getChars` and are 0-origin. The parameters are not saved if the query is serialized. The default range for query execution if this method is not called are (0, `Long.MAX_VALUE`).

```
setRange(long fromIncl, long toExcl);
```

The `fromIncl` parameter is the number of instances of the query result to skip over before returning the `List` to the user. If specified as 0 (the default), no instances are skipped.

The `toExcl` parameter is the last instance of the query result (before skipping) to return to the user.

The expression `(toExcl - fromIncl)` is the maximum number of instances in the query result to be returned to the user. If fewer instances are available, then fewer instances will be returned. If `((toExcl - fromIncl)<= 0)` evaluates to true ,

- if the result of the query execution is a `List`, the returned `List` contains no instances, and an `Iterator` obtained from the `List` returns `false` to `hasNext()`.
- if the result of the query execution is a single instance (`setUnique(true)`), it will have a value of `null`.

```
setRange(String range);
```

When using the string form of `setRange` both parameter values are specified either as numbers or as parameters. The `fromIncl` and `toExcl` values are comma separated and evaluated as either long values or as parameter names (beginning with ":"). For example, `setRange(":fromRange, :toRange")` or `setRange("100, 130")`.

14.6.9 Specifying the Result of a Query (Projections, Aggregates)

The application might want to get results from a query that are not instances of the candidate class. The results might be single-valued fields of persistent instances, instances of classes other than the candidate class, or aggregates of single-valued fields. Note that this means that fields of Collection and Map types are not allowed in the projection.

```
void setResult(String result);
```

The `result` parameter consists of the optional keyword `distinct` followed by a comma-separated list of named result expressions or a constructor expression.

A constructor expression consists of the keyword `new` followed by the name of a result class and a comma-separated parenthesis-enclosed list of named result expressions. See 14.6.12 for a detailed description of the constructor expression.

Distinct results

If `distinct` is specified, the query result does not include any duplicates. If the `result` parameter specifies more than one result expression, duplicates are those with matching values for each result expression.

Queries against an extent always consider only distinct candidate instances, regardless of whether distinct is specified. Queries against a collection might contain duplicate candidate instances; the distinct keyword removes duplicates from the candidate collection in this case.

Result expressions begin with either an instance of the candidate class (with an explicit or implicit "this") or an instance of a variable (using the variable name). The candidate tuples are the cartesian product of the candidate class and all variables used in the result. The result tuples are the tuples of the candidate class and all variables used in the result that satisfy the filter. The result is the collection of result expressions projected from the result tuples. If variables are not used in the result expression, then the filter is evaluated for all possible values for each such variable, and if the filter evaluates to true for any combination of such variables, then the candidate tuple becomes a result tuple.

The distinct specification requires removing duplicates from projected expressions.

If any result is a navigational expression, and a non-terminal field or variable has a null value for a particular set of conditions (the result calculation would throw NullPointerException), then the result is null for that result expression. This is known in relational algebra as "outer join semantics". For example, to exclude results of "this.department.category.name" where either department or category is null, the user must explicitly add a clause to the filter: "this.department != null && this.department.category != null".

The result expressions include:

- "this": indicates that the candidate instance is returned
- <field>: this indicates that a field is returned as a value; the field might be in the candidate class or in a class referenced by a variable
- <variable>: this indicates that a variable's value is returned as a persistent instance
- <aggregate>: this indicates that an aggregate of multiple values is returned; if null values are aggregated, they do not participate in the aggregate result; if all of the expressions to be aggregated evaluate to null, the result is the same as if there were no instances that match the filter.
 - count(<expression>): the count of the number of instances of the expression is returned; the expression is preceded by an optional "distinct" and can be "this", a navigational expression that terminates in a single-valued field, or a variable name
 - sum(<numeric field expression>): the sum of field expressions is returned; the expression is preceded by an optional "distinct"
 - min(<orderable field expression>): the minimum value of the field expression is returned
 - max(<orderable field expression>): the maximum value of the field expression is returned
 - avg(<numeric field expression>): the average value of all field expressions is returned; the expression is preceded by an optional "distinct"
- <field expression>: the value of an expression using any of the operators allowed in queries applied to fields is returned
- <navigational expression>: this indicates a navigational path through single-valued fields or variables as specified by the Java language syntax; the navigational path starts with the keyword "this", a variable, a parameter, or a field name followed by field names separated by dots.
- <parameter>: one of the parameters provided to the query.

The result expression can be explicitly cast using the (cast) operator.

Named Result Expressions

<result expression> as <name>: identify the <result expression> (any of the result expressions specified above) as a named element for the purpose of matching a method or field name in the result class.

If the name is not specified explicitly, the default for name is the expression itself.

Aggregate Types

Count returns Long.

Sum returns Long for integral types and the field's type for other Number types (BigDecimal, BigInteger, Float, and Double). Sum and avg are invalid if applied to non-Number types.

Avg, min, and max return the type of the expression.

If there are no instances that match the filter,

- count returns 0;
- avg, sum, min, and max return null.

If null values are aggregated, they do not participate in the aggregate result. If all of the expressions to be aggregated evaluate to null, the result is the same as if there were no instances that match the filter.

Primitive Types

If a result expression has a primitive type, its value is returned as an instance of the corresponding java wrapper class.

Null Results

If the returned value from a query specifying a result is null, this indicates that the expression specified as the result was null. Note that the semantics of this result are different from the returned value where no instances satisfied the filter.

Default Result

If not specified, the result defaults to “distinct this as C” where C is the unqualified name of the candidate class. For example, the default result specification for a query where the candidate class is com.acme.hr.Employee is “distinct this as Employee”.

Projected Second Class Result

If an SCO field is in the result, the projected field is not owned by any persistent instance, and modifying the SCO value has no effect on any persistent instance. If an FCO field is in the result, the projected field is a persistent instance, and modifications made to the instance are reflected as changes to the datastore per transaction requirements.

14.6.10 Grouping Aggregate Results

Aggregates are most useful if they can be grouped based on an element of the result. Grouping is required if there are aggregate expressions in the result.

```
void setGrouping(String grouping);
```

The grouping parameter consists of one or more expressions separated by commas followed by an optional “having” followed by one Boolean expression.

When grouping is specified, each result expression must be one of:

- an expression contained in the grouping expression; or,
- an aggregate expression evaluated once per group.

When grouping is specified with ordering, each ordering expression must be one of:

- an expression contained in the grouping expression; or,
- an aggregate expression evaluated once per group.

The query groups all elements where all expressions specified in setGrouping have the same values. The query result consists of one element per group.

When “having” is specified, the “having” expression consists of arithmetic and boolean expressions containing expressions that are either aggregate expressions or contained in a grouping expression.

14.6.11 Specifying Uniqueness of the Query Result

If the application knows that there can be exactly zero or one instance returned from a query, the result of the query is most conveniently returned as an instance (possibly null) instead of a List.

```
void setUnique(boolean unique);
```

When the value of the Unique flag is true, then the result of a query is a single value, with null used to indicate that none of the instances in the candidates satisfied the filter. If more than one instance satisfies the filter, and the range is not limited to one result, then execute throws a JDOUserException.

Default Unique setting

The default Unique setting is true for aggregate results without a grouping expression, and false otherwise.

14.6.12 Specifying the Class of the Result

The application may have a user-defined class that best represents the results of a query. In this case, the application can specify that instances of this class should be returned.

```
void setResultClass(Class resultClass);
```

The default result class is the candidate class if the parameter to setResult is null or not specified. When the result is specified and not null, the default result class is the type of the expression if the result consists of one expression, or Object[] if the result consists of more than one expression.

Result Class Requirements

- The result class may be one of the java.lang classes Character, Boolean, Byte, Short, Integer, Long, Float, Double, String, or Object[]; or one of the java.math classes BigInteger or BigDecimal; or the java.util class Date; or the java.util interface Map; or one of the java.sql classes Date, Time, or Timestamp; or a user-defined class.
- If there are multiple result expressions, the result class must be able to hold all elements of the result specification or a JDOUserException is thrown.
- If there is only one result expression, the result class must be assignable from the type of the result expression or must be able to hold all elements of the result specification. A single value must be able to be coerced into the specified result class (treating wrapper classes as equivalent to their unwrapped primitive types) or by matching. If the result class does not satisfy these conditions, a JDOUserException is thrown.
- A constructor of a result class specified in the constructor expression of the setResult method or in the setResultClass method will be used if the results specification matches the parameters of the constructor by position and type. If more than one constructor satisfies the requirements, the JDO implementation chooses one of them. If no constructor satisfies the results requirements, the following requirements apply:

- A user-defined result class must have a no-args constructor and one or more public “set” or “put” methods or fields.
- Each result expression must match one of:
 - *a public field that matches the name of the result expression and is of the type (treating wrapper types the same as primitive types) of the result expression;*
 - *or if no public field matches the name and type, a public “set” method that returns void and matches the name of the result expression and takes a single parameter which is the exact type of the result expression;*
 - *or if neither of the above applies, a public method must be found with the signature void put(Object, Object) in which the first argument is the name of the result expression and the second argument is the value from the query result.*
- Portable result classes do not invoke any persistence behavior during their no-args constructor or “set” methods.

Table 6: Shape of Result (C is the candidate class)

setResult	setResultClass	setUnique	shape of result
null, or “distinct this as C”	null	false	List<C>
null, or “distinct this as C”	null	true	C
not null, one result expression of type T	null	false	List<T>
not null, one result expression of type T	null	true	T
not null, more than one result expression	null	false	List<Object[]>
not null, more than one result expression	null	true	Object[]
null or not null	UserResult.class	false	List<UserResult>
null or not null	UserResult.class	true	UserResult

14.6.13 Single-string Query element binding

The String version of Query represents all query elements using a single string. The string contains the following structure:

```

select [unique] [ <result> ] [into <result-class-name>]
[from <candidate-class-name> [exclude subclasses] ]
[where <filter>]
[variables <variables-clause> ]
[parameters <parameters-clause>]
[<imports-clause>]
[group by <grouping-clause> ]
[order by <ordering-clause>]
[range <from-range> ,<to-range>]

```

Keywords, identified in **bold**, are either all upper-case or all lower-case. Keywords cannot be mixed case.

The select clause must be the first clause in the query.

The order of the other clauses must be as described above.

If implicit parameters are used, their order of appearance in the query determines their order for binding to positional parameters for execution.

<result> is the result as in 14.6.9.

<result-class-name> is the name of the result class as in 14.6.12.

<filter> is the filter as in 14.6.2. The filter in the single String version might include subqueries. A subquery must be enclosed in parentheses, and has the following structure:

(**select** <subquery-result-clause> **from** <subquery-from-clause> [**where** <filter>] [**variables** <variables-clause>] [**parameters** <parameters-clause>] [<imports-clause>])

The subquery-result-clause consists of an optional keyword **distinct** followed by a single expression.

The subquery-from-clause may have one of two forms:

- A candidate class name followed by an optional alias definition followed by an optional **exclude subclasses**
- A field access expression followed by an optional alias definition

An alias definition consists of an optional keyword **as** followed by an identifier.

- If the **as** clause is used, the identifier is used instead of **this** to access the candidate instances of the subquery. In this case, fields of the outer query can be accessed from the inner query.
- If the **as** clause is not used, any usage of **this** in the subquery refers to the candidate instances of the subquery. In this case, fields of the outer query cannot be accessed from the inner query.

<variables-clause> is the variable declaration as in 14.6.5. As in Java, variables in the clause are separated by semicolons.

<parameters-clause> is the parameter declaration as in 14.6.3. As in Java, parameters in the clause are separated by commas.

<imports-clause> is the imports declaration as in 14.6.4. As in Java, imports in the clause are separated by semicolons.

<grouping-clause> is the grouping specification as in 14.6.10.

<ordering-clause> is the ordering specification as in 14.6.6.

<from-range> and <to-range> are as in 14.6.8.

14.7 SQL Queries

If the developer knows that the underlying datasource supports SQL, and knows the mapping from the JDO domain model to the SQL schema, it might be convenient in some cases to execute SQL instead of expressing the query as JDOQL. In this case, the factory method that takes the language string and Object is used: newQuery (String language, Object query). The language parameter is “javax.jdo.query.SQL” and the query parameter is the SQL query string.

The SQL query string must be well-formed. The JDO implementation must not make any changes to the query string. The tokens “?” must be used to identify parameters in the SQL query string.

When this factory method is used, the behavior of the Query instance changes significantly. The only methods that can be used are setClass to establish the candidate class, setUnique to declare that there is only one result row, and setResultClass to establish the result class.

- there is no filter, and the `setFilter` method throws `JDOUserException`.
- there is no ordering specification, and the `setOrdering` method throws `JDOUserException`.
- there are no variables, and the `declareVariables` method throws `JDOUserException`.
- the parameters are untyped, and the `declareParameters` method throws `JDOUserException`.
- there is no grouping specification, and the `setGrouping` method throws `JDOUserException`.
- the candidate collection can only be the `Extent` of instances of the candidate class, including subclasses, and the `setCandidates` method throws `JDOUserException`.
- parameters are bound by position. If the parameter list is an `Object[]` then the first element in the array is bound to the first “?” in the SQL statement, and so forth. If the parameter list is a `Map`, then the keys of the `Map` must be instances of `Integer` whose `intValue` is 1..n. The value in the `Map` corresponding to the key whose `intValue` is 1 is bound to the first “?” in the SQL statement, and so forth.
- there are no imports, and the `declareImports` method throws `JDOUserException`.
- for queries in which the candidate class is specified, the columns selected in the SQL statement must at least contain the primary key columns of the mapped candidate class, and additionally the discriminator column if defined and the version column(s) if defined.
- results are taken from the `SELECT` clause of the query, and the `setResult` method throws `JDOUserException`.
- the cardinality of the result is determined by the SQL query itself, and the `setRange` method throws `JDOUserException`.

SQL queries can be defined without a candidate class. These queries can be found by name using the factory method `newNamedQuery`, specifying the class as null, or can be constructed without a candidate class.

Table 7: Shape of Result of SQL Query

Candidate class	Selected columns	setResultClass	setUnique	shape of result
C	must include primary key columns	null	false	<code>List<C></code>
C	must include primary key columns	null	true	C
null	single column of type T	null	false	<code>List<T></code>
null	single column of type T	null	true	T
null	more than one result column	null	false	<code>List<Object[]></code>
null	more than one result column	null	true	<code>Object[]</code>

Table 7: Shape of Result of SQL Query

Candidate class	Selected columns	setResultClass	setUnique	shape of result
null or not null		UserResult.class	false	List<UserResult>
null or not null		UserResult.class	true	UserResult

14.7.1 Mapping Columns of SQL Queries to User-specified Result Classes

There are two specified means by which columns of SQL queries can be mapped to user-specified result classes: by name and by position.

Each labeled column in the result set is mapped according to the mapping defined in Section 14.6.12, using the result set column name as the public field or property name of the result class. Since SQL is generally case-insensitive, matching of labels to field and property names is not case-sensitive. Labels that differ only in case cause a JDOUserException to be thrown when the query is executed.

A result set column is considered labeled if:

- the return value from `java.sql.ResultSetMetaData.getColumnLabel (int oneBasedColumnIndex)` is non-null and of non-zero length; or,
- if `getColumnLabel` is null or of zero length, (`int oneBasedColumnIndex`) is non-null and of non-zero length.

Other determinations of whether a column is considered labeled are unspecified and not portable. Each character in a column label that is not a valid character in a Java field or method identifier is converted to an underscore character for the purposes of mapping; other name conversion strategies are not specified and not portable.

Each unlabeled column in the result set is mapped positionally. As required by Section 14.6.12, the result class must expose a public method with the signature `void put(Object, Object)` for data that do not have a public field or set method; it is this method that is used by the implementation to map columns positionally, using the integral position of the column, as an Integer, as the first argument, and the column's value as the second. Positional indexes passed to the result class's `void put(Object, Object)` method are zero-based; that is, the value of the Integer given is one less than the SQL column index, as SQL column indexes are one-based.

14.8 Deletion by Query

An application may want to delete a number of instances in the datastore without instantiating them in memory. The instances to be deleted can be described by a query.

```
long deletePersistentAll(Object... parameters);
long deletePersistentAll(Map parameters);
long deletePersistentAll();
```

These methods delete the instances of affected classes that pass the filter, and all dependent instances. Affected classes are the candidate class and its persistence-capable subclasses. The number of instances of affected classes that were deleted is returned. Embedded instances and dependent instances are not counted in the return value.

Query elements filter, parameters, imports, variables, and unique are valid in queries used for delete. Elements result, result class, range, grouping, and ordering are invalid. If any of these elements is set to its non-default value when one of the deletePersistentAll methods is called, a JDOUserException is thrown and no instances are deleted.

When the value of the Unique flag is true, then at most one instance will be deleted. If more than one instance satisfies the filter, then deletePersistentAll throws a JDOUserException.

Dirty instances of affected classes are first flushed to the datastore. Instances already in the cache when deleted via these methods or brought into the cache as a result of these methods undergo the life cycle transitions as if deletePersistent had been called on them.

That is, if an affected class implements the DeleteCallback interface, the instances of that class to be deleted are instantiated in memory and the jdoPreDelete method is called prior to deleting the instance in the datastore. If any LifecycleListener instances are registered with affected classes, these listeners are called for each deleted instance.

Before returning control to the application, instances of affected classes in the cache are refreshed by the implementation so their status in the cache reflects whether they were deleted from the datastore.

14.9 Extensions

Some JDO vendors provide extensions to the query, and these extensions must be set in the query instance prior to execution.

```
void setExtensions(Map extensions);
```

This method replaces all current extensions with the extensions contained as entries in the parameter Map. A parameter value of null means to remove all extensions. The keys are immediately evaluated; entries where the key refers to a different vendor are ignored; entries where the key prefix matches this vendor but where the full key is unrecognized cause a JDOUserException to be thrown. The extensions become part of the state of the Query instance that is serialized. The parameter Map is not used after the method returns.

```
void addExtension(String key, Object value);
```

This method adds one extension to the Query instance. This extension will remain until the next setExtensions method is called, or addExtension with an equal key. Key recognition behavior is identical to setExtensions.

14.10 Examples:

The following class definitions for persistence capable classes are used in the examples:

```
package com.xyz.hr;
class Employee {
    String name;
    float salary;
    Department dept;
    Employee boss;
}
package com.xyz.hr;
class Department {
    String name;
    Collection emps;
}
```

14.10.1 Basic query.

This query selects all Employee instances from the candidate collection where the salary is greater than the constant 30000.

Note that the `float` value for `salary` is unwrapped for the comparison with the literal `int` value, which is promoted to `float` using numeric promotion. If the value for the `salary` field in a candidate instance is `null`, then it cannot be unwrapped for the comparison, and the candidate instance is rejected.

```
Query q = pm.newQuery (Employee.class, "salary > 30000");
Collection emps = (Collection) q.execute ();
<query name="basic">
    [ !CDATA[
        select where salary > 30000
    ]]
</query>
```

14.10.2 Basic query with ordering.

This query selects all Employee instances from the candidate collection where the salary is greater than the constant 30000, and returns a `Collection` ordered based on employee salary.

```
Query q = pm.newQuery (Employee.class, "salary > 30000");
q.setOrdering ("salary ascending");
Collection emps = (Collection) q.execute ();
<query name="ordering">
    [ !CDATA[
        select where salary > 30000
        order by salary ascending
    ]]
</query>
```

14.10.3 Parameter passing.

This query selects all Employee instances from the candidate collection where the salary is greater than the value passed as a parameter and the name starts with the value passed as a second parameter.

If the value for the `salary` field in a candidate instance is `null`, then it cannot be unwrapped for the comparison, and the candidate instance is rejected.

```
Query q = pm.newQuery (Employee.class,
    "salary > sal && name.startsWith(begin)");
q.declareParameters ("Float sal, String begin");
Collection emps = (Collection) q.execute (new Float (30000.));
<query name="parameter">
    [ !CDATA[
        select where salary > :sal && name.startsWith(:begin)
    ]]
</query>
```

14.10.4 Navigation through single-valued field.

This query selects all Employee instances from the candidate collection where the value of the `name` field in the `Department` instance associated with the `Employee` instance is equal to the value passed as a parameter.

If the value for the `dept` field in a candidate instance is `null`, then it cannot be navigated for the comparison, and the candidate instance is rejected.

```
Query q = pm.newQuery (Employee.class, "dept.name == dep");
q.declareParameters ("String dep");
String rnd = "R&D";
```

```
Collection emps = (Collection) q.execute (rnd);
<query name="navigate">
    [ !CDATA[
select where dept.name == :dep
]]
</query>
```

14.10.5 Navigation through multi-valued field.

This query selects all Department instances from the candidate collection where the collection of Employee instances contains at least one Employee instance having a salary greater than the value passed as a parameter.

```
String filter = "emps.contains (emp) & emp.salary > sal";
Query q = pm.newQuery (Department.class, filter);
q.declareParameters ("float sal");
q.declareVariables ("Employee emp");
Collection deps = (Collection) q.execute (new Float (30000.));
<query name="multivalue">
    [ !CDATA[
select where emps.contains(e)
&& e.salary > :sal
]]
</query>
```

14.10.6 Membership in a collection

This query selects all Department instances where the name field is contained in a parameter collection, which in this example consists of three department names.

```
String filter = "depts.contains(name)";
Query q = pm.newQuery (Department.class, filter);
List depts =
    Arrays.asList(new String [] {"R&D", "Sales", "Marketing"});
q.declareParameters ("Collection depts");
Collection deps = (Collection) q.execute (depts);
<query name="collection">
    [ !CDATA[
select where :depts.contains(name)
]]
</query>
```

14.10.7 Projection of a Single Field

This query selects names of all Employees who work in the parameter department.

```
Query q = pm.newQuery (Employee.class, "dept.name == deptName");
q.declareParameters ("String deptName");
q.setResult("name");
Collection names = (Collection) q.execute("R&D");
Iterator it = names.iterator();
while (it.hasNext()) {
    String name = (String) it.next();
    ...
}
<query name="project">
    [ !CDATA[
select name where dept.name == :deptName
]]
</query>
```

14.10.8 Projection of Multiple Fields and Expressions

This query selects names, salaries, and bosses of Employees who work in the parameter department.

```
class Info {
    public String name;
    public Float salary;
    public Employee reportsTo;
}
Query q = pm.newQuery (Employee.class, "dept.name == deptName");
q.declareParameters ("String deptName");
q.setResult("name, salary, boss as reportsTo");
q.setResultClass(Info.class);
Collection names = (Collection) q.execute("R&D");
Iterator it = names.iterator();
while (it.hasNext()) {
    Info info = (Info) it.next();
    String name = info.name;
    Employee boss = info.reportsTo;
    ...
}
<query name="resultclass">
    [<!CDATA[
        select name, salary, boss as reportsTo into Info
        where dept.name == :deptName
    ]</!CDATA>
</query>
```

14.10.9 Projection of Multiple Fields and Expressions into a Constructed instance

This query selects names, salaries, and bosses of Employees who work in the parameter department, and uses the constructor for the result class.

```
class Info {
    public String name;
    public Float salary;
    public Employee reportsTo;
    public Info (String name, Float salary, Employee reportsTo) {
        this.name = name;
        this.salary = salary;
        this.reportsTo = reportsTo;
    }
}
Query q = pm.newQuery (Employee.class, "dept.name == deptName");
q.declareParameters ("String deptName");
q.setResult("new Info(name, salary, boss)");
q.setResultClass(Info.class);
Collection names = (Collection) q.execute("R&D");
Iterator it = names.iterator();
while (it.hasNext()) {
    Info info = (Info) it.next();
    String name = info.name;
    Employee boss = info.reportsTo;
    ...
}
<query name="construct">
    [<!CDATA[
        select new Info (name, salary, boss)
        where dept.name == :deptName
    ]</!CDATA>
</query>
```

14.10.10 Aggregation of a single Field

This query averages the salaries of Employees who work in the parameter department and returns a single value.

```
Query q = pm.newQuery (Employee.class, "dept.name == deptName");
q.declareParameters ("String deptName");
q.setResult("avg(salary)");
Float avgSalary = (Float) q.execute("R&D");
<query name="aggregate">
    [ !CDATA[
select avg(salary)
where dept.name == :deptName
]]
</query>
```

14.10.11 Aggregation of Multiple Fields and Expressions

This query averages and sums the salaries of Employees who work in the parameter department.

```
Query q = pm.newQuery (Employee.class, "dept.name == deptName");
q.declareParameters ("String deptName");
q.setResult("avg(salary), sum(salary)");
Object[] avgSum = Object[] q.execute("R&D");
Float average = (Float)avgSum[0];
Float sum = (Float)avgSum[1];
<query name="multiple">
    [ !CDATA[
select avg(salary), sum(salary)
where dept.name == :deptName
]]
</query>
```

14.10.12 Aggregation of Multiple fields with Grouping

This query averages and sums the salaries of Employees who work in all departments having more than one employee and aggregates by department name.

```
Query q = pm.newQuery (Employee.class);
q.setResult("avg(salary), sum(salary), dept.name");
q.setGrouping("dept.name having count(dept.name) > 1");
Collection results = (Collection)q.execute();
Iterator it = results.iterator();
while (it.hasNext()) {
    Object[] info = (Object[]) it.next();
    Float average = (Float)info[0];
    Float sum = (Float)info[1];
    String deptName = (String)info[2];
    ...
}
<query name="group">
    [ !CDATA[
select avg(salary), sum(salary), dept.name from com.xyz.hr.Employee where
dept.name == :deptName group by dept.name having count(dept.name) > 1
]]
</query>
```

14.10.13 Selection of a Single Instance

This query returns a single instance of Employee.

```
Query q = pm.newQuery (Employee.class, "name == empName");
q.declareParameters ("String empName");
q.setUnique(true);
Employee emp = (Employee) q.execute("Michael");
<query name="unique">
    [ !CDATA[
select unique this
where dept.name == :deptName
]]

```

```
</query>
```

14.10.14 Selection of a Single Field

This query returns a single field of a single Employee.

```
Query q = pm.newQuery (Employee.class, "name == empName");
q.declareParameters ("String empName");
q.setResult("salary");
q.setResultClass(Float.class);
q.setUnique(true);
Float salary = (Float) q.execute ("Michael");
<query name="single">
    [<!CDATA[
        select unique new Float(salary)
        where dept.name == :deptName
    ]</query>
```

14.10.15 Projection of “this” to User-defined Result Class with Matching Field

This query selects instances of Employee who make more than the parameter salary and stores the result in a user-defined class. Since the default is “distinct this as Employee”, the field must be named Employee and be of type Employee.

```
class EmpWrapper {
    public Employee Employee;
}
Query q = pm.newQuery (Employee.class, "salary > sal");
q.declareParameters ("Float sal");
q.setResultClass(EmpWrapper.class);
Collection infos = (Collection) q.execute (new Float (30000.));
Iterator it = infos.iterator();
while (it.hasNext()) {
    EmpWrapper info = (EmpWrapper)it.next();
    Employee e = info.Employee;
    ...
}
<query name="thisfield">
    [<!CDATA[
        select into EmpWrapper
        where salary > sal
    ]</query>
```

14.10.16 Projection of “this” to User-defined Result Class with Matching Method

This query selects instances of Employee who make more than the parameter salary and stores the result in a user-defined class.

```
class EmpInfo {
    private Employee worker;
    public Employee getWorker() {return worker;}
    public void setEmployee(Employee e) {worker = e;}
}
Query q = pm.newQuery (Employee.class, "salary > sal");
q.declareParameters ("Float sal");
q.setResultClass(EmpInfo.class);
Collection infos = (Collection) q.execute (new Float (30000.));
Iterator it = infos.iterator();
while (it.hasNext()) {
    EmpInfo info = (EmpInfo)it.next();
    Employee e = info.getWorker();
```

```
    ...
}

<query name="thisismethod">
    [ !CDATA[
select into EmpInfo
where salary > sal
]]
</query>
```

14.10.17 Projection of variables

This query returns the names of all Employees of all "Research" departments:

```
Query q = pm.newQuery(Department.class);
q.declareVariables("Employee e");
q.setFilter("name.startsWith('Research') && emps.contains(e)");
q.setResult("e.name");
Collection names = q.execute();
Iterator it = names.iterator();
while (it.hasNext()) {
    String name = (String)it.next();
    ...
}
<query name="variables">
    [ !CDATA[
select e.name
where name.startsWith('Research')
&& emps.contains((com.xyz.hr.Employee) e)
]]
</query>
```

14.10.18 Non-correlated subquery

This query returns names of employees who work more than the average of all employees:

```
// single string form
Query q = pm.newQuery(
    "select name from com.xyz.hr.Employee
     where this.weeklyhours >
        (select avg(e.weeklyhours) from com.xyz.hr.Employee e)");
Collection names = q.execute();
Iterator it = names.iterator();
while (it.hasNext()) {
    String name = (String)it.next();
    ...
}
// subquery instance form
Query subq = pm.newQuery(Employee.class);
subq.setFilter("select avg(weeklyhours)");
Query q = pm.newQuery(Employee.class);
q.setFilter("this.weeklyhours > average_hours");
q.setResult("this.name");
q.setSubquery(subq, "double average_hours", null);
Collection names = q.execute();
Iterator it = names.iterator();
while (it.hasNext()) {
    String name = (String)it.next();
    ...
}
```

```
<query name="noncorrelated_subquery">
    [ !CDATA[
        select name from com.xyz.hr.Employee
        where this.weeklyhours >
            (select avg(e.weeklyhours) from com.xyz.hr.Employee e)
    ] ]
</query>
```

14.10.19 Correlated subquery

This query returns names of employees who work more than the average of employees in the same department having the same manager. The candidate collection of the subquery is the collection of employees in the department of the candidate employee and the parameter passed to the subquery is the manager of the candidate employee.

```
// single string form
Query q = pm.newQuery(
    "select name from com.xyz.hr.Employee
     where this.weeklyhours >
         (select AVG(e.weeklyhours) from this.department.employees as e
          where e.manager == this.manager)");
Collection names = q.execute();
Iterator it = names.iterator();
while (it.hasNext()) {
    String name = (String)it.next();
    ...
}
// subquery instance form
Query subq = pm.newQuery(Employee.class);
subq.setFilter("this.manager == :manager");
subq.setResult("avg(weeklyhours)");
Query q = pm.newQuery(Employee.class);
q.setFilter("this.weeklyhours > average_hours");
q.setResult("name");
q.setSubquery(subq, "double average_hours", "department.employees",
    "this.manager");
Collection names = q.execute();
Iterator it = names.iterator();
while (it.hasNext()) {
    String name = (String)it.next();
    ...
}
<query name="correlated_subquery">
    [ !CDATA[
        select name from com.xyz.hr.Employee
        where this.weeklyhours >
            (select AVG(e.weeklyhours) from this.department.employees e
             where e.manager == this.manager)
    ] ]
</query>
```

14.10.20 Deleting Multiple Instances

This query deletes all Employees who make more than the parameter salary.

```
Query q = pm.newQuery (Employee.class, "salary > sal");
q.declareParameters ("Float sal");
q.deletePersistentAll(new Float(30000.));
```

15 Object-Relational Mapping

JDO is datastore-independent. However, many JDO implementations support storage of persistent instances in relational databases, and this storage requires that the domain object model be mapped to the relational schema. The mapping strategies for simple cases are for the most part the same from one JDO implementation to another. For example, typically a class is mapped to one or more tables, and fields are mapped to one or more columns.

The most common mapping paradigms are standardized, which allows users to define their mapping once and use the mapping for multiple implementations.

Mapping Overview

Mapping between the domain object model and the relational database schema is specified from the perspective of the object model. Each class is mapped to a primary table and possibly multiple secondary tables and multiple join tables. Fields in the class are mapped to columns in either the primary table, secondary tables, or join tables. Simple field types typically map to single columns. Complex field types (Collections, Maps, and arrays) typically map to multiple columns.

Secondary tables represent non-normalized tables that contain zero or one row corresponding to each row in the primary table, and contain field values for the persistent class. These tables might be modeled as one-to-one relationships, but they can be modeled as containing nullable field values instead.

Secondary tables might be used by a single field mapping or by multiple field mappings. If used by a single field mapping, the join conditions linking the primary and secondary table might be specified in the field mapping itself. If used by multiple field mappings, the join conditions might be specified in each field mapping or specified in the class mapping.

Complex field types are mapped by mapping each of the components individually. Collections map the element and optional order components. Maps map the key and value components. Arrays map the element and order components.

Mapping Strategies

The specification does not standardize how the mapping files are generated. Most implementations will support one or more of the following strategies for creating mapping files:

- starting with a relational schema, generate persistence-capable classes and the mapping to relate them (sometimes referred to as reverse mapping or class generation);
- starting with persistence-capable classes, generate the relational schema and the mapping to relate them (sometimes called forward mapping or schema generation);
- starting with a relational schema and persistence-capable classes, create the mapping to relate them (sometimes called meet-in-the-middle mapping).

This specification does not standardize how the mapping files are created. Implementations might support command-line or interactive GUI-based tools to assist in the process.

There is no portable behavior for incompletely specified mappings. When a portable application runs, the mapping is completely specified by the mapping metadata, regardless of whether the user

created the mapping or the mapping was created by a tool. If the mapping is incompletely specified, the JDO implementation might silently use mapping defaults or throw an exception.

15.1 Column Elements

Column elements used for simple, non-relationship field value mapping specify at least the column name. The field value is loaded from the value of the named column.

The column element might contain additional information about the column, for use in generating schema. This might include the scale and precision for numeric types, the maximum length for variable-length field types, the jdbc type of the column, or the sql type of the column. This information is ignored for runtime use, with the following exception: if the jdbc type of the column does not match the default jdbc type for the field's class (for example, a String field is mapped to a CLOB rather than a VARCHAR column), the jdbc type information is required at runtime.

Column elements that contain only the column name can be omitted, if the column name is instead contained in the enclosing element. Thus, a field element is defined to allow a column attribute if only the name is needed, or a column element if more than the name is needed. If both column attribute and column element are specified for any element, it is a user error.

Mapping enums

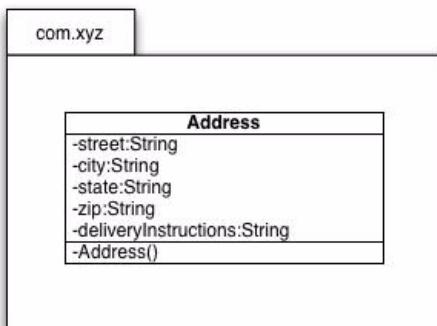
Mapping an enum to a fixed-precision numeric type uses the `ordinal()` value for storage; mapping to a character column type (CHAR, VARCHAR, etc.) uses the `name()` value for storage; mapping to any other column type is not portable.

The default jdbc-type for columns mapped to enums is VARCHAR. This provides maximum flexibility as the enum evolves, as it uses the name of the enum for storage. As more enum values are added, the name does not change, whereas the ordinal value will change if enum values are added anywhere except at the end.

For portability, if the mapping should use the ordinal value for storage, then the jdbc-type must be specified in the column metadata as a fixed precision numeric type. An implementation might support floating point types for storage, and might auto-detect the column type but this behavior is not portable.

15.1.1 Mapping single-valued fields to columns

This example demonstrates mappings between fields and value columns.



```

package com.xyz;
public class Address {
  
```

```
String street;
String city;
State state;
String zip;
String deliveryInstructions;
}
package com.xyz;
public enum State {
AL("Alabama"),
...
WY("Wyoming");
}

CREATE TABLE ADDR (
STREET VARCHAR(255) PRIMARY KEY,
CITY VARCHAR(255),
STATE CHAR(2),
ZIPCODE VARCHAR(10),
DELIV_INS CLOB
)

<orm>
<package name="com.xyz">
<class name="Address" table="ADDR">
<field name="street" column="STREET"/>
<field name="city" column="CITY"/>
<field name="state" column="STATE"/>
<field name="zip" column="ZIPCODE"/>
<field name="deliveryInstructions">
<column name="DELIV_INS" jdbc-type="CLOB"/>
</field>
</class>
</package>
</orm>
```

15.2 Join Condition

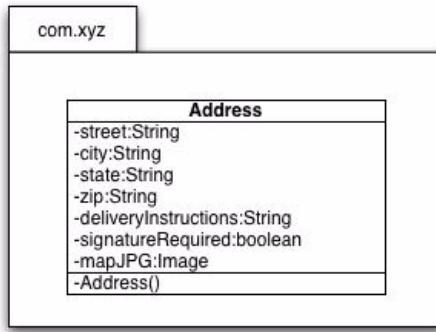
Secondary tables and join tables are mapped using a join condition that associates a column or columns in the secondary or join table with a column or columns in the primary table, typically the primary table's primary key columns.

Column elements used for relationship mapping or join conditions specify the column name and optionally the target column name. The target column name is the name of the column in the associated table corresponding to the named column. The target column name is optional when the target column is the single primary key column of the associated table, or when the target column name is identical to the join column name.

NOTE: *This usage of column elements is fundamentally different from the usage of column elements for value mapping. For value mapping, the name attribute names the column that contains the value to be used. For join conditions, the name attribute names the column that contains the reference data to be joined to the primary key column of the target.*

15.2.1 Secondary Table mapping

This example demonstrates the use of join elements to represent join conditions linking a class' primary table and secondary tables used by fields.



```

package com.xyz;
public class Address {
    String street;
    String city;
    String state;
    String zip;
    String deliveryInstructions;
    boolean signatureRequired;
    byte[] mapJPG;
}

CREATE TABLE ADDR (
    STREET VARCHAR(255) PRIMARY KEY,
    CITY VARCHAR(255),
    STATE CHAR(2),
    ZIPCODE VARCHAR(10)
)

CREATE TABLE DELIV (
    ADDR_STREET VARCHAR(255),
    SIG_REQUIRED BIT,
    DELIV_INS CLOB
)

CREATE TABLE MAPQUEST_INFO (
    ADDR_STREET VARCHAR(255),
    MAPQUEST_IMAGE BLOB
)

<orm>
<package name="com.xyz">
    <class name="Address" table="ADDR">
        <!-- shared join condition used by fields in DELIV -->
        <join table="DELIV" column="ADDR_STREET"/>
        <field name="street" column="STREET"/>
        <field name="city" column="CITY"/>
        <field name="state" column="STATE"/>
        <field name="zip" column="ZIPCODE"/>
        <field name="signatureRequired" table="DELIV"
              column="SIG_REQUIRED"/>
        <field name="deliveryInstructions" table="DELIV">
            <column name="DELIV_INS" jdbc-type="CLOB"/>
        </field>
        <field name="mapJPG" table="MAPQUEST_INFO"
              column="MAPQUEST_IMAGE">

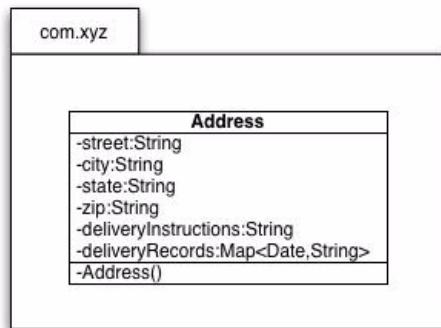
```

```

<!-- join condition defined for this field only -->
    <join column="ADDR_STREET"/>
</field>
</class>
</package>
</orm>
```

15.2.2 Map using join table

This example uses the <join> element to map a Map<Date, String> field to a join table. Note that in this example, the primary table has a compound primary key, requiring the use of the target attribute in join conditions.



```

package com.xyz;
public class Address {
    String street;
    String city;
    String state;
    String zip;
    String deliveryInstructions;
    boolean signatureRequired;
    Map<Date, String> deliveryRecords;
}

CREATE TABLE ADDR (
    STREET VARCHAR(255),
    CITY VARCHAR(255),
    STATE CHAR(2),
    ZIPCODE VARCHAR(10),
    PRIMARY KEY (STREET, ZIPCODE)
)

CREATE TABLE DELIV_RECORDS (
    ADDR_STREET VARCHAR(255),
    ADDR_ZIPCODE VARCHAR(10),
    DELIV_DATE TIMESTAMP,
    SIGNED_BY VARCHAR(255)
)

<orm>
<package name="com.xyz">
    <class name="Address" table="ADDR">
        <field name="street" column="STREET"/>
        <field name="city" column="CITY"/>
        <field name="state" column="STATE"/>
        <field name="zip" column="ZIPCODE"/>
        <join column="ADDR_STREET"/>
    </class>
</package>
</orm>
```

```
<!-- field type is Map<Date, String> -->
<field name="deliveryRecords" table="DELIV_RECORDS">
    <join>
        <column name="ADDR_STREET" target="STREET"/>
        <column name="ADDR_ZIPCODE" target="ZIPCODE"/>
    </join>
    <key column="DELIV_DATE"/>
    <value column="SIGNED_BY"/>
</field>
</class>
</package>
</orm>
```

15.3 Relationship Mapping

Column elements used for relationship mapping are contained in either the field element directly in the case of a simple reference, or in one of the collection, map, or array elements contained in the field element.

In case only the column name is needed for mapping, the column name might be specified in the field, collection, or array element directly instead of requiring a column element with only a name.

If two relationships (one on each side of an association) are mapped to the same column, the field on only one side of the association needs to be explicitly mapped.

The field on the other side of the relationship can be mapped by using the mapped-by attribute identifying the field on the side that defines the mapping. Regardless of which side changes the relationship, flush (whether done as part of commit or explicitly by the user) will modify the datastore to reflect the change and will update the memory model for consistency. There is no further behavior implied by having both sides of the relationship map to the same database column(s). In particular, making a change to one side of the relationship does not imply any runtime behavior by the JDO implementation to change the other side of the relationship in memory prior to flush, and there is no requirement to load fields affected by the change if they are not already loaded. This implies that if the RetainValues flag or DetachAllOnCommit is set to true, and the relationship field is loaded, then the implementation will change the field on the other side so it is visible after transaction completion.

Similarly, if one side is deleted, the other side will be updated to be consistent at flush. During flush, each relationship in which the instance is involved is updated for consistency. These changes are applied to the object model instances. If the relationship is marked as dependent, the related instance is deleted. If the relationship is not marked as dependent, the corresponding field in the related instance is updated to not refer to the instance being deleted:

- If the related field is a collection, then any referencing element is removed.
- If the related field is a map, then any referencing map entry is removed.
- If the related field is a reference, then it is set to null.

If the related instances are not instantiated in memory, there is no requirement to instantiate them. Changes are applied to the second level cache upon commit.

The object model changes are synchronized to the database according to the declared mapping of the relationships to the database. If related instances are to be deleted, and there is a foreign key declared with a delete action of cascade delete, then the jdo implementation need do nothing to cause the delete of the related instance. Similarly, if there is a foreign key declared with a delete action of nullify, then the jdo implementation need do nothing to cause the column of the mapped relationship to be set to null. If there is a foreign key declared to be not nullable, and the requirement is to nullify the related field, then `JDODataStoreException` is thrown at flush.

Conflicting changes to relationships cause a JDOUserException to be thrown at flush time. Conflicting changes include:

- adding a related instance with a single-valued mapped-by relationship field to more than one one-to-many collection relationship
- setting both sides of a one-to-one relationship such that they do not refer to each other

Mapping Strategies

For single-valued relationships, there are three basic ways to map references from one persistence-capable class (the referring class) to a related class:

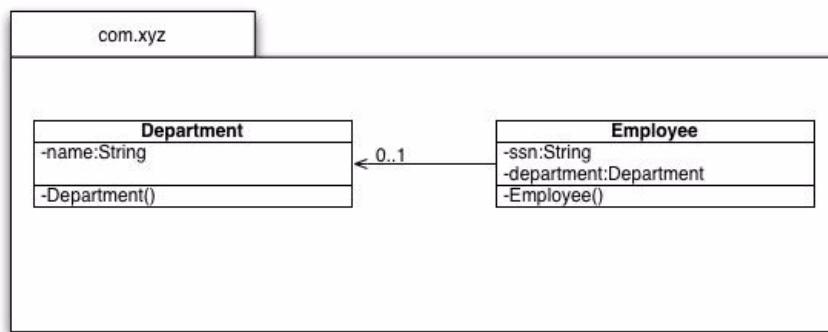
- serialized: The entire related instance is serialized into a single column in the primary or secondary table of the referring class.
- embedded: The related instance is mapped, field by field, to columns in the primary or secondary table of the referring class.
- by reference: The related instance is in a different table, and the column in the primary or secondary table of the referring class contains a reference (often, a foreign key) to the primary table of the related class.

For multi-valued relationships, there are five basic ways to map references from one persistence-capable class (the referring class) to a related class:

- serialized: The entire collection, array, or map is serialized into a single column in the primary or secondary table of the referring class.
- serialized in a join table: A join table is used to associate multiple rows in the join table with a single row in the primary or secondary table of the referring class, and the related instances are serialized, one per row, into a single column in the join table.
- embedded in a join table: A join table is used to associate multiple rows in the join table with a single row in the primary or secondary table of the referring class, and each related instance is mapped, one per row, field by field, into multiple columns in the join table.
- by reference to the primary table of the related class: The related class has a reference (often, a foreign key) to the primary table of the referring class.
- by reference in a join table: A join table is used to associate multiple rows in the join table with a single row in the primary or secondary table of the referring class, and a column in the join table contains a reference (often, a foreign key) to the primary table of the related class.

15.3.1 Many-to-One using foreign key

A many-one mapping (Employee has a reference to Department).



```

package com.xyz;
public class Department {
    String name;
}

public class Employee {
    String ssn;
    Department department;
}

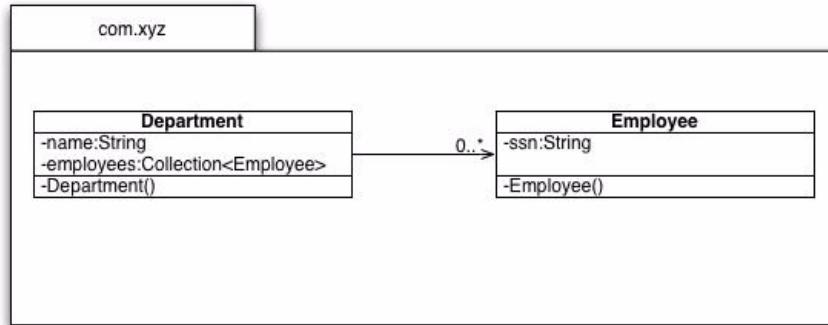
CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    DEP_NAME VARCHAR(255)
)
CREATE TABLE DEP (
    NAME VARCHAR(255) PRIMARY KEY
)

<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN"/>
        <!-- field type is Department -->
        <field name="department" column="DEP_NAME" />
    </class>
    <class name="Department" table="DEP">
        <field name="name" column="NAME" />
    </class>
</package>
</orm>

```

15.3.2 One-to-Many using foreign key

A one-many mapping (Department has a collection of Employees). This example uses the same schema as Example 4.



```

package com.xyz;
public class Department {
    String name;
    Collection<Employee> employees;
}

public class Employee {
    String ssn;
}

```

```

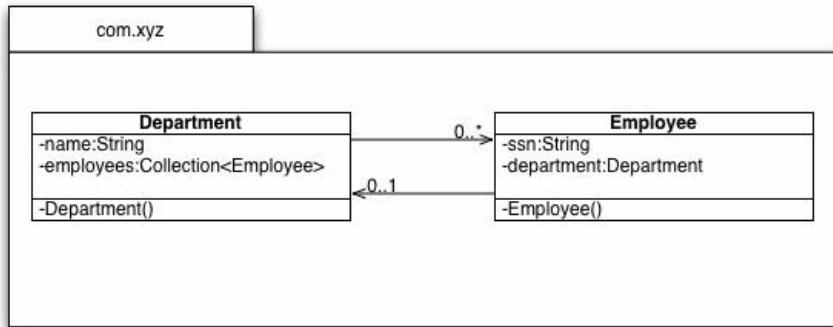
}

<orm>
<package name="com.xyz">
    <class name="Department" table="DEP">
        <field name="name" column="NAME" />
        <!-- field type is Collection<Employee> -->
        <field name="employees">
            <element column="DEP_NAME" />
        </field>
    </class>
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN" />
    </class>
</package>
</orm>

```

15.3.3 Many-to-One and One-to-Many using mapped-by

If both the Employee.department and Department.employees fields exist, only one needs to be mapped explicitly; one side is specified to be “mapped-by” the other side. The Department side is marked as using the same mapping as a field on the Employee side. This example uses the same schema as Examples 4 and 5.



```

package com.xyz;

public class Department {
    String name;
    Collection<Employee> employees;
}

public class Employee {
    String ssn;
    Department department;
}

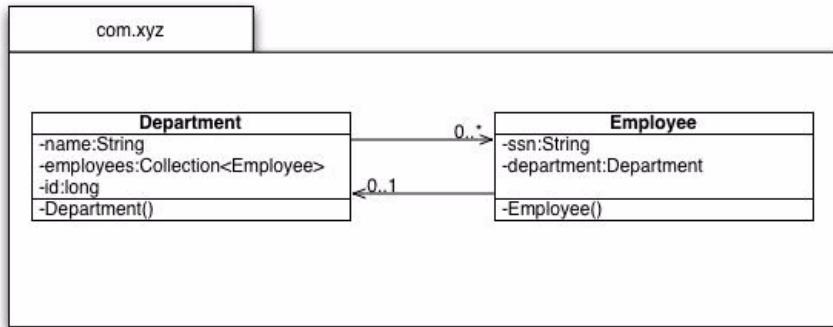
<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN" />
        <field name="department" column="DEP_NAME" />
    </class>
    <class name="Department" table="DEP">
        <field name="name" column="NAME" />
        <field name="employees" mapped-by="department" />
    </class>
</orm>

```

```
</package>
</orm>
```

15.3.4 Many-to-One and One-to-Many using compound foreign key

This example mirrors Example 6, but now Department has a compound primary key.



```

package com.xyz;
public class Department {
    String name;
    Collection<Employee> employees;
    long id;
}

public class Employee {
    String ssn;
    Department department;
}

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    DEP_NAME VARCHAR(255),
    DEP_ID BIGINT
)

CREATE TABLE DEP (
    NAME VARCHAR(255),
    ID BIGINT,
    PRIMARY KEY (NAME, DEP_ID)
)

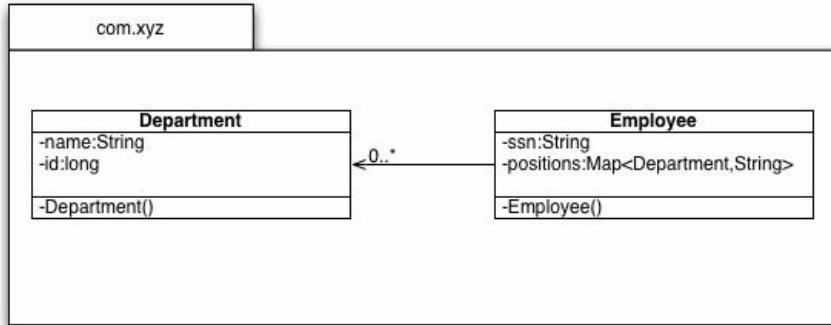
<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN"/>
        <field name="department">
            <column name="DEP_NAME" target="NAME"/>
            <column name="DEP_ID" target="ID"/>
        </field>
    </class>
    <class name="Department" table="DEP">
        <field name="name" column="NAME"/>
        <field name="id" column="ID"/>
        <field name="employees" mapped-by="department"/>
    </class>
</orm>
```

```
</package>
</orm>
```

15.3.5 Many-to-One and One-to-Many using Map<Department, String>

Employee has a Map<Department, String> mapping each department the employee is a member of to her position within that department. Department still has a compound primary key.

The Map uses a join table that contains one row for each entry in the Map. The columns in the join table refer to the Employee, the Department, and the position.



```

package com.xyz;
public class Department {
    String name;
    long id;
}

public class Employee {
    String ssn;
    Map<Department, String> positions;
}

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY
)

CREATE TABLE DEP (
    NAME VARCHAR(255),
    ID BIGINT,
    PRIMARY KEY (NAME, ID)
)

CREATE TABLE EMP_POS (
    EMP_SSN CHAR(10),
    DEP_NAME VARCHAR(255)
    DEP_ID BIGINT,
    POS VARCHAR(255)
)

<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN"/>
        <!-- field type is Map<Department, String> -->
        <field name="positions" table="EMP_POS">

```

```
<join column="EMP_SSN" />
<key>
    <column name="DEP_NAME" target="NAME" />
    <column name="DEP_ID" target="ID" />
</key>
<value column="POS" />
</field>
</class>
<class name="Department" table="DEP">
    <field name="name" column="NAME" />
    <field name="id" column="ID" />
</class>
</package>
</orm>
```

15.3.6 Many-to-One and One-to-Many using Map<String, Employee>

Department has a Map<String, Employee> mapping the role in the department to the employee. Department still has a compound primary key.

The Map uses the employee's table that contains the role as well as other employee information. The mapping on the Department side uses the mapped-by attribute naming the field in the Employee that refers to Department. The key uses the mapped-by attribute naming the field in Employee that contains the key for the map.

```
package com.xyz;
public class Department {
    String name;
    long id;
    Map<String, Employee> roles;
}

public class Employee {
    String ssn;
    Department dept;
    String role;
}

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    DEPT BIGINT,
    ROLE VARCHAR
)

CREATE TABLE DEP (
    NAME VARCHAR(255),
    ID BIGINT,
    PRIMARY KEY (NAME, ID)
)

<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN" />
        <field name="dept" column="DEP" />
        <field name="role" column="ROLE" />
    </class>
    <class name="Department" table="DEP">
        <field name="name" column="NAME" />
        <field name="id" column="ID" />
        <!-- field type is Map<String, Employee> -->
        <field name="roles" mapped-by="dept" />
    </class>
</package>
</orm>
```

```

        <key mapped-by="role" />
    </field>
</class>
</package>
</orm>

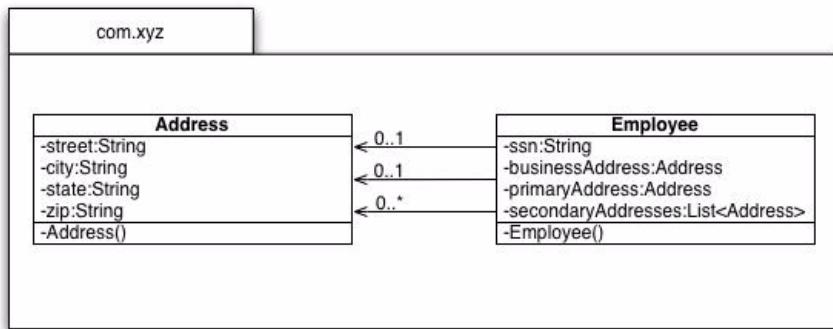
```

15.4 Embedding

Some of the columns in a table might be mapped as a separate Java class to better match the object model. Embedding works to arbitrary depth.

15.4.1 Mapping relationships using embedded, referenced, and join table

Employee has a reference to a business address, which is a standard many-one. Employee also has a primary Address, whose data is embedded within the Employee record. Finally, Employee has a List<Address> of secondary Address references, whose data is embedded in the join table.



```

package com.xyz;
public class Address {
    String street;
    String city;
    String state;
    String zip;
}

public class Employee {
    String ssn;
    Address businessAddress;
    Address primaryAddress;
    List<Address> secondaryAddresses;
}

CREATE TABLE ADDR (
    STREET VARCHAR(255) PRIMARY KEY,
    CITY VARCHAR(255),
    STATE CHAR(2),
    ZIPCODE VARCHAR(10)
)

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    BUSADDR_STREET VARCHAR(255),
    PADDR_STREET VARCHAR(255),
    ...
)

```

```
PADDR_CITY VARCHAR(255),  
PADDR_STATE CHAR(2),  
PADDR_ZIPCODE VARCHAR(10)  
)  
  
CREATE TABLE EMP_ADDRS (   
    EMP_SSN CHAR(10),  
    IDX INTEGER,  
    SADDR_STREET VARCHAR(255),  
    SADDR_CITY VARCHAR(255),  
    SADDR_STATE CHAR(2),  
    SADDR_ZIPCODE VARCHAR(10)  
)  
  
<orm>  
    <package name="com.xyz">  
        <class name="Employee" table="EMP">  
            <field name="ssn" column="SSN"/>  
            <!-- field type is Address -->  
            <field name="businessAddress" column="BUSADDR_STREET"/>  
            <!-- field type is Address -->  
            <field name="primaryAddress">  
                <embedded null-indicator-column="PADDR_STREET">  
                    <field name="street" column="PADDR_STREET"/>  
                    <field name="city" column="PADDR_CITY"/>  
                    <field name="state" column="PADDR_STATE"/>  
                    <field name="zip" column="PADDR_ZIPCODE"/>  
                </embedded>  
            </field>  
            <!-- field type is List<Address> -->  
            <field name="secondaryAddresses" table="EMP_ADDRS">  
                <join column="EMP_SSN"/>  
                <element>  
                    <embedded>  
                        <field name="street" column="SADDR_STREET"/>  
                        <field name="city" column="SADDR_CITY"/>  
                        <field name="state" column="SADDR_STATE"/>  
                        <field name="zip" column="SADDR_ZIPCODE"/>  
                    </embedded>  
                </element>  
                <order column="IDX"/>  
            </field>  
        </class>  
    </package>  
</orm>
```

15.5 Foreign Key Constraints

Foreign keys in metadata serve two quite different purposes. First, when generating schema, the foreign key element identifies foreign keys to be generated. Second, when using the database, foreign key elements identify foreign keys that are assumed to exist in the database. This is important for the runtime to properly order insert, update, and delete statements to avoid constraint violations. Foreign keys are part of ORM metadata and are probably meaningless in non-relational implementations.

Foreign key constraints can be generated in three ways:

- Most elements that can include nested `column` elements can define `delete-action` or `update-action` attributes.

- Most elements that can contain nested column elements can define a nested foreign-key element. This element has the following attributes:
 - name: the name of the generated constraint
 - deferred: boolean attribute describing whether the constraint evaluation is deferred until datastore commit
 - delete-action: the foreign key delete action; see below. In this case, the "none" value is not allowed.
 - update-action: the foreign key update action; see below.
- The class element can define foreign-key elements. A class-level foreign-key element has the name, deferred, delete-action, and update-action attributes as above.

Note that regardless of which side of a relationship in the object model is mapped, the meaning of delete action and update action refer to the columns in the datastore, not to the fields in the object model.

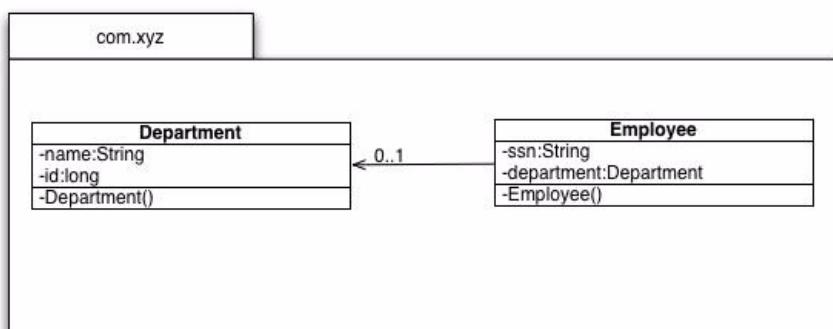
Delete Action, Update Action

The delete-action and update-action attributes have the following permitted values:

- “none”: no foreign key is generated and none is assumed to exist; no special action is required of the implementation
- “restrict” (the default): a foreign key with the “restrict” delete action is generated or is assumed to exist; the implementation will require update and delete statements to be executed in proper sequence
- “cascade”: a foreign key with the “cascade” delete action is generated or is assumed to exist; the database will automatically delete all rows that refer to the row being deleted
- “null”: a foreign key with the “null” delete action is generated or is assumed to exist; a referring key will be nullified if the target key is updated or deleted
- “default”: a foreign key with the “default” delete action is generated or is assumed to exist

15.5.1 Many-to-One with foreign key constraint

A many-one relation from Employee to Department, represented by a standard restrict-action database foreign key.



```

package com.xyz;
public class Department {
    String name;
    long id;
}
  
```

```
public class Employee {
    String ssn;
    Department department;
}

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    DEP_NAME VARCHAR(255),
    DEP_ID BIGINT,
    FOREIGN KEY EMP_DEP_FK (DEP_NAME, DEP_ID) REFERENCES DEP (NAME, ID)
)

CREATE TABLE DEP (
    NAME VARCHAR(255),
    ID BIGINT,
    PRIMARY KEY (NAME, ID)
)

<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <field name="ssn" column="SSN"/>
        <field name="department">
            <column name="DEP_NAME" target="NAME"/>
            <column name="DEP_ID" target="ID"/>
            <foreign-key name="EMP_DEP_FK"/>
        </field>
    </class>
    <class name="Department" table="DEP">
        <field name="name" column="NAME"/>
        <field name="id" column="ID"/>
    </class>
</package>
</orm>
```

15.6 Indexes

Index definitions are used for schema generation and are not used at runtime. In relational implementations, they are part of the ORM metadata because their names and extensions might differ for each database. In non-relational implementations, indexes are part of the JDO metadata.

Indexes can be defined in three ways:

- Most elements that can include nested `column` elements can define an `indexed` attribute. This attribute has three possible values:
 - `true`: generate a standard index on the datastore representation of the element
 - `false`: do not generate an index on the element
 - `unique`: generate a unique index on the element
- Most elements that can contain nested `column` elements can define a nested `index` element. The element does not contain any elements (aside from possible extensions). The index is generated on the datastore representation of the parent element. This element has the following attributes:
 - `name`: the name of the generated index
 - `unique`: boolean attribute describing whether to generate a unique index

- The `class` element can define nested `index` elements. A class-level `index` element has the attributes outlined above. It can contain `column` and/or `field` elements, each of which is limited to a `name` attribute referencing a column or field defined elsewhere. Field names can use `<superclass-name>. <field-name>` syntax to reference superclass fields, `<field-name>. <embedded-field-name>` to reference embedded relation fields, and the `#key`, `#value`, and `#element` suffixes defined for fetch groups to reference parts of a field.

Unique Constraints

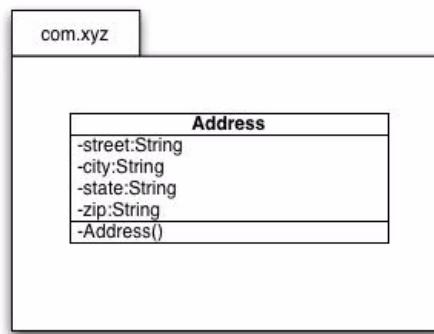
Unique constraints are used during schema generation, and may be used at runtime to order datastore operations. Like indexes, they are part of ORM metadata in relational implementations, and part of JDO metadata in non-relational implementations.

Unique constraints can be defined in the same three general ways as indexes:

- Most elements that can include nested `column` elements can define an `unique` attribute. Possible values are `true` and `false`.
- Most elements that can contain nested `column` elements can define a nested `unique` element. This element has the following attributes:
 - `name`: the name of the generated constraint
 - `deferred`: boolean attribute describing whether the constraint evaluation is deferred until datastore commit
- The `class` element can contain `unique` elements. A class-level `unique` element has the attributes outlined above. It contains the same possible elements as a class-level index.

15.6.1 Single-field and Compound Indexes

This example demonstrates single-field and compound indexes.



```

package com.xyz;
public class Address {
    String street;
    String city;
    String state;
    String zip;
}

CREATE TABLE ADDR (
    STREET VARCHAR(255) PRIMARY KEY,
    CITY VARCHAR(255),
    STATE CHAR(2),
    ZIPCODE VARCHAR(10)
  
```

```
)  
  
<orm>  
  <package name="com.xyz">  
    <class name="Address" table="ADDR">  
      <index name="ADDR_CITYSTATE_IDX">  
        <column name="CITY"/>  
        <column name="STATE"/>  
      </index>  
      <field name="street" column="STREET"/>  
      <field name="city" column="CITY"/>  
      <field name="state" column="STATE"/>  
      <field name="zip" column="ZIPCODE">  
        <index name="ADDR_ZIP_IDX"/>  
      </field>  
    </class>  
  </package>  
</orm>
```

15.7 Inheritance

Each class can declare an inheritance strategy. Three strategies are supported by standard metadata: new-table, superclass-table, and subclass-table.

- new-table creates a new table for the fields of the class.
- superclass-table maps the fields of the class into the superclass table.
- subclass-table forces subclasses to map the fields of the class to their own table.

Using these strategies, standard metadata directly supports several common inheritance patterns, as well as combinations of these patterns within a single inheritance hierarchy.

One common pattern uses one table for an entire inheritance hierarchy. A column called the discriminator column is used to determine to which class each row belongs. This pattern is achieved by a strategy of new-table for the base class, and superclass-table for all subclasses. These are the default strategies for base classes and subclasses when no explicit strategy is given.

Another pattern uses multiple tables joined by their primary keys. In this pattern, the existence of a row in a table determines the class of the row. A discriminator column is not required, but may be used to increase the efficiency of certain operations. This pattern is achieved by a strategy of new-table for the base class, and new-table for all subclasses. In this case, the join element specifies the columns to be used for associating the columns in the table mapped by the subclass(es) and the table mapped by the superclass.

A third pattern maps fields of superclasses and subclasses into subclass tables. This pattern is achieved by a strategy of subclass-table for the base class, and new-table for direct subclasses.

15.8 Versioning

Three common strategies for versioning instances are supported by standard metadata. These include state-comparison, timestamp, and version-number.

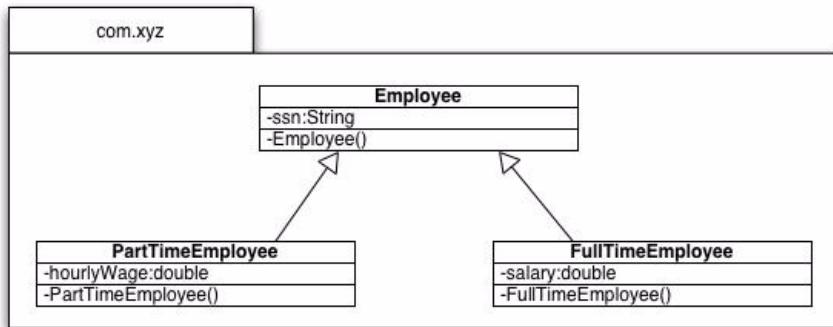
State-comparison involves comparing the values in specific columns to determine if the database row was changed.

Timestamp involves comparing the value in a date-time column in the table. The first time in a transaction the row is updated, the timestamp value is updated to the current time.

Version-number involves comparing the value in a numeric column in the table. The first time in a transaction the row is updated, the version-number column value is incremented.

15.8.1 Inheritance with superclass-table and version

Mapping a subclass to the base class table, and using version-number optimistic versioning. Note that in this example, the inheritance strategy attribute is not needed, because this is the default inheritance pattern. The version strategy attribute is also using the default value, and could have been omitted. These attributes are included for clarity.



```

package com.xyz;
public class Employee {
    String ssn;
}
public class PartTimeEmployee extends Employee {
    double hourlyWage;
}
public class FullTimeEmployee extends Employee {
    double salary;
}

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    TYPE CHAR(1),
    WAGE FLOAT,
    SALARY FLOAT,
    VERS INTEGER
)

<orm>
<package name="com.xyz">
    <class name="Employee" table="EMP">
        <inheritance strategy="new-table">
            <discriminator value="E" column="TYPE"/>
        </inheritance>
        <version strategy="version-number" column="VERS"/>
        <field name="ssn" column="SSN"/>
    </class>
    <class name="PartTimeEmployee">
        <inheritance strategy="superclass-table">
            <discriminator value="P"/>
        </inheritance>
        <field name="hourlyWage" column="WAGE"/>
    </class>
    <class name="FullTimeEmployee">
        <inheritance strategy="superclass-table">
            <discriminator value="F"/>
        </inheritance>
        <field name="salary" column="SALARY"/>
    </class>
</package>
  
```

The code defines three Java classes: 'Employee', 'PartTimeEmployee', and 'FullTimeEmployee'. The 'Employee' class has attributes 'ssn' and a constructor. 'PartTimeEmployee' and 'FullTimeEmployee' inherit from 'Employee' and add their own attributes ('hourlyWage' and 'salary' respectively). A SQL 'CREATE TABLE' statement for 'EMP' is provided, with columns 'SSN' (primary key), 'TYPE', 'WAGE', 'SALARY', and 'VERS' (version number). An XML fragment for an ORM (Object-Relational Mapping) configuration is shown, defining the classes and their inheritance strategies. The 'Employee' class uses a 'new-table' inheritance strategy with a discriminator column 'TYPE'. The subclasses 'PartTimeEmployee' and 'FullTimeEmployee' use a 'superclass-table' inheritance strategy with discriminators 'P' and 'F' respectively, and map to the 'EMP' table.

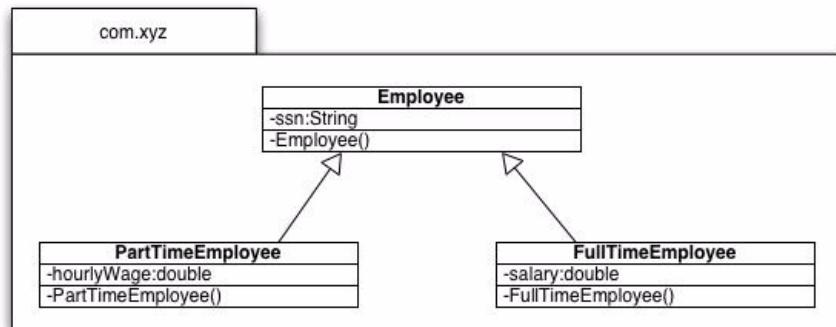
```

<inheritance strategy="superclass-table">
    <discriminator value="F"/>
</inheritance>
<field name="salary" column="SALARY"/>
</class>
</package>
</orm>

```

15.8.2 Inheritance with new-table and version

Mapping each class to its own table, and using state-image versioning. Though a discriminator is not required for this inheritance pattern, this mapping chooses to use one to make some actions more efficient. It stores the full Java class name in each row of the base table.



```

CREATE TABLE EMP (
    SSN CHAR(10) PRIMARY KEY,
    JAVA_CLS VARCHAR(255)
)

CREATE TABLE PART_EMP (
    EMP_SSN CHAR(10) PRIMARY KEY,
    WAGE FLOAT
)

CREATE TABLE FULL_EMP (
    EMP_SSN CHAR(10) PRIMARY KEY,
    SALARY FLOAT
)

<orm>
    <package name="com.xyz">
        <class name="Employee" table="EMP">
            <inheritance strategy="new-table">
                <discriminator strategy="class-name" column="JAVA_CLS"/>
            </inheritance>
            <version strategy="state-comparison"/>
            <field name="ssn" column="SSN"/>
        </class>
        <class name="PartTimeEmployee" table="PART_EMP">
            <inheritance strategy="new-table">
                <join column="EMP_SSN"/>
            </inheritance>
            <field name="hourlyWage" column="WAGE"/>
        </class>
        <class name="FullTimeEmployee" table="FULL_EMP">
            <inheritance strategy="new-table">
                <join column="EMP_SSN"/>
            </inheritance>

```

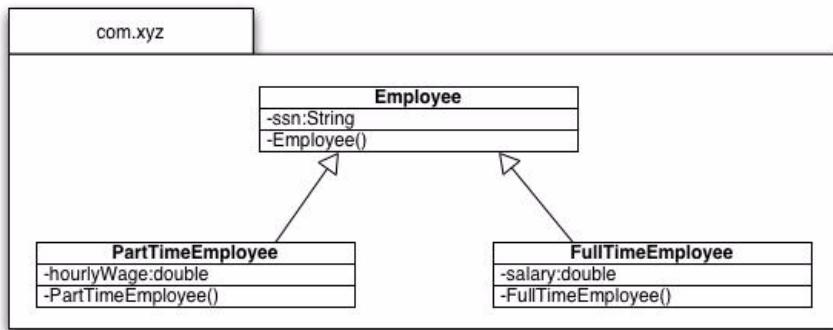
```

        </inheritance>
        <field name="salary" column="SALARY" />
    </class>
</package>
</orm>

```

15.8.3 Inheritance with subclass-table

This example maps superclass fields to each subclass table.



```

CREATE TABLE PART_EMP (
    EMP_SSN CHAR(10) PRIMARY KEY,
    WAGE FLOAT
)

CREATE TABLE FULL_EMP (
    EMP_SSN CHAR(10) PRIMARY KEY,
    SALARY FLOAT
)

<orm>
<package name="com.xyz">
    <class name="Employee">
        <inheritance strategy="subclass-table"/>
    </class>
    <class name="PartTimeEmployee" table="PART_EMP">
        <inheritance strategy="new-table"/>
        <field name="Employee.ssn" column="EMP_SSN" />
        <field name="hourlyWage" column="WAGE" />
    </class>
    <class name="FullTimeEmployee" table="FULL_EMP">
        <inheritance strategy="new-table"/>
        <field name="Employee.ssn" column="EMP_SSN" />
        <field name="salary" column="SALARY" />
    </class>
</package>
</orm>

```

16 Enterprise Java Beans

Enterprise Java Beans (EJB) is a component architecture for development and deployment of distributed business applications. Java Data Objects is a suitable component for integration with EJB in these scenarios:

- Session Beans with JDO persistence-capable classes used to implement dependent objects;
- Entity Beans with JDO persistence-capable classes used as delegates for both Bean Managed Persistence and Container Managed Persistence.

16.1 Session Beans

A session bean should be associated with an instance of `PersistenceManagerFactory` that is established during a session life cycle event, and each business method should use an instance of `PersistenceManager` obtained from the `PersistenceManagerFactory`. The timing of when the `PersistenceManager` is obtained will vary based on the type of bean.

The bean class should contain instance variables that hold the associated `PersistenceManager` and `PersistenceManagerFactory`.

During activation of the bean, the `PersistenceManagerFactory` should be found via JNDI lookup. The `PersistenceManagerFactory` should be the same instance for all beans sharing the same datastore resource. This allows for the `PersistenceManagerFactory` to manage an association between the distributed transaction and the `PersistenceManager`.

When appropriate during the bean life cycle, the `PersistenceManager` should be acquired by a call to the `PersistenceManagerFactory`. The `PersistenceManagerFactory` should look up the transaction association of the caller, and return a `PersistenceManager` with the same transaction association. If there is no `PersistenceManager` currently enlisted in the caller's transaction, a new `PersistenceManager` should be created and associated with the transaction. The `PersistenceManager` should be registered for synchronization callbacks with the `TransactionManager`. This provides for transaction completion callbacks asynchronous to the bean life cycle.

The instance variables for a session bean of any type include:

- a reference to the `PersistenceManagerFactory`, which should be initialized by the method `setSessionContext`. This method looks up the `PersistenceManagerFactory` by JNDI access to the named object "`java:comp/env/jdo/<persistence manager factory name>`".
- a reference to the `PersistenceManager`, which should be acquired by each business method, and closed at the end of the business method; and
- a reference to the `SessionContext`, which should be initialized by the method `setSessionContext`.

16.1.1 Stateless Session Bean with Container Managed Transactions

Stateless session beans are service objects that have no state between business methods. They are created as needed by the container and are not associated with any one user. A business method invocation on a remote reference to a stateless session bean might be dispatched by the container to any of the available beans in the ready pool.

Each business method must acquire its own `PersistenceManager` instance from the `PersistenceManagerFactory`. This is done via the method `getPersistenceManager` on the `PersistenceManagerFactory` instance. This method must be implemented by the JDO vendor to find a `PersistenceManager` associated with the instance of `javax.transaction.Transaction` of the executing thread.

At the end of the business method, the `PersistenceManager` instance must be closed. This allows the transaction completion code in the `PersistenceManager` to free the instance and return it to the available pool in the `PersistenceManagerFactory`.

16.1.2 Stateful Session Bean with Container Managed Transactions

Stateful session beans are service objects that are created for a particular user, and may have state between business methods. A business method invocation on a remote reference to a stateful session bean will be dispatched to the specific instance created by the user.

The behavior of stateful session beans with container managed transactions is otherwise the same as for stateless session beans. All business methods in the remote interface must acquire a `PersistenceManager` at the beginning of the method, and close it at the end, since the transaction context is managed by the container.

16.1.3 Stateless Session Bean with Bean Managed Transactions

Bean managed transactions offer additional flexibility to the session bean developer, with additional complexity. Transaction boundaries are established by the bean developer, but the state (including the `PersistenceManager`) cannot be retained across business method boundaries. Therefore, the `PersistenceManager` must be acquired and closed by each business method.

The alternative techniques for transaction boundary demarcation are:

- `javax.transaction.UserTransaction`

If the bean developer directly uses `UserTransaction`, then the `PersistenceManager` must be acquired from the `PersistenceManagerFactory` only after establishing the correct transaction context of `UserTransaction`. During the `getPersistenceManager` method, the `PersistenceManager` will be enlisted in the `UserTransaction`. *How to test? (JDO must know JTA..)* For example, if non-transactional access is required, a `PersistenceManager` must be acquired when there is no `UserTransaction` active. After beginning a `UserTransaction`, a different `PersistenceManager` must be acquired for transactional access. The user must keep track of which `PersistenceManager` is being used for which transaction.

- `javax.jdo.Transaction`

If the bean developer chooses to use the same `PersistenceManager` for multiple transactions, then transaction completion must be done entirely by using the `javax.jdo.Transaction` instance associated with the `PersistenceManager`. In this case, acquiring a `PersistenceManager` without beginning a `UserTransaction` results in the `PersistenceManager` being able to manage transaction boundaries via `begin`, `commit`, and `rollback` methods on `javax.jdo.Transaction`. The `PersistenceManager` will automatically begin the `UserTransaction` during `javax.jdo.Transaction.begin` *How to test?* and automatically commit the `UserTransaction` during `javax.jdo.Transaction.commit`. *How to test?*

16.1.4 Stateful Session Bean with Bean Managed Transactions

Stateful session beans allow the bean developer to manage the transaction context as part of the conversational state of the bean. Thus, it is no longer required to acquire a `PersistenceManager` in each business method. Instead, the `PersistenceManager` can be managed over a longer period of time, and it might be stored as an instance variable of the bean.

The behavior of stateful session beans is otherwise the same as for stateless session beans. The user has the choice of using `javax.transaction.UserTransaction` or `javax.jdo.Transaction` for transaction completion.

16.2 Entity Beans

While it is possible for container-managed persistence entity beans to be implemented by the container using JDO, the implementation details are beyond the scope of this document.

It is possible for users to implement bean-managed persistence entity beans using JDO, but implementation details are container-specific and no recommendations for the general case are given.

17 JDO Exceptions

The exception philosophy of JDO is to treat all exceptions as runtime exceptions. This preserves the transparency of the interface to the degree possible, allowing the user to choose to catch specific exceptions only when required by the application.

JDO implementations will often be built as layers on an underlying datastore interface, which itself might use a layered protocol to another tier. Therefore, there are many opportunities for components to fail that are not under the control of the application.

Exceptions thus fall into several broad categories, each of which is treated separately:

- user errors that can be corrected and retried;
- user errors that cannot be corrected because the state of underlying components has been changed and cannot be undone;
- internal logic errors that should be reported to the JDO vendor's technical support;
- errors in the underlying datastore that can be corrected and retried;
- errors in the underlying datastore that cannot be corrected due to a failure of the datastore or communication path to the datastore;

Exceptions that are documented in interfaces that are used by JDO, such as the `Collection` interfaces, are used without modification by JDO. JDO exceptions that reflect underlying datastore exceptions will wrap the underlying datastore exceptions. JDO exceptions that are caused by user errors will contain the reason for the exception.

JDO Exceptions must be serializable.

17.1 JDOException

This is the base class for all JDO exceptions. It is a subclass of `RuntimeException`, and need not be declared or caught. It includes a descriptive String, an optional nested Exception array, and an optional failed Object.

Methods are provided to retrieve the nested exception array and failed object. If there are multiple nested exceptions, then each might contain one failed object. This will be the case where an operation requires multiple instances, such as commit, makePersistentAll, etc.

If the `JDO PersistenceManager` is internationalized, then the descriptive string should be internationalized.

```
public Throwable[] getNestedExceptions();
```

This method returns an array of Throwables or null if there are no nested exceptions.

```
public Object getFailedObject();
```

This method returns the failed object or null if there is no failed object for this exception.

```
public Throwable getCause();
```

This method returns the first nested Throwables or null if there are no nested exceptions.

17.1.1 JDOFatalException

This is the base class for errors that cannot be retried. It is a derived class of `JDOException`. This exception generally means that the transaction associated with the `PersistenceManager` has been rolled back, and the transaction should be abandoned.

17.1.2 JDOCanRetryException

This is the base class for errors that can be retried. It is a derived class of `JDOException`.

17.1.3 JDOUnsupportedOptionException

This class is a derived class of `JDOUserException`. This exception is thrown by an implementation to indicate that it does not implement a JDO optional feature.

17.1.4 JDOUserException

This is the base class for user errors that can be retried. It is a derived class of `JDOCanRetryException`. Some of the reasons for this exception include:

- Object not persistence-capable. This exception is thrown when a method requires an instance of `PersistenceCapable` and the instance passed to the method does not implement `PersistenceCapable`. The failed Object has the failed instance.
- Extent not managed. This exception is thrown when `getExtent` is called with a class that does not have a managed extent.
- Object exists. This exception is thrown during flush of a new instance or an instance whose primary key changed where the primary key of the instance already exists in the datastore. It might also be thrown during `makePersistent` if an instance with the same primary key is already in the `PersistenceManager` cache. The failed Object is the failed instance.
- Object owned by another `PersistenceManager`. This exception is thrown when calling `makePersistent`, `makeTransactional`, `makeTransient`, `evict`, `refresh`, or `getObjectId` where the instance is already persistent or transactional in a different `PersistenceManager`. The failed Object has the failed instance.
- Non-unique `ObjectId` not valid after transaction completion. This exception is thrown when calling `getObjectId` on an object after transaction completion where the `ObjectId` is not managed by the application or datastore.
- Unbound query parameter. This exception is thrown during query compilation or execution if there is an unbound query parameter.
- Query filter cannot be parsed. This exception is thrown during query compilation or execution if the filter cannot be parsed.
- Transaction is not active. This exception is thrown if the transaction is not active and `makePersistent`, `deletePersistent`, `commit`, or `rollback` is called.
- Object deleted. This exception is thrown if an attempt is made to access any fields of an instance that was deleted in this transaction (except to read key fields). This is not the exception thrown if the instance does not exist in the datastore (see `JDOObjectNotFoundException`).
- Primary key contains null values. This exception is thrown if the application identity parameter to `getObjectById` contains any key field whose value is null.

17.1.5 JDOFatalUserException

This is the base class for user errors that cannot be retried. It is a derived class of `JDOFatalException`.

- `PersistenceManager` was closed. This exception is thrown after `close()` was called, when any method except `isClosed()` is executed on the `PersistenceManager` instance, or any method is called on the `Transaction` instance, or any `Query` instance, `Extent` instance, or `Iterator` instance created by the `PersistenceManager`.
- Metadata unavailable. This exception is thrown if a request is made to the `JDOImplHelper` for metadata for a class, when the class has not been registered with the helper.

17.1.6 JDOFatalInternalException

This is the base class for JDO implementation failures. It is a derived class of `JDOFatalException`. This exception should be reported to the vendor for corrective action. There is no user action to recover.

17.1.7 JDODataStoreException

This is the base class for datastore errors that can be retried. It is a derived class of `JDOCanRetryException`.

17.1.8 JDOFatalDataStoreException

This is the base class for fatal datastore errors. It is a derived class of `JDOFatalException`. When this exception is thrown, the transaction has been rolled back.

- Transaction rolled back. This exception is thrown when the datastore rolls back a transaction without the user asking for it. The cause may be a connection timeout, an unrecoverable media error, an unrecoverable concurrency conflict, or other cause outside the user's control.

17.1.9 JDOObjectNotFoundException

This exception is to notify the application that an object does not exist in the datastore. It is a derived class of `JDODataStoreException`. When this exception is thrown during a transaction, there has been no change in the status of the transaction in progress. If this exception is a nested exception thrown during commit, then the transaction is rolled back. This exception is never the result of executing a query. The `failedObject` contains a reference to the failed instance. The failed instance is in the hollow state, and has an identity which can be obtained by calling `getObjectId` with the instance as a parameter. This might be used to determine the identity of the instance that cannot be found.

This exception is thrown when a hollow instance is being fetched and the object does not exist in the datastore. This exception might result from the user executing `getById` with the validate parameter set to true, or from navigating to an object that no longer exists in the datastore.

17.1.10 JDOOptimisticVerificationException

This exception is the result of a user flush operation in an optimistic transaction where the verification of new, modified, or deleted instances fails the verification. It is a derived class of `JDOFatalDataStoreException`. This exception contains an array of nested exceptions, each of which contains an instance that failed verification. The user will never see this exception except as a result of flush, which occurs as a result of commit or explicit flush.

17.1.11 JDODetachedFieldAccessException

This exception is the result of a user accessing a field of a detached instance, where the field was not copied to the detached instance. It is a derived class of JDOUserException.

17.1.12 JDOUserCallbackException

This exception is the result of an exception thrown during execution of a user-defined callback method. It is a derived class of JDOUserException.

18 XML Metadata

This chapter specifies the metadata that describes a persistence-capable class, optionally including its mapping to a relational database. The metadata is stored in XML format. For implementations that support binary compatibility, the information must be available when the class is enhanced, and might be cached by an implementation for use at runtime. If the metadata is changed between enhancement and runtime, the behavior is unspecified.

NOTE: J2SE 5 introduced standard elements for defining the types of collections and maps. Because of these features, programs compiled with suitable type information might not need a separate file to describe type information.

Metadata files must be available via resources loaded by the same class loader as the class. These rules apply both to enhancement and to runtime. Hereinafter, the term "metadata" refers to the aggregate of all XML data for all packages, classes, and mappings, regardless of their physical packaging.

The metadata associated with each persistence capable class must be contained within one or more files, and its format is defined by the DTD or xsd. If the metadata in a file is for only one class, then its file name is <class-name>.jdo. If the metadata is for a package, or a number of packages, then its file name is package.jdo. In this case, the file is located in one of several directories: "META-INF"; "WEB-INF"; <none>, in which case the metadata file name is "package.jdo" with no directory; "<package>/.../<package>", in which case the metadata directory name is the partial or full package name with "package.jdo" as the file name.

Metadata for all classes and interfaces found while processing metadata for any class or interface must be remembered by the implementation.

Metadata for relational mapping might be contained in the same file as the persistence information, in which case the naming convention above is used. The mapping metadata might be contained in a separate file, in which case the metadata file name suffix must be specified in the PersistenceManagerFactory property javax.jdo.option.Mapping. This property is used to construct the file names for the mapping.

NOTE: If the javax.jdo.option.Mapping property is set, then mapping metadata contained in the .jdo file **is not used**.

The extension .orm refers to "object repository metadata". If the mapping is to a repository type other than relational, the document type will be different, but the file naming conventions are the same.

For example, if the value of javax.jdo.option.Mapping is "mySQL", then the file name for the metadata is <class-name>-mySQL.orm or package-mySQL.orm. Similar to package.jdo, the package-mySQL.orm file is located in one of the following directories: "META-INF"; "WEB-INF"; <none>, in which case the metadata file name is "package-mySQL.orm" with no directory; "<package>/.../<package>", in which case the metadata directory name is the partial or full package name with "package-mySQL.orm" as the file name. If mapping metadata is for only one class, the name of the file is <package>/.../<package>/<class-name>-mySQL.orm.

When metadata information is needed for a class, and the metadata for that class has not already been loaded, the metadata is searched for as follows: META-INF/package.jdo, WEB-INF/package.jdo, package.jdo, <package>/.../<package>/package.jdo, and <package>/<class>.jdo. Once

metadata for a class has been loaded, the metadata will not be replaced in memory as long as the class is not garbage collected. Therefore, metadata contained higher in the search order will always be used instead of metadata contained lower in the search order.

Similarly, when mapping metadata information is needed for a class, and the mapping metadata for that class has not already been loaded, the mapping metadata is searched for as follows: META-INF/package-mySQL.orm, WEB-INF/package-mySQL.orm, package-mySQL.orm, <package>/.../ <package>/package-mySQL.orm, and <package>/.../ <package>/<class-name>-mySQL.orm. Once mapping metadata for a class has been loaded, it will not be replaced as long as the class is not garbage collected. Therefore, mapping metadata contained higher in the search order will always be used instead of metadata contained lower in the search order.

For example, if the persistence-capable class is com.xyz.Wombat, and there is a file "META-INF/package.jdo" containing xml for this class, then its definition is used. If there is no such file, but there is a file "WEB-INF/package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "com/package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "com/xyz/package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "com/xyz/Wombat.jdo", then it is used. If there is no such file, then com.xyz.Wombat is not persistence-capable.

Note that this search order is optimized for implementations that cache metadata information as soon as it is encountered so as to optimize the number of file accesses needed to load the metadata. Further, if metadata is not in the natural location, it might override metadata that is in the natural location. For example, while looking for metadata for class com.xyz.Wombat, the file com/package.jdo might contain metadata for class org.acme.Grumpy. In this case, subsequent search of metadata for org.acme.Grumpy will find the cached metadata and none of the usual locations for metadata will be searched.

The metadata must declare all persistence-capable classes. If any field or property declarations are missing from the metadata, then field or property metadata is defaulted for the missing declarations. The JDO implementation is able to determine based on the metadata whether a class is persistence-capable or not. Any class not known to be persistence-capable by the JDO specification (for example, java.lang.Integer) and not explicitly named in the metadata is not persistence-capable.

Classes and interfaces used in metadata follow the Java rules for naming. If the class or interface name is unqualified, the package name is the name of the enclosing package. Inner classes are identified by the "\$" marker.

For compatibility with installed applications, a JDO implementation might first use the search order as specified in the JDO 1.0 or 1.0.1 releases. In this case, if metadata is not found, then the search order as specified in JDO 2.0 must be used. Refer to Chapter 25 for details.

For convenience, the metadata allows for the same information to be declared in multiple places. It is an error if conflicting information is declared in more than one place. For example, the name of the column for a field might be declared either in the column attribute on the field element, or in the name attribute in the column element contained in the field. If declared in both places, the information must be identical or an error must be reported by the JDO implementation.

Mapping to Relational Databases

Mapping is done by specifying associations from classes and interfaces to tables, and fields to columns.

Tables are generally specified by name. Table names can be declared as "<database>. <catalog>. <schema>. <table-name>", where database, catalog, and schema are optional. If not specified in any metadata, catalog and schema are taken from the PersistenceManagerFactory prop-

erties catalog and schema. If not specified in PersistenceManagerFactory, they are defaulted by the JDBC connection.

Catalog and schema attributes apply to jdo, orm, package, class, and interface elements, and specify the catalog and schema to be used when defining and using schema. If declared at the jdo, orm, package, class or interface level, it specifies the catalog and/or schema to be used as the default for tables contained therein.

18.1 ELEMENT jdo

This element is the highest level element in the xml document. It is used to allow multiple packages to be described in the same document. It contains multiple package and query elements and optional extension elements.

18.2 ELEMENT package

This element includes all classes in a particular package. The complete qualified package name defaults to the empty package, but it is highly recommended to specify it. It contains multiple class and interface elements and optional extension elements.

18.3 ELEMENT interface

The interface element declares a persistence-capable interface. Instances of a vendor-specific type that implement this interface can be created using the newInstance(Class persistenceCapable) method in PersistenceManager, and these instances may be made persistent.

The JDO implementation must maintain an extent for persistent instances of persistence-capable classes that implement this interface.

The requires-extent attribute is optional. If set to "false", the JDO implementation does not need to support extents of factory-made persistent instances. It defaults to "true".

The attribute name is required, and is the name of the interface.

The attribute table is optional, and is the name of the table to be used to store persistent instances of this interface.

The detachable attribute specifies whether persistent instances of this interface can be detached from the persistence context and later attached to the same or a different persistence context. The default is false.

Persistent properties declared in the interface are defined as those that have both a get and a set method or both an is and a set method, named according to the JavaBeans naming conventions, and of a type supported as a persistent type.

The implementing class will provide a suitable implementation for all property access methods.

This element might contain property elements to specify the mapping to relational columns.

Interface inheritance is supported.

The serialize-read attribute specifies that access to instances from multiple parallel transactions should be serialized, for example by placing an exclusive lock on the instances when loaded from the datastore.

18.4 ELEMENT column

The `column` element identifies a column in a mapped table. This element is used for mapping fields, collection elements, array elements, keys, values, datastore identity, application identity, and properties.

NOTE: Any time an element can contain a `column` element that is only used to name the column, a `column` attribute can be used instead.

The `name` attribute declares the name of the column in the database. The name might be fully qualified as `<table-name>. <column-name>` and `<table-name>` might be defaulted in context.

The `target` attribute declares the name of the primary key column for the referenced table. For columns contained in join elements, this is the name of the primary key column in the primary table. For columns contained in field, element, key, value, or array elements, the `target` attribute is the name of the primary key column of the primary table of the other side of the relationship.

The `target-field` attribute might be used instead of the `target` attribute to declare the name of the field to which the column refers. This is useful in cases where there are different mappings of the referenced field in different subclasses.

The `jdbc-type` attribute is used to determine the type of the column in the database. This type is defaulted based on the type of the field being mapped. Valid types are all upper-case or all lower-case CHAR, VARCHAR, LONGVARCHAR, NUMERIC, DECIMAL, BIT, TINYINT, SMALLINT, INTEGER, BIGINT, REAL, FLOAT, DOUBLE, BINARY, VARBINARY, LONGVARBINARY, DATE, TIME, and TIMESTAMP, and others as may be defined by future versions of the JDBC specification. This attribute is only needed if the default type is not suitable.

The `jdbc-type` is also used when mapping `element`, `key`, `value`, and `order` elements of collections, arrays, and maps. The java type for the column mapped to an `order` element is assumed to be `int`.

For example, when mapping a `Map<Integer, Employee>` to a join table, the `jdbc-type` for the column mapped to the key (`Integer`) will default to `INTEGER`, whereas there is no default `jdbc-type` for the column mapped to the value (`Employee`).

Table 8: Default jdbc-type

Java type	Default jdbc-type	Comments
boolean	BIT	
java.lang.Boolean	BIT	
char	CHAR	
java.lang.Character	CHAR	
byte	TINYINT	
java.lang.Byte	TINYINT	
short	SMALLINT	
java.lang.Short	SMALLINT	
int	INTEGER	
java.lang.Integer	INTEGER	
long	BIGINT	
java.lang.Long	BIGINT	
float	FLOAT	
java.lang.Float	FLOAT	
double	DOUBLE	
enum	VARCHAR	
java.lang.Double	DOUBLE	
java.util.Date	TIMESTAMP	
java.sql.Date	DATE	
java.sql.Time	TIME	
java.sql.Timestamp	TIMESTAMP	
java.lang.Object	none	
java.lang.String	VARCHAR	
java.util.Locale	VARCHAR	
java.util.Currency	VARCHAR	
java.math.BigInteger	NUMERIC	
java.math.BigDecimal	DECIMAL	

Table 8: Default jdbc-type

Java type	Default jdbc-type	Comments
interfaces	none	
mapped as serialized	LONG VARBINARY	
persistence-capable types	none	

In many cases, the default for the `jdbc-type` attribute based on the field type is sufficient. For cases where this information is used to create datastore schema, the JDO implementation is free to map the column type suitable for the datastore being used based on the specified `jdbc-type`, `length`, and `scale`.

The `sql-type` attribute declares the type of the column in the database. This type is database-specific and should only be used where the user needs more explicit control over the mapping. Normally, the combination of `jdbc-type`, `length`, and `scale` are sufficient for the JDO implementation to calculate the `sql-type`.

The `length` attribute declares the number of characters in the datastore representation of numeric, `char[]`, and `Character[]` types; and the maximum number of characters in the datastore representation of `String` types. The default is 256.

The `scale` attribute declares the scale of the numeric representation in the database. The default is 0.

The `allows-null` attribute specifies whether `null` values are allowed in the column, and is defaulted based on the type of the field being mapped. The default is "true" for reference field types and "false" for primitive field types.

The `insert-value` attribute specifies the value to be inserted into the datastore in case a column is not mapped to any field in the object model. In this case, the `column` element must be directly contained in a `class` element, and the column must not be mapped to a field.

The `default-value` attribute specifies the database-assigned default value for the column if no value is explicitly assigned to the column on insert. Implementations might use the value of this attribute to set the appropriate column default when generating schema.

18.5 ELEMENT class

The `class` element includes `field` elements declared in a persistence-capable class, and optional vendor extensions.

The `name` attribute of the `class` element is required. It specifies the unqualified class name of the class. The class name is scoped by the name of the package in which the `class` element is contained.

The `persistence-modifier` attribute specifies whether this class is `persistence-capable`, `persistence-aware`, or `non-persistent`. Persistence-aware and non-persistent classes must not include any attributes or elements except for the `name` and `persistence-modifier` attributes. Declaring persistence-aware and non-persistent classes might provide a performance improvement for enhancement and runtime, as the search algorithm for metdata need not be exhaustive.

The `detachable` attribute specifies whether instances of this class can be detached from the persistence context and later attached to the same or a different persistence context. If a class is declared as detachable, then all its persistence-capable subclasses are also detachable. The default is `false`.

The `embedded-only` attribute declares whether instances of this class are permitted to exist as first-class instances in the datastore. A value of “true” means that instances can only be embedded in other first-class instances., and precludes mapping this class to its own table.

The identity type of the least-derived persistence-capable class defines the identity type for all persistence-capable classes that extend it.

The identity type of the least-derived persistence-capable class is defaulted to `application` if any field declares the `primary-key` attribute to be `true`; and `datastore`, if not. If the identity type is `application`, the object-id class is not specified, and there is one primary key field that matches the type of a single field identity class, then the object-id class defaults to that single field identity class.

The `requires-extent` attribute specifies whether an extent must be managed for this class. The `PersistenceManager.getExtent` method can be executed only for classes whose metadata attribute `requires-extent` is specified or defaults to `true`. If the `PersistenceManager.getExtent` method is executed for a class whose metadata specifies `requires-extent` as `false`, a `JDOUserException` is thrown. If `requires-extent` is specified or defaults to `true` for a class, then `requires-extent` must not be specified as `false` for any subclass.

The `persistence-capable-superclass` attribute is deprecated for this release. The attribute will be ignored so metadata files from previous releases can be used.A number of `join` elements might be contained in the `class` element. Each `join` element defines a table and associated join conditions that can be used by multiple fields in the mapping.

The `objectid-class` attribute identifies the name of the objectid class. If not specified, there must be only one primary key field, and the `objectid-class` defaults to the appropriate simple identity class.

The `objectid-class` attribute is required only for abstract classes and classes with multiple key fields. If the `objectid-class` attribute is defined in any concrete persistence-capable class, then the objectid class itself must be concrete, and no subclass of the persistence-capable class may include the `objectid-class` attribute. If the `objectid-class` attribute is defined for any abstract class, then:

- the objectid class of this class must directly inherit `Object` or must be a subclass of the objectid class of the most immediate abstract persistence-capable superclass that defines an objectid class; and
- if the objectid class is abstract, the objectid class of this class must be a superclass of the objectid class of the most immediate subclasses that define an objectid class; and
- if the objectid class is concrete, no subclass of this persistence-capable class may define an objectid class.

The effect of this is that objectid classes form an inheritance hierarchy corresponding to the inheritance hierarchy of the persistence-capable classes. Associated with every concrete persistence-capable class is exactly one objectid class.

The objectid class must declare fields identical in name and type to fields declared in this class.

The `table` attribute names the primary table to which fields declared in this class metadata are mapped.

Foreign keys, indexes, and join tables can be specified at the class level. If they are specified at this level, column information might only be the names of the columns.

Column elements can be added to the `class` element to describe columns that are not mapped to fields. In this case, the `insert-value` attribute can be used to specify the value to insert into the column when a new instance is inserted into the datastore.

The `serialize-read` attribute specifies that access to instances from multiple parallel transactions should be serialized, for example by placing an exclusive lock on the instances when loaded from the datastore.

18.5.1 ELEMENT `datastore-identity`

The `datastore-identity` element declares the strategy for implementing datastore identity for the class, including the mapping of the identity columns of the relational table.

The `strategy` attribute identifies the strategy for mapping.

- The value "`native`" allows the JDO implementation to pick the most suitable strategy based on the underlying database.
- The value "`sequence`" specifies that a named database sequence is used to generate key values for the table. If `sequence` is used, then the `sequence` attribute is required.
- The value "`identity`" specifies that the column identified as the key column is managed by the database as an identity type.
- The value "`increment`" specifies a strategy that simply finds the largest key already in the database and increments the key value for new instances. It can be used with integral column types when the JDO application is the only database user inserting new instances.
- The value "`uuid-string`" specifies a strategy that generates a 128-bit UUID unique within a network (the IP address of the machine running the application is part of the id) and represents the result as a 16-character String.
- The value "`uuid-hex`" specifies a strategy that generates a 128-bit UUID unique within a network (the IP address of the machine running the application is part of the id) and represents the result as a 32-character String.

The `sequence` attribute names the sequence used to generate key values. This must correspond to a named sequence in the JDO metadata. If this attribute is used, the `strategy` defaults to "`sequence`".

The `column` elements identify the primary key columns for the table in the database.

18.5.2 ELEMENT `version`

The `version` element is contained in the `class` element, and declares the version strategy and optionally the column(s) used for the version strategy.

The `strategy` attribute defines the strategy for managing the version of an instance. Four `strategy` attribute values are standard:

- `none`: no version checking is done; changed values overwrite values in the datastore
- `version-number`: a rolling number is used as the version number
- `state-image`: the values of fields are used in aggregate as the version
- `date-time`: a clock timestamp (date-plus-time) value is used as the version

The `column` attribute declares the name of the column to hold the version. It is used instead of the contained `column` element in case only the column name is needed.

The `version` element might contain one or more `column` elements that declare the columns to use to hold the `version`.

18.6 ELEMENT primary-key

The `primary-key` element provides the mapping for the primary key constraint for the table associated with the enclosing element (`class`, `join`, or `interface`). Its primary use is to specify the name of the primary key constraint in case of Java-to-database mapping. In this case, the element is typically specified as:

```
<primary-key name="EMP_PK" />
```

It is also optionally used to specify the column to be used for surrogate primary key with application identity. In this case, the primary key fields do not provide the primary key of the database. This mapping is not required to be supported by the JDO implementation. For example:

```
<class name="Employee" identity-type="application">
  <primary-key name="EMP_PK" column="SURR_PK"/>
  ...
</class>
```

It is also optionally used to specify the constraint name and column names of a primary key constraint for tables associated with the class, such as join tables or secondary tables. To specify the primary key constraint for a join table, the `primary-key` element is contained within the `join` element. For example:

```
<field name="projects" table="EMP_PROJ">
  <collection element-type="Project" />
  <join>
    <primary-key name="EMP_PROJ_PK">
      <column name="EMPID" />
      <column name="PROJID" />
    </primary-key>
    <column name="EMPID" target="ID" />
  </join>
  <element>
    <column name="PROJID" target="ID" />
  </element>
</field>
```

If used to specify the primary key for a subclass using new-table inheritance strategy with a join to the superclass table, the `primary-key` element is put at the class level and not in the `join` element of the inheritance element.

18.7 ELEMENT join

The `join` element declares the table to be used in the mapping and the join conditions to associate rows in the joined table to the primary table.

The `table` attribute specifies the name of the table in the case of secondary table mappings (at least one table in addition to the primary table contain columns mapped to fields). In this case, the `join` element is nested in the `class` element.

For `join` elements nested inside `field` elements, the `table` attribute is not allowed. The `table` attribute from the `field` element specifies the table to which the join applies.

One or more `column` elements are contained within the `join` element. The `column` elements name the columns used to join to the primary key columns of the primary table. If there are multiple key columns, then the `target` attribute is required in each `column` element, and each names the corresponding primary key column of the primary table.

The table being joined might not have a row for each row in the referring table; in order to access rows in this table, an outer join is needed. The `outer` attribute indicates that an outer join is needed. The default is `false`.

18.8 ELEMENT inheritance

The `inheritance` element declares the mapping for inheritance.

The `strategy` attribute declares the strategy for mapping:

- The value "subclass-table" means that this class does not have its own table. All of its fields are mapped by subclasses.
- The value "new-table" means that this class has its own table into which by default all of its fields are mapped. There might be a table attribute specified in the `class` element. This is the default for the topmost (least derived) class in an inheritance hierarchy.
- The value "superclass-table" means that this class does not have its own table. All of its fields by default are mapped into tables of its superclass(es). This is the default for all classes except for the topmost class in an inheritance hierarchy.

18.9 ELEMENT discriminator

The `discriminator` element is used when a column is used to identify what class is associated with the primary key value in a table mapped to a superclass.

In the least-derived class in the hierarchy that uses the discriminator strategy, declare the `discriminator` element with a `strategy` and `column`. If the `strategy` is "value-map", then for each concrete subclass, define the `discriminator` element with a `value` attribute. If the `strategy` is "class-name" then subclasses do not need a `discriminator` element; the name of the class is stored as the value for the row in the table. If the `value` attribute is given, then the `strategy` defaults to "value-map".

The strategy "none" declares that there is no discriminator column.

18.10 ELEMENT implements

The `implements` element declares a persistence-capable interface implemented by the persistence-capable class that contains this element. An extent of persistence-capable classes that implement this interface is managed by the JDO implementation. The extent can be used for queries or for iteration just like an extent of persistence-capable instances.

The attribute `name` is required, and is the name of the interface. The java class naming rules apply: if the interface name is unqualified, the package is the name of the enclosing package.

18.11 ELEMENT foreign-key

The `foreign-key` element specifies characteristics of a foreign key associated with the containing join, field, key, value, or element.

To specify that there is a foreign key associated with the containing element, without specifying the name of the foreign key, the `foreign-key` element can be used with no attributes or contained elements.

If this element is specified at the class level, then `column` elements contained in the `foreign-key` element might contain only the `name` attribute.

18.11.1 ATTRIBUTE update-action

The `update-action` attribute specifies the generated or assumed foreign key constraint defined in the datastore. The implementation might optimize its behavior based on these constraints but they do not affect the object model. The permitted values `restrict`, `cascade`, `default`, `null`, and `none` correspond to the meaning of these terms in SQL.

18.11.2 ATTRIBUTE delete-action

The `delete-action` attribute specifies the generated or assumed foreign key constraint defined in the datastore. The implementation might optimize its behavior based on these constraints but they do not affect the object model. The permitted values `restrict`, `cascade`, `default`, `null`, and `none` correspond to the meaning of these terms in SQL.

18.11.3 ATTRIBUTE deferred

The `deferred` attribute specifies whether constraint checking on the containing element is defined in the database as being deferred until commit. This allows an optimization by the JDO implementation, and might allow certain operations to succeed where they would normally fail. For example, to exchange unique references between pairs of objects requires that the unique constraint columns temporarily contain duplicate values.

Possible values are “`true`” and “`false`”. The default is “`false`”.

18.11.4 ATTRIBUTE name

The `name` attribute specifies the name of the foreign key constraint to generate for this mapping. This attribute is used if the name of the foreign key needs to be specified.

18.12 ELEMENT unique

The `unique` element specifies characteristics of a unique key associated with the containing join, field, key, value, or element.

To specify that there is a unique key associated with the containing element, without specifying the name of the unique key, the `unique` element can be used with no attributes or contained elements. Alternatively, the `unique` attribute can be used.

If this element is specified at the class level, then column elements contained in the `unique` element might contain only the `name` attribute.

18.13 ELEMENT index

The `index` element specifies characteristics of an index associated with the containing join, field, key, value, or element.

To specify that there is an index associated with the containing element, without specifying the name of the index, the `index` element can be used with no attributes or contained elements. Alternatively, the `indexed` attribute can be used.

If this element is specified at the class level, then column elements contained in the `foreign-key` element might contain only the `name` attribute.

18.14 ELEMENT property

When contained in a `class` element,

- the `property` element declares the mapping between a virtual field of an implemented interface and the corresponding persistent field of the persistence-capable class.

- the `name` attribute is required, and declares the name for the property. The naming conventions for JavaBeans property names is used: the property name is the same as the corresponding `get` method for the property with the `get` or `is` removed and the resulting name lower-cased.
- the `mapped-by` attribute specifies that the field is mapped to the same database column(s) as the named field in the other class and that the fields are managed such that changes made to one side of the pair of fields are reflected in the other side.
- the `field-name` attribute is required; it associates a persistent field with the named property.

When contained in an `interface` element,

- `property` elements declare the mapping for persistent properties of the interface.
- The `name` attribute is required and must match the name of a property in the interface.
- This element might contain `column` elements to specify the mapping to relational columns.
- the `mapped-by` attribute specifies that the property is mapped to the same database column(s) as the named property in the other interface.
- The element might contain `collection`, `map`, or `array` elements to specify the characteristics of the property.

18.15 ELEMENT field

The `field` element is optional, and the `name` attribute is the field name as declared in the class. If the field declaration is omitted in the xml, then the values of the attributes are defaulted.

The `persistence-modifier` attribute specifies whether this field is persistent, transactional, or none of these. The `persistence-modifier` attribute can be specified only for fields declared in the Java class, and not fields inherited from superclasses. There is special treatment for fields whose `persistence-modifier` is `persistent` or `transactional`.

Default persistence-modifier

The default for the `persistence-modifier` attribute is based on the Java type and modifiers of the field:

- Fields with modifier `static`: `none`. No accessors or mutators will be generated for these fields during enhancement.
- Fields with modifier `transient`: `none`. Accessors and mutators will be generated for these fields during enhancement, but they will not delegate to the `StateManager`.
- Fields with modifier `final`: `none`. Accessors will be generated for these fields during enhancement, but they will not delegate to the `StateManager`.
- Fields of a type declared to be persistence-capable: `persistent`.
- Fields of the following types: `persistent`:
 - primitives: `boolean`, `byte`, `short`, `int`, `long`, `char`, `float`, `double`;
 - enums;
 - `java.lang` wrappers: `Boolean`, `Byte`, `Short`, `Integer`, `Long`, `Character`, `Float`, `Double`;
 - `java.lang`: `String`, `Number`;

- `java.math.BigDecimal, BigInteger;`
- `java.util.Currency, Date, Locale, ArrayList, HashMap, HashSet, Hashtable, LinkedHashMap, LinkedHashSet, LinkedList, TreeMap, TreeSet, Vector, Collection, Set, List, and Map;`
- Arrays of primitive types, `java.util.Date, java.util.Locale, java.lang` and `java.math` types specified immediately above, and persistence-capable types.
- Fields of types of user-defined classes and interfaces not mentioned above: `none`. No accessors or mutators will be generated for these fields.

The `null-value` attribute specifies the treatment of `null` values for persistent fields during storage in the datastore. The default is `"none"`.

- `"none"`: store `null` values as `null` in the datastore, and throw a `JDOUserException` if `null` values cannot be stored by the datastore.
- `"exception"`: always throw a `JDOUserException` if this field contains a `null` value at runtime when the instance must be stored;
- `"default"`: convert the value to the datastore default value if this field contains a `null` value at runtime when the instance must be stored.

The `default-fetch-group` attribute specifies whether this field is managed as a group with other fields. It defaults to `"true"` for non-key fields of primitive types, `java.util.Date`, and fields of `java.lang, java.math` types specified above.

The `load-fetch-group` attribute specifies the name of the fetch group to be used when this field is loaded due to being referenced when unloaded. It does not apply to queries, navigation, or `getObjectById` of instances of the declaring class.

- The `load-fetch-group` is added to the fetch groups in the `PersistenceManager's FetchPlan` to create the effective fetch groups for loading the unloaded field. The unloaded field is also added to the fields in the effective fetch groups in case the unloaded field is not already defined in the effective fetch groups.
- The effective fetch groups are used to retrieve unloaded fields into the instance containing the unloaded field.
- If any relationship fields are included in the effective fetch groups, then the referred instances are loaded according to the effective fetch groups.

Embedded

The `embedded` attribute specifies whether the field should be stored as part of the containing instance instead of as its own instance in the datastore. It must be specified or default to `"true"` for fields of primitive types, wrappers, `java.lang, java.math, java.util, collection, map`, and array types specified above; and `"false"` for other types including persistence-capable types, interface types and the `Object` type. Thus, specifying this attribute is not usually necessary. While a compliant implementation is permitted to support these types as first class instances in the datastore, the semantics of `embedded="true"` imply containment. That is, the embedded instances have no independent existence in the datastore and have no `Extent` representation.

For relational mapping, the `embedded` attribute is not used for collection, map, and array types, but is only used for persistence-capable types, interface types, and the `Object` type. For other datastores, it only applies to the structure of the type, not to the elements, keys, and values. That is, the collection instance itself is considered separate from its contents. The contents of these types may separately be specified to be embedded or not, using `embedded-element, embedded-key,` and `embedded-value` attributes of the `collection, array, and map` elements.

Embedded-element, embedded-key, and embedded-value apply to the storage of the element, key, and value instances contained in the collection, array, or map. Similar to the embedded attribute, for relational mapping these are only applicable to persistence-capable types, interface types, and the Object type. For other datastores, these attributes default to “true” for elements, keys, and values of wrapper types, java.lang types, java.math types and for the types explicitly mapped using the embedded element contained in the element, key, and value elements. Like the embedded attribute, usually embedded-element, embedded-key, and embedded-value will default appropriately and need not be specified.

The embedded attribute applied to a field of a persistence-capable type specifies that the implementation will treat the field as a Second Class Object.

The serialized attribute indicates that the field is to be serialized for storage using writeObject, and cannot be queried.

The attributes serialized="true" and embedded="true" are mutually exclusive.

A portable application must not assign instances of mutable classes to multiple embedded fields, and must not compare values of these fields using Java identity (“f1==f2”).

The embedded element is used to specify the field mappings for embedded persistence-capable types.

The dependent attribute specifies that the field contains a reference to a referred instance that is to be deleted from the datastore if the instance in which the field is declared is deleted, or if the referring field is nullified. If the field is a multi-valued type such as Array, Collection, or Map, then the referred instance is deleted when the referring element is removed from the Array, Collection, or Map.

Dependent defaults to true if either serialized="true" or embedded="true" is specified.

The field-type attribute is used to specify a more restrictive type than the field definition in the class. This might be required in order to map the field to the datastore. To be portable, specify the name of a single type that is itself able to be mapped to the datastore (e.g. a field of type Object can specify field-type="Integer"). To specify multiple types that the field might contain, use a comma-separated list of types, although this cannot be portably mapped. Rules for type names are as specified in collection element-type.

Column Mapping

Non-relationship fields are mapped to one or more columns in the primary table, a secondary table, or a join table. Relationship fields can additionally be mapped to columns in the primary or secondary table of the associated class. The table attribute in the field element identifies one of the three tables. If not specified, the table attribute defaults to the primary table.

Secondary tables are used for mapping single-valued types (primitive, wrapper, java.util.Date, String, etc.). There is one row in the secondary table for each row in the primary table. The column or columns to which the field is mapped refers to a column or columns in the secondary table.

Join tables can be used for mapping multi-valued types (collection, array, and map types). There are multiple rows in the join table for each row in the primary table. The column or columns to which the field is mapped refers to a column or columns in the join table.

A portable mapping for arrays, collections, and maps will include a primary key on the join table.

A special case involves self-referencing fields, in which the type of a field is the same as its class (or the element, key, or value type is the same). A column mapped to a self-referencing field is in the primary table of the class, and contains a reference to the primary key of the primary table.

If a join element is specified as part of the field mapping, the join column (or columns) provide the join condition to relate the primary table of the class to the table specified in the field. In this case the table attribute in the join element is not used.

The following field declarations are mutually exclusive; it is a user error to specify more than one mutually exclusive declaration:

- default-fetch-group = "true"
- primary-key = "true"
- persistence-modifier = "transactional" or "none"

If default-fetch-group is specified as true, then primary-key is set to false and persistence-modifier is set to persistent.

If primary-key is specified as true, then default-fetch-group is set to false and persistence-modifier is set to persistent.

If persistence-modifier is specified as transactional or none, default-fetch-group is set to false and primary-key is set to false.

The table attribute specifies the name of the table mapped to this field. It defaults to the table declared in the enclosing class element.

The column elements specify the column(s) mapped to this field. Normally, only one column is mapped to a field. If multiple columns are mapped, then the behavior is implementation-specific.

The mapped-by attribute specifies that the field is mapped to the same database column(s) as the named field in the other class.

The value-strategy attribute specifies the strategy used to generate values for the field. This attribute has the same values and meaning as the strategy attribute in datastore-identity.

If the value-strategy is sequence, the sequence attribute specifies the name of the sequence to use to automatically generate a value for the field. This value is used only for persistent-new instances at the time `makePersistent` is called.

Subclasses might map fields of their superclasses. In this case, the field name is specified as <superclass>. <superclass-field-name>.

Foreign key

The delete-action, update-action, indexed, and unique attributes specify the characteristics of a constraint to be generated or assumed to exist in the database, corresponding to the mapped column or columns.

18.15.1 ELEMENT collection

This element specifies the element type of collection typed fields. The default is Collection typed fields are persistent, and the element type is Object.

The element-type attribute specifies the type of the elements. The type name uses Java language rules for naming: if no package is included in the name, the package name is assumed to be the same package as the persistence-capable class. Inner classes are identified by the "\$" marker. Classes Boolean, Byte, Character, Double, Float, Integer, Long, Number, Object, Short, String, and StringBuffer are treated exactly as in the Java language: they are first checked to see if they are in the package in which they are used, and if not, assumed to be in the java.lang package. To be portable, specify the name of a single type that is itself able to be mapped to the datastore (e.g. an element of type Object can specify element-type="Integer"). To specify multiple types that the field might contain, use a comma-separated list of types, although this cannot be portably mapped.

The `embedded-element` attribute specifies whether the values of the elements should be stored as part of the containing instance instead of as their own instances in the datastore. It defaults to "false" for persistence-capable types, the `Object` type, interface types and multi-valued types; and "true" for primitive types, wrapper types, and single-valued `Object` types including `String`, `Date`, and `Locale`. It also defaults to true if the `element` element contains the `embedded` element specifying the embedded mapping of the element.

The embedded treatment of the collection instance itself is governed by the `embedded` attribute of the `field` element.

The `dependent-element` attribute indicates that the collection's element contains a reference to a referred instance that is to be deleted if the referring instance is deleted, the collection is replaced, or the reference is nullified or removed from the collection. The default is "false".

The `element` element contained in the `field` element specifies the mapping of elements in the collection.

The `serialized-element` attribute indicates that the array element is to be serialized for storage using `writeObject`, and cannot be queried.

The attributes `serialized-element="true"` and `embedded-element="true"` are mutually exclusive.

18.15.2 ELEMENT map

This element specifies the treatment of keys and values of map typed fields. The default is map typed fields are persistent, and the key and value types are `Object`.

The `key-type` and `value-type` attributes specify the types of the key and value, respectively. They follow the same rules as `element-type` in element collection.

The `embedded-key` and `embedded-value` attributes specify whether the key and value should be stored as part of the containing instance instead of as their own instances in the datastore. They default to "false" for persistence-capable types, the `Object` type, interface types and multi-valued types; and "true" for primitive types, wrapper types, and single-valued `Object` types including `String`, `Date`, and `Locale`. They also default to "true" if the key or value elements contain the `embedded` element specifying the embedded mapping of the key or value.

The `serialized-key` attribute indicates that the map key is to be serialized for storage using `writeObject`, and cannot be queried.

The attributes `serialized-key="true"` and `embedded-key="true"` are mutually exclusive.

The embedded treatment of the map instance itself is governed by the `embedded` attribute of the `field` element.

The `dependent-key` attribute indicates that the collection's key contains references that are to be deleted if the referring instance is deleted, the map is replaced, or the key is removed from the map. The default is "false".

The `dependent-value` attribute indicates that the collection's value contains references that are to be deleted if the referring instance is deleted, the map is replaced, or the value is removed from the map. The default is "false".

The `serialized-value` attribute indicates that the map value is to be serialized for storage using `writeObject`, and cannot be queried.

The attributes `serialized-value="true"` and `embedded-value="true"` are mutually exclusive.

18.15.3 ELEMENT array

This element specifies the treatment of array typed fields. The default persistence-modifier for array typed fields is based on the Java type of the component and modifiers of the field, according to the rules in section 18.10.

The `element-type` attribute is used to specify a more restrictive type than the field definition in the class. This might be required in order to map the field to the datastore. It follows the same rules as `element-type` in element collection.

The `embedded-element` attribute specifies whether the values of the components should be stored as part of the containing instance instead of as their own instances in the datastore. It defaults to "false" for persistence-capable types, the `Object` type, interface types and multi-valued types; and "true" for primitive types, wrapper types, and single-valued `Object` types including `String`, `Date`, and `Locale`. It also defaults to true if the `element` element contains the `embedded` element specifying the embedded mapping of the element.

The `dependent-element` attribute indicates that the array element contains a reference that is to be deleted if the referring instance is deleted, the array is replaced, or the reference is nullified.

The `serialized-element` attribute indicates that the array element is to be serialized for storage using `writeObject`, and cannot be queried.

The attributes `serialized-element="true"` and `embedded-element="true"` are mutually exclusive.

The embedded treatment of the array instance itself is governed by the `embedded` attribute of the `field` element.

18.15.4 ELEMENT embedded

The `embedded` element specifies the mapping for an embedded type. It contains multiple field and property elements, one for each field and property in the type.

The `null-indicator-column` attribute optionally identifies the name of the column used to indicate whether the embedded instance is null. By default, if the value of this column is null, then the embedded instance is null. This column might be mapped to a field or property of the embedded instance but might be a synthetic column for the sole purpose of indicating a null reference.

The `null-indicator-value` attribute specifies the value to indicate that the embedded instance is null. This is only used for non-nullable columns.

If `null-indicator-column` is omitted, then the embedded instance is assumed always to exist.

The `owner-field` attribute specifies the name of the field or property in the embedded type that should contain a reference to the owning instance. This field or property is automatically instantiated by the implementation, and is not mapped to anything in the data store.

18.15.5 ELEMENT key

This element specifies the mapping for the key component of a `Map` field.

If only one column is mapped, and no additional information is needed for the column, then the `column` attribute can be used. Otherwise, the `column` element(s) are used.

If the `Map` field is mapped using the `mapped-by` attribute in the field metadata, then the key can be mapped to a field in the same class. In this case, use the `mapped-by` attribute in the key metadata to name the field containing the key data.

The `mapped-by` attribute specifies that the field is mapped to the same database column(s) as the named field in the other class.

The delete-action, update-action, indexed, and unique attributes specify the characteristics of a constraint to be generated.

18.15.6 ELEMENT value

This element specifies the mapping for the value component of a Map field.

If only one column is mapped, and no additional information is needed for the column, then the column attribute can be used. Otherwise, the column element(s) are used.

If the Map field is mapped using the mapped-by attribute in the field metadata, then the value can be mapped to a field in the same class. In this case, use the mapped-by attribute in the value metadata to name the field containing the value data.

The mapped-by attribute specifies that the field is mapped to the same database column(s) as the named field in the other class.

The delete-action, update-action, indexed, and unique attributes specify the characteristics of a constraint to be generated.

18.15.7 ELEMENT element

This element specifies the mapping for the element component of arrays and collections.

If only one column is mapped, and no additional information is needed for the column, then the column attribute can be used. Otherwise, the column element(s) are used.

The mapped-by attribute specifies that the field is mapped to the same database column(s) as the named field in the other class.

The delete-action, update-action, indexed, and unique attributes specify the characteristics of a constraint to be generated.

18.15.8 ELEMENT order

This element specifies the mapping for the ordering component of arrays and lists.

If no additional information is needed for the ordering column except for the name, then the column attribute can be used. Otherwise, the column element(s) are used.

If the array or list field is mapped using the mapped-by attribute in the field metadata, then the ordering can be mapped to a field in the same class. In this case, use the mapped-by attribute in the order metadata to name the field containing the ordering data.

The field named in the mapped-by attribute in the order element must refer to a field or property of an integral type. This field is managed by the JDO implementation at flush time.

If an instance of the target type is created and not explicitly added to the array or list on the other side, at flush time the instance is added to the array or list at the end.

18.16 ELEMENT query

This element specifies the serializable components of a query. Queries defined using metadata are used with the newNamedQuery method of PersistenceManager.

The name attribute specifies the name of the query, and is required.

The language attribute specifies the language of the query. The default is "javax.jdo.query.JDOQL". To specify SQL, use "javax.jdo.query.SQL". Names for languages other than these are not standard.

The unmodifiable attribute specifies whether the query can be modified by the program.

The body of the `query` element specifies the text of the query. This is the single-string query as defined in section 14.6.13. For convenience, single quotes can be used to delimit string constants in the filter.

For SQL queries, in which it is not possible to specify uniqueness and the result class in the query itself, the attributes `unique` and `result-class` can be used.

18.17 ELEMENT sequence

The `sequence` element identifies a sequence number generator that can be used for several purposes:

- by the JDO implementation to generate application identity primary key values;
- by the JDO implementation to generate datastore identity primary key values;
- by the JDO implementation to generate non-key field values;
- by an application to generate unique identifiers for application use.

The `name` attribute specifies the name for the sequence number generator.

The `strategy` attribute specifies the strategy for generating sequence numbers. Standard values are:

- `nontransactional`: values are obtained outside of the transaction
- `transactional`: values are obtained in a transaction; if the transaction rolls back, gaps might occur in the sequence numbers
- `contiguous`: values are obtained in a transaction; all sequence numbers are guaranteed to be used. This implies that use of the sequence is serialized by transactions.

The `datastore-sequence` attribute names the sequence used to generate key values. This must correspond to a named sequence in the database schema.

The `factory-class` attribute names the user-defined class of the factory for the sequence. The class must have a static method `newInstance()` that returns an instance of `Sequence`. This method will be invoked once per named sequence per `PersistenceManagerFactory` and the same instance will be used for every reference to the same named sequence in the context of that `PersistenceManagerFactory`.

This element is used in conjunction with the `getSequence(String name)` method in `PersistenceManager`. The `name` parameter is the fully qualified name of the sequence.

18.18 ELEMENT extension

This element specifies JDO vendor extensions. The `vendor-name` attribute is required. The vendor name "JDORI" is reserved for use by the JDO reference implementation. The `key` and `value` attributes are optional, and have vendor-specific meanings. They may be ignored by any JDO implementation.

18.19 ELEMENT orm

This element specifies mapping information. It is the top-level element in a mapping file whose extension is .orm. Many of the same elements in the jdo document are valid for orm.

18.20 ELEMENT jdoquery

This element specifies named query information separate from the persistence and mapping metadata. It is the top-level element in a file whose extension is .jdoquery. Many of the same elements in the jdo document are valid for jdoquery.

18.21 The jdo Schema Descriptor

This describes files stored as .jdo files.

Note: The document type descriptors are descriptive, not normative. The xml schema in the binary distribution is normative. [see Appendix E].

JDO vendors must support XSD and might support DTD. If using XSD, the declaration of the jdo element must include the following:

```
<?xml version="1.0" encoding="UTF-8" ?>
<jdo xmlns="http://java.sun.com/xml/ns/jdo/jdo"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://java.sun.com/xml/ns/jdo/jdo
                           http://java.sun.com/xml/ns/jdo/jdo_2_3.xsd">
```

The document type descriptor is referred by the xml, and must be identified with a DOCTYPE so that the parser can validate the syntax of the metadata file. Either the SYSTEM or PUBLIC form of DOCTYPE can be used.

- If SYSTEM is used, the URI must be accessible; a jdo implementation might optimize access for the URI "http://java.sun.com/dtd/jdo_2_3.dtd"
- If PUBLIC is used, the public id should be "-//Sun Microsystems, Inc.//DTD Java Data Objects Metadata 2.3//EN"; a jdo implementation might optimize access for this id.

```
<!-- The DOCTYPE should be as follows for metadata documents.
<!DOCTYPE jdo
  PUBLIC "-//Sun Microsystems, Inc.//DTD Java Data Objects Metadata 2.3//EN"
  "http://java.sun.com/dtd/jdo_2_3.dtd">
-->
<!ELEMENT jdo (extension*, (package|query|fetch-plan)+, extension*)>
<!ATTLIST jdo catalog CDATA #IMPLIED>
<!ATTLIST jdo schema CDATA #IMPLIED>

<!ELEMENT package (extension*, (interface|class|sequence)+, extension*)>
<!ATTLIST package name CDATA ''>
<!ATTLIST package catalog CDATA #IMPLIED>
<!ATTLIST package schema CDATA #IMPLIED>

<!ELEMENT interface (extension*, datastore-identity?, primary-key?, inheritance?,
version?, join*, foreign-key*, index*, unique*, property*, query*, fetch-group*,
extension*)>
<!ATTLIST interface name CDATA #REQUIRED>
<!ATTLIST interface table CDATA #IMPLIED>
<!ATTLIST interface identity-type (datastore|application|nondurable) #IMPLIED>
<!ATTLIST interface objectid-class CDATA #IMPLIED>
<!ATTLIST interface requires-extent (true|false) 'true'>
<!ATTLIST interface detachable (true|false) 'false'>
<!ATTLIST interface embedded-only (true|false) #IMPLIED>
<!ATTLIST interface catalog CDATA #IMPLIED>
```

```
<!ATTLIST interface schema CDATA #IMPLIED>
<!ATTLIST interface cacheable (true|false) 'true'>
<!ATTLIST interface serialize-read (true|false) 'false'>

<!ELEMENT property (extension*, (array|collection|map)?, join?, embedded?,
element?, key?, value?, order?, column*, foreign-key?, index?, unique?,
extension*)>
<!ATTLIST property name CDATA #REQUIRED>
<!ATTLIST property persistence-modifier (persistent|transactional|none) #IMPLIED>
<!ATTLIST property default-fetch-group (true|false) #IMPLIED>
<!ATTLIST property load-fetch-group CDATA #IMPLIED>
<!ATTLIST property null-value (default|exception|none) 'none'>
<!ATTLIST property dependent (true|false) #IMPLIED>
<!ATTLIST property embedded (true|false) #IMPLIED>
<!ATTLIST property primary-key (true|false) 'false'>
<!ATTLIST property value-strategy CDATA #IMPLIED>
<!ATTLIST property sequence CDATA #IMPLIED>
<!ATTLIST property serialized (true|false) #IMPLIED>
<!ATTLIST property field-type CDATA #IMPLIED>
<!ATTLIST property table CDATA #IMPLIED>
<!ATTLIST property column CDATA #IMPLIED>
<!ATTLIST property delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST property indexed (true|false|unique) #IMPLIED>
<!ATTLIST property unique (true|false) #IMPLIED>
<!ATTLIST property mapped-by CDATA #IMPLIED>
<!ATTLIST property recursion-depth CDATA #IMPLIED>
<!ATTLIST property field-name CDATA #IMPLIED>
<!ATTLIST property cacheable (true|false) 'true'>

<!ELEMENT class (extension*, implements*, datastore-identity?, primary-key?,
inheritance?, version?, join*, foreign-key*, index*, unique*, column*, field*,
property*, query*, fetch-group*, extension*)>
<!ATTLIST class name CDATA #REQUIRED>
<!ATTLIST class identity-type (application|datastore|nondurable) #IMPLIED>
<!ATTLIST class objectid-class CDATA #IMPLIED>
<!ATTLIST class table CDATA #IMPLIED>
<!ATTLIST class requires-extent (true|false) 'true'>
<!ATTLIST class persistence-capable-superclass CDATA #IMPLIED>
<!ATTLIST class detachable (true|false) 'false'>
<!ATTLIST class embedded-only (true|false) #IMPLIED>
<!ATTLIST class persistence-modifier (persistence-capable|persistence-aware|non-
persistent) #IMPLIED>
<!ATTLIST class catalog CDATA #IMPLIED>
<!ATTLIST class schema CDATA #IMPLIED>
<!ATTLIST class cacheable (true|false) 'true'>
<!ATTLIST class serialize-read (true|false) 'false'>

<!ELEMENT primary-key (extension*, column*, extension*)>
<!ATTLIST primary-key name CDATA #IMPLIED>
<!ATTLIST primary-key column CDATA #IMPLIED>

<!ELEMENT join (extension*, primary-key?, column*, foreign-key?, index?, unique?,
extension*)>
<!ATTLIST join table CDATA #IMPLIED>
<!ATTLIST join column CDATA #IMPLIED>
<!ATTLIST join outer (true|false) 'false'>
<!ATTLIST join delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST join indexed (true|false|unique) #IMPLIED>
<!ATTLIST join unique (true|false) #IMPLIED>

<!ELEMENT version (extension*, column*, index?, extension*)>
```

```
<!ATTLIST version strategy CDATA #IMPLIED>
<!ATTLIST version column CDATA #IMPLIED>
<!ATTLIST version indexed (true|false|unique) #IMPLIED>

<!ELEMENT datastore-identity (extension*, column*, extension*)>
<!ATTLIST datastore-identity column CDATA #IMPLIED>
<!ATTLIST datastore-identity strategy CDATA 'native'>
<!ATTLIST datastore-identity sequence CDATA #IMPLIED>

<!ELEMENT implements (extension*, property*, extension*)>
<!ATTLIST implements name CDATA #REQUIRED>

<!ELEMENT inheritance (extension*, join?, discriminator?, extension*)>
<!ATTLIST inheritance strategy CDATA #IMPLIED>

<!ELEMENT discriminator (extension*, column*, index?, extension*)>
<!ATTLIST discriminator column CDATA #IMPLIED>
<!ATTLIST discriminator value CDATA #IMPLIED>
<!ATTLIST discriminator strategy CDATA #IMPLIED>
<!ATTLIST discriminator indexed (true|false|unique) #IMPLIED>

<!ELEMENT column (extension*)>
<!ATTLIST column name CDATA #IMPLIED>
<!ATTLIST column target CDATA #IMPLIED>
<!ATTLIST column target-field CDATA #IMPLIED>
<!ATTLIST column jdbc-type CDATA #IMPLIED>
<!ATTLIST column sql-type CDATA #IMPLIED>
<!ATTLIST column length CDATA #IMPLIED>
<!ATTLIST column scale CDATA #IMPLIED>
<!ATTLIST column allows-null (true|false) #IMPLIED>
<!ATTLIST column default-value CDATA #IMPLIED>
<!ATTLIST column insert-value CDATA #IMPLIED>

<!ELEMENT field (extension*, (array|collection|map)?, join?, embedded?, element?, key?, value?, order?, column*, foreign-key?, index?, unique?, extension*)>
<!ATTLIST field name CDATA #REQUIRED>
<!ATTLIST field persistence-modifier (persistent|transactional|none) #IMPLIED>
<!ATTLIST field field-type CDATA #IMPLIED>
<!ATTLIST field table CDATA #IMPLIED>
<!ATTLIST field column CDATA #IMPLIED>
<!ATTLIST field primary-key (true|false) 'false'>
<!ATTLIST field null-value (exception|default|none) 'none'>
<!ATTLIST field default-fetch-group (true|false) #IMPLIED>
<!ATTLIST field embedded (true|false) #IMPLIED>
<!ATTLIST field serialized (true|false) #IMPLIED>
<!ATTLIST field dependent (true|false) #IMPLIED>
<!ATTLIST field value-strategy CDATA #IMPLIED>
<!ATTLIST field delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST field indexed (true|false|unique) #IMPLIED>
<!ATTLIST field unique (true|false) #IMPLIED>
<!ATTLIST field sequence CDATA #IMPLIED>
<!ATTLIST field load-fetch-group CDATA #IMPLIED>
<!ATTLIST field recursion-depth CDATA #IMPLIED>
<!ATTLIST field mapped-by CDATA #IMPLIED>
<!ATTLIST field cacheable (true|false) 'true'>

<!ELEMENT foreign-key (extension*, (column* | field* | property*), extension*)>
<!ATTLIST foreign-key table CDATA #IMPLIED>
<!ATTLIST foreign-key deferred (true|false) #IMPLIED>
<!ATTLIST foreign-key delete-action (restrict|cascade|null|default|none) 'restrict'>
```

```
<!ATTLIST foreign-key update-action (restrict|cascade|null|default|none)
  'restrict'
<!ATTLIST foreign-key unique (true|false) #IMPLIED>
<!ATTLIST foreign-key name CDATA #IMPLIED>

<!ELEMENT collection (extension*)>
<!ATTLIST collection element-type CDATA #IMPLIED>
<!ATTLIST collection embedded-element (true|false) #IMPLIED>
<!ATTLIST collection dependent-element (true|false) #IMPLIED>
<!ATTLIST collection serialized-element (true|false) #IMPLIED>

<!ELEMENT map (extension*)>
<!ATTLIST map key-type CDATA #IMPLIED>
<!ATTLIST map embedded-key (true|false) #IMPLIED>
<!ATTLIST map dependent-key (true|false) #IMPLIED>
<!ATTLIST map serialized-key (true|false) #IMPLIED>
<!ATTLIST map value-type CDATA #IMPLIED>
<!ATTLIST map embedded-value (true|false) #IMPLIED>
<!ATTLIST map dependent-value (true|false) #IMPLIED>
<!ATTLIST map serialized-value (true|false) #IMPLIED>

<!ELEMENT key (extension*, embedded?, column*, foreign-key?, index?, unique?,
  extension*)>
<!ATTLIST key column CDATA #IMPLIED>
<!ATTLIST key table CDATA #IMPLIED>
<!ATTLIST key delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST key update-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST key indexed (true|false|unique) #IMPLIED>
<!ATTLIST key unique (true|false) #IMPLIED>
<!ATTLIST key mapped-by CDATA #IMPLIED>

<!ELEMENT value (extension*, embedded?, column*, foreign-key?, index?, unique?,
  extension*)>
<!ATTLIST value column CDATA #IMPLIED>
<!ATTLIST value table CDATA #IMPLIED>
<!ATTLIST value delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST value update-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST value indexed (true|false|unique) #IMPLIED>
<!ATTLIST value unique (true|false) #IMPLIED>
<!ATTLIST value mapped-by CDATA #IMPLIED>

<!ELEMENT array (extension*)>
<!ATTLIST array element-type CDATA #IMPLIED>
<!ATTLIST array embedded-element (true|false) #IMPLIED>
<!ATTLIST array dependent-element (true|false) #IMPLIED>
<!ATTLIST array serialized-element (true|false) #IMPLIED>

<!ELEMENT element (extension*, embedded?, column*, foreign-key?, index?, unique?,
  extension*)>
<!ATTLIST element column CDATA #IMPLIED>
<!ATTLIST element table CDATA #IMPLIED>
<!ATTLIST element delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST element update-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST element indexed (true|false|unique) #IMPLIED>
<!ATTLIST element unique (true|false) #IMPLIED>
<!ATTLIST element mapped-by CDATA #IMPLIED>

<!ELEMENT order (extension*, column*, index?, extension*)>
<!ATTLIST order column CDATA #IMPLIED>
<!ATTLIST order mapped-by CDATA #IMPLIED>
```

```
<!ELEMENT fetch-group (extension*, (fetch-group|field|property)*, extension*)>
<!ATTLIST fetch-group name CDATA #REQUIRED>
<!ATTLIST fetch-group post-load (true|false) #IMPLIED>

<!ELEMENT fetch-plan (fetch-group*)>
<!ATTLIST fetch-plan name CDATA #REQUIRED>
<!ATTLIST fetch-plan max-fetch-depth CDATA #IMPLIED>
<!ATTLIST fetch-plan fetch-size CDATA #IMPLIED>

<!ELEMENT embedded (extension*, (field|property)*, extension*)>
<!ATTLIST embedded owner-field CDATA #IMPLIED>
<!ATTLIST embedded null-indicator-column CDATA #IMPLIED>
<!ATTLIST embedded null-indicator-value CDATA #IMPLIED>

<!ELEMENT sequence (extension*)>
<!ATTLIST sequence name CDATA #REQUIRED>
<!ATTLIST sequence datastore-sequence CDATA #IMPLIED>
<!ATTLIST sequence factory-class CDATA #IMPLIED>
<!ATTLIST sequence strategy (nontransactional|contiguous|noncontiguous) #REQUIRED>

<!ELEMENT index (extension*, (column* | field* | property*), extension*)>
<!ATTLIST index name CDATA #IMPLIED>
<!ATTLIST index table CDATA #IMPLIED>
<!ATTLIST index unique (true|false) 'false'>

<!ELEMENT query (#PCDATA|extension)*>
<!ATTLIST query name CDATA #REQUIRED>
<!ATTLIST query language CDATA #IMPLIED>
<!ATTLIST query unmodifiable (true|false) 'false'>
<!ATTLIST query unique (true|false) #IMPLIED>
<!ATTLIST query result-class CDATA #IMPLIED>
<!ATTLIST query fetch-plan CDATA #IMPLIED>

<!ELEMENT unique (extension*, (column* | field* | property*), extension*)>
<!ATTLIST unique name CDATA #IMPLIED>
<!ATTLIST unique table CDATA #IMPLIED>
<!ATTLIST unique deferred (true|false) 'false'>

<!ELEMENT extension ANY>
<!ATTLIST extension vendor-name CDATA #REQUIRED>
<!ATTLIST extension key CDATA #IMPLIED>
<!ATTLIST extension value CDATA #IMPLIED>
```

18.22 The orm Schema Descriptor

This describes files stored as .orm files.

Note: The document type descriptors are descriptive, not normative. The xml schema in the binary distribution is normative. [see Appendix F].

JDO vendors must support XSD and might support DTD. If using XSD, the declaration of the orm element must include the following:

```
<?xml version="1.0" encoding="UTF-8" ?>
<orm xmlns="http://java.sun.com/xml/ns/jdo/orm"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://java.sun.com/xml/ns/jdo/orm"
```

```
http://java.sun.com/xml/ns/jdo/orm_2_2.xsd">
```

The document type descriptor is referred by the xml, and must be identified with a DOCTYPE so that the parser can validate the syntax of the metadata file. Either the SYSTEM or PUBLIC form of DOCTYPE can be used.

- If SYSTEM is used, the URI must be accessible; a jdo implementation might optimize access for the URI "http://java.sun.com/dtd/orm_2_2.dtd"
- If PUBLIC is used, the public id should be "-//Sun Microsystems, Inc.//DTD Java Data Objects Mapping Metadata 2.2//EN"; a jdo implementation might optimize access for this id.

```
<!--  
Licensed to the Apache Software Foundation (ASF) under one or more  
contributor license agreements. See the NOTICE file distributed with  
this work for additional information regarding copyright ownership.  
The ASF licenses this file to You under the Apache License, Version 2.0  
(the "License"); you may not use this file except in compliance with  
the License. You may obtain a copy of the License at
```

```
http://www.apache.org/licenses/LICENSE-2.0
```

Unless required by applicable law or agreed to in writing, software
distributed under the License is distributed on an "AS IS" BASIS,
WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
See the License for the specific language governing permissions and
limitations under the License.

```
-->  
<!-- The DOCTYPE should be as follows for metadata documents.  
<!DOCTYPE orm  
PUBLIC "-//Sun Microsystems, Inc.//DTD Java Data Objects Mapping Metadata 2.2//  
EN"  
"http://java.sun.com/dtd/orm_2_2.dtd">  
-->  
<!ELEMENT orm (extension*, (package|query)+, extension*)>  
<!ATTLIST orm catalog CDATA #IMPLIED>  
<!ATTLIST orm schema CDATA #IMPLIED>  
  
<!ELEMENT package (extension*, (interface|class|sequence)+, extension*)>  
<!ATTLIST package name CDATA ''>  
<!ATTLIST package catalog CDATA #IMPLIED>  
<!ATTLIST package schema CDATA #IMPLIED>  
  
<!ELEMENT interface (extension*, datastore-identity?, primary-key?, inheritance?,  
version?, join*, foreign-key*, index*, unique*, property*, query*, extension*)>  
<!ATTLIST interface name CDATA #REQUIRED>  
<!ATTLIST interface table CDATA #IMPLIED>  
<!ATTLIST interface catalog CDATA #IMPLIED>  
<!ATTLIST interface schema CDATA #IMPLIED>  
  
<!ELEMENT property (extension*, join?, embedded?, element?, key?, value?, order?,  
column*, foreign-key?, index?, unique?, extension*)>  
<!ATTLIST property name CDATA #REQUIRED>  
<!ATTLIST property value-strategy CDATA #IMPLIED>  
<!ATTLIST property sequence CDATA #IMPLIED>  
<!ATTLIST property table CDATA #IMPLIED>  
<!ATTLIST property column CDATA #IMPLIED>  
<!ATTLIST property delete-action (restrict|cascade|null|default|none) #IMPLIED>  
<!ATTLIST property indexed (true|false|unique) #IMPLIED>  
<!ATTLIST property unique (true|false) #IMPLIED>  
<!ATTLIST property mapped-by CDATA #IMPLIED>
```

```
<!ELEMENT class (extension*, datastore-identity?, primary-key?, inheritance?,
version?, join*, foreign-key*, index*, unique*, column*, field*, property*, query*,
extension*)>
<!ATTLIST class name CDATA #REQUIRED>
<!ATTLIST class table CDATA #IMPLIED>
<!ATTLIST class catalog CDATA #IMPLIED>
<!ATTLIST class schema CDATA #IMPLIED>

<!ELEMENT primary-key (extension*, column*, extension*)>
<!ATTLIST primary-key name CDATA #IMPLIED>
<!ATTLIST primary-key column CDATA #IMPLIED>

<!ELEMENT join (extension*, primary-key?, column*, foreign-key?, index?, unique?,
extension*)>
<!ATTLIST join table CDATA #IMPLIED>
<!ATTLIST join column CDATA #IMPLIED>
<!ATTLIST join outer (true|false) 'false'>
<!ATTLIST join delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST join indexed (true|false|unique) #IMPLIED>
<!ATTLIST join unique (true|false) #IMPLIED>

<!ELEMENT version (extension*, column*, index?, extension*)>
<!ATTLIST version strategy CDATA #IMPLIED>
<!ATTLIST version column CDATA #IMPLIED>
<!ATTLIST version indexed (true|false|unique) #IMPLIED>

<!ELEMENT datastore-identity (extension*, column*, extension*)>
<!ATTLIST datastore-identity column CDATA #IMPLIED>
<!ATTLIST datastore-identity strategy CDATA 'native'>
<!ATTLIST datastore-identity sequence CDATA #IMPLIED>

<!ELEMENT implements (extension*, property*, extension*)>
<!ATTLIST implements name CDATA #REQUIRED>

<!ELEMENT inheritance (extension*, join?, discriminator?, extension*)>
<!ATTLIST inheritance strategy CDATA #IMPLIED>

<!ELEMENT discriminator (extension*, column*, index?, extension*)>
<!ATTLIST discriminator column CDATA #IMPLIED>
<!ATTLIST discriminator value CDATA #IMPLIED>
<!ATTLIST discriminator strategy CDATA #IMPLIED>
<!ATTLIST discriminator indexed (true|false|unique) #IMPLIED>

<!ELEMENT column (extension*)>
<!ATTLIST column name CDATA #IMPLIED>
<!ATTLIST column target CDATA #IMPLIED>
<!ATTLIST column target-field CDATA #IMPLIED>
<!ATTLIST column jdbc-type CDATA #IMPLIED>
<!ATTLIST column sql-type CDATA #IMPLIED>
<!ATTLIST column length CDATA #IMPLIED>
<!ATTLIST column scale CDATA #IMPLIED>
<!ATTLIST column allows-null (true|false) #IMPLIED>
<!ATTLIST column default-value CDATA #IMPLIED>
<!ATTLIST column insert-value CDATA #IMPLIED>

<!ELEMENT field (extension*, join?, embedded?, element?, key?, value?, order?,
column*, foreign-key?, index?, unique?, extension*)>
<!ATTLIST field name CDATA #REQUIRED>
<!ATTLIST field table CDATA #IMPLIED>
<!ATTLIST field column CDATA #IMPLIED>
```

```
<!ATTLIST field value-strategy CDATA #IMPLIED>
<!ATTLIST field delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST field indexed (true|false|unique) #IMPLIED>
<!ATTLIST field unique (true|false) #IMPLIED>
<!ATTLIST field sequence CDATA #IMPLIED>
<!ATTLIST field mapped-by CDATA #IMPLIED>

<!ELEMENT foreign-key (extension*, (column* | field* | property*), extension*)>
<!ATTLIST foreign-key table CDATA #IMPLIED>
<!ATTLIST foreign-key deferred (true|false) #IMPLIED>
<!ATTLIST foreign-key delete-action (restrict|cascade|null|default|none)
  'restrict'>
<!ATTLIST foreign-key update-action (restrict|cascade|null|default|none)
  'restrict'>
<!ATTLIST foreign-key unique (true|false) #IMPLIED>
<!ATTLIST foreign-key name CDATA #IMPLIED>

<!ELEMENT key (extension*, embedded?, column*, foreign-key?, index?, unique?,
  extension*)>
<!ATTLIST key column CDATA #IMPLIED>
<!ATTLIST key table CDATA #IMPLIED>
<!ATTLIST key delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST key update-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST key indexed (true|false|unique) #IMPLIED>
<!ATTLIST key unique (true|false) #IMPLIED>
<!ATTLIST key mapped-by CDATA #IMPLIED>

<!ELEMENT value (extension*, embedded?, column*, foreign-key?, index?, unique?,
  extension*)>
<!ATTLIST value column CDATA #IMPLIED>
<!ATTLIST value table CDATA #IMPLIED>
<!ATTLIST value delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST value update-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST value indexed (true|false|unique) #IMPLIED>
<!ATTLIST value unique (true|false) #IMPLIED>
<!ATTLIST value mapped-by CDATA #IMPLIED>

<!ELEMENT element (extension*, embedded?, column*, foreign-key?, index?, unique?,
  extension*)>
<!ATTLIST element column CDATA #IMPLIED>
<!ATTLIST element table CDATA #IMPLIED>
<!ATTLIST element delete-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST element update-action (restrict|cascade|null|default|none) #IMPLIED>
<!ATTLIST element indexed (true|false|unique) #IMPLIED>
<!ATTLIST element unique (true|false) #IMPLIED>
<!ATTLIST element mapped-by CDATA #IMPLIED>

<!ELEMENT order (extension*, column*, index?, extension*)>
<!ATTLIST order column CDATA #IMPLIED>
<!ATTLIST order mapped-by CDATA #IMPLIED>

<!ELEMENT embedded (extension*, (field|property)*, extension*)>
<!ATTLIST embedded owner-field CDATA #IMPLIED>
<!ATTLIST embedded null-indicator-column CDATA #IMPLIED>
<!ATTLIST embedded null-indicator-value CDATA #IMPLIED>

<!ELEMENT sequence (extension*)>
<!ATTLIST sequence name CDATA #REQUIRED>
<!ATTLIST sequence datastore-sequence CDATA #IMPLIED>
<!ATTLIST sequence factory-class CDATA #IMPLIED>
<!ATTLIST sequence strategy (nontransactional|contiguous|noncontiguous) #REQUIRED>
```

```
<!ELEMENT index (extension*, (column* | field* | property*), extension*)>
<!ATTLIST index name CDATA #IMPLIED>
<!ATTLIST index table CDATA #IMPLIED>
<!ATTLIST index unique (true|false) 'false'>

<!ELEMENT query (#PCDATA|extension)*>
<!ATTLIST query name CDATA #REQUIRED>
<!ATTLIST query language CDATA #IMPLIED>
<!ATTLIST query unmodifiable (true|false) 'false'>
<!ATTLIST query unique (true|false) #IMPLIED>
<!ATTLIST query result-class CDATA #IMPLIED>

<!ELEMENT unique (extension*, (column* | field* | property*), extension*)>
<!ATTLIST unique name CDATA #IMPLIED>
<!ATTLIST unique table CDATA #IMPLIED>
<!ATTLIST unique deferred (true|false) 'false'>

<!ELEMENT extension ANY>
<!ATTLIST extension vendor-name CDATA #REQUIRED>
<!ATTLIST extension key CDATA #IMPLIED>
<!ATTLIST extension value CDATA #IMPLIED>
```

18.23 The jdoquery Schema Descriptor

This describes files stored as .jdoquery files.

Note: The document type descriptors are descriptive, not normative. The xml schema in the binary distribution is normative.

JDO vendors must support XSD and might support DTD. If using XSD, the declaration of the jdoquery element must include the following:

```
<?xml version="1.0" encoding="UTF-8" ?>
<jdoquery xmlns="http://java.sun.com/xml/ns/jdo/jdoquery"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://java.sun.com/xml/ns/jdo/jdoquery
        http://java.sun.com/xml/ns/jdo/jdoquery_2_2.xsd">
```

The document type descriptor is referred by the xml, and must be identified with a DOCTYPE so that the parser can validate the syntax of the metadata file. Either the SYSTEM or PUBLIC form of DOCTYPE can be used.

- If SYSTEM is used, the URI must be accessible; a jdo implementation might optimize access for the URI "http://java.sun.com/dtd/jdoquery_2_2.dtd"
- If PUBLIC is used, the public id should be "-//Sun Microsystems, Inc.//DTD Java Data Objects Query Metadata 2.2//EN"; a jdo implementation might optimize access for this id.

```
<!--
Licensed to the Apache Software Foundation (ASF) under one or more
contributor license agreements. See the NOTICE file distributed with
this work for additional information regarding copyright ownership.
The ASF licenses this file to You under the Apache License, Version 2.0
(the "License"); you may not use this file except in compliance with
the License. You may obtain a copy of the License at
```

<http://www.apache.org/licenses/LICENSE-2.0>

Unless required by applicable law or agreed to in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License.

```
-->
<!-- The DOCTYPE should be as follows for jdoquery documents.
<!DOCTYPE jdoquery
  PUBLIC "-//Sun Microsystems, Inc.//DTD Java Data Objects Query Metadata 2.2//EN"
  "http://java.sun.com/dtd/jdoquery_2_2.dtd">
-->
<!ELEMENT jdoquery (extension*, (package|query)+, (extension)*)>

<!ELEMENT package (extension*, (interface|class)+, (extension)*)>
<!ATTLIST package name CDATA ''>

<!ELEMENT interface (extension*, query+, extension*)>
<!ATTLIST interface name CDATA #REQUIRED>

<!ELEMENT class (extension*, query+, extension*)>
<!ATTLIST class name CDATA #REQUIRED>

<!ELEMENT query (#PCDATA|extension)*>
<!ATTLIST query name CDATA #REQUIRED>
<!ATTLIST query language CDATA #IMPLIED>
<!ATTLIST query unmodifiable (true|false) 'false'>
<!ATTLIST query unique (true|false) #IMPLIED>
<!ATTLIST query result-class CDATA #IMPLIED>

<!ELEMENT extension ANY>
<!ATTLIST extension vendor-name CDATA #REQUIRED>
<!ATTLIST extension key CDATA #IMPLIED>
<!ATTLIST extension value CDATA #IMPLIED>
```

18.24 Example XML file

An example XML file for the query example classes follows. Note that all fields of both classes are persistent, which is the default for fields. The `emps` field in `Department` contains a collection of elements of type `Employee`, with a relationship to the `dept` field in `Employee`.

In directory `com/xyz`, a file named `hr.jdo` contains:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jdo SYSTEM "jdo.dtd">
<jdo>
  <package name="com.xyz.hr">
    <class name="Employee" identity-type="application">
      <field name="name" primary-key="true">
        <extension vendor-name="sunw" key="index" value="btree"/>
      </field>
      <field name="salary" default-fetch-group="true"/>
      <field name="dept">
        <extension vendor-name="sunw" key="inverse" value="emps"/>
      </field>
      <field name="boss" />
    </class>
  </package>
</jdo>
```

```
<class name="Department" identity-type="application" objectid-
      class="DepartmentKey">
  <field name="name" primary-key="true"/>
  <field name="emps">
    <collection element-type="Employee">
      <extension vendor-name="sunw" key="element-inverse" value="dept" />
    </collection>
  </field>
</class>
</package>
</jdo>
```

19 Annotations and Metadata API

This chapter specifies the annotations that describe a persistence-capable class or interface, optionally including its mapping to a relational database; and an API to dynamically access and create metadata. The annotations for metadata are stored in the Java class mixed with the definition of the class. For implementations that support binary compatibility, the information must be available when the class is enhanced, and might be cached by an implementation for use at runtime. If the metadata is changed between enhancement and runtime, the behavior is unspecified. Regardless of whether the metadata was provided via annotations, xml, or API, the metadata can be obtained at runtime via the API.

The annotations described herein support the entire range of metadata that can be expressed using the xml format. Annotations have identical semantics to the corresponding xml metadata.

All annotations are defined in the package javax.jdo.annotations. Annotations apply to classes, fields, or methods, depending on their purpose. If xml metadata is defined for annotated classes, fields, or methods, xml metadata overrides the annotation.

Annotations can be applied to classes and interfaces; and within classes and interfaces, to fields and methods. Annotations applied to methods identify properties, and are applied to the `getXXX` method of a `getXXX/setXXX` pair or the `isXXX` method of a `isXXX/setXXX` pair in which the return type of the method is the same type as the parameter of the `setXXX` method.

To the extent possible, mapping from the xml metadata to the annotation metadata is done by translating the xml elements to annotation interfaces and xml attributes to annotation elements. Annotation interfaces and enums follow the Java class naming convention: upper case the first character and camel case compound words. Annotation element names follow the Java field naming convention: lower case the first character and camel case compound words.

Annotations differ from xml metadata in the richness of usage. The differences become significant in several areas:

- Multiple annotations of the same interface type cannot be applied to a class, interface, field, or method. Therefore, where multiple xml elements are permitted, the corresponding annotation has an additional annotation for multiple instances. For example, `@Index` can appear only once so there is an `@Indices` that contains an array of `@Index` annotations.
- Annotations cannot have null defaults. Therefore, `boolean` element types are not used. Instead, elements that have `boolean` values are declared to have `String` type, and the default is the empty `String`. This allows identical semantics between xml and annotations. For example, `@Persistent` has an element `primaryKey()` which defaults to the empty `String`, and if unspecified, defaults to `true` if the `@PrimaryKey` annotation is used, and to `false` if not.
- Annotation elements of annotation types cannot have default values, since there is no way to construct an instance of an annotation type to use as the default. When translating xml metadata to annotations, where annotation elements would need to be of an annotation type, the element is instead promoted to directly annotate the class, interface, field, or method. For example, xml element `key` is a contained element of xml element `field` but in annotations it is a separate `@Key` annotation applied to the field or property directly.

Java Persistence API Annotations

A JDO implementation that supports jdo annotations must also support Java Persistence API annotations.

Overrides

Metadata can be specified by the user in several places, and at runtime there must be a single metadata model that governs the behavior of the system. Metadata specified in .orm files override metadata specified in .jdo files, which override metadata specified in Java Persistence API orm files, which override metadata specified in jdo annotations, which override metadata specified in Java Persistence API annotations.

19.1 Metadata Annotations

The following describes each jdo annotation, in alphabetical order.

19.1.1 Cacheable Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Cacheable
{
    String value() default "true";
}
```

19.1.2 Column Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Column
{
    /**
     * Name of the column.
     * @return the name of the column
     */
    String name() default "";

    /**
     * Target column for this column in the other table when part of a
     * foreign key relation.
     * @return the target column in the other table for this column
     * when part of a foreign key relation.
     */
    String target() default "";

    /**
     * Target member in the other class or interface for this column
     * when part of a bidirectional relation.
     * @return the target member for this column when part of
     * a bidirectional relation.
     */
    String targetMember() default "";

    /**
     * JDBC Type for this column.
     * @return JDBC type for this column
     */
    String jdbcType() default "";
}
```

```
 /**
 * SQL Type for this column.
 * @return SQL type for this column
 */
String sqlType() default "";

 /**
 * Maximum length of data stored in this column.
 * @return the maximum length of data stored in this column
 */
int length() default -1;

 /**
 * Scale for the column when handling floating point values.
 * @return the scale for the column when handling floating point values
 */
int scale() default -1;

 /**
 * Whether the column allows null values to be inserted.
 * @return whether the column allows null values to be inserted
 */
String allowsNull() default "";

 /**
 * Default value for this column.
 * @return the default value for this column
 */
String defaultValue() default "";

 /**
 * Value to be inserted when this is an "unmapped" column
 * @return the value to be inserted when this is an "unmapped" column
 */
String insertValue() default "";

 /**
 * Vendor extensions.
 * @return the vendor extensions
 */
Extension[] extensions() default {};
}
```

19.1.3 Columns Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD, ElementType.TYPE})
@Retention(RetentionPolicy.RUNTIME)
public @interface Columns
{
    /**
     * The columns annotation information.
     * @return the columns
     */
    Column[] value();
}
```

19.1.4 DatastoreIdentity Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface DatastoreIdentity
{
    /**

```

```
 * Strategy to use when generating datastore identities
 * @return Strategy to use when generating datastore identities
 */
IdGeneratorStrategy strategy() default IdGeneratorStrategy.UNSPECIFIED;

/** Custom strategy to use to generate the value for the identity.
 * If customStrategy is non-empty, then strategy must be UNSPECIFIED.
 * @return the custom strategy
 */
String customStrategy() default "";

/**
 * Name of sequence to use when the strategy involves sequences
 * @return Name of sequence to use when the strategy involves sequences
 */
String sequence() default "";

/**
 * Name of the column for the datastore identity
 * @return Name of the column for the datastore identity
 */
String column() default "";

/**
 * The column(s) making up the datastore identity.
 * @return The column(s) making up the datastore identity.
 */
Column[] columns() default {};

/**
 * Vendor extensions.
 * @return the vendor extensions
 */
Extension[] extensions() default {};
}
```

19.1.5 Discriminator Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Discriminator
{
    /**
     * Strategy to use for the discriminator. The discriminator determines
     * the class associated with a row in the datastore.
     * @return the strategy to use for the discriminator
     */
    DiscriminatorStrategy strategy()
        default DiscriminatorStrategy.UNSPECIFIED;

    /** Custom strategy to use for the discriminator.
     * If customStrategy is non-empty, then strategy must be UNSPECIFIED.
     * @return the custom strategy
     */
    String customStrategy() default "";

    /**
     * Whether the discriminator is indexed.
     * @return whether the discriminator is indexed
     */
    String indexed() default "";
```

```
    /**
     * Name of the column for the discriminator
     * @return the name of the column for the discriminator
     */
    String column() default "";

    /**
     * The value for the discriminator for objects of this class
     * when using "value-map" strategy.
     * @return The value for the discriminator for objects of this class
     * when using "value-map" strategy
     */
    String value() default "";

    /**
     * The column(s) making up the discriminator.
     * @return the column(s) making up the discriminator
     */
    Column[] columns() default {};
}
```

19.1.6 DiscriminatorStrategy Enum

```
public enum DiscriminatorStrategy
{
    UNSPECIFIED,
    NONE,
    VALUE_MAP,
    CLASS_NAME
}
```

19.1.7 Element Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Element
{
    /**
     * Types of the elements. This can be determined if using JDK1.5 generics
     * but is required otherwise. Multiple types can be specified if the
     * implementation supports multiple types.
     * @return the types of elements
     */
    Class[] types() default {};

    /**
     * Whether the element is to be stored serialized (into a join table)
     * @return whether the element is to be stored serialized
     * (into a join table)
     */
    String serialized() default "";

    /**
     * Whether this element is embedded.
     * @return whether this element is embedded
     */
    String embedded() default "";

    /**
     * The embedded mapping for the element.
     * @return the embedded mapping for the element
     */
}
```

```
        */
    Embedded[] embeddedMapping() default {};

    /**
     * Whether the element is dependent on the owner, and will be deleted
     * when the owner is deleted.
     * @return whether the element is dependent on the owner, and will be
     * deleted when the owner is deleted
     */
    String dependent() default "";

    /**
     * Name of the table for the element.
     * @return name of the table for the element
     */
    String table() default "";

    /**
     * Name of the column to store the element in.
     * @return name of the column to store the element in
     */
    String column() default "";

    /**
     * Delete action to apply to any foreign key for the element.
     * @return delete action to apply to any foreign key for the element
     */
    ForeignKeyAction deleteAction() default ForeignKeyAction.UNSPECIFIED;

    /**
     * Update action to apply to any foreign key for the element
     * @return update action to apply to any foreign key for the element
     */
    ForeignKeyAction updateAction() default ForeignKeyAction.UNSPECIFIED;

    /**
     * Whether the value column(s) should be indexed.
     * @return whether the value column(s) should be indexed.
     */
    String indexed() default "";

    /**
     * The name of the index to generate.
     * @return the name of the index
     */
    String index() default "";

    /**
     * Whether a unique constraint should be generated or assumed.
     * @return whether a unique constraint should be generated or assumed
     */
    String unique() default "";

    /**
     * The name of the unique key constraint to generate.
     * @return the name of the unique key constraint
     */
    String uniqueKey() default "";

    /**
     * Name of the member in the target class that forms a bidirectional
     * relationship with this member.
```

```
* @return name of the member in the target class that forms a bidirectional
* relationship with this member
*/
String mappedBy() default "";

/**
 * The column(s) for the element.
 * @return the column(s) for the element
 */
Column[] columns() default {};

/** Generate or assume a foreign key constraint exists on the column
 * or columns associated with this join. Specify "true" or "false".
 * @return whether to generate or assume a primary key constraint
 */
String generateForeignKey() default "";

/** Name for a generated foreign key constraint.
 * @return the name of the generated foreign key constraint
 */
String foreignKey() default "";

/** Vendor extensions.
 * @return the vendor extensions
 */
Extension[] extensions() default {};
}
```

19.1.8 Embedded Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Embedded
{
    /** The member in the embedded object that links back to the owning object
     * where it has a bidirectional relationship.
     * @return the member that refers to the owner
     */
    String ownerMember() default "";

    /** The column in the embedded object used to judge if the embedded object
     * is null.
     * @return the null indicator column
     */
    String nullIndicatorColumn() default "";

    /** The value in the null column to interpret the object as being null.
     * @return the null indicator value
     */
    String nullIndicatorValue() default "";

    /** Members for this embedding.
     * @return the members embedded in the field or property being annotated
     */
    Persistent[] members() default {};
}
```

19.1.9 EmbeddedOnly Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
```

```
public @interface EmbeddedOnly
{
}
```

19.1.10 Extension Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Extension
{
    /** Vendor that the extension applies to (required).
     * @return the vendor
     */
    String vendorName();

    /** The key for the extension (required).
     * @return the key
     */
    String key();

    /** The value for the extension (required).
     * @return the value
     */
    String value();
}
```

19.1.11 Extensions Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Extensions
{
    /**
     * The extensions.
     * @return the extensions
     */
    Extension[] value();
}
```

19.1.12 FetchGroup Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface FetchGroup
{
    /**
     * Name of the fetch group.
     * @return the name of the fetch group
     */
    String name() default "";

    /**
     * Whether we should load this group as part of the post load process.
     * @return whether we should load this group as part of the post load
     * process.
     */
    String postLoad() default "";

    /**
     * Members (fields and properties) of the fetch group. The members
     */
}
```

```
 * should contain only name and recursionDepth.  
 * @return members for the fetch group  
 */  
 Persistent[] members();  
  
 /**  
 * Fetch groups to be nested (included) in this fetch group.  
 */  
 String[] fetchGroups() default {};  
}
```

19.1.13 FetchGroups Annotation

```
@Target(ElementType.TYPE)  
@Retention(RetentionPolicy.RUNTIME)  
public @interface FetchGroups  
{  
    /**  
     * The Fetch Groups  
     * @return The Fetch Groups  
     */  
    FetchGroup[] value();  
}
```

19.1.14 FetchPlan Annotation

```
@Target(ElementType.TYPE)  
@Retention(RetentionPolicy.RUNTIME)  
public @interface FetchPlan  
{  
    /**  
     * Name of the fetch plan.  
     * @return the name of the fetch plan  
     */  
    String name() default "";  
  
    /**  
     * The fetch groups in this fetch plan.  
     * @return the fetch groups  
     */  
    String[] fetchGroups() default {};  
  
    /**  
     * The depth of references to instantiate, starting with the root object.  
     * @return the maximum fetch depth  
     */  
    int maxFetchDepth() default 1;  
  
    /**  
     * The number of instances of multi-valued fields retrieved by queries.  
     * @return the fetch size  
     */  
    int fetchSize() default 0;  
}
```

19.1.15 FetchPlans Annotation

```
@Target(ElementType.TYPE)  
@Retention(RetentionPolicy.RUNTIME)  
public @interface FetchPlans
```

```
{  
    /**  
     * The Fetch Plans  
     * @return The Fetch Plans  
     */  
    FetchPlan[] value();  
}
```

19.1.16 ForeignKey Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})  
@Retention(RetentionPolicy.RUNTIME)  
public @interface ForeignKey  
{  
    /** Name of the foreign key.  
     * @return the name of the foreign key  
     */  
    String name() default "";  
  
    /** Table for the foreign key. This is needed iff annotating a type where  
     * the foreign key is not defined on the primary table for the type.  
     * @return the table on which the foreign key is defined  
     */  
    String table() default "";  
  
    /** Whether this foreign key is deferred  
     * (constraint is checked only at commit).  
     * @return whether this foreign key is deferred  
     */  
    String deferred() default "";  
  
    /** Whether this foreign key is unique.  
     * @return whether this foreign key is unique  
     */  
    String unique() default "";  
  
    /** The delete action of this foreign key.  
     * @return the delete action of this foreign key  
     */  
    ForeignKeyAction deleteAction() default ForeignKeyAction.RESTRICT;  
  
    /** The update action of this foreign key.  
     * @return the update action of this foreign key  
     */  
    ForeignKeyAction updateAction() default ForeignKeyAction.RESTRICT;  
  
    /** Member (field and property) names that compose this foreign key.  
     * @return the member names that compose this foreign key  
     */  
    String[] members() default {};  
  
    /** Columns that compose this foreign key.  
     * @return the columns that compose this foreign key  
     */  
    Column[] columns() default {};  
}
```

19.1.17 ForeignKeyAction Enum

```
public enum ForeignKeyAction
```

```
{  
    UNSPECIFIED,  
    RESTRICT,  
    CASCADE,  
    NULL,  
    DEFAULT,  
    NONE  
}
```

19.1.18 ForeignKeys Annotation

```
@Target(ElementType.TYPE)  
@Retention(RetentionPolicy.RUNTIME)  
public @interface ForeignKeys  
{  
    /**  
     * The foreign keys.  
     * @return The foreign keys  
     */  
    ForeignKey[] value();  
}
```

19.1.19 IdGeneratorStrategy Enum

```
public enum IdGeneratorStrategy  
{  
    UNSPECIFIED,  
    NATIVE,  
    SEQUENCE,  
    IDENTITY,  
    INCREMENT,  
    UUIDSTRING,  
    UUIDHEX  
}
```

19.1.20 IdentityType Enum

```
public enum IdentityType  
{  
    UNSPECIFIED,  
    APPLICATION,  
    DATASTORE,  
    NONDURABLE  
}
```

19.1.21 Index Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})  
@Retention(RetentionPolicy.RUNTIME)  
public @interface Index  
{  
    /** Name of the index  
     * @return the name of the index  
     */  
    String name() default "";  
  
    /** Table for the index. This is needed iff annotating a type where  
     * the index is not defined on the primary table for the type.  
    */  
}
```

```
* @return the table on which the index is defined
*/
String table() default "";

/** Whether this index is unique
 * @return whether this index is unique
 */
String unique() default "";

/** Member (field and property) names that compose this index.
 * @return member names that compose this index
 */
String[] members() default {};

/** Columns that compose this index.
 * @return columns that compose this index
 */
Column[] columns() default {};
}
```

19.1.22 Indices Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Indices
{
    /**
     * The indices
     * @return The indices
     */
    Index[] value();
}
```

19.1.23 Inheritance Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Inheritance
{
    /** Strategy to use for inheritance. Specifies in which table(s)
     * the members for the class are stored.
     * @return the inheritance strategy
     */
    InheritanceStrategy strategy() default InheritanceStrategy.UNSPECIFIED;

    /** Custom inheritance strategy. If customStrategy is non-empty, then
     * strategy must be UNSPECIFIED.
     * @return the custom inheritance strategy
     */
    String customStrategy() default "";
}
```

19.1.24 InheritanceStrategy Enum

```
public enum InheritanceStrategy
{
    UNSPECIFIED,
    NEW_TABLE,
    SUBCLASS_TABLE,
```

```
    SUPERCLASS_TABLE  
}
```

19.1.25 Join Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})  
@Retention(RetentionPolicy.RUNTIME)  
public @interface Join  
{  
    /** Table to join to (used when joining to secondary tables).  
     * @return the table  
     */  
    String table() default "";  
  
    /** Name of the column in the join table.  
     * @return the name of the column in the join table  
     */  
    String column() default "";  
  
    /** Whether the join column is indexed.  
     * @return whether the join column(s) is(are) indexed  
     */  
    String indexed() default "";  
  
    /** The name of the index to generate.  
     * @return the name of the index  
     */  
    String index() default "";  
  
    /** Whether the join column is unique.  
     * @return whether the join column(s) is(are) unique  
     */  
    String unique() default "";  
  
    /**  
     * The name of the unique key constraint to generate.  
     * @return the name of the unique key constraint  
     */  
    String uniqueKey() default "";  
  
    /** Whether to use an outer join.  
     * @return whether to use an outer join  
     */  
    String outer() default "";  
  
    /** Delete action to be applied to any ForeignKey on this join.  
     * @return the delete action  
     */  
    ForeignKeyAction deleteAction() default ForeignKeyAction.UNSPECIFIED;  
  
    /** Detail definition of the join column(s). This is needed for  
     * more than one join column.  
     * @return the join columns  
     */  
    Column[] columns() default {};  
  
    /** Generate or assume a primary key constraint exists on the column  
     * or columns associated with this join. Specify "true" or "false".  
     * @return whether to generate or assume a primary key constraint  
     */  
    String generatePrimaryKey() default "";
```

```
/** Name for a generated primary key constraint.
 * @return the name of the generated primary key constraint
 */
String primaryKey() default "";

/** Generate or assume a foreign key constraint exists on the column
 * or columns associated with this join. Specify "true" or "false".
 * @return whether to generate or assume a foreign key constraint
 */
String generateForeignKey() default "";

/** Name for a generated foreign key constraint.
 * @return the name of the generated foreign key constraint
 */
String foreignKey() default "";

/** Vendor extensions.
 * @return the vendor extensions
 */
Extension[] extensions() default {};
}
```

19.1.26 Joins Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Joins
{
    /**
     * The join definitions used for the mapping of this type. Joins for
     * secondary tables are usually defined at the type level and not the
     * field or property level. This allows multiple fields and properties
     * to share the same join definition and avoid redundancies.
     * @return the join definitions
     */
    Join[] value();
}
```

19.1.27 Key Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Key
{
    /**
     * Types of the keys. This can be determined if using JDK1.5 generics
     * but is required otherwise. Multiple types can be specified if the
     * implementation supports multiple types.
     * @return the types of keys
     */
    Class[] types() default {};

    /**
     * Whether the key is to be stored serialized (into a single column of a
     * join table).
     * @return whether the key is to be stored serialized
     */
    String serialized() default "";

    /**
     * Whether this key is embedded.
     */
}
```

```
* @return whether this key is embedded
*/
String embedded() default "";

/**
 * The embedded mapping for the key.
 * @return the embedded mapping for the key
 */
Embedded[] embeddedMapping() default {};

/**
 * Whether the key is dependent on the owner (and will be deleted
 * when the owner is deleted).
 * @return whether the key is dependent on the owner
 */
String dependent() default "";

/**
 * Name of the table for the key.
 * @return name of the table for the key
 */
String table() default "";

/**
 * Name of the column to store the key in.
 * @return name of the column to store the key in
 */
String column() default "";

/**
 * Delete action to apply to the foreign key for the key.
 * @return delete action to apply to the foreign key for the key
 */
ForeignKeyAction deleteAction() default ForeignKeyAction.UNSPECIFIED;

/**
 * Update action to apply to the foreign key for the key.
 * @return update action to apply to the foreign key for the key
 */
ForeignKeyAction updateAction() default ForeignKeyAction.UNSPECIFIED;

/**
 * Whether the value column(s) should be indexed.
 * @return whether the value column(s) should be indexed.
 */
String indexed() default "";

/** The name of the index to generate.
 * @return the name of the index
 */
String index() default "";

/**
 * Whether the element column(s) contents should be considered unique
 * @return whether the element column(s) contents should be considered unique
 */
String unique() default "";

/**
 * The name of the unique key constraint to generate.
 * @return the name of the unique key constraint
*/
```

```
        */
    String uniqueKey() default "";

    /**
     * Name of a member in the value class where this key is stored.
     * @return the name of a member in the value class where this key is stored
     */
    String mappedBy() default "";

    /**
     * The column(s) for the key
     * @return the column(s) for the key
     */
    Column[] columns() default {};

    /**
     * Generate or assume a foreign key constraint exists on the column
     * or columns associated with this join. Specify "true" or "false".
     * @return whether to generate or assume a foreign key constraint
     */
    String generateForeignKey() default "";

    /**
     * Name for a generated foreign key constraint.
     * @return the name of the generated foreign key constraint
     */
    String foreignKey() default "";

    /**
     * Vendor extensions.
     * @return the vendor extensions
     */
    Extension[] extensions() default {};
}
```

19.1.28 NotPersistent Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface NotPersistent
{
}
```

19.1.29 NullValue Enum

```
public enum NullValue
{
    NONE,
    EXCEPTION,
    DEFAULT
}
```

19.1.30 Order Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Order
{
    /**
     * The name of the column to use for ordering the elements of the member.
     * @return the name of the ordering column
     */
    String column() default "";
}
```

```
/** Name of a field or property in the target class that acts as the
 * ordering field or property for this member.
 * Return the name of the field or property in the target class
 */
String mappedBy() default "";

/** The definition of the column(s) to use for ordering.
 * @return the columns to use for ordering
 */
Column[] columns() default {};

/** Vendor extensions.
 * @return the vendor extensions
 */
Extension[] extensions() default {};
}
```

19.1.31 PersistenceAware Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface PersistenceAware
{
}
```

19.1.32 PersistenceCapable Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface PersistenceCapable
{
    /** Member declarations. Annotations for persistent members of this
     * class or interface can be specified either here or on each member.
     * Annotations for inherited members can only be specified here.
     * @return member declarations
     */
    Persistent[] members() default {};

    /** Table to use for persisting this class or interface.
     */
    String table() default "";

    /** Catalog to use for persisting this class or interface.
     */
    String catalog() default "";

    /** Schema to use for persisting this class or interface.
     */
    String schema() default "";

    /** Whether this class or interface manages an extent.
     */
    String requiresExtent() default "";

    /** Whether objects of this class or interface can only be embedded.
     */
    String embeddedOnly() default "";

    /** Whether this class or interface is detachable.
     */
}
```

```
String detachable() default "";

/** Type of identity for this class or interface.
 */
IdentityType identityType() default IdentityType.UNSPECIFIED;

/** Primary key class when using application identity and using own PK.
 */
Class objectIdClass() default void.class;

/** Whether this class is cacheable in a Level2 cache.
 * @since 2.2
 */
String cacheable() default "true";

/** Whether objects of this type should, by default, be locked when read.
 * @since 2.3
 */
String serializeRead() default "false";

/** Any vendor extensions.
 */
Extension[] extensions() default {};
}
```

19.1.33 PersistenceModifier Enum

```
public enum PersistenceModifier
{
    UNSPECIFIED,
    PERSISTENT,
    TRANSACTIONAL,
    NONE
}
```

19.1.34 Persistent Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Persistent
{
    /** Modifier for this field. This is normally not specified, and the
     * defaults are used, or the @Transactional or @NotPersistent
     * annotation is specified directly on the member. One possible use
     * for specifying persistenceModifier is for embedded instances in which
     * a member is not persistent but in the non-embedded instances the
     * member is persistent. Note that it is not portable to specify a
     * member to be not persistent in the non-embedded case and persistent
     * in the embedded usage.
     * @return the persistence modifier
     */
    PersistenceModifier persistenceModifier()
        default PersistenceModifier.UNSPECIFIED;

    /** Table to use for persisting this member.
     * @return the table to use for persisting this member
     */
    String table() default "";

    /** Whether this member is in the default fetch group.
     */
}
```

```
* @return whether this member is in the default fetch group
*/
String defaultFetchGroup() default "";

/** Behavior when this member contains a null value.
 * @return the behavior when this member contains a null value
 */
NullValue nullValue() default NullValue.NONE;

/** Whether this member is embedded.
 * @return whether this member is embedded
 */
String embedded() default "";

/** Whether the elements of this member are embedded.
 * @return whether the elements of this member are embedded
 */
String embeddedElement() default "";

/** Whether the keys of this member are embedded.
 * @return whether the keys of this member are embedded
 */
String embeddedKey() default "";

/** Whether the values of this member are embedded.
 * @return whether the values of this member are embedded
 */
String embeddedValue() default "";

/** Whether this member is serialized into a single column.
 * @return whether this member is serialized into a single column
 */
String serialized() default "";

/** Whether the elements of this member are serialized.
 * @return whether the elements of this member are serialized
 */
String serializedElement() default "";

/** Whether the keys of this member are serialized.
 * @return whether the keys of this member are serialized
 */
String serializedKey() default "";

/** Whether the values of this member are serialized.
 * @return whether the values of this member are serialized
 */
String serializedValue() default "";

/** Whether related object(s) of this member are dependent
 * and so deleted when this object is deleted.
 * @return whether the related object(s) of this member
 * are dependent
 */
String dependent() default "";

/** Whether the elements of this member are dependent.
 * @return whether the elements of this member are dependent
 */
String dependentElement() default "";
```

```
/** Whether the keys of this member are dependent.
 * @return whether the keys of this member are dependent
 */
String dependentKey() default "";

/** Whether the values of this member are dependent.
 * @return whether the values of this member are dependent
 */
String dependentValue() default "";

/** Whether this member is part of the primary key for application
 * identity. This is equivalent to specifying @PrimaryKey as
 * a separate annotation on the member.
 * @return whether this member is part of the primary key
 */
String primaryKey() default "";

/** Value strategy to use to generate the value for this field
 * or property (if any).
 * @return the generated value strategy
 */
IdGeneratorStrategy valueStrategy() default IdGeneratorStrategy.UNSPECIFIED;

/** Custom value strategy to use to generate the value for this field
 * or property (if any). If customValueStrategy is non-empty, then
 * valueStrategy must be UNSPECIFIED.
 * @return the custom value strategy
 */
String customValueStrategy() default "";

/** Name of the sequence to use with particular value strategies.
 * @return the name of the sequence
 */
String sequence() default "";

/** Name of the fetch-group to use when this member is loaded
 * due to being referenced when not already loaded.
 * @return the name of the load fetch group
 */
String loadFetchGroup() default "";

/** Types of the member. Used when the declared
 * member type is a supertype of the actual type that is stored in the
 * member. For example, the declared member type might be an interface type
 * that must contain an object of a concrete type when used
 * for persistence.
 * @return the types
 */
Class[] types() default {};

/** Name of the related member in the other class
 * where this value is mapped (bidirectional relationship).
 * @return the related member in the other class
 */
String mappedBy() default "";

/** Column definition(s) for this member. Used for mapping
 * multiple columns
 * to the same member, for example relationships with
 * multiple column foreign keys.
 * @return the columns for this member
```

```
        */
    Column[] columns() default {};

    /** Column name where the values are stored for this member.
     * @return the name of the column
     */
    String column() default "";

    /** Null indicator column for this member. Used for nested
     * embedded fields or properties to indicate whether the embedded
     * instance should have a null value.
     * @return the null indicator column
     */
    String nullIndicatorColumn() default "";

    /** Name of the member when this is embedded in another object.
     * The fully-qualified member name is used. For example,
     * "line.point1.x" refers to the member x in class Point
     * that is embedded as member point1 in class Line that is embedded
     * in a member called line.
     * @return the name of the member
     */
    String name() default "";

    /** Recursion depth for this member. Used only when
     * the annotation is used within the definition of a FetchGroup.
     * @return the recursion depth
     */
    int recursionDepth() default 1;

    /** Whether this field/property is cacheable in a Level2 cache.
     * @since 2.2
     */
    String cacheable() default "true";

    /** Vendor extensions for this member.
     * @return the vendor extensions
     */
    Extension[] extensions() default {};
}
```

19.1.35 PrimaryKey Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface PrimaryKey
{
    /**
     * Name of the primary key constraint
     * @return the name of the primary key constraint
     */
    String name() default "";

    /**
     * Name of the column to use for the primary key
     * @return the name of the column to use for the primary key
     */
    String column() default "";

    /**
     * The column(s) for the primary key
     */
```

```
    * @return the column(s) for the primary key
    */
Column[] columns() default {};
}
```

19.1.36 Queries Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Queries
{
    /**
     * The named queries
     * @return The named queries
     */
    Query[] value();
}
```

19.1.37 Query Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Query
{
    /** Name of the query (mandatory)
     * @return the name of the query
     */
    String name();

    /** The query string (mandatory)
     * @return the query string
     */
    String value();

    /** The query language
     * @return the query language
     */
    String language() default "JDOQL";

    /** Whether the query is unmodifiable.
     * @return whether the query is unmodifiable
     */
    String unmodifiable() default "";

    /** Whether the query returns a single unique result.
     * @return whether the query returns a single unique result
     */
    String unique() default "";

    /** Result class into which to put the results.
     * @return the class of the result
     */
    Class resultClass() default void.class;

    /** The name of the fetch plan used by this query
     * @return the fetch plan
     */
    String fetchPlan() default "";

    /** Vendor extensions.
     * @return the vendor extensions
     */
}
```

```
    */
    Extension[] extensions() default {};
}
```

19.1.38 Sequence Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Sequence
{
    /** The symbolic name of the datastore sequence.
     * @return the name of the sequence
     */
    String name();

    /** Strategy for the sequence.
     * @return the strategy for the sequence
     */
    SequenceStrategy strategy();

    /** Name of the sequence in the datastore.
     * @return the name of the datastore sequence
     */
    String datastoreSequence() default "";

    /** Name of a factory class for generating the sequence values.
     * @return the name of the factory class for the sequence
     */
    Class factoryClass() default void.class;

    /** Vendor extensions for this sequence.
     * @return vendor extensions
     */
    Extension[] extensions() default {};
}
```

19.1.39 SequenceStrategy Enum

```
public enum SequenceStrategy
{
    NONTRANSACTIONAL,
    CONTIGUOUS,
    NONCONTIGUOUS
}
```

19.1.40 Serialized Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Serialized
{
}
```

19.1.41 Transactional Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Transactional
{
```

```
}
```

19.1.42 Unique Annotation

```
@Target({ElementType.TYPE, ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Unique
{
    /** Name of the unique constraint.
     * @return the name of the unique constraint
     */
    String name() default "";

    /** Table for the unique constraint. This is needed iff annotating a type
     * where this unique constraint is not for the primary table for
     * the persistent class or interface.
     * @return the table on which the unique constraint is defined
     */
    String table() default "";

    /** Whether this unique constraint is deferred until commit.
     * @return whether this unique constraint is deferred until commit
     */
    String deferred() default "";

    /** Member (field and property) names that compose this unique constraint.
     * @return member names that compose this unique constraint
     */
    String[] members() default {};

    /** Columns that compose this unique constraint.
     * @return columns that compose this unique constraint
     */
    Column[] columns() default {};
}
```

19.1.43 Uniques Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Uniques
{
    /**
     * The unique constraints.
     * @return The unique constraints
     */
    Unique[] value();
}
```

19.1.44 Value Annotation

```
@Target({ElementType.FIELD, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
public @interface Value
{
    /**
     * Types of the values. This can be determined if using JDK1.5 generics
     * but is required otherwise. Multiple types can be specified if the
     * implementation supports multiple types.
     * @return the types of values
}
```

```
/*
Class[] types() default {};

/**
 * Whether the value is to be stored serialized (into a single column of a
 * join table).
 * @return Whether the value is to be stored serialized (into a join table)
 */
String serialized() default "";

/** Whether this value is embedded.
 * @return whether this value is embedded
 */
String embedded() default "";

/**
 * The embedded mapping for the value.
 * @return the embedded mapping for the value
 */
Embedded[] embeddedMapping() default {};

/**
 * Whether the value is dependent on the owner (and will be deleted
 * when the owner is deleted).
 * @return whether the value is dependent on the owner
 */
String dependent() default "";

/**
 * Name of the table for the value.
 * @return the name of the table for the value
 */
String table() default "";

/**
 * Name of the column to store the value in.
 * @return the name of the column to store the value in
 */
String column() default "";

/**
 * Delete action to apply to any foreign key for the value.
 * @return delete action to apply to any foreign key for the value
 */
ForeignKeyAction deleteAction() default ForeignKeyAction.UNSPECIFIED;

/**
 * Update action to apply to any foreign key for the value.
 * @return update action to apply to any foreign key for the value
 */
ForeignKeyAction updateAction() default ForeignKeyAction.UNSPECIFIED;

/**
 * Whether the value column(s) should be indexed.
 * @return whether the value column(s) should be indexed.
 */
String indexed() default "";

/** The name of the index to generate.
 * @return the name of the index
 */
```

```
String index() default "";

/**
 * Whether the element column(s) contents should be considered unique
 * @return whether the element column(s) contents should be considered unique
 */
String unique() default "";

/**
 * The name of the unique key constraint to generate.
 * @return the name of the unique key constraint
 */
String uniqueKey() default "";

/**
 * Name of a member in the key class where this value is stored.
 * @return the name of a member in the key class where this value is stored
 */
String mappedBy() default "";

/**
 * The column(s) for the value.
 * @return the column(s) for the value
 */
Column[] columns() default {};

/** Generate or assume a foreign key constraint exists on the column
 * or columns associated with this join. Specify "true" or "false".
 * @return whether to generate or assume a foreign key constraint
 */
String generateForeignKey() default "";

/** Name for a generated foreign key constraint.
 * @return the name of the generated foreign key constraint
 */
String foreignKey() default "";

/** Vendor extensions.
 * @return the vendor extensions
 */
Extension[] extensions() default {};
}
```

19.1.45 Version Annotation

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
public @interface Version
{
    /**
     * Strategy for versioning of objects of this class.
     * @return the strategy for versioning objects of this class
     */
    VersionStrategy strategy() default VersionStrategy.UNSPECIFIED;

    /**
     * Custom strategy for versioning of objects of this class.
     * If customStrategy is non-empty, strategy must be UNSPECIFIED.
     * @return the custom strategy for versioning objects of this class
     */
    String customStrategy() default "";
}
```

```

    /**
     * Name of the column for the version.
     * @return the name of the column for the version
     */
    String column() default "";

    /**
     * Whether the version column(s) is(are) indexed.
     * @return whether the version column(s) is(are) indexed
     */
    String indexed() default "";

    /**
     * The column(s) making up the version.
     * @return the column(s) making up the version
     */
    Column[] columns() default {};

    /**
     * Vendor extensions.
     * @return the vendor extensions
     */
    Extension[] extensions() default {};
}

```

19.1.46 VersionStrategy Enum

```

public enum VersionStrategy
{
    UNSPECIFIED,
    NONE,
    STATE_IMAGE,
    DATE_TIME,
    VERSION_NUMBER
}

```

Table 9: Annotation correspondence to xml metadata

Annotation	xml	Comments
Column	element column	
Columns	element column	Used for multiple Column annotations on the same field or method
DatastoreIdentity	element datastore-identity	
Discriminator	element discriminator	
DiscriminatorStrategy	attribute strategy	

Table 9: Annotation correspondence to xml metadata

Annotation	xml	Comments
Element	element element	
Cacheable	attribute cacheable	
Embedded	element embedded	
EmbeddedOnly	attribute embedded-only	
Extension	element extension	
Extensions	element extension	Used for multiple Extensions on the same class, interface, field, or method
FetchGroup	element fetch-group	
FetchGroups	element fetch-group	Used for multiple FetchGroups
FetchPlan	element fetch-plan	
FetchPlans	element fetch-plan	Used for multiple FetchPlans on the same class or interface
ForeignKey	element foreign-key	
ForeignKeyAction	attributes update-action, delete-action	
ForeignKeys	element foreign-key	
IdGeneratorStrategy	element data-store-identity, attribute value-strategy	
IdentityType	attribute identity-type	
Index	element index	

Table 9: Annotation correspondence to xml metadata

Annotation	xml	Comments
Indices	element index	
Inheritance	element inheritance	
InheritanceStrategy	element inheritance, attribute strategy	
Join	element join	
JoinTable	element join, attribute table	
Joins	element join	
Key	element key	
NullValue	attribute null-value	
Order	element order	
PersistenceAware	attribute persistence-modifier	
PersistenceCapable	elements class, interface	
Persistent	elements field, property	
PrimaryKey	element primary-key	
Queries	element query	
Query	element query	
Sequence	element sequence	
SequenceStrategy	element sequence, attribute strategy	
Serialized	elements field, property, attribute serialized	

Table 9: Annotation correspondence to xml metadata

Annotation	xml	Comments
Transactional	elements field, property; attribute persis- tence-modifier	
Unique	element unique	
Uniques	element unique	
Value	element value	
Version	element version	
VersionStrategy	element version; attribute strategy	

19.2 Metadata API

Metadata is created at runtime via the PersistenceManagerFactory method newJDOMetadata which returns a new metadata instance that can subsequently be modified and made active by the registerMetadata method.

19.2.1 Metadata

Metadata is the base interface for all metadata.

```
/**
 * This interface provides base level definitions for all metadata components.
 *
 * @version 2.3
 */
public interface Metadata {
    /**
     * Add a vendor extension to this metadata component.
     *
     * @param vendor Identifier for the vendor
     * @param key The extension key
     * @param value Value for the extension
     * @return The ExtensionMetaData
     */
    ExtensionMetadata newExtensionMetaData(String vendor, String key, String
value);

    /**
     * Number of extensions on this component.
     *
     * @return Number of extensions
    
```

```
        */
    int getNumberOfExtensions();

    /**
     * Accessor for the defined extensions for this component
     *
     * @return The extensions
     */
    ExtensionMetadata[] getExtensions();

    /**
     * Accessor for the parent metadata component.
     *
     * @return The parent
     */
    Metadata getParent();
}
```

19.2.2 JDO Metadata

JDOMetadata represents the root of the metadata.

```
/**
 * Represents the top-level JDO metadata.
 * @since 2.3
 */
public interface JDOMetadata extends Metadata {
    /**
     * Method to set the catalog (ORM) to apply to all classes in this
     * JDO Metadata.
     *
     * @param catalog Catalog name
     */
    JDOMetadata setCatalog(String catalog);

    /**
     * Accessor for the catalog (ORM) that all classes in this JDO Metadata
     * default to.
     *
     * @return The catalog
     */
    String getCatalog();

    /**
     * Method to set the schema (ORM) to apply to all classes in this JDO
     * Metadata.
     *

```

```
* @param schema Schema name
*/
JDOMetadata setSchema(String schema);

/**
 * Accessor for the schema (ORM) that all classes in this JDO Metadata
 * default to.
 *
 * @return The schema
 */
String getSchema();

/**
 * Accessor for all packages defined on the JDO Metadata.
 *
 * @return The packages
 */
PackageMetadata[] getPackages();

/**
 * Add a new package to this JDO Metadata.
 *
 * @param pkgName Name of the package
 * @return The PackageMetadata
 */
PackageMetadata newPackageMetadata(String pkgName);

/**
 * Add a new package to this JDO Metadata.
 *
 * @param pkg The package
 * @return The PackageMetadata
 */
PackageMetadata newPackageMetadata(Package pkg);

/**
 * Accessor for the number of packages defined in this JDO Metadata.
 *
 * @return The number of packages.
 */
int getNumberOfPackages();

/**
 * Add a new class to this JDO Metadata.
 * Adds its package also if not yet existing.
 */

```

```
    * @param cls Class to add
    * @return The ClassMetadata
    */
ClassMetadata newClassMetadata(Class cls);

/**
 * Add a new interface to this JDO Metadata.
 * Adds its package also if not yet existing.
 *
 * @param cls Class to add
 * @return The InterfaceMetadata
 */
InterfaceMetadata newInterfaceMetadata(Class cls);

/**
 * Accessor for any named queries defined on the JDO Metadata.
 *
 * @return The queries
 */
QueryMetadata[] getQueries();

/**
 * Add a new named query to this JDO Metadata.
 *
 * @param name Name of the query
 * @return The QueryMetadata
 */
QueryMetadata newQueryMetadata(String name);

/**
 * Accessor for the number of named queries defined in this JDO Metadata.
 *
 * @return The number of queries.
 */
int getNumberOfQueries();

/**
 * Accessor for any fetch plans defined on the JDO Metadata.
 *
 * @return The fetch plans
 */
FetchPlanMetadata[] getFetchPlans();

/**
 * Add a new fetch plan to this JDO Metadata.
 *
```

```
    * @param name Name of the query
    * @return The FetchPlanMetadata
    */
FetchPlanMetadata newFetchPlanMetadata(String name);

/**
 * Accessor for the number of fetch plans defined in this JDO Metadata.
 *
 * @return The number of fetch plans.
 */
int getNumberOfFetchPlans();
}
```

19.2.3 Package Metadata

PackageMetadata represents the collection of metadata that share the same package.

```
/**
 * Represents a package within a JDOMetadata.
 * @since 2.3
 */
public interface PackageMetadata extends Metadata {
    /**
     * Accessor for the name of this package (set on construction).
     *
     * @return The name
     */
    String getName();

    /**
     * Method to set the catalog (ORM) to apply to all classes in this package.
     *
     * @param catalog Catalog name
     */
    PackageMetadata setCatalog(String catalog);

    /**
     * Accessor for the catalog (ORM) that all classes in this package default
     * to.
     *
     * @return The catalog
     */
    String getCatalog();

    /**
     * Method to set the schema (ORM) to apply to all classes in this package.
     *
```

```
* @param schema Schema name
*/
PackageMetadata setSchema(String schema);

/**
 * Accessor for the schema (ORM) that all classes in this package default to.
 *
 * @return The schema
 */
String getSchema();

/**
 * Accessor for all classes defined in this package.
 *
 * @return The classes
 */
ClassMetadata[] getClasses();

/**
 * Add a new class to this package.
 *
 * @param name Name of the class
 * @return The ClassMetadata
 */
ClassMetadata newClassMetadata(String name);

/**
 * Add a new class to this package.
 *
 * @param cls The class
 * @return The ClassMetadata
 */
ClassMetadata newClassMetadata(Class cls);

/**
 * Accessor for the number of classes defined in this package.
 *
 * @return The number of classes.
 */
int getNumberOfClasses();

/**
 * Accessor for all interfaces defined in this package.
 *
 * @return The interfaces
 */
```

```
InterfaceMetadata[] getInterfaces();

/**
 * Add a new interface to this package.
 *
 * @param name The interface name
 * @return The InterfaceMetadata
 */
InterfaceMetadata newInterfaceMetadata(String name);

/**
 * Add a new interface to this package.
 *
 * @param cls The class
 * @return The ClassMetadata
 */
InterfaceMetadata newInterfaceMetadata(Class cls);

/**
 * Accessor for the number of interfaces defined in this package.
 *
 * @return The number of interfaces.
 */
int getNumberOfInterfaces();

/**
 * Accessor for any sequences defined on the package.
 *
 * @return The sequences
 */
SequenceMetadata[] getSequences();

/**
 * Add a new sequence to this package.
 *
 * @param name Name of the sequence
 * @param strategy Strategy for the sequence
 * @return The SequenceMetadata
 */
SequenceMetadata newSequenceMetadata(String name,
                                    SequenceStrategy strategy);

/**
 * Accessor for the number of sequences defined for this package.
 *
 * @return The number of sequences.

```

```
        */
        int getNumberOfSequences();
    }

19.2.4 Component Metadata
ComponentMetadata represents the metadata for classes and interfaces.

/**
 * Represents a class or interface. Extended for the specifics of those cases.
 * @since 2.3
 */
public interface ComponentMetadata extends Metadata {
    /**
     * Accessor for the name of this component (set on construction).
     *
     * @return The name
     */
    String getName();

    /**
     * Method to define the identity type to use.
     *
     * @param id identity type
     */
    ComponentMetadata setIdentityType(IdentityType id);

    /**
     * Accessor for the identity type to use.
     *
     * @return identity type
     */
    IdentityType getIdentityType();

    /**
     * Method to set the object-id (PK) class.
     *
     * @param idclass Object-id class
     */
    ComponentMetadata setObjectIdClass(String idclass);

    /**
     * Accessor for the object-id class (if defined).
     *
     * @return The object-id class
     */
    String getObjectIdClass();
```

```
/***
 * Method to set whether the component requires an extent.
 *
 * @param extent Requires extent?
 */
ComponentMetadata setRequiresExtent(boolean extent);

/***
 * Accessor for whether the component requires an extent.
 *
 * @return Requires extent?
 */
boolean getRequiresExtent();

/***
 * Method to set whether this is detachable
 *
 * @param detachable Detachable?
 */
ComponentMetadata setDetachables(boolean detachable);

/***
 * Accessor for whether this is detachable.
 *
 * @return Detachable?
 */
boolean getDetachables();

/***
 * Method to set whether this is cacheable
 *
 * @param cacheable Cacheable?
 */
ComponentMetadata setCacheable(boolean cacheable);

/***
 * Accessor for whether this is cacheable.
 *
 * @return Cacheable?
 */
boolean getCacheable();

/***
 * Method to set whether this is serializeRead
 *
 */
```

```
* @param serializeRead serializeRead?
*/
ComponentMetadata setSerializeRead(boolean serializeRead);

/**
 * Accessor for whether this is serializeRead.
 *
 * @return serializeRead?
 */
boolean getSerializeRead();

/**
 * Method to set whether it is stored only as embedded in other objects.
 *
 * @param embedded Whether it is only stored embedded
 */
ComponentMetadata setEmbeddedOnly(boolean embedded);

/**
 * Accessor for whether this is embedded only.
 *
 * @return Only stored as embedded
 */
Boolean getEmbeddedOnly();

/**
 * Method to set the catalog (ORM) for this component
 *
 * @param catalog Catalog name
 */
ComponentMetadata setCatalog(String catalog);

/**
 * Accessor for the catalog (ORM) for this component
 *
 * @return The catalog
 */
String getCatalog();

/**
 * Method to set the schema (ORM) for this component
 *
 * @param schema Schema name
 */
ComponentMetadata setSchema(String schema);
```

```
/**  
 * Accessor for the schema (ORM) for this component  
 *  
 * @return The schema  
 */  
String getSchema();  
  
/**  
 * Method to set the table name.  
 *  
 * @param table Table name  
 */  
ComponentMetadata setTable(String table);  
  
/**  
 * Accessor for the name of the table.  
 *  
 * @return The name  
 */  
String getTable();  
  
/**  
 * Method to define the inheritance metadata.  
 *  
 * @return The InheritanceMetadata  
 */  
InheritanceMetadata newInheritanceMetadata();  
  
/**  
 * Accessor for the inheritance (if any).  
 *  
 * @return inheritance  
 */  
InheritanceMetadata getInheritanceMetadata();  
  
/**  
 * Method to define the version metadata.  
 *  
 * @return The VersionMetadata  
 */  
VersionMetadata newVersionMetadata();  
  
/**  
 * Accessor for the version (if any).  
 *  
 * @return version  
 */
```

```
/*
VersionMetadata getVersionMetadata();

/** 
 * Method to define the datastore identity metadata details.
 *
 * @return The DatastoreIdentityMetadata
 */
DatastoreIdentityMetadata newDatastoreIdentityMetadata();

/** 
 * Accessor for the datastore identity details.
 *
 * @return datastore identity details
 */
DatastoreIdentityMetadata getDatastoreIdentityMetadata();

/** 
 * Method to define the primary key details.
 *
 * @return The PrimaryKeyMetadata
 */
PrimaryKeyMetadata newPrimaryKeyMetadata();

/** 
 * Accessor for the primary key (if any).
 *
 * @return primary key details
 */
PrimaryKeyMetadata getPrimaryKeyMetadata();

/** 
 * Accessor for all joins(s) defined on the component.
 *
 * @return The join(s)
 */
JoinMetadata[] getJoins();

/** 
 * Add a join for this component.
 *
 * @return The JoinMetadata
 */
JoinMetadata newJoinMetadata();

/**
```

```
 * Accessor for the number of join(s) defined for this component.  
 *  
 * @return The number of join(s)  
 */  
 int getNumberOfJoins();  
  
/**  
 * Accessor for all fk(s) defined on the component.  
 *  
 * @return The fk(s)  
 */  
 ForeignKeyMetadata[] getForeignKeys();  
  
/**  
 * Add a new FK for this component.  
 *  
 * @return The ForeignKeyMetadata  
 */  
 ForeignKeyMetadata newForeignKeyMetadata();  
  
/**  
 * Accessor for the number of FKs defined for this component.  
 *  
 * @return The number of FKs  
 */  
 int getNumberOfForeignKeys();  
  
/**  
 * Accessor for all index(s) defined on the component.  
 *  
 * @return The index(s)  
 */  
 IndexMetadata[] getIndices();  
  
/**  
 * Add a new index for this component.  
 *  
 * @return The IndexMetadata  
 */  
 IndexMetadata newIndexMetadata();  
  
/**  
 * Accessor for the number of indices defined for this component.  
 *  
 * @return The number of indices  
 */
```

```
int getNumberOfIndices();

/**
 * Accessor for all unique constraints defined on the component.
 *
 * @return The unique constraints
 */
UniqueMetadata[] getUniques();

/**
 * Add a new unique constraint for this component.
 *
 * @return The UniqueMetadata
 */
UniqueMetadata newUniqueMetadata();

/**
 * Accessor for the number of unique constraints defined for this component.
 *
 * @return The number of unique constraints
 */
int getNumberOfUniques();

/**
 * Accessor for all fields/properties defined on the component.
 *
 * @return The members
 */
MemberMetadata[] getMembers();

/**
 * Accessor for the number of fields/properties defined for this component.
 *
 * @return The number of members
 */
int getNumberOfMembers();

/**
 * Add a new property for this component.
 *
 * @param name Name of the property
 * @return The PropertyMetadata
 */
PropertyMetadata newPropertyMetadata(String name);

/**
```

```
    * Add a new property for this component.  
    *  
    * @param method Java bean getter/setter method  
    * @return The PropertyMetadata  
    */  
PropertyMetadata newPropertyMetadata(Method method);  
  
/**  
 * Accessor for all named queries defined on the component.  
 *  
 * @return The queries  
 */  
QueryMetadata[] getQueries();  
  
/**  
 * Add a new query for this component.  
 *  
 * @param name  
 *          Name of the query to add  
 * @return The QueryMetadata  
 */  
QueryMetadata newQueryMetadata(String name);  
  
/**  
 * Accessor for the number of named queries defined for this component.  
 *  
 * @return The number of named queries  
 */  
int getNumberOfQueries();  
  
/**  
 * Accessor for all FetchGroup defined on the component.  
 *  
 * @return The FetchGroups  
 */  
FetchGroupMetadata[] getFetchGroups();  
  
/**  
 * Add a new FetchGroup for this component.  
 *  
 * @param name Name of the FetchGroup  
 * @return The FetchGroupMetadata  
 */  
FetchGroupMetadata newFetchGroupMetadata(String name);  
  
/**
```

```
    * Accessor for the number of fetchGroups defined for this component.  
    *  
    * @return The number of fetch groups  
    */  
    int getNumberOfFetchGroups();  
  
    /**  
     * Accessor for all column(s) defined on the join.  
     *  
     * @return The column(s)  
     */  
    ColumnMetadata[] getColumns();  
  
    /**  
     * Add a new column for this join.  
     *  
     * @return The ColumnMetadata  
     */  
    ColumnMetadata newColumnMetadata();  
  
    /**  
     * Accessor for the number of columns defined for this join.  
     *  
     * @return The number of columns  
     */  
    int getNumberOfColumns();  
}
```

19.2.5 Class Metadata

ClassMetadata represents metadata for a specific persistence-capable class.

```
/**  
 * Represents a class.  
 * @since 2.3  
 */  
public interface ClassMetadata extends ComponentMetadata {  
    /**  
     * Method to define the persistence modifier.  
     * @param mod persistence modifier  
     */  
    ClassMetadata setPersistenceModifier(ClassPersistenceModifier mod);  
  
    /**  
     * Accessor for the persistence modifier.  
     * @return persistence modifier  
     */
```

```
ClassPersistenceModifier getPersistenceModifier();

/**
 * Add a new field to this class.
 * @param name Name of the field
 * @return The FieldMetadata
 */
FieldMetadata newFieldMetadata(String name);

/**
 * Add a new field to this class.
 * @param fld The field
 * @return The FieldMetadata
 */
FieldMetadata newFieldMetadata(Field fld);
}
```

19.2.6 Interface Metadata

InterfaceMetadata represents metadata for a specific persistence-capable interface.

```
/**
 * Represents a persistent-interface.
 * @since 2.3
 */
public interface InterfaceMetadata extends ComponentMetadata {

}
```

19.2.7 Field Metadata

FieldMetadata represents metadata for persistent fields.

```
/**
 * Represents a field in a class.
 * @since 2.3
 */
public interface FieldMetadata extends MemberMetadata {

}
```

19.2.8 Property Metadata

PropertyMetadata represents metadata for persistent properties.

```
/**
 * Represents a property in a class/persistent-interface.
 * @since 2.3
 */
public interface PropertyMetadata extends MemberMetadata {
```

```
 /**
 * Method to set the field name (persistent interfaces)
 *
 * @param name field name
 */
PropertyMetadata setFieldName(String name);

/**
 * Accessor for the field name
 *
 * @return Field name
 */
String getFieldName();
}
```

19.2.9 Query Metadata

QueryMetadata represents metadata for queries.

```
 /**
 * Represents a named query.
 * @since 2.3
 */
public interface QueryMetadata extends Metadata {
    /**
     * Accessor for the name of the query (set on construction).
     *
     * @return The name
     */
    String getName();

    /**
     * Method to set the language of the query.
     *
     * @param lang Query language
     */
    QueryMetadata setLanguage(String lang);

    /**
     * Accessor for the query language.
     *
     * @return The language
     */
    String getLanguage();

    /**
     * Method to set the single-string query.
     */
}
```

```
* @param query The query
*/
QueryMetadata setQuery(String query);

/**
 * Accessor for the single-string query.
 *
 * @return The query
 */
String getQuery();

/**
 * Method to set the result class name for the query
 *
 * @param clsName Result class name
 */
QueryMetadata setResultClass(String clsName);

/**
 * Accessor for the result class name for the query.
 *
 * @return The result class name
 */
String getResultClass();

/**
 * Method to set if the query results are unique
 *
 * @param unique Whether they are unique
 */
QueryMetadata setUnique(boolean unique);

/**
 * Accessor for whether results from the query are unique
 *
 * @return Results are unique?
 */
Boolean getUnique();

/**
 * Method to set the query as not being modifiable from now.
 */
QueryMetadata setUnmodifiable();

/**
```

```
 * Accessor for whether the query is unmodifiable.
 *
 * @return Can't be changed?
 */
boolean getUnmodifiable();

/**
 * Method to set the FetchPlan to use for this named query.
 *
 * @param fetchPlanName name of the FetchPlan
 */
QueryMetadata setFetchPlan(String fetchPlanName);

/**
 * Accessor for the name of a fetch plan to use (if any).
 *
 * @return The fetch plan name
 */
String getFetchPlan();
}
```

20 Java Persistence API (JSRs 220, 317) Alignment

JPA (Java Persistence API) specifies annotations and interfaces for Java persistence, similar to the goals of JDO. In order to facilitate interoperation of applications in both JPA and JDO, several compatibility items have been implemented:

- Persistence-capable classes can be specified using JPA annotations, JDO annotations, JPA metadata in xml document format (e.g. `orm.xml`), or JDO metadata in xml document format(e.g. `package.jdo`).
- Bootstrapping using `JDOHelper` can define the properties of the `PersistenceManagerFactory` using a Map of properties, a JDO configuration file `META-INF/jdoconfig.xml`, or a JPA configuration file (`META-INF/persistence.xml`).
- A `PersistenceManagerFactory` from a JDO implementation that supports the JPA `EntityManagerFactory` can also implement `JDOEntityManagerFactory`, which is an interface that extends both JDO `PersistenceManagerFactory` and JPA `EntityManagerFactory`; some methods are overloaded to return more specific types.
- A `PersistenceManager` from a JDO implementation that supports the JPA `EntityManager` can also implement `JDOEntityManager`, which is an interface that extends both JDO `PersistenceManager` and JPA `EntityManager`.

20.1 JDOEntityManagerFactory

This interface extends both JDO `PersistenceManagerFactory` and JPA `EntityManagerFactory`. Certain methods overload the corresponding methods in `PersistenceManagerFactory` to return the more specific type `JDOEntityManager`.

```
public interface JDOEntityManagerFactory
    extends EntityManagerFactory, PersistenceManagerFactory {

    JDOEntityManager getPersistenceManager();
    JDOEntityManager getPersistenceManagerProxy();
    JDOEntityManager getPersistenceManager(String userid, String password);
}
```

20.2 JDOEntityManager

This interface extends both JDO `PersistenceManager` and JPA `EntityManager`.

```
public interface JDOEntityManager
    extends EntityManager, PersistenceManager {

    JDOEntityManagerFactory getPersistenceManagerFactory();
}
```

This method overloads the corresponding method in `PersistenceManager` to return the more specific type `JDOEntityManagerFactory`.

21 Extent

This chapter specifies the `Extent` contract between an application component and the JDO implementation.

21.1 Overview

An application needs to provide a candidate collection of instances to a query. If the query filtering is to be performed in the datastore, then the application must supply the collection of instances to be filtered. This is the primary function of the `Extent` interface.

An `Extent` instance is logically a holder for information:

- the class of instances;
- whether subclasses are part of the `Extent`; and
- a collection of active iterators over the `Extent`.

Thus, no action is taken at the time the `Extent` is constructed. The contents of the `Extent` are calculated at the point in time when a query is executed and when an iterator is obtained via the `iterator()` method.

A query may be executed against either a `Collection` or an `Extent`. The `Extent` is used when the query is intended to be filtered by the datastore, not by in-memory processing. There are no `Collection` methods in `Extent` except for `iterator()`. Thus, common `Collection` behaviors are not possible, including determining whether one `Extent` contains another, determining the size of the `Extent`, or determining whether a specific instance is contained in the `Extent`. Any such operations must be performed by executing a query against the `Extent`.

If the `Extent` is large, then an appropriate iteration strategy should be adopted by the JDO implementation.

The `Extent` for classes of embedded instances is not affected by changes to fields in referencing class instances.

21.2 Goals

The `Extent` interface has the following goals:

- Large result set support. Queries might return massive numbers of JDO instances that match the query. The JDO Query architecture must provide for processing the results within the resource constraints of the execution environment.
- Application resource management. Iterating an `Extent` might use resources that should be released when the application has finished an iteration. The application should be provided with a means to release iterator resources.
- Language support for Java 5 iteration. `Extent` extends the `Iterable` interface so that the native Java iteration using the `for ...` operator works transparently with `Extent`. For example,

- for (Employee e: pm.getExtent(Employee.class) // do something}

21.3 Interface Extent

```
package javax.jdo;
public interface Extent<E> extends Iterable<E> {
    Iterator<E> iterator();
```

This method returns an `Iterator` over all the instances in the `Extent`. If `NontransactionalRead` property is set to false, this method will throw a `JDOUserException` if called outside a transaction.

If the `IgnoreCache` option is set to `true` in the `PersistenceManager` at the time that this `Iterator` instance is obtained, then new and deleted instances in the current transaction might be ignored by the `Iterator` at the option of the implementation. That is, new instances might not be returned; and deleted instances might be returned.

If the `IgnoreCache` option is set to `false` in the `PersistenceManager` at the time that this `Iterator` instance is obtained, then:

- If instances were made persistent in the transaction prior to the execution of this method, the returned `Iterator` will contain the instances.
- If instances were deleted in the transaction prior to the execution of this method, the returned `Iterator` will not contain the instances.

The above describes the behavior of an extent-based query at query execution.

If any mutating method, including the `remove` method, is called on the `Iterator` returned by this method, a `UnsupportedOperationException` is thrown. If an iterator is acquired by the compiled `for...` operator, the iterator has no explicit reference from application code. Therefore, the implementation must not hold a strong reference to an iterator, allowing it to be garbage collected once the iterator goes out of scope.

```
boolean hasSubclasses();
```

This method returns an indicator of whether the extent includes subclasses.

```
Class<E> getCandidateClass();
```

This method returns the class of the instances contained in it.

```
FetchPlan getFetchPlan();
```

This method returns the fetch plan associated with the `Extent`. The fetch plan originally is a copy of the fetch plan that is active at the time the `Extent` is obtained from the `PersistenceManager`, and thereafter can be changed independent of the fetch plan of the `PersistenceManager`.

The fetch plan settings affect iterators obtained from the `Extent`. When instances are retrieved from the datastore, the fetch plan settings that are current in the `Extent` affect the retrieval. Note that this means that portable applications do not change the fetch plan of an `Extent` while an iterator is active.

```
PersistenceManager getPersistenceManager();
```

This method returns the `PersistenceManager` that created it.

```
void close(Iterator i);
```

This method closes an `Iterator` acquired from this `Extent`. After this call, the parameter `Iterator` will return `false` to `hasNext()`, and will throw `NoSuchElementException` to `next()`. The `Extent` itself can still be used to acquire other iterators and can be used as the `Ex-`

tent for queries. Iterators must be automatically closed by the jdo implementation if iterated to completion.

```
void closeAll();
```

This method closes all iterators acquired from this Extent. After this call, all iterators acquired from this Extent will return `false` to `hasNext()`, and will throw `NoSuchElementException` to `next()`.

Any change made to the fetch plan of the associated `PersistenceManager` affects instance retrievals via `next()`. Only instances not already in memory are affected by the `PersistenceManager`'s fetch plan. Fetch plan is described in Section 12.7.

22 Portability Guidelines

One of the objectives of JDO is to allow an application to be portable across multiple JDO implementations. This Chapter summarizes portability rules that are expressed elsewhere in this document. If all of these programming rules are followed, then the application will work in any JDO compliant implementation.

22.1 Optional Features

These features may be used by the application if the JDO vendor supports them. Since they are not required features, a portable application must not use them.

22.1.1 Optimistic Transactions

Optimistic transactions are enabled by the `PersistenceManagerFactory` or `Transaction` method `setOptimistic(true)`. JDO implementations that do not support optimistic transactions throw `JDOUnsupportedOptionException`.

22.1.2 Nontransactional Read

Nontransactional read is enabled by the `PersistenceManagerFactory` or `Transaction` method `setNontransactionalRead(true)`. JDO implementations that do not support nontransactional read throw `JDOUnsupportedOptionException`.

22.1.3 Nontransactional Write

Nontransactional write is enabled by the `PersistenceManagerFactory` or `Transaction` method `setNontransactionalWrite(true)`. JDO implementations that do not support nontransactional write throw `JDOUnsupportedOptionException`.

22.1.4 Transient Transactional

Transient transactional instances are created by the `PersistenceManager` `makeTransactional(Object)`. JDO implementations that do not support transient transactional throw `JDOUnsupportedOptionException`.

22.1.5 RetainValues

A portable application should run the same regardless of the setting of the `retainValues` flag.

22.1.6 IgnoreCache

A portable application should set this flag to `false`. The results of iterating `Extents` and executing queries might be different among different implementations.

22.2 Object Model

References among persistence-capable classes must be defined as First Class Objects in the model.

SCO instances must not be shared among multiple persistent instances.

Arrays must not be shared among multiple persistent instances.

If arrays are passed by reference outside the defining class, the owning persistent instance must be notified via `jdoMakeDirty`.

The application must not depend on any sharing semantics of immutable class objects.

The application must not depend on knowing the exact class of an SCO instance, as they may be substituted by a subclass of the type.

Persistence-capable classes must not contain final non-static fields or methods or fields that start with "jdo". Persistence-capable classes must not contain final or static persistent fields.

22.3 JDO Identity

Applications must be aware that support for application identity and datastore identity are optional, and some implementations might support only one of these identity types. The supported identity type(s) of the implementation should be checked by using the `supportedOptions` method of `PersistenceManagerFactory`.

Applications must construct only `ObjectId` instances for classes that use application-defined JDO identity, or use the `PersistenceManager` `getObjectIdClass` to obtain the `ObjectId` class.

Classes that use application identity must only use key field types of primitive, `String`, `Date`, `Byte`, `Short`, `Integer`, `Long`, `Float`, `Double`, `BigDecimal`, or `BigInteger`.

Applications must only compare `ObjectId` instances from different JDO implementations for classes that use application-defined JDO identity.

The `equals` and `hashCode` methods of any persistence-capable class using application identity must depend on all of the key fields.

Key fields can be defined only in the least-derived persistence-capable class in an inheritance hierarchy. All of the classes in the hierarchy use the same key class.

A JDO implementation might not support changing primary key field values (which has the effect of changing the primary key of the underlying datastore instance). Portable applications do not change primary key fields.

22.4 PersistenceManager

To be portable, instances of `PersistenceManager` must be obtained from a `PersistenceManagerFactory`, and not by construction. The recommended way to instantiate a `PersistenceManagerFactory` is to use the `JDOHelper.getPersistenceManagerFactory(Map)` method.

22.5 Query

Using a query language other than JDOQL is not portable.

A query must constrain all variables used in any expressions with a `contains` clause referencing a persistent field of a persistence-capable class.

Not all datastores allow storing null-valued collections. Portable queries on these collections should use `isEmpty()` instead of comparing to `null`.

Portable queries must only use persistent or public final static field names in filter expressions.

Portable queries must pass persistent or transactional instances as parameters of persistence-capable types.

Wild card queries must use “matches” with a regular expression including only “(?i)” for case-in-sensitivity, “.” for matching a single character, and “.*” for matching multiple characters.

22.6 XML metadata

Portable applications will define all persistence-capable classes in the XML metadata.

22.7 Life cycle

Portable applications will not depend on requiring instances to be hollow or persistent-nontransactional, or to remain non-transactional in a transaction.

22.8 JDOHelper

Portable applications will use JDOHelper for state interrogations of instances of persistence-capable classes and for determining if an instance is of a persistence-capable class.

22.9 Transaction

Portable applications must not depend on isolation levels stronger than read-committed provided by the underlying datastore. Some fields might be read at different times by the JDO implementation, and there is no guarantee as to read consistency compared to previously read data. A JDO persistence-capable instance might contain fields instantiated by multiple datastore accesses, with no guarantees of consistency (read-committed isolation level).

22.10 Binary Compatibility

Portable applications must not use the PersistenceCapable interface. Compliant implementations might use persistence-capable classes that do not implement the PersistenceCapable interface. Instances can be queried as to their state by using the methods in JDOHelper.

Readers primarily interested in developing applications with the JDO API can ignore the following chapters. Skip to 25 – JDOPermission.

23 JDO Reference Enhancer

This chapter specifies the JDO Reference Enhancement, which specifies the contract between JDO persistence-capable classes and JDO StateManager in the binary-compatible runtime environment. The JDO Reference Enhancer modifies persistence-capable classes to run in the JDO environment and implement the required contract. The resulting classes, hereinafter referred to as enhanced classes, implement a contract used by the `JDOHelper`, the `JDOImplHelper`, and the `StateManager` classes.

The JDO Reference Enhancer is just one possible implementation of the JDO Reference Enhancement contract. Tools may instead preprocess or generate source code to create classes that implement this contract.

Enhancement is just one possible strategy for JDO implementations. If a JDO implementation supports BinaryCompatibility, it must support the PersistenceCapable contract. Otherwise, it need only support the rest of the user-visible contracts (e.g. PersistenceManagerFactory, PersistenceManager, Query, Transaction, and Extent).

NOTE: This chapter is not intended to be used by application programmers. It is for use only by implementations. Applications should use the methods defined in class `JDOHelper` instead of these methods and fields.

23.1 Overview

The JDO Reference Enhancer will be used to modify each persistence-capable class before using that persistence-capable class with the Reference Implementation `PersistenceManager` in the Java VM. It might be used before class loading or during the class loading process.

The JDO Reference Enhancer transforms the class by making specific changes to the class definition to enable the state of any persistent instances to be synchronized with the representation of the data in the datastore.

A standard API to invoke an implementation's enhancer is provided as part of the specification jar. A command line tool to invoke a byte code enhancer is provided. The tool is distributed as part of the specification jar. The tool analyzes command line arguments and passes control to an implementation-provided class to perform the enhancement of classes. The tool locates the implementation-provided class using the services locator architecture.

Tools that generate source code or modify the Java source code files must generate classes that meet the defined contract in this chapter.

The Reference Enhancer provides an implementation for the `PersistenceCapable` interface.

23.2 Goals

The following are the goals for the JDO Reference Enhancer:

- Binary compatibility and portability of application classes among JDO vendor implementations

- Binary compatibility between application classes enhanced by different JDO vendors at different times.
- Minimal intrusion into the operation of the class and class instances
- Provide metadata at runtime without requiring implementations to be granted reflect permission for non-private fields
- Values of fields can be read and written directly without wrapping code with accessors or mutators (`field1 += 13` is allowed, instead of requiring the user to code `setField1(getField1() + 13)`)
- Navigation from one instance to another uses natural Java syntax without any requirement for explicit fetching of referenced instances
- Automatically track modification of persistent instances without any explicit action by the application or component developer
- Highest performance for transient instances of persistence-capable classes
- Support for all class and field modifiers
- Transparent operation of persistent and transient instances as seen by application components and persistence-capable classes
- Shared use of persistence-capable classes (utility components) among multiple JDO `PersistenceManager` instances in the same Java VM
- Preservation of the security of instances of `PersistenceCapable` classes from unauthorized access
- Support for debugging enhanced classes by line number
- Support for static enhancement of classes by a tool run after compilation but before execution
- Support for dynamic enhancement of static (compiled with javac) and dynamic (created at runtime) classes by user- or implementation-written class loader
- Support for build tools such as maven plugins, eclipse plugins, and ant plugins

23.3 Standard Enhancement

The enhancement process consists of two distinct functions: analyzing user input as to how and what to enhance; and performing the enhancement of the persistent classes. A Java main program is distributed as part of the java specification jar. Plugins for Interactive Development Environments are anticipated by the architecture but not provided by the JDO specification jar itself. Enhancing the persistent classes is the function of a JDO implementation, and in particular, the Reference Implementation. The Enhancer main program calls a standard enhancer by using the services locator architecture. Thus, the Enhancer main program can call any enhancer provided by a JDO implementation and made available on the class path.

The name of the class that implements the `JDOEnhancer` API must be in the class path in the file called `META-INF/services/javax.jdo.JDOEnhancer`.

The enhancer operates on the byte code representation of persistent classes, and creates new byte code representations of the classes. The input byte code representations can come from four sources:

- a byte array such as might be created by a dynamic class generator;
- a file that contains the byte codes as generated by the javac compiler;
- a jar file containing multiple classes and metadata files;

- a resource loaded from a class loader that contains the byte codes as generated by the javac compiler

The output byte code representations can be written to one of three destinations:

- the same file as was provided as input;
- the same jar file as was provided as input, in which case all contents of the jar file that are not enhanced are preserved intact;
- a directory that contains package names as directory names with identical semantics to the javac compiler's output directive.

Restrictions: if a resource is used as input, then the only output possible is a directory. If a class file or jar file is used as input, the file must be read/write. If a byte array is used as input, then the enhanced byte array is available via a separate method call and is not written to output.

23.3.1 Enhancer Main

The Enhancer main class is intended to be run from an interactive shell (command line). It analyzes arguments and delegates to an implementation. The implementation must be identified via an entry in the class loader's resource file META-INF/services/javax.jdo.JDOEnhancer. If multiple such files exist, the Enhancer main uses the first file containing the name of a class that can be loaded by the Class.forName method, containing a public no-args constructor, that returns an instance that implements javax.jdo.JDOEnhancer.

The enhancer is invoked with the following command line:

```
java -cp <classpath> javax.jdo.Enhancer <options> <directory, class, jdo, or jar file names>
```

- <classpath> must contain the jdo specification jar, the implementation jar and any implementation dependencies, the statically-compiled classes, and the jdo metadata files loadable as resources
- <options> include:
 - -pu <persistence-unit-name> : the name of a persistence unit
 - -d <target directory> : write the enhanced classes to the specified directory
 - -checkonly : just check the classes for enhancement status
 - -v : verbose output
 - -r : recurse through directories to find all classes and metadata files to enhance
 - -cp <enhancer class loader path> : if not already included in the java class loader, this parameter must contain the statically-compiled classes, and the jdo metadata files loadable as resources
 - <directory, file, or resource names>

Each entry following the options must be a directory, a file, or a resource name.

The enhancer main program processes the command line and passes the parameters to the enhancer found via services lookup.

Parameters are processed until the first non-option parameter is found. All subsequent parameters are treated as directory, file, or resource names. Parameters beginning with "-" are considered to be options. If an option is not a standard option, it is added to the non-standard options list. If a non-standard option is not recognized, the enhancer program exits with error code 3 (ENHANCER_USAGE_ERROR).

Parameters are processed as follows:

- `-cp <enhancer class loader path>`: If this option is present, a new class loader is constructed, parented with the context class loader, to which the urls in the `<enhancer class loader path>` are added. The format of `<enhancer class loader path>` is the same as the `-cp` option of the `java` command. The class loader is passed to the enhancer via the `setClassLoader` method.
- `-pu <persistence-unit-name>`: If this option is present, each `persistence-unit-name` is passed to the enhancer via the `addPersistenceUnit` method.
- `-d <target directory>`: If this option is present, the target directory is passed to the enhancer via the `setOutputDirectory` method.
- `-v`: If this option is present, the verbose flag is set via the `setVerbose` method.
- `-r`: If this option is present, directories are recursively searched for files.
- `-checkonly`: If this option is present, the files are not enhanced, but verified via the `validate` method. If this option is absent, the files are enhanced via the `enhance` method.

Parameters that follow the last option are passed to the enhancer. The enhancer handles the files as follows:

- For a `.class` file, the file must contain the byte codes of a persistent class consistent with the file name. Metadata is found using the algorithm detailed in Chapter 18, using the path specified for the `.class` file and recursing through parent directories in the file system. All class file names are passed to the enhancer via the `addClasses` method.
- For a `.jdo` file, the file must be a valid metadata file and the classes described in the file are treated as described (persistence-capable, persistence-aware, or not persistent). Metadata is found using the algorithm detailed in Chapter 18. All file names are passed to the enhancer via the `addFiles` method.
- For a `.jar` file, the file may contain `.class` files and `.jdo` metadata files. Each jar file name is passed to the enhancer via the `addJar` method.
- For a directory, the contents of the directory are analyzed for `.class`, `.jdo`, and `.jar` files which are then treated as if they were passed directly, as `directory/*.class` `directory/*.jdo` or `directory/*.jar`. If the `-r` option is specified, each subdirectory of the directory is treated as if it were itself the directory parameter, recursively. Thus, every `.class` file, `.jdo` file, and `.jar` file in the directory are included as files for enhancement.
- Files that are not recognized as above are silently ignored.

23.4 Enhancement: Architecture

The reference enhancement of persistence-capable classes has the primary objective of preserving transparency for the classes. Specifically, accesses to fields in the JDO instance are mediated to allow for initializing values of fields from the associated values in the datastore and for storing the values of fields in the JDO instance into the associated values in the datastore at transaction boundaries.

To avoid conflicts in the name space of the persistence-capable classes, all methods and fields added to the persistence-capable classes have the “`jdo`” prefix.

Enhancement might be performed at any time prior to use of the class by the application. During enhancement, special JDO class metadata must be available if any non-default actions are to be taken. The metadata is in XML format .

Specifically, the following will require access to special class metadata at class enhancement time, because these are not the defaults:

- classes are to use primary key or non-managed object identity;
- fields declared as transient in the class definition are to be persistent in the datastore;
- fields not declared as transient in the class definition are to be non-persistent in the datastore;
- fields are to be transactional non-persistent;
- fields with domains of references to persistence-capable classes are to be part of the default fetch group;
- fields with domains of primitive types (`boolean`, `char`, `byte`, `short`, `int`, `long`, `float`, `double`) or primitive wrapper types (`Boolean`, `Char`, `Byte`, `Short`, `Integer`, `Long`, `Float`, `Double`) are not to be part of the default fetch group;
- fields with domains of `String` are not to be part of the default fetch group;
- fields with domains of array types are to be part of the default fetch group.

Enhancement makes changes to two categories of classes: persistence-capable and persistence-aware. Persistence-capable classes are those whose instances are allowed to be stored in a JDO-managed datastore. Persistence aware classes are those that while not necessarily persistence-capable themselves, contain references to managed fields of classes that are persistence-capable. Thus, persistence-capable classes may also be persistence-aware.

Enhancement also treats Detachable classes specially, by adding fields and methods needed to manage the detached state of the instance.

To preserve the security of instances of `PersistenceCapable` classes, access restrictions to fields before enhancement will be propagated to accessor methods after enhancement. Further, to become the delegate of field access (`StateManager`) the caller must be authorized for `JDOPermission`.

A JDO implementation must interoperate with classes enhanced by the Reference Enhancer and with classes enhanced with other Vendor Enhancers. Additionally, classes enhanced by any Vendor Enhancers must interoperate with the Reference Implementation.

Name scope issues are minimized because the Reference Enhancement contract adds methods and fields that begin with “`jdo`”, while methods and fields added by Vendor Enhancers must not begin with “`jdo`”. Instead, they may begin with “`sunwjdo`”, “`exlnjdo`” or other string that includes a vendor-identifying name and the “`jdo`” string.

Debugging by source line number must be preserved by the enhancement process. If any code modification within a method body changes the byte code offsets within the method, then the line number references of the method must be updated to reflect the change.

The Reference Enhancer makes the following changes to the least-derived (topmost) persistence-capable classes:

- adds a field named `jdoStateManager`, of type `javax.jdo.spi.StateManager` to associate each instance with zero or one instance of JDO `StateManager`;
- adds a synchronized method `jdoReplaceStateManager` (to replace the value of the `jdoStateManager`), which invokes security checking for declared `JDOPermission`;
- adds a field named `jdoFlags` of type `byte` in the least-derived persistence capable class, to distinguish readable and writable instances from non-readable and non-writable instances;

- adds a method `jdoReplaceFlags` to require the instance to request an updated value for the `jdoFlags` field from the `StateManager`;
- adds methods to implement status query methods by delegating to the `StateManager`;
- adds method `jdoReplaceFields(int[])` to obtain values of specified fields from the `StateManager` and cache the values in the instance;
- adds method `jdoProvideFields(int[])` to supply values of specific fields to the `StateManager`;
- adds a method `void jdoCopyFields(Object other, int[] fieldNumbers)` to allow the `StateManager` to manage multiple images of the persistence capable instance;
- adds a method `void jdoCopyField(Object other, int fieldNumber)` to allow the `StateManager` to manage multiple images of the persistence capable instance;
- adds a method `jdoPreSerialize` to load all non-transient fields into the instance prior to serialization;

The Reference Enhancer makes the following changes to least-derived (topmost) persistence-capable classes and classes that declare an `objectid-class` in their xml:

- adds methods `jdoCopyKeyFieldsToObjectId(PersistenceCapable pc, Object oid)` and `jdoCopyKeyFieldsToObjectId(ObjectIdFieldSupplier fs, Object oid)`.
- adds methods `jdoCopyKeyFieldsFromObjectId(Object oid)` and `jdoCopyKeyFieldsFromObjectId(ObjectIdFieldConsumer fc, Object oid)`.
- adds a method `jdoNewObjectIdInstance()` which creates an instance of the `jdo ObjectId` for this class.

The Reference Enhancer makes the following changes to the least-derived class marked as Detachable:

- adds “`implements javax.jdo.spi.Detachable`” to the class definition;
- adds a serializable field “`Object[] jdoDetachedState`” to the class definition;
- adds a method “`void jdoReplaceDetachedState()`” to the class definition.

The Reference Enhancer makes the following changes to all classes:

- adds “`implements javax.jdo.spi.PersistenceCapable`” to the class definition;
- adds two methods `jdoNewInstance`, one of which takes a parameter of type `StateManager`, to be used by the implementation when a new persistent instance is required (this method allows a performance optimization), and the other takes a parameter of type `StateManager` and a parameter of an `ObjectId` for key field initialization; adds two methods, `makeDirty(String fieldName)` and `makeDirty(int fieldNumber)`, to manage making fields dirty.
- adds method `jdoReplaceField(int)` to obtain values of specified fields from the `StateManager` and cache the values in the instance;
- adds method `jdoProvideField(int)` to supply values of specific fields to the `StateManager`;

- adds an accessor method and mutator method for each field declared in the class, which delegates to the `StateManager` for values;
- leaves the modifiers of all persistent fields the same as the unenhanced class to allow the enhanced classes to be used for compilation of other classes;
- adds a method `jdoCopyField(<class> other, int fieldNumber)` to allow the `StateManager` to manage multiple images of the persistence capable instance;
- adds a method `jdoGetManagedFieldCount()` to manage the numbering of fields with respect to inherited managed fields.
- adds a field `jdoInheritedFieldCount`, which is set at class initialization time to the returned value of `super.jdoGetManagedFieldCount()`.
- adds fields `jdoFieldNames`, `jdoFieldTypes`, and `jdoFieldFlags`, which contain the names, types, and flags of managed fields.
- adds field `Class jdoPersistenceCapableSuperclass`, which contains the `Class` of the `PersistenceCapable` superclass.
- adds a static initializer to register the class with the `JDOImplHelper`.
- adds a field `serialVersionUID` if it does not already exist, and calculates its initial value based on the non-enhanced class definition.

Enhancement makes the following changes to persistence aware classes:

- modifies executable code that accesses fields of `PersistenceCapable` classes not known to be not managed, replacing `getfield` and `putfield` calls with calls to the generated accessor and mutator methods.

23.5 Inheritance

Enhancement allows a class to manage the persistent state only of declared fields. It is a future objective to allow a class to manage fields of a non-persistence capable superclass.

Fields that hide inherited fields (because they have the same name) are fully supported. The enhancer delegates accesses of inherited hidden fields to the appropriate class by referencing the appropriate method implemented in the declaring class.

All persistence capable classes in the inheritance hierarchy must use the same kind of JDO identity.

23.6 Field Numbering

Enhancement assigns field numbers to all managed (transactional or persistent) fields. Generated methods and fields that refer to fields (`jdoFieldNames`, `jdoFieldTypes`, `jdoFieldFlags`, `jdoGetManagedFieldCount`, `jdoCopyFields`, `jdoMakeDirty`, `jdoProvideField`, `jdoProvideFields`, `jdoReplaceField`, and `jdoReplaceFields`) are generated to include both transactional and persistent fields.

Relative field numbers are calculated at enhancement time. For each persistence capable class the enhancer determines the declared managed fields. To calculate the relative field number, the declared fields array is sorted by field name. Each managed field is assigned a relative field number, starting with zero.

Absolute field numbers are calculated at runtime, based on the number of inherited managed fields, and the relative field number. The absolute field number used in method calls is the relative field number plus the number of inherited managed fields.

The absolute field number is used in method calls between the `StateManager` and `PersistenceCapable`; and in the reference implementation, between the `StateManager` and `StoreManager`.

23.7 Serialization

Serialization of a transient instance results in writing an object graph of objects connected via non-transient fields. The explicit intent of JDO enhancement of serializable classes is to permit serialization of transient instances or persistent instances to a format that can be deserialized by either an enhanced or non-enhanced class.

Classes marked as `Detachable` are not serialization-compatible with un-enhanced classes. This is intentional, and requires that the enhanced version of the class be used wherever the instance might be instantiated. If a `Detachable` class were used in an environment where the un-enhanced class was not used, then access to unloaded fields would not be restricted, and field modifications could not be tracked.

When the `writeObject` method is called on a class to serialize it, all fields not declared as transient must be loaded into the instance. This function is performed by the enhancer-generated method `jdoPreSerialize`. This method simply delegates to the `StateManager` to ensure that all persistent non-transient fields are loaded into the instance. [Fields not declared as transient and not declared as persistent must have been loaded by the `PersistenceCapable` class an application-specific way.]

For `Detachable` classes, the `jdoPreSerialize` method must also initialize the `jdoDetachedState` instance so that the detached state is serialized along with the instance.

The `jdoPreSerialize` method need be called only once for a persistent instance. Therefore, the `writeObject` method in the least-derived pc class that implements `Serializable` in the inheritance hierarchy needs to be modified or generated to call it.

If a standard serialization is done to an enhanced class instance, the fields added by the enhancer will not be serialized because they are declared to be transient.

To allow a non-enhanced class to deserialize the stream, the `serialVersionUID` for the enhanced and non-enhanced classes must be identical. If the `serialVersionUID` field does not already exist in the non-enhanced class, the enhancer will calculate it (excluding any enhancer-generated fields or methods) and add it to the enhanced class.

If a `PersistenceCapable` class is assignable to `java.io.Serializable` but its persistence-capable superclass is not, then the enhancer will modify the class in the following way:

- if the class does not contain implementations of `writeObject`, or `writeReplace`, then the enhancer will generate `writeObject`. Fields that are required to be present during serialization operations will be explicitly instantiated by the generated method `jdoPreSerialize`, which will be called by the enhancer-generated `writeObject`.
- if the class contains an implementation of `writeObject` or `writeReplace`, it will be changed to call `jdoPreSerialize` prior to any user-written code in the method.

If a `PersistenceCapable` class is assignable to `java.io.Serializable`, then the non-transient fields might be instantiated prior to serialization. However, the closure of instances reachable from this instance might include a large part of instances in the datastore.

For non-`Detachable` classes, the results of restoring a serialized persistent instance graph is a graph of interconnected transient instances. The method `readObject` is not enhanced, as it deals only with transient instances.

For Detachable classes, the results of restoring a serialized persistent instance graph is a graph of interconnected detached instances that might be attached via the `makePersistent` methods.

23.8 Cloning

If a standard clone is made of a persistent instance, the `jdoFlags` and `jdoStateManager` fields will also be cloned. The clone will eventually invoke the `StateManager` if the source of the cloned instance is not transient. This condition will be detected by the runtime, but disconnecting the clone is a convoluted process. To avoid this situation where possible, the enhancer modifies the cloning behavior by modifying certain methods that invoke `clone`, setting these two fields to indicate that the clone is a transient instance. Otherwise, all of the fields in the clone contain the standard shallow copy of the fields of the cloned instance.

The reference enhancement will modify the `clone()` method in the persistence-capable root class (the least-derived (topmost) `PersistenceCapable` class) to reset these two fields immediately after returning from `super.clone()`. This caters for the normal case where `clone` methods in subclasses call `super.clone()` and the clone is disconnected immediately after being cloned.

The `clone` method is also modified to copy the `jdoDetachedState` field of an instance of a `Detachable` class to the clone if the instance is detached. The effect of this is that while detached, the clone is also a detached object. While attached, the detached state will not be cloned, and the clone will therefore be transient.

This technique does not address these cases:

- A non-persistence-capable superclass `clone` method calls a runtime method (for example, `makePersistent`) on the newly created clone. In this case, the `makePersistent` will succeed, but the `clone` method in the persistence-capable subclass will disconnect the clone, thereby undoing the `makePersistent`. Thus, calling any life cycle change methods with the clone as an argument is not permitted in `clone` methods.
- Where there is no `clone` method declared in the persistence-capable root class, the clone will not be disconnected, and the runtime will disconnect the clone the first time the `StateManager` is called by the clone.

23.9 Introspection (Java core reflection)

No changes are made to the behavior of introspection. The current state of all fields is exposed to the reflection APIs.

This is not at all what some users might expect. It is a future objective to more gracefully support introspection of fields in persistent instances of persistence capable classes.

23.10 Field Modifiers

Fields in persistence-capable classes are treated by the enhancer in one of several ways, based on their modifiers as declared in the Java language and their enhanced modifiers as declared by the persistence-capable MetaData.

These modifiers are orthogonal to the modifiers defined by the Java language. They have default values based on modifiers defined in the class for the fields. They may be specified in the XML metadata used at enhancement time.

23.10.1 Non-persistent

Non-persistent fields are ignored by the enhancer. They are assumed to lie outside the domain of persistence. They might be changed at will by any method based only on the private/protected/public modifiers. There is no enhancement of accesses to non-persistent fields.

The default modifier is non-persistent for fields identified as transient in the class declaration.

23.10.2 Transactional non-persistent

Transactional non-persistent fields are non-persistent fields whose values are saved and restored during rollback. Their values are not stored in the datastore. There is no enhancement of read accesses to transactional non-persistent fields. Write accesses are always mediated (the `StateManager` is called on write).

23.10.3 Persistent

Persistent fields are fields whose values are synchronized with values in the datastore. The synchronization is performed transparent to the methods in the persistence-capable class.

The default persistence-modifier for fields is based on their modifiers and type, as detailed in the XML metadata chapter.

The modification to the class by the enhancer depends on whether the persistent field is a member of the default fetch group.

If the persistent field is a member of the default fetch group, then the enhanced code behaves as follows. The constant values `READ_OK`, `READ_WRITE_OK`, and `LOAD_REQUIRED` are defined in interface `PersistenceCapable`.

- for read access, `jdoFlags` is checked for `READ_OK` or `READ_WRITE_OK`. If it is then the value in the field is retrieved. If it is not, then the `StateManager` instance is requested to load the value of the field from the datastore, which might cause the `StateManager` to populate values of all default fetch group fields in the instance, and other values as defined by the JDO vendor policy. This behavior is not required, but optional. If the `StateManager` chooses, it may simply populate the value of the specific field requested. Upon conclusion of this process, the `jdoFlags` value might be set by the `StateManager` to `READ_OK` and the value of the field is retrieved. If not all fields in the default fetch group were populated, the `StateManager` must not set the `jdoFlags` to be `READ_OK`.
- for write access, `jdoFlags` is checked for `READ_WRITE_OK`. If it is `READ_WRITE_OK`, then the value is stored in the field. If it is not `READ_WRITE_OK`, then the `StateManager` instance is requested to load the state of the values from the datastore, which might cause the `StateManager` to populate values of all default fetch group fields in the instance. Upon conclusion of the load process, the `jdoFlags` value might be set by the `StateManager` to `READ_WRITE_OK` and the value of the field is stored.

If the persistent field is not a member of the default fetch group, then each read and write access to the field is delegated to the `StateManager`. For read, the value of the field is obtained from the `StateManager`, stored in the field, and returned to the caller. For write, the proposed value is given to the `StateManager`, and the returned value from the `StateManager` is stored in the field.

The enhanced code that fetches or modifies a field that is not in the default fetch group first checks to see if there is an associated `StateManager` instance and if not (the case for transient instances) the access is allowed without intervention.

23.10.4 PrimaryKey

Primary key fields are not part of the default fetch group; all changes to the field can be intercepted by the `StateManager`. This allows special treatment by the implementation if any primary key fields are changed by the application.

Primary key fields are always available in the instance, regardless of the state. Therefore, read access to these fields is never mediated.

23.10.5 Embedded

Fields identified as embedded in the XML metadata are treated as containing embedded instances. The default for `Array`, `Collection`, and `Map` types is embedded. This is to allow JDO implementations to map persistence-capable field types to embedded objects (aggregation by containment pattern).

23.10.6 Null-value

Fields of `Object` types might be mapped to datastore elements that do not allow null values. The default behavior “none” is that no special treatment is done for null-valued fields. In this case, null-valued fields throw a `JDOUserException` when the instance is flushed to the datastore and the datastore does not support null values.

However, the treatment of null-valued fields can be modified by specifying the behavior in the XML metadata. The null-value setting of “default” is used when the default value for the datastore element is to be used for null-valued fields.

If the application requires non-null values to be stored in this field, then the setting should be “exception”, which throws a `JDOUserException` if the value of the field is null at the time the instance is stored in the datastore.

For example, if a field of type `Integer` is mapped to a datastore `int` value, committing an instance with a field value of null where the null-value setting is “default” will result in a zero written to the datastore element. Similarly, a null-valued `String` field would be written to the datastore as an empty (zero length) `String` where the null-value setting is “default”.

23.11 Treatment of standard Java field modifiers

23.11.1 Static

Static fields are ignored by the enhancer. They are not initialized by JDO; accesses to values are not mediated.

23.11.2 Final

Final fields are treated as non-persistent and non-transactional by the enhancer. Final fields are initialized only by the constructor, and their values cannot be changed after construction of the instance. Therefore, their values cannot be loaded or stored by JDO; accesses are not mediated.

This treatment might not be what users expect; therefore, final fields are not supported as persistent or transactional instance fields, final static fields are supported by ignoring them.

23.11.3 Private

Private fields are accessed only by methods in the class itself. JDO handles private fields according to the semantic that values are stored in private fields by the enhancement-generated `jdoSetXXX` methods or `jdoReplaceField`, which become part of the class definition. The enhancement-generated `jdoGetXXX` or `jdoProvideField` methods, which become part of the class definition, load values from private fields.

23.11.4 Public, Protected

Public fields are not recommended to be persistent in persistence capable classes. Classes that make reference to persistent public fields (persistence aware) must be enhanced themselves prior to execution. Protected fields and fields without an explicit access modifier (commonly referred to as package access) may be persistent.

Users must enhance all classes, regardless of package, that reference any persistent or transactional field.

23.12 Fetch Groups

Fetch groups represent a grouping of fields that are retrieved from the datastore together. Typically, a datastore associates a number of data values together and efficiently retrieves these values. Other values require extra method calls to retrieve.

For example, in a relational database, the Employee table defines columns for Employee id, Name, and Position. These columns are efficiently retrieved with one data transfer request. The corresponding fields in the Employee class might be part of the default fetch group.

Continuing this example, there is a column for Department dept, defined as a foreign key from the Employee table to the Department table, which corresponds to a field in the Employee class named dept of type Department. The runtime behavior of this field depends on the mapping to the Department table. The reference might be to a derived class and it might be expensive to determine the class of the Department instance. Therefore, the dept field will not be defined as part of the default fetch group, even though the foreign key that implements the relationship might be fetched when the Employee is fetched. Rather, the value for the dept field will be retrieved from the StateManager every time it is requested. Similarly, the StateManager will be called for each modification of the value of dept.

The jdoFlags field is the indicator of the state of the default fetch group.

23.13 jdoFlags Definition

The value of the jdoFlags field is entirely determined by the StateManager. The StateManager calls the jdoReplaceFlags method to inform the persistence capable class to retrieve a new value for the jdoFlags field. The values permitted are constants defined in the interface PersistenceCapable: READ_OK, READ_WRITE_OK, and LOAD_REQUIRED.

During the transition from transient to a managed life cycle state, the jdoFlags field is set to LOAD_REQUIRED by the persistence capable instance, to indicate that the instance is not ready. During the transition from a managed state to transient, the jdoFlags field is set to READ_WRITE_OK by the persistence capable instance, to indicate that the instance is available for read and write of any field.

The jdoFlags field is a byte with these possible values and associated meanings:

- 0 - READ_WRITE_OK: the values in the default fetch group can be read or written without intermediation of the associated StateManager instance.
- -1 - READ_OK: the values in the default fetch group can be read but not written without intermediation of the associated StateManager instance.
- 1 - LOAD_REQUIRED: the values in the default fetch group cannot be accessed, either for read or write, without intermediation of the associated StateManager instance.

Regardless of the jdoFlags setting, detached instances will disallow access to non-key fields that are not marked as loaded in the detached state.

23.14 Exceptions

Generated methods validate the state of the persistence-capable class and the arguments to the method.

If an argument is illegal, then `IllegalArgumentException` is thrown. For example, an illegal field number argument is less than zero or greater than the number of managed fields.

Some methods require a non-null state manager. In these cases, if the `jdoStateManager` is null, then `JDOFatalInternalException` is thrown.

23.15 Modified field access

The enhancer modifies field accesses to guarantee that the values of fields are retrieved from the datastore prior to application usage.

For any field access that reads the value of a field, the `getfield` byte code is replaced with a call to a generated local method, `jdoGetXXX`, which determines based on the kind of field (default fetch group or not) and the state of the `jdoFlags` whether to call the `StateManager` with the field number needed.

For any field access that stores the new value of a field, the `putfield` byte code is replaced with a call to a generated local method, `jdoSetXXX`, which determines based on the kind of field (default fetch group or not) and the state of the `jdoFlags` whether to call the `StateManager` with the field number needed. A JDO implementation might perform field validation during this operation and might throw a `JDOUserException` if the value of the field does not meet the criterion.

The following table specifies the values of the `jdoFieldFlags` for each type of mediated field.

Table 10: Field access mediation

field type	read access	write access	flags
transient transactional	not checked	checked	CHECK_WRITE
primary key	not checked	mediated	MEDIATE_WRITE
default fetch group	checked	checked	CHECK_READ + CHECK_WRITE
non-default fetch group	mediated	mediated	MEDIATE_READ + MEDIATE_WRITE

not checked: access is always granted

checked: the condition of `jdoFlags` is checked to see if access should be mediated

mediated: access is always mediated (delegated to the `StateManager`)

flags: the value in the `jdoFieldFlags` field

The flags are defined in `PersistenceCapable` and may be combined only as in the above table (`SERIALIZABLE` may be combined with any other flags):

- 1 - CHECK_READ
- 2 - MEDIATE_READ
- 4 - CHECK_WRITE
- 8 - MEDIATE_WRITE

23.16 Generated fields in least-derived PersistenceCapable class

These fields are generated only in the least-derived (topmost) class in the inheritance hierarchy of persistence-capable classes.

```
protected transient javax.jdo.spi.StateManager jdoStateManager;
```

This field contains the managing StateManager instance, if this instance is being managed.

```
protected transient byte jdoFlags;
```

This field contains the detached state, if this instance is detached.

```
protected Object[] jdoDetachedState;
```

23.17 Generated fields in all PersistenceCapable classes

The following fields are generated in all persistence-capable classes.

```
private final static int jdoInheritedFieldCount;
```

This field is initialized at class load time to be the number of fields managed by the superclasses of this class, or to zero if there is no persistence capable superclass.

```
private final static String[] jdoFieldNames;
```

This field is initialized at class load time to an array of names of persistent and transactional fields. The position in the array is the relative field number of the field.

```
private final static Class[] jdoFieldTypes;
```

This field is initialized at class load time to an array of types of persistent and transactional fields. The position in the array is the relative field number of the field.

```
private final static byte[] jdoFieldFlags;
```

This field is initialized at class load time to an array of flags indicating the characteristics of each persistent and transactional field.

```
private final static Class jdoPersistenceCapableSuperclass;
```

This field is initialized at class load time to the class instance of the PersistenceCapable superclass, or null if there is none.

```
private final static long serialVersionUID;
```

This field is declared only if it does not already exist, and it is initialized to the value that would obtain prior to enhancement.

Generated static initializer

The generated static initializer uses the values for jdoFieldNames, jdoFieldTypes, jdoFieldFlags, and jdoPersistenceCapableSuperclass, and calls the static registerClass method in JDOImplHelper to register itself with the runtime environment. If the class is abstract, then it does not register a helper instance. If the class is not abstract, it registers a newly constructed instance.

The generated static initialization code is placed after any user-defined static initialization code.

23.18 Generated methods in least-derived PersistenceCapable class

These methods are declared in interface PersistenceCapable.

```
public final boolean jdoIsPersistent();
public final boolean jdoIsTransactional();
public final boolean jdoIsNew();
public final boolean jdoIsDeleted();
```

These methods check if the `jdoStateManager` field is null. If so, they return `false`. If not, they delegate to the corresponding method in `StateManager`.

```
public final boolean jdoIsDetached();
```

This method checks if the instance is detached. If so, it returns true.

```
public final boolean jdoIsDirty();
```

This method checks if the instance is detached. If so, it returns the modified state of the field from the detached state. If not, it checks if the `jdoStateManager` field is null. If so, it returns `false`. If not, it delegates to the corresponding method in `StateManager`.

```
public final void jdoMakeDirty (String fieldName);
```

```
public final void jdoMakeDirty (int fieldNumber);
```

This method checks if the `jdoStateManager` field is null. If so, it returns silently. If not, it delegates to the `makeDirty` method in `StateManager`.

```
public final PersistenceManager jdoGetPersistenceManager();
```

This method checks if the `jdoStateManager` field is null. If so, it returns null. If not, it delegates to the `getPersistenceManager` method in `StateManager`.

```
public final Object jdoGetObjectID();
```

```
public final Object jdoGetVersion();
```

```
public final Object jdoGetTransactionalObjectId();
```

These methods check if the instance is detached. If so, they return the appropriate element of the detached state. If not detached, the methods check if the `jdoStateManager` field is null. If so, they return null. If not, they delegate to the corresponding method in `StateManager`.

```
public synchronized final void jdoReplaceStateManager (StateManager sm);
```

NOTE: This method will be called by the `StateManager` on state changes when transitioning an instance from transient to a managed state, and from a managed state to transient.

This method is implemented as synchronized to resolve race conditions, if more than one `StateManager` attempts to acquire ownership of the same `PersistenceCapable` instance.

If the current `jdoStateManager` is not null, this method replaces the current value for `jdoStateManager` with the result of calling `jdoStateManager.replaceStateManager(this, sm)`. If successful, the method ends. If the change was not requested by the `StateManager`, then the `StateManager` throws a `JDOUserException`.

If the current `jdoStateManager` field is null, then a security check is performed by calling `JDOImplHelper.checkAuthorizedStateManager` with the `StateManager` parameter `sm` passed as the parameter to the check. Thus, only `StateManager` instances in code bases authorized for `JDOPermission("setStateManager")` are allowed to set the `StateManager`. If the security check succeeds, the `jdoStateManager` field is set to the value of the parameter `sm`, and the `jdoFlags` field is set to `LOAD_REQUIRED` to indicate that mediation is required.

```
public final void jdoReplaceFlags ();
```

NOTE: This method will be called by the `StateManager` on state changes when transitioning an instance from a managed state to transient.

If the current `jdoStateManager` field is null, then this method silently returns with no effect.

If the current `jdoStateManager` is not null, this method replaces the current value for `jdoflags` with the result of calling `jdoStateManager.replaceFlags(this)`.

```
public final void jdoReplaceFields (int[] fields);
```

For each field number in the `fields` parameter, `jdoReplaceField` method is called.

```
public final void jdoProvideFields (int[] fields);
```

For each field number in the `fields` parameter, `jdoProvideField` method is called.

```
protected final void jdoPreSerialize();
```

This method is called by the generated or modified `writeObject` to allow the instance to fully populate serializable fields. This method delegates to the `StateManager` method `preSerialize` so that fields can be fetched by the JDO implementation prior to serialization. If the `jdoStateManager` field is null, this method returns with no effect.

23.19 Generated methods in PersistenceCapable root classes

These methods are generated for `PersistenceCapable` root classes and all classes that declare `objectid-class` in xml metadata.

```
public void jdoCopyKeyFieldsToObjectId (ObjectIdFieldSupplier fs,  
Object oid)
```

This method is called by the JDO implementation (or implementation helper) to populate key fields in object id instances. If this class is not the persistence-capable root class, it first calls the method of the same name in the root class. Then, for each key field declared in the metadata, this method calls the object id field supplier and stores the result in the `oid` instance.

If the `oid` parameter is not assignment compatible with the object id class of this instance, then `ClassCastException` is thrown. If this class does not use application identity, then this method silently returns.

```
public void jdoCopyKeyFieldsToObjectId (Object oid)
```

This method is called by the JDO implementation (or implementation helper) to populate key fields in object id instances from persistence-capable instances. This might be used to implement `getObjectId` or `getTransactionalObjectId`. If this class is not the persistence-capable root class, it first calls the method of the same name in the root class. Then, for each key field declared in the metadata, this method copies the value of the key field to the `oid` instance.

If the `oid` parameter is not assignment compatible with the object id class of this instance, then `ClassCastException` is thrown. If this class does not use application identity, then this method silently returns.

```
public void jdoCopyKeyFieldsFromObjectId (ObjectIdFieldConsumer fc,  
Object oid)
```

This method is called by the JDO implementation (or implementation helper) to export key fields from object id instances. If this class is not the persistence-capable root class, it first calls the method of the same name in the root class. Then, for each key field declared in the metadata, this method passes the value of the key field in the `oid` instance to the store method of the object id field consumer.

If the `oid` parameter is not assignment compatible with the object id class of this instance, then `ClassCastException` is thrown. If this class does not use application identity, then this method silently returns.

```
protected void jdoCopyKeyFieldsFromObjectId (Object oid)
```

This method is called by the `jdoNewInstance(Object oid)` method. If this class is not the persistence-capable root class, it first calls the method of the same name in the root class. Then, for each key field declared in the metadata, this method copies the value of the key field in the oid instance to the key field in this instance.

If the oid parameter is not assignment compatible with the object id class of this instance, then `ClassCastException` is thrown. If this class does not use application identity, then this method silently returns.

```
public Object jdoNewObjectIdInstance();
public Object jdoNewObjectIdInstance(Object obj);
```

In the case of single field identity, the parameter is an instance of one of the following:

- `Number`: the parameter is converted to the appropriate type and passed to the constructor of the single-field identity class
- `String`: the parameter is converted to the appropriate type and passed to the constructor of the single-field identity class
- `ObjectIdFieldSupplier`: the parameter is used to fetch the value of the object id field which is passed to the constructor of the single-field identity class
- `Object`: for `ObjectIdentity` only, the parameter is passed to the constructor of `ObjectIdentity`

NOTE: This method is called by the JDO implementation (or implementation helper) to populate key fields in object id instances.

If this class uses application identity, then this method returns a new instance of the `ObjectId` class. Otherwise, `null` is returned.

23.20 Generated method in least-derived `Detachable` classes

```
public void jdoReplaceDetachedState();
```

This method delegates to the `jdoStateManager` method `replacingDetachedState`, passing the current value of the detached state and replacing the detached state with the result of the method call.

23.21 Generated methods in all `PersistenceCapable` classes

```
public PersistenceCapable jdoNewInstance(StateManager sm);
```

This method uses the default constructor, assigns the `sm` parameter to the `jdoStateManager` field, and assigns `LOAD_REQUIRED` to the `jdoFlags` field. If the class is abstract, a `JDOFatalInternalException` is thrown.

```
public PersistenceCapable jdoNewInstance(StateManager sm, Object objectid);
```

This method uses the default constructor, assigns the `StateManager` parameter to the `jdoStateManager` field, assigns `LOAD_REQUIRED` to the `jdoFlags` field, and copies the key fields from the `objectid` parameter. If the class is abstract, a `JDOFatalInternalException` is thrown. If the `objectid` parameter is not of the correct class, then `ClassCastException` is thrown.

```
protected static int jdoGetManagedFieldCount();
```

This method returns the number of managed fields declared by this class plus the number inherited from all superclasses. This method is generated in the class to allow the class to determine at runtime the number of inherited fields, without having introspection code in the enhanced class.

```
final static mmm ttt jdoGet<field>(<class> instance);
```

The generated `jdoGet` methods have exactly the same stack signature as the byte code `get-field`. They return the value of one specific field. The field returned was either cached in the instance or retrieved from the `StateManager`.

The name of the generated method is constructed from the field name. This allows for hidden fields to be supported explicitly, and for classes to be enhanced independently.

The modifier `mmm` is the same access modifier as the corresponding field in the unenhanced class. The return type `ttt` is the same type as the corresponding field in the unenhanced class.

The generated code depends on the type of field and whether the class is marked as `Detachable`:

- If the instance is detached, the method checks to see if the field is marked as loaded in the detached state. If the field is not loaded, then `JDODetachedFieldAccessException` is thrown.
- If the field is `CHECK_READ`, then the method first checks to see if `jdoFlags` field is anything except `LOAD_REQUIRED`. If so, the value of the field is returned. If not, then the value of `jdoStateManager` is checked. If it is `null`, the value of the field is returned. If non-null, then method `isLoaded` is called on the `jdoStateManager`. If the result of `isLoaded` is `true`, then the value of the field is returned. If the result of `isLoaded` is `false`, then the result of method `getXXXField` on the `jdoStateManager` is returned.
- If the field is `MEDIATE_READ`, then the value of `jdoStateManager` is checked. If it is `null`, the value of the field is returned. If non-null, then method `isLoaded` is called on the `jdoStateManager`. If the result of `isLoaded` is `true`, then the value of the field is returned. If the result of `isLoaded` is `false`, then the result of method `getXXXField` on the `jdoStateManager` is returned.
- If the field is neither of the above, then the value of the field is returned.

```
final static mmm void jdoSet<field> (<class> instance, ttt  
newValue);
```

The generated `jdoSet` methods have exactly the same stack signature as the byte code `put-field`. They set the value of one specific field. The field might be provided to the `StateManager`.

The name of the generated method is constructed from the field name. This allows for hidden fields to be supported explicitly, and for classes to be enhanced independently.

The modifier `mmm` is the same access modifier as the corresponding field in the unenhanced class. The type `ttt` is the same type as the corresponding field in the unenhanced class.

The generated code depends on the type of field and whether the class is marked as `Detachable`:

- If the instance is detached, the method checks to see if the field is marked as loaded in the detached state. If the field is not loaded, then `JDODetachedFieldAccessException` is thrown. If the field is loaded, then the field is marked as modified in the detached state.
- If the field is `CHECK_WRITE`, then the method first checks to see if the `jdoFlags` field is `READ_WRITE_OK`. If so, then the field is set to the new value. If not, then the value of `jdoStateManager` is checked. If it is `null`, the value of the field is set to the new value. If non-null, then method `setXXXField` is executed on the `jdoStateManager`, passing the new value.

- If the field is MEDIATE_WRITE, then the value of jdoStateManager is checked. If it is null, then the field is set to the parameter. If non-null, then method setXXXField is executed on the jdoStateManager, passing the new value.
- If the field is neither of the above, then the value of the field is set to the new value.

```
public void jdoReplaceField (int field);
```

NOTE: This method is used by the StateManager to store values from the datastore into the instance. If there is no StateManager (the jdoStateManager field is null), then this method throws JDOFatalInternalException.

This method calls the StateManager replacingXXXField to get a new value for one field from the StateManager.

The field number is examined to see if it is a declared field or an inherited field. If it is inherited, then the call is delegated to the superclass. If it is declared, then the appropriate StateManager replacingXXXField method is called, which retrieves the new value for the field.

If the field is out of range (less than zero or greater than the number of managed fields in the class) then a JDOFatalInternalException is thrown.

```
public void jdoReplaceFields (int[] fields);
```

This method internally calls jdoReplaceField for each field number in the parameter.

```
public void jdoProvideField (int field);
```

NOTE: This method is used by the StateManager to retrieve values from the instance, during flush to the datastore or for in-memory query processing. If there is no StateManager (the jdoStateManager field is null), then this method throws JDOFatalInternalException.

This method calls the StateManager providedXXXField method to supply the value of the specified field to the StateManager.

The field number is examined to see if it is a declared field or an inherited field. If it is inherited, then the call is delegated to the superclass. If it is declared, then the appropriate StateManager providedXXXField method is called, which provides the StateManager with the value for the field.

If the field is out of range (less than zero or greater than the number of managed fields in the class) then a JDOFatalInternalException is thrown.

```
public void jdoProvideFields (int[] fields);
```

This method internally calls jdoProvideField for each field number in the parameter.

```
public void jdoCopyFields (Object other, int[] fieldNumbers);
```

This method is called by the StateManager to create before images of instances for the purpose of rollback. This method copies the specified fields from the other instance, which must be the same class as this instance, and owned by the same StateManager.

If the other instance is not assignment compatible with this instance, then ClassCastException is thrown. If the other instance is not owned by the same StateManager, then JDOFatalInternalException is thrown.

```
public final void jdoCopyField (<class> other, int fieldNumber);
```

This method is called by the jdoCopyFields method to copy the specified field from the other instance. If the field number corresponds to a field in a persistence-capable superclass, this method delegates to the superclass method. If the field is out of range (less than zero or greater than the number of managed fields in the class) then a JDOFatalInternalException is thrown.

```
private void writeObject (java.io.ObjectOutputStream out)
```

```
throws java.io.IOException{
```

If no user-written method `writeObject` exists, then one will be generated. The generated `writeObject` makes sure that all persistent and transactional serializable fields are loaded into the instance, by calling `jdoPreSerialize()`, and then the default output behavior is invoked on the output stream.

If the class is serializable (either by explicit declaration or by inheritance) then this code will guarantee that the fields are loaded prior to standard serialization. If the class is not serializable, then this code will never be executed.

-
- 23.22** Note that there is no modification of a user's `readObject`. During the execution of `readObject`, a new transient instance is created. This instance might be made persistent later, but while it is being constructed by serialization, it remains transient.**Example class: Employee**

The following class definitions for persistence capable classes are used in the examples. The `Employee` class is enhanced for application identity using `IntIdentity` as the object id class.

```
package com.xyz.hr;
import javax.jdo.spi.*; // generated by enhancer...
class Employee
    implements Detachable // generated by enhancer...
{
    Employee boss; // relative field 0
    Department dept; // relative field 1
    int empid; // relative field 2, key field
    String name; // relative field 3
```

23.22.1 Generated fields

```
protected transient javax.jdo.spi.StateManager jdoStateManager = null;
protected transient byte jdoFlags =
    javax.jdo.spi.PersistenceCapable.READ_WRITE_OK;
// if no superclass, the following:
private final static int jdoInheritedFieldCount = 0;
/* otherwise,
private final static int jdoInheritedFieldCount =
    <persistence-capable-superclass>.jdoGetManagedFieldCount();
*/
private final static String[] jdoFieldNames = {"boss", "dept", "empid", "name"};
private final static Class[] jdoFieldTypes = {Employee.class, Department.class,
    int.class, String.class};
private final static byte[] jdoFieldFlags = {
    MEDIEATE_READ+MEDIEATE_WRITE,
    MEDIEATE_READ+MEDIEATE_WRITE,
    MEDIEATE_WRITE,
    CHECK_READ+CHECK_WRITE
};
// if no PersistenceCapable superclass, the following:
private final static Class jdoPersistenceCapableSuperclass = null;
/* otherwise,
private final static Class jdoPersistenceCapableSuperclass = <pc-super>;
private final static long serialVersionUID = 1234567890L;
*/
```

23.22.2 Generated static initializer

```
static {
    javax.jdo.spi.JDOImplHelper.registerClass (
        Employee.class,
```

```
        jdoFieldNames,
        jdoFieldTypes,
        jdoFieldFlags,
        jdoPersistenceCapableSuperclass,
        new Employee());
    }
```

23.22.3 Generated interrogatives

```
public final boolean jdoIsPersistent() {
    return jdoStateManager==null?false:
           jdoStateManager.isPersistent(this);
}
public final boolean jdoIsTransactional(){
    return jdoStateManager==null?false:
           jdoStateManager.isTransactional(this);
}
public final boolean jdoIsNew(){
    return jdoStateManager==null?false:
           jdoStateManager.isNew(this);
}
public final boolean jdoIsDirty(){
    return jdoStateManager==null?false:
           jdoStateManager.isDirty(this);
}
public final boolean jdoIsDeleted(){
    return jdoStateManager==null?false:
           jdoStateManager.isDeleted(this);
}
public final boolean jdoIsDetached(){
    return jdoStateManager==null?false:
           jdoStateManager.isDetached(this);
}
public final void jdoMakeDirty (String fieldName){
    if (jdoStateManager==null) return;
    jdoStateManager.makeDirty(this, fieldName);
}
public final PersistenceManager jdoGetPersistenceManager(){
    return jdoStateManager==null?null:
           jdoStateManager.getPersistenceManager(this);
}
public final Object jdoGetObjectID(){
    return jdoStateManager==null?null:
           jdoStateManager.getObjectId(this);
}
public final Object jdoGetTransactionalObjectId(){
    return jdoStateManager==null?null:
           jdoStateManager.getTransactionalObjectId(this);
}
```

23.22.4 Generated jdoReplaceStateManager

The generated method asks the current StateManager to approve the change or validates the caller's authority to set the state.

```
public final synchronized void jdoReplaceStateManager
    (javax.jdo.spi.StateManager sm) {
// throws exception if current sm didn't request the change
if (jdoStateManager != null) {
    jdoStateManager = jdoStateManager.replacingStateManager (this, sm);
} else {
```

```
// the following will throw an exception if not authorized
    JDOImplHelper.checkAuthorizedStateManager(sm);
    jdoStateManager = sm;
    this.jdoFlags = LOAD_REQUIRED;
}
}
```

23.22.5 Generated jdoReplaceFlags

```
public final void jdoReplaceFlags () {
    if (jdoStateManager != null) {
        jdoFlags = jdoStateManager.replacingFlags (this);
    }
}
```

23.22.6 Generated jdoNewInstance helpers

The first generated helper assigns the value of the passed parameter to the `jdoStateManager` field of the newly created instance.

```
public PersistenceCapable jdoNewInstance(StateManager sm) {
// if class is abstract, throw new JDOFatalInternalException()
    Employee pc = new Employee ();
    pc.jdoStateManager = sm;
    pc.jdoFlags = LOAD_REQUIRED;
    return pc;
}
/* The second generated helper assigns the value of the passed parameter to the jdoStateManager field of the newly created instance, and initializes the values of the key fields from the oid parameter.
*/
public PersistenceCapable jdoNewInstance(StateManager sm, Object oid) {
// if class is abstract, throw new JDOFatalInternalException()
    Employee pc = new Employee ();
    pc.jdoStateManager = sm;
    pc.jdoFlags = LOAD_REQUIRED;
// now copy the key fields into the new instance
    jdoCopyKeyFieldsFromObjectId (oid);
    return pc;
}
```

23.22.7 Generated jdoGetManagedFieldCount

The generated method returns the number of managed fields in this class plus the number of inherited managed fields. This method is expected to be executed only during class loading of the subclasses.

The implementation for topmost classes in the hierarchy:

```
protected static int jdoGetManagedFieldCount () {
    return <enhancer-generated constant>;
}
```

The implementation for subclasses:

```
protected static int jdoGetManagedFieldCount () {
    return <pc-superclass>.jdoGetManagedFieldCount() +
        <enhancer-generated constant>;
}
```

23.22.8 Generated jdoGetXXX methods (one per persistent field)

The access modifier is the same modifier as the corresponding field definition. Therefore, access to the method is controlled by the same policy as for the corresponding field.

```
final static String
jdoGetname(Employee x) {
    // this field is in the default fetch group (CHECK_READ)
    if (x.jdoFlags <= READ_WRITE_OK) {
        // ok to read
        return x.name;
    }
    // field needs to be fetched from StateManager
    // this call might result in name being stored in instance
   StateManager sm = x.jdoStateManager;
    if (sm != null) {
        if (sm.isLoaded (x, jdoInheritedFieldCount + 3))
            return x.name;

        return sm.getStringField(x, jdoInheritedFieldCount + 3,
                               x.name);
    } else {
        return x.name;
    }
}

final static com.xyz.hr.Department
jdoGetdept(Employee x) {
    // this field is not in the default fetch group (MEDIATE_READ)
    StateManager sm = x.jdoStateManager;
    if (sm != null) {
        if (sm.isLoaded (x, jdoInheritedFieldCount + 1))
            return x.dept;
        return (com.xyz.hr.Department)
            sm.getObjectField(x,
                jdoInheritedFieldCount + 1,
                x.dept);
    } else {
        return x.dept;
    }
}
```

23.22.9 Generated jdoSetXXX methods (one per persistent field)

The access modifier is the same modifier as the corresponding field definition. Therefore, access to the method is controlled by the same policy as for the corresponding field.

```
final static void jdoSetname(Employee x, String newValue) {
    // this field is in the default fetch group
    if (x.jdoFlags == READ_WRITE_OK) {
        // ok to read, write
        x.name = newValue;
        return;
    }
    StateManager sm = x.jdoStateManager;
    if (sm != null) {
        sm.setStringField(x,
            jdoInheritedFieldCount + 3,
            x.name,
            newValue);
    } else {
```

```
        x.name = newValue;
    }
}

final static void jdoSetDept(Employee x, com.xyz.hr.Department newValue) {
    // this field is not in the default fetch group
   StateManager sm = x.jdoStateManager;
    if (sm != null) {
        sm.setObjectField(x,
                           jdoInheritedFieldCount + 1,
                           x.dept, newValue);
    } else {
        x.dept = newValue;
    }
}
```

23.22.10 Generated jdoReplaceField and jdoReplaceFields

The generated `jdoReplaceField` retrieves a new value from the `StateManager` for one specific field based on field number. This method is called by the `StateManager` whenever it wants to update the value of a field in the instance, for example to store values in the instance from the datastore.

This may be used by the `StateManager` to clear fields and handle cleanup of the objects currently referred to by the fields (e.g., embedded objects).

```
public void jdoReplaceField (int fieldNumber) {
    int relativeField = fieldNumber - jdoInheritedFieldCount;
    switch (relativeField) {
        case (0): boss = (Employee)
                    jdoStateManager.replacingObjectField (this,
                                                       fieldNumber);
                    break;
        case (1): dept = (Department)
                    jdoStateManager.replacingObjectField (this,
                                                       fieldNumber);
                    break;
        case (2): empid =
                    jdoStateManager.replacingIntField (this,
                                                       fieldNumber);
                    break;
        case (3): name =
                    jdoStateManager.replacingStringField (this,
                                                       fieldNumber);
                    break;
        default:
            /* if there is a pc superclass, delegate to it
            if (relativeField < 0) {
                super.jdoReplaceField (fieldNumber);
            } else {
                throw new IllegalArgumentException("fieldNumber");
            }
            */
            // if there is no pc superclass, throw an exception
            throw new IllegalArgumentException("fieldNumber");
    } // switch
}
public final void jdoReplaceFields (int[] fieldNumbers) {
    for (int i = 0; i < fieldNumbers.length; ++i) {
```

```
        int fieldNumber = fieldNumbers[i];
        jdoReplaceField (fieldNumber);
    }
}
```

23.22.11 Generated `jdoProvideField` and `jdoProvideFields`

The generated `jdoProvideField` gives the current value of one field to the `StateManager`. This method is called by the `StateManager` whenever it wants to get the value of a field in the instance, for example to store the field in the datastore.

```
public void jdoProvideField (int fieldNumber) {
    int relativeField = fieldNumber - jdoInheritedFieldCount;
    switch (relativeField) {
        case (0): jdoStateManager.providedObjectField(this,
            fieldNumber, boss);
        break;
        case (1): jdoStateManager.providedObjectField(this,
            fieldNumber, dept);
        break;
        case (2): jdoStateManager.providedIntField(this,
            fieldNumber, empid);
        break;
        case (3): jdoStateManager.providedStringField(this,
            fieldNumber, name);
        break;
        default:
            /* if there is a pc superclass, delegate to it
            if (relativeField < 0) {
                super.jdoProvideField (fieldNumber);
            } else {
                throw new IllegalArgumentException("fieldNumber");
            }
            */
            // if there is no pc superclass, throw an exception
            throw new IllegalArgumentException("fieldNumber");
    } // switch
}
public final void jdoProvideFields (int[] fieldNumbers) {
    for (int i = 0; i < fieldNumbers.length; ++i) {
        int fieldNumber = fieldNumbers[i];
        jdoProvideField (fieldNumber);
    }
}
```

23.22.12 Generated `jdoCopyField` and `jdoCopyFields` methods

The generated `jdoCopyFields` copies fields from another instance to this instance. This method might be used by the `StateManager` to create before images of instances for rollback, or to restore instances in case of rollback.

This method delegates to method `jdoCopyField` to copy values for all fields requested.

To avoid security exposure, `jdoCopyFields` can be invoked only when both instances are owned by the same `StateManager`. Thus, a malicious user cannot use this method to copy fields from a managed instance to a non-managed instance, or to an instance managed by a malicious `StateManager`.

```
public void jdoCopyFields (Object pc, int[] fieldNumbers){
    // the other instance must be owned by the same StateManager
```

```
// and our StateManager must not be null!
if (((PersistenceCapable)other).jdoStateManager
    != this.jdoStateManager)
    throw new IllegalArgumentException("this.jdoStateManager != other.jdoStateManager");
if (this.jdoStateManager == null)
    throw new IllegalStateException("this.jdoStateManager == null");

// throw ClassCastException if other class is the wrong class
Employee other = (Employee) pc;
for (int i = 0; i < fieldNumbers.length; ++i) {
    jdoCopyField (other, fieldNumbers[i]);
} // for loop
} // jdoCopyFields

protected void jdoCopyField (Employee other, int fieldNumber) {
    int relativeField = fieldNumber - jdoInheritedFieldCount;
    switch (relativeField) {
        case (0): this.boss = other.boss;
                    break;
        case (1): this.dept = other.dept;
                    break;
        case (2): this.empid = other.empid;
                    break;
        case (3): this.name = other.name;
                    break;
        default: // other fields handled in superclass
    // this class has no superclass, so throw an exception
    throw new IllegalArgumentException("fieldNumber");
    /* if it had a superclass, it would handle the field as follows:
       super.jdoCopyField (other, fieldNumber);
    */
    break;
    } // switch
} // jdoCopyField
```

23.22.13 Generated writeObject method

If no user-written method `writeObject` exists, then one will be generated. The generated `writeObject` makes sure that all persistent and transactional serializable fields are loaded into the instance, and then the default output behavior is invoked on the output stream.

```
private void writeObject(java.io.ObjectOutputStream out)
    throws java.io.IOException{
    jdoPreSerialize();
    out.defaultWriteObject ();
}
```

23.22.14 Generated jdoPreSerialize method

The generated `jdoPreSerialize` method makes sure that all persistent and transactional serializable fields are loaded into the instance by delegating to the corresponding method in `StateManager`.

```
private final void jdoPreSerialize() {
    if (jdoStateManager != null)
        jdoStateManager.preSerialize(this);
}
```

23.22.15 Generated jdoNewObjectIdInstance

The generated methods create and return a new instance of the object id class.

```
public Object jdoNewObjectIdInstance() {
    return new IntIdentity(Employee.class, empid);
}
public Object jdoNewObjectIdInstance(Object obj) {
    if (obj instanceof String) {
        return new IntIdentity(Employee.class, (String)str);
    } else if (obj instanceof Integer) {
        return new IntIdentity(Employee.class, (Integer)obj);
    } else if (obj instanceof ObjectIdFieldSupplier) {
        return new IntIdentity(Employee.class,
            ((ObjectIdFieldSupplier)obj).fetchIntField(2));
    } else
        throw new JDOUserException("illegal object id type");
}
```

23.22.16 Generated jdoCopyKeyFieldsToObjectId

The generated methods copy key field values from the PersistenceCapable instance or from the ObjectIdFieldSupplier.

```
public void jdoCopyKeyFieldsToObjectId (ObjectIdFieldSupplier fs, Object oid) {
    throw new JDOFatalInternalException("Object id is immutable");
}
public void jdoCopyKeyFieldsToObjectId (Object oid) {
    throw new JDOFatalInternalException("Object id is immutable");
}
```

23.22.17 Generated jdoCopyKeyFieldsFromObjectId

The generated methods copy key fields from the object id instance to the PersistenceCapable instance or to the ObjectIdFieldConsumer.

```
public void jdoCopyKeyFieldsFromObjectId (ObjectIdFieldConsumer fc, Object oid) {
    fc.storeIntField (2, ((IntIdentity)oid).getKey());
}
```

This method is part of the PersistenceCapable contract. It copies key fields from the object id instance to the ObjectIdFieldConsumer.

```
protected void jdoCopyKeyFieldsFromObjectId (Object oid) {
    empid = ((IntIdentity)oid).getKey();
}
```

This method is used internally to copy key fields from the object id instance to a newly created PersistenceCapable instance.

23.22.18 Generated Detachable methods

```
public void jdoReplaceDetachedState() {
    jdoDetachedState = sm.replacingDetachedState(this,
        jdoDetachedState);
}
} // end class definition
```

24 Interface StateManager

This chapter specifies the `StateManager` interface, which is responsible for managing the state of fields of persistence-capable classes in the JDO environment.

*NOTE: This interface is not intended to be used by application programmers.
It is for use only by implementations.*

24.1 Overview

A class that implements the JDO `StateManager` interface must be supplied by the JDO implementation. There is no user-visible behavior for this implementation; its only caller from the user's perspective is the `PersistenceCapable` class. Goals

This interface allows the JDO implementation to completely control the behavior of the `PersistenceCapable` classes under management. In particular, the implementation may choose to exploit the caching capabilities of `PersistenceCapable` or not.

The architecture permits JDO implementations to have a singleton `StateManager` for all `PersistenceCapable` instances; a `StateManager` for all `PersistenceCapable` instances associated with a particular `PersistenceManager` or `PersistenceManagerFactory`; a `StateManager` for all `PersistenceCapable` instances of a particular class; or a `StateManager` for each `PersistenceCapable` instance. This list is not intended to be exhaustive, but simply to identify the cases that might be typical.

Clone support

Note that any of the methods in this interface might be called by a clone of a persistence-capable instance, and the implementation of `StateManager` must disconnect the clone upon detecting it. Disconnecting the clone requires setting the clone's `jdoFlags` to `READ_WRITE_OK`; setting the clone's `jdoStateManager` to `null`; and then returning from the method as if the clone were transient. For example, in response to `isLoaded`, the `StateManager` calls `clone.jdoReplaceFlags(READ_WRITE_OK); clone.jdoReplaceStateManager(null); return true;`.

```
package javax.jdo.spi;  
public interface StateManager {
```

24.2 StateManager Management

The following methods provide for updating the corresponding `PersistenceCapable` fields. These methods are intended to be called only from the `PersistenceCapable` instance.

It is possible for these methods to be called from a cloned instance of a persistent instance (between the time of the execution of `clone()` and the enhancer-generated reset of the `jdoStateManager` and `jdoFlags` fields). In this case, the `StateManager` is not managing the clone. The `StateManager` must detect this case and disconnect the clone from the `StateManager`. The

end result of disconnecting is that the `jdoFlags` field is set to `READ_WRITE_OK` and the `jdoStateManager` field is set to null.

```
public StateManager replacingStateManager (PersistenceCapable pc,  
StateManager sm);
```

When the current `StateManager` is not null, it should be the only caller of `PersistenceCapable.jdoReplaceStateManager`, which calls this method. This method should be called when the current `StateManager` wants to set the `jdoStateManager` field to null to transition the instance to transient.

The `jdoFlags` are completely controlled by the `StateManager`. The meaning of the values are the following:

```
0: READ_WRITE_OK  
any negative number: READ_OK  
1: LOAD_REQUIRED  
2: DETACHED
```

```
public byte replacingFlags(PersistenceCapable pc);
```

This method is called by the `PersistenceCapable` in response to the `StateManager` calling `jdoReplaceFlags`. The `PersistenceCapable` will store the returned value into its `jdoFlags` field.

24.3 PersistenceManager Management

The following method provides for getting the `PersistenceManager`. This method is intended to be called only from the `PersistenceCapable` instance.

```
public PersistenceManager getPersistenceManager  
(PersistenceCapable pc);
```

24.4 Dirty management

The following methods provide for marking the `PersistenceCapable` instance dirty:

```
public void makeDirty (PersistenceCapable pc, String fieldName);  
public void makeDirty (PersistenceCapable pc, int fieldNumber);
```

24.5 State queries

The following methods are delegated from the `PersistenceCapable` class, to implement the associated behavior of `PersistenceCapable`.

```
public boolean isPersistent (PersistenceCapable pc);  
public boolean isTransactional (PersistenceCapable pc);  
public boolean isNew (PersistenceCapable pc);  
public boolean isDirty (PersistenceCapable pc);  
public boolean isDeleted (PersistenceCapable pc);
```

24.6 JDO Identity

```
public Object getObjectId (PersistenceCapable pc);
```

This method returns the JDO identity of the instance.

```
public Object getTransactionalObjectId (PersistenceCapable pc);
```

This method returns the transactional JDO identity of the instance.

24.7 Serialization support

```
public void preSerialize (PersistenceCapable pc);
```

This method loads all non-transient persistent fields in the `PersistenceCapable` instance, as a precursor to serializing the instance. It is called by the generated `jdoPreSerialize()` method in the `PersistenceCapable` class.

24.8 Field Management

The `StateManager` completely controls the behavior of the `PersistenceCapable` with regard to whether fields are loaded or not. Setting the value of the `jdoFlags` field in the `PersistenceCapable` directly affects the behavior of the `PersistenceCapable` with regard to fields in the default fetch group.

- The `StateManager` might choose to never cache any field values in the `PersistenceCapable`, but rather to retrieve the values upon request. To implement this strategy, the `StateManager` will always use the `LOAD_REQUIRED` value for the `jdoFlags`, and will always return `false` to any call to `isLoaded`.
- The `StateManager` might choose to selectively retrieve and cache field values in the `PersistenceCapable`. To implement this strategy, the `StateManager` will always use the `LOAD_REQUIRED` value for `jdoFlags`, and will return `true` to calls to `isLoaded` that refer to fields that are cached in the `PersistenceCapable`.
- The `StateManager` might choose to retrieve at one time all field values for fields in the default fetch group, and to take advantage of the performance optimization in the `PersistenceCapable`. To implement this strategy, the `StateManager` will use the `LOAD_REQUIRED` value for `jdoFlags` only when the fields in the default fetch group are not cached. Once all of the fields in the default fetch group are cached in the `PersistenceCapable`, the `StateManager` will set the value of the `jdoFlags` to `READ_OK`. This will probably be done during the call to `isLoaded` made for one of the fields in the default fetch group, and before returning `true` to the method, the `StateManager` will call `jdoReplaceFields` with the field numbers of all fields in the default fetch group, and will call `jdoReplaceFlags` to set `jdoFlags` to `READ_OK`.
- The `StateManager` might choose to manage updates of fields in the default fetch group individually. To implement this strategy, the `StateManager` will not use the `READ_WRITE_OK` value for `jdoFlags`. This will result in the `PersistenceCapable` always delegating to the `StateManager` for any change to any field. In this way, the `StateManager` can reliably tell when any field changes, and can optimize the writing of data to the store.

The following method is used by the `PersistenceCapable` to determine whether the value of the field is already cached in the `PersistenceCapable` instance. If it is cached (perhaps during

the execution of this method) then the value of the field is returned by the `PersistenceCapable` method without further calls to the `StateManager`.

```
boolean isLoaded (PersistenceCapable pc, int field);
```

24.8.1 User-requested value of a field

The following methods are used by the `PersistenceCapable` instance to inform the `StateManager` of a user-initiated request to access the value of a persistent field.

The `pc` parameter is the instance of `PersistenceCapable` making the call; the `field` parameter is the field number of the field; and the `currentValue` parameter is the current value of the field in the instance.

The current value of the field is passed as a parameter to allow the `StateManager` to cache values in the `PersistenceCapable`. If the value is cached in the `PersistenceCapable`, then the `StateManager` can simply return the current value provided with the method call.

```
public boolean getBooleanField (PersistenceCapable pc, int field,
                                boolean currentValue);

public char getCharField (PersistenceCapable pc, int field, char
                           currentValue);

public byte getByteField (PersistenceCapable pc, int field, byte
                           currentValue);

public short getShortField (PersistenceCapable pc, int field, short
                             currentValue);

public int getIntField (PersistenceCapable pc, int field, int
                           currentValue);

public long getLongField (PersistenceCapable pc, int field, long
                           currentValue);

public float getFloatField (PersistenceCapable pc, int field, float
                            currentValue);

public double getDoubleField (PersistenceCapable pc, int field,
                               double currentValue);

public String getStringField (PersistenceCapable pc, int field,
                               String currentValue);

public Object getObjectField (PersistenceCapable pc, int field,
                               Object currentValue);
```

24.8.2 User-requested modification of a field

The following methods are used by the `PersistenceCapable` instance to inform the `StateManager` of a user-initiated request to modify the value of a persistent field.

The `pc` parameter is the instance of `PersistenceCapable` making the call; the `field` parameter is the field number of the field; the `currentValue` parameter is the current value of the field in the instance; and the `newValue` parameter is the value of the field given by the user method.

```
public void setBooleanField (PersistenceCapable pc, int field,
                             boolean currentValue, boolean newValue);

public void setCharField (PersistenceCapable pc, int field, char
                           currentValue, char newValue);

public void setByteField (PersistenceCapable pc, int field, byte
                           currentValue, byte newValue);
```

```
public void setShortField (PersistenceCapable pc, int field, short
currentValue, short newValue);
public void setIntField (PersistenceCapable pc, int field, int
currentValue, int newValue);
public void setLongField (PersistenceCapable pc, int field, long
currentValue, long newValue);
public void setFloatField (PersistenceCapable pc, int field, float
currentValue, float newValue);
public void setDoubleField (PersistenceCapable pc, int field,
double currentValue, double newValue);
public void setStringField (PersistenceCapable pc, int field,
String currentValue, String newValue);
public void setObjectField (PersistenceCapable pc, int field,
Object currentValue, Object newValue);
```

24.8.3 StateManager-requested value of a field

The following methods inform the StateManager of the value of a persistent field requested by the StateManager.

The pc parameter is the instance of PersistenceCapable making the call; the field parameter is the field number of the field; and the currentValue parameter is the current value of the field in the instance.

```
public void providedBooleanField (PersistenceCapable pc, int field,
boolean currentValue);
public void providedCharField (PersistenceCapable pc, int field,
char currentValue);
public void providedByteField (PersistenceCapable pc, int field,
byte currentValue);
public void providedShortField (PersistenceCapable pc, int field,
short currentValue);
public void providedIntField (PersistenceCapable pc, int field, int
currentValue);
public void providedLongField (PersistenceCapable pc, int field,
long currentValue);
public void providedFloatField (PersistenceCapable pc, int field,
float currentValue);
public void providedDoubleField (PersistenceCapable pc, int field,
double currentValue);
public void providedStringField (PersistenceCapable pc, int field,
String currentValue);
public void providedObjectField (PersistenceCapable pc, int field,
Object currentValue);
```

24.8.4 StateManager-requested modification of a field

The following methods ask the StateManager for the value of a persistent field requested to be modified by the StateManager.

The `pc` parameter is the instance of `PersistenceCapable` making the call; and the `field` parameter is the field number of the field.

```
public boolean replacingBooleanField (PersistenceCapable pc, int field);
public char replacingCharField (PersistenceCapable pc, int field);
public byte replacingByteField (PersistenceCapable pc, int field);
public short replacingShortField (PersistenceCapable pc, int field);
public int replacingIntField (PersistenceCapable pc, int field);
public long replacingLongField (PersistenceCapable pc, int field);
public float replacingFloatField (PersistenceCapable pc, int field);
public double replacingDoubleField (PersistenceCapable pc, int field);
public String replacingStringField (PersistenceCapable pc, int field);
public Object replacingObjectField (PersistenceCapable pc, int field);
```

24.9 Detached instance support

```
public Object[] replacingDetachedState (
    Detached pc, Object[] loaded);
```

This method is called by a detachable instance in response to the `StateManager` calling `replaceDetachedState`. It provides the Detachable and the detached state to the `StateManager`.

25 JDOPermission

A permission represents access to a system resource. For a resource access to be allowed for an applet (or an application running with a security manager), the corresponding permission must be explicitly granted to the code attempting the access.

The `JDOPermission` class provides a marker for the security manager to grant access to a class to perform privileged operations necessary for JDO implementations.

The following JDO permissions are defined:

- `setStateManager`: this permission allows an instance to manage an instance of `PersistenceCapable`, which allows the instance to access and modify any fields defined as persistent or transactional. This permission is similar to but allows access to only a subset of the broader `ReflectPermission ("suppressAccessChecks")`. This permission is checked by the `PersistenceCapable.jdoReplaceStateManager` method.
- `getMetadata`: this permission allows an instance to access the metadata for any registered `PersistenceCapable` class. This permission allows access to a subset of the broader `RuntimePermission("accessDeclaredMembers")`. This permission is checked by the `JDOImplHelper.getJDOImplHelper` method.
- `closePersistenceManagerFactory`: this permission allows a caller to close a `PersistenceManagerFactory`, thereby releasing resources. This permission is checked by the `close()` method of `PersistenceManagerFactory.manageMetadata`: this permission allows a caller to unload metadata for a class or a class loader, thereby releasing resources. This permission is checked by the `unregisterClass()` and `unregisterClasses()` methods of `JDOImplHelper`.

These permissions are defined in the `JDOPermission` class.

```
package javax.jdo.spi;
public final class JDOPermission extends
    java.security.BasicPermission {
    ...
    public static final javax.jdo.spi.JDOPermission
        CLOSE_PERSISTENCE_MANAGER_FACTORY = "closePersistenceManagerFactory";
    public static final javax.jdo.spi.JDOPermission GET_METADATA = "getMetadata";
    public static final javax.jdo.spi.JDOPermission MANAGE_METADATA =
        "manageMetadata";
    public static final javax.jdo.spi.JDOPermission SET_STATE_MANAGER =
        "setStateManager";
}
```

Use of `JDOPermission` allows the security manager to restrict potentially malicious classes from accessing information contained in instances of `PersistenceCapable`.

A sample policy file entry granting code from the `/home/jdoImpl` directory permission to get metadata, manage `PersistenceCapable` instances, and close `PersistenceManagerFactory` instances is

```
grant codeBase "file:/home/jdoImpl/" {
```

```
permission javax.jdo.spi.JDOPermission "getMetadata";
permission javax.jdo.spi.JDOPermission "setStateManager";
permission javax.jdo.spi.JDOPermission
    "closePersistenceManagerFactory";
permission javax.jdo.spi.JDOPermission "manageMetadata";
};
```

26 JDOQL BNF

Grammar Notation

The grammar notation is taken from the Java Language Specification, section 2.4 Grammar Notation.

- Terminal symbols are shown in bold fixed width font in the productions of the lexical and syntactic grammars, and throughout this specification whenever the text is directly referring to such a terminal symbol. These are to appear in a program exactly as written.
- Nonterminal symbols are shown in italic type. The definition of a nonterminal is introduced by the name of the nonterminal being defined followed by a colon. One or more alternative right-hand sides for the nonterminal then follow on succeeding lines.
- The subscripted suffix "opt", which may appear after a terminal or nonterminal, indicates an optional symbol. The alternative containing the optional symbol actually specifies two right-hand sides, one that omits the optional element and one that includes it.
- When the words "one of" follow the colon in a grammar definition, they signify that each of the terminal symbols on the following line or lines is an alternative definition.

26.1 Single-String JDOQL

This section describes the syntax of single-string JDOQL.

SingleStringJDOQL:

`Select Fromopt Whereopt Decls Groupingopt Orderingopt Rangeopt`

Select:

`select uniqueopt ResultClauseopt IntoClauseopt`

IntoClause:

`into ResultClassName`

From:

`from CandidateClassName ExcludeClauseopt`

ExcludeClause:

`exclude subclasses`

Where:

`where Expression`

Decl_s:

`Variablesopt Parametersopt Importsopt`

Variables:

`variables VariableList`

Parameters:

parameters *ParameterList*

Imports:

ImportList

Grouping:

group by *GroupingClause*

Ordering:

order by *OrderingClause*

Range:

range *Expression , Expression*

26.2 Filter Specification

This section describes the syntax of the setFilter argument.

Basically, the query filter expression is a Java boolean expression, where some of the Java operators are not permitted. Specifically, pre- and post- increment and decrement (++ and - -), shift (>> and <<) and assignment expressions (+=, -=, etc.) are not permitted.

The Nonterminal *InfixOp* lists the valid operators for binary expressions in decreasing precedence. Operators one the same line have the same precedence. As in Java operators require operands of appropriate types. See the Java Language Specification for more information.

Please note, the grammar allows arbitrary method calls (see *MethodInvocation*), where JDO only permits the following methods:

Collection methods	<code>contains(Object)</code> , <code>isEmpty()</code> , <code>size()</code>
Map methods	<code>containsKey(Object)</code> , <code>containsValue(Object)</code> , <code>isEmpty()</code> , <code>size()</code> , <code>get()</code>
String methods	<code>startsWith(String)</code> , <code>endsWith(String)</code> , <code>matches(String)</code> , <code>toLowerCase()</code> , <code>toUpperCase()</code> , <code>indexOf(String)</code> , <code>indexOf(String, int)</code> , <code>substring(int)</code> , <code>substring(int, int)</code>
Math methods	<code>Math.abs(numeric)</code> , <code>Math.sqrt(numeric)</code>
JDOHelper methods	<code>getObjectId(Object)</code>

Expression:

UnaryExpression

Expression InfixOp UnaryExpression

InfixOp: one of

`*` / `%`

`+` `-`

`>` `>=` `<` `<=` `instanceof`

`==` `!=`

`&`

`|`

&&

||

UnaryExpression:

PrefixOp UnaryExpression
(Type) UnaryExpression
Primary

PrefixOp: one of

+ **-** **~** **!**

Primary:

Literal
VariableName
ParameterName
this
FieldAccess
MethodInvocation
ClassOrInterfaceName
(Expression)
(Subquery)
*AggregateExpression*¹

FieldAccess:

FieldName
Primary . FieldName

MethodInvocation:

Primary . MethodName (ArgumentList_{opt})

ArgumentList:

Expression
ArgumentList , Expression

AggregateExpression:

count (**distinct**_{opt} *CountArgument*)
sum (**distinct**_{opt} *Expression*)
min (*Expression*)
max (*Expression*)
avg (**distinct**_{opt} *Expression*)

CountArgument:

this
FieldAccess
VariableName

¹ Please note, an *AggregateExpression* is only allowed as part of a result specification or a having specification.

26.3 Subqueries

This section describes the syntax of subqueries in JDOQL.

```
Subquery:  
    SubquerySelect SubqueryFrom Whereopt Decls  
  
SubquerySelect:  
    select SubqueryResultClause  
  
SubqueryResultClause:  
    distinctopt Expression ,opt  
  
SubqueryFrom:  
    from CandidateClassName Aliasopt ExcludeClauseopt  
    from FieldAccess Aliasopt  
  
Alias:  
    asopt Identifier
```

26.4 Parameter Declaration

This section describes the syntax of the declareParameters argument.

```
ParameterList:  
    Parameters ,opt  
  
ParameterDecls:  
    ParameterDecl  
    ParameterDecls , ParameterDecl  
  
ParameterDecl:  
    Type ParameterName
```

Please note, as a usability feature *ParameterList* supports an optional trailing comma (in addition to what the Java syntax allows in a parameter declaration).

26.5 Variable Declaration

This section describes the syntax of the declareVariables argument.

```
VariableList:  
    VariableDecls ;opt  
  
VariableDecls:  
    VariableDecl  
    VariableDecls ; VariableDecl  
  
VariableDecl:  
    Type ParameterName
```

Please note, as a usability feature *VariableList* defines the trailing semicolon as optional (in addition to what the Java syntax allows in a variable declaration).

26.6 Import Declaration

This section describes the syntax of the declareImports argument.

```
ImportList:  
    ImportDecls ;opt  
  
ImportDecls:  
    ImportDecl  
    ImportDecls ; ImportDecl  
  
ImportDecl:  
    import QualifiedIdentifier  
    import QualifiedIdentifier . *
```

Please note, as a usability feature *ImportList* defines the trailing semicolon as optional (in addition to what the Java syntax allows in an import statement).

26.7 Ordering Specification

This section describes the syntax of the setOrdering argument.

```
OrderingClause:  
    OrderingSpecs ,opt  
  
OrderingSpecs:  
    OrderingSpec  
    OrderingSpecs , OrderingSpec  
  
OrderingSpec:  
    Expression Ascending  
    Expression Descending  
  
Ascending: one of  
    asc ascending  
  
Descending: one of  
    desc descending
```

Please note, as a usability feature *OrderingClause* supports an optional trailing comma.

26.8 Result Specification

This section describes the syntax of the setResult argument.

```
ResultClause:  
    distinctopt ResultSpecs ,opt  
  
ResultSpecs:  
    ResultSpec  
    ResultSpecs , ResultSpec
```

ResultSpec:
 *Expression ResultNaming*_{opt}

ResultNaming:
 as *Identifier*

Please note, a result specification expression may be an aggregate expression. As a usability feature *ResultClause* supports an optional trailing comma.

26.9 Grouping Specification

This section describes the syntax of the setGrouping argument.

GroupingClause:
 *GroupingSpecs ,*_{opt} *HavingSpec*_{opt}

GroupingSpecs:
 Expression
 GroupingSpecs , Expression

HavingSpec:
 having *Expression*

Please note, a having specification expression may include an aggregate expression. As a usability feature *GroupingClause* supports an optional trailing comma.

26.10 Types

This section describes a type specification, used in a parameter or variable declaration or in a cast expression.

Type
 PrimitiveType
 ClassName

PrimitiveType:
 NumericType
 boolean

NumericType:
 IntegralType
 FloatingPointType

IntegralType: one of
 byte short int long char

FloatingPointType: one of
 float double

26.11 Literals

A literal is the source code representation of a value of a primitive type, or the String type. Please refer to the Java Language Specification for the lexical structure of Integer-, Floating Point-, and String-Literals. JDOQL allows String-Literals being enclosed in either single quotes or double quotes. A single character enclosed in either single or double quotes is considered to be both: a char and a string literal.

Literal:

IntegerLiteral
FloatingPointLiteral
BooleanLiteral
StringLiteral
NullLiteral

IntegerLiteral: ...

FloatingPointLiteral: ...

BooleanLiteral: one of
 true **false**

StringLiteral: ...

NullLiteral:
 null

26.12 Names

A name is a possibly qualified identifier. Please refer to the Java Language Specification for the lexical structure of identifiers.

QualifiedIdentifier:
 Identifier
 QualifiedIdentifier . *Identifier*

CandidateClassName:
 QualifiedIdentifier

ResultClassName:
 QualifiedIdentifier

ClassOrInterfaceName:
 QualifiedIdentifier

VariableName:
 Identifier

ParameterName:
 Identifier
 ColonPrefixedIdentifier

FieldName:
Identifier

MethodName:
Identifier

26.13 Keywords

Keywords must not be used as package names, class names, parameter names, or variable names in queries. Keywords are permitted as field names only if they are on the right side of the “.” in field access expressions as defined in the Java Language Specification second edition, section 15.11. Keywords include the Java language keywords and the JDOQL keywords. Java keywords are as defined in the Java language specification section 3.9, plus the boolean literals true and false, and the null literal. JDOQL keywords maybe written in all lower case or all upper case.

JDOQLKeyword: one of

as	AS	asc	ASC
ascending	ASCENDING	avg	AVG
by	BY	count	COUNT
desc	DESC	descending	DESCENDING
distinct	DISTINCT	exclude	EXCLUDE
from	FROM	group	GROUP
having	HAVING	into	INTO
max	MAX	min	MIN
order	ORDER	parameters	PARAMETERS
range	RANGE	select	SELECT
subclasses	SUBCLASSES	sum	SUM
unique	UNIQUE	variables	VARIABLES
where	WHERE		

27 Items Deferred to the Next Release

This chapter contains the list of items that were raised during the development of JDO but were not resolved.

27.1 Nested Transactions

Define the semantics of nested transactions.

This proposal is still pending as of JDO 2.0.

27.2 Savepoint, Undosavepoint

Related to nested transactions, savepoints allow for making changes to instances and then undoing those changes without making any datastore changes. It is a single-child nested transaction.

This proposal is still pending as of JDO 2.0.

27.3 Inter-PersistenceManager References

Explain how to establish and maintain relationships between persistent instances managed by different PersistenceManagers.

This proposal is still pending as of JDO 2.0.

27.4 Enhancer Invocation API

A standard interface to call the enhancer will be defined.

This proposal is resolved as of JDO 2.3.

27.5 Prefetch API

A standard interface to specify prefetching of instances by policy will be defined. The intended use it to allow the application to specify a policy whereby instances of persistence capable classes will be prefetched from the datastore when related instances are fetched. This should result in improved performance characteristics if the prefetch policy matches actual application access patterns.

This functionality is now part of JDO 2.0.

27.6 BLOB/CLOB datatype support

JDO implementations can choose to implement mapping from java.sql.Blob datatype to byte arrays, and java.sql.Clob to String or other java type; but these mappings are not standard, and may not have the performance characteristics desired.

This functionality is now part of JDO 2.0.

27.7 Managed (inverse) relationship support

In order for JDO implementations to be used for container managed persistence entity beans, relationships among persistent instances need to be explicitly managed. See the EJB Specification 2.0, sections 9.4.6 and 9.4.7 for requirements. The intent is to support these semantics when the relationships are identified in the metadata as inverse relationships.

This functionality is part of JDO 2.0.

27.8 Case-Insensitive Query

Use of `String.toLowerCase()` as a supported method in query filters would allow case-insensitive queries.

This functionality is now part of JDO 2.0.

27.9 String conversion in Query

Supported `String` constructors `String(<integer expression>)` and `String(<floating-point expression>)` would make queries more flexible.

This proposal is still pending as of JDO 2.0.

27.10 Read-only fields

Support (probably marking the fields in the XML metadata) for read-only fields would allow better support for databases where modification of data elements is proscribed. The metadata annotation would permit earlier detection of incorrect modification of the corresponding fields.

27.11 Enumeration pattern

The enumeration pattern is a powerful technique for emulating enums. The pattern in summary allows for fields to be declared as:

```
class Foo {
    Bar myBar = Bar.ONE;
    Bar someBar = new Bar("illegal"); // doesn't compile
}
class Bar {
    private String istr;
    private Bar(String s) {
        istr = s;
    }
    public static Bar ONE = new Bar("one");
    public static Bar TWO = new Bar("two");
}
```

The advantage of this pattern is that fields intended to contain only certain values can be constrained to those values. Supporting this pattern explicitly allows for classes that use this pattern to be supported as persistence-capable classes.

Enums are supported as persistent field types as of JDO 2.0

27.12 Non-static inner classes

Allow non-static inner classes to be persistence-capable. The implication is that the enclosing class must also be persistence-capable, and there is a one-many relationship between the enclosing class and the inner class.

27.13 Projections in query

Currently the only return value from a JDOQL query is a Collection of persistent instances. Many applications need values returned from queries, not instances. For example, to properly support EJBQL, projections are required. One way to provide projections is to model what EJBQL has already done, and add a method setResult (String projection) to javax.jdo.Query. This method would take as a parameter a single-valued navigation expression. The result of execute for the query would be a Collection of instances of the expression.

This functionality is now part of JDO 2.0.

27.14 LogWriter support

Currently, there is no direct support for writing log messages from an implementation, although there is a connection factory property that can be used for this purpose. A future revision could define how an implementation should use a log writer.

27.15 New Exceptions

Some exceptions might be added to more clearly define the cause of an exception. Candidates include `JDODuplicateObjectException`, `JDOClassNotPersistenceCapableException`, `JDOExtentNotManagedException`, `JDOConcurrentModificationException`, `JDOQueryException`, `JDOQuerySyntaxException`, `JDOUnboundQueryParameterException`, `JDOTransactionNotActiveException`, `JDODeletedObjectFieldAccessException`.

27.16 Distributed object support

Provide for remote object graph support, including instance reconciliation, relationship graph management, instance insertion ordering, etc.

This functionality is now part of JDO 2.0.

27.17 Object-Relational Mapping

Extend the current xml metadata to include optional O/R mapping information. This could include tables to map to classes, columns to map to fields, and foreign keys to map to relationships.

Other O/R mapping issues include sequence generation for primary key support.

This functionality is now part of JDO 2.0.

28 JDO 1.0.1 Metadata

This chapter specifies the metadata that describes a persistence-capable class. The metadata is stored in XML format. The information must be available when the class is enhanced, and might be cached by an implementation for use at runtime. If the metadata is changed between enhancement and runtime, the behavior is unspecified.

Metadata files must be available via resources loaded by the same class loader as the class. These rules apply both to enhancement and to runtime. Hereinafter, the term "metadata" refers to the aggregate of all XML data for all packages and classes, regardless of their physical packaging.

The metadata associated with each persistence capable class must be contained within a file, and its format is defined by the DTD. If the metadata is for only one class, then its file name is <classname>.jdo. If the metadata is for a package, or a number of packages, then its file name is package.jdo. In this case, the file is located in one of several directories: "META-INF", "WEB-INF"; <none>, in which case the metadata file name is "package.jdo" with no directory; "<package>/.../ <package>", in which case the metadata directory name is the partial or full package name with "package.jdo" as the file name.

When metadata information is needed for a class, and the metadata for that class has not already been loaded, the metadata is searched as follows: META-INF/package.jdo, WEB-INF/package.jdo, package.jdo, <package>/.../ <package>/package.jdo, and <package>/<class>.jdo. Once metadata for a class has been loaded, the metadata will not be replaced in memory. Therefore, metadata contained higher in the search order will always be used instead of metadata contained lower in the search order.

For example, if the persistence-capable class is com.xyz.Wombat, and there is a file "META-INF/package.jdo" containing xml for this class, then its definition is used. If there is no such file, but there is a file "WEB-INF/package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "com/package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "com/xyz/package.jdo" containing metadata for com.xyz.Wombat, then it is used. If there is no such file, but there is a file "com/xyz/Wombat.jdo", then it is used. If there is no such file, then com.xyz.Wombat is not persistence-capable.

Note that this search order is optimized for implementations that cache metadata information as soon as it is encountered so as to optimize the number of file accesses needed to load the metadata. Further, if metadata is not in the natural location, it might override metadata that is in the natural location. For example, while looking for metadata for class com.xyz.Wombat, the file com/package.jdo might contain metadata for class org.acme.Foo. In this case, subsequent search of metadata for org.acme.Foo will find the cached metadata and none of the usual locations for metadata will be searched.

The metadata must declare all persistence-capable classes. If any field declarations are not provided in the metadata, then field metadata is defaulted for the missing field declarations. Therefore, the JDO implementation is able to determine based on the metadata whether a class is persistence-capable or not. And any class not known to be persistence-capable by the JDO specification (for example, java.lang.Integer) and not explicitly named in the metadata is not persistence-capable.

For compatibility with installed applications, an implementation might first use the search order as specified in the JDO 1.0 release. In this case, if metadata is not found, then the search order as specified in JDO 1.0.1 must be used.

28.1 ELEMENT jdo

This element is the highest level element in the xml document. It is used to allow multiple packages to be described in the same document.

28.2 ELEMENT package

This element includes all classes in a particular package. The complete qualified package name is required.

28.3 ELEMENT class

This element includes fields declared in a particular class, and optional vendor extensions. The name of the class is required. The name is relative to the package name of the enclosing package.

Only persistence-capable classes may be declared. Non-persistence-capable classes must not be included in the metadata.

The identity type of the least-derived persistence-capable class defines the identity type for all persistence-capable classes that extend it.

The identity type of the least-derived persistence-capable class is defaulted to application if objectid-class is specified, and datastore, if not.

The objectid-class attribute is required only for application identity. The objectid class name uses Java rules for naming: if no package is included in the name, the package name is assumed to be the same package as the persistence-capable class. Inner classes are identified by the "\$" marker. If the objectid-class attribute is defined in any concrete class, then the objectid class itself must be concrete, and no subclass of the class may include the objectid-class attribute. If the objectid-class attribute is defined for any abstract class, then:

- the objectid class of this class must directly inherit Object or must be a subclass of the objectid class of the most immediate abstract persistence-capable superclass that defines an objectid class; and
- if the objectid class is abstract, the objectid class of this class must be a superclass of the objectid class of the most immediate subclasses that define an objectid class; and
- if the objectid class is concrete, no subclass of this persistence-capable class may define an objectid class.

The effect of this is that objectid classes form an inheritance hierarchy corresponding to the inheritance hierarchy of the persistence-capable classes. Associated with every concrete persistence-capable class is exactly one objectid class.

The objectid class must declare fields identical in name and type to fields declared in this class.

The requires-extent attribute specifies whether an extent must be managed for this class. The PersistenceManager.getExtent method can be executed only for classes whose metadata attribute requires-extent is specified or defaults to true. If the PersistenceManager.getExtent method is executed for a class whose metadata specifies requires-extent as false, a JDOUserException is thrown. If requires-extent is specified or defaults to true for a class, then requires-extent must not be specified as false for any subclass.

The `persistence-capable-superclass` attribute is deprecated for this release. It is ignored so metadata files from previous releases can be used.

28.4 ELEMENT field

The `element` field is optional, and the `name` attribute is the field name as declared in the class. If the field declaration is omitted in the xml, then the values of the attributes are defaulted.

The `persistence-modifier` attribute specifies whether this field is persistent, transactional, or none of these. The `persistence-modifier` attribute can be specified only for fields declared in the Java class, and not fields inherited from superclasses. There is special treatment for fields whose `persistence-modifier` is `persistent` or `transactional`.

Default persistence-modifier

The default for the `persistence-modifier` attribute is based on the Java type and modifiers of the field:

- Fields with modifier `static: none`. No accessors or mutators will be generated for these fields during enhancement.
- Fields with modifier `transient: none`. Accessors and mutators will be generated for these fields during enhancement, but they will not delegate to the `StateManager`.
- Fields with modifier `final: none`. Accessors will be generated for these fields during enhancement, but they will not delegate to the `StateManager`.
- Fields of a type declared to be `persistence-capable: persistent`.
- Fields of the following types: `persistent`:
 - primitives: `boolean, byte, short, int, long, char, float, double`;
 - `java.lang` wrappers: `Boolean, Byte, Short, Integer, Long, Character, Float, Double`;
 - `java.lang`: `String, Number`;
 - `java.math`: `BigDecimal, BigInteger`;
 - `java.util`: `Currency, Date, Locale, ArrayList, HashMap, HashSet, Hashtable, LinkedHashMap, LinkedHashSet, LinkedList, TreeMap, TreeSet, Vector, Collection, Set, List, and Map`;
 - Arrays of primitive types, `java.util.Date, java.util.Locale, java.lang` and `java.math` types specified immediately above, and `persistence-capable` types.
- Fields of types of user-defined classes and interfaces not mentioned above: `none`. No accessors or mutators will be generated for these fields.

The `primary-key` attribute is used to identify fields that have special treatment by the enhancer and by the runtime. The enhancer generates accessor methods for primary key fields that always permit access, regardless of the state of the instance. The mutator methods always delegate to the `jdoStateManager`, if it is non-null, regardless of the state of the instance.

The `null-value` attribute specifies the treatment of `null` values for persistent fields during storage in the datastore. The default is "none".

- "none": store `null` values as `null` in the datastore, and throw a `JDOUserException` if `null` values cannot be stored by the datastore.
- "exception": always throw a `JDOUserException` if this field contains a `null` value at runtime when the instance must be stored;

- "default": convert the value to the datastore default value if this field contains a null value at runtime when the instance must be stored.

The `default-fetch-group` attribute specifies whether this field is managed as a group with other fields. It defaults to "true" for non-key fields of primitive types, `java.util.Date`, and fields of `java.lang`, `java.math` types specified above.

The `embedded` attribute specifies whether the field should be stored as part of the containing instance instead of as its own instance in the datastore. It must be specified or default to "true" for fields of primitive types, wrappers, `java.lang`, `java.math`, `java.util`, collection, map, and array types specified above; and "false" otherwise. While a compliant implementation is permitted to support these types as first class instances in the datastore, the semantics of `embedded="true"` imply containment. That is, the embedded instances have no independent existence in the datastore and have no Extent representation.

If the `embedded` attribute is "true" the field values are stored as persistent references to the referred instances in the datastore.

The `embedded` attribute applied to a field of a persistence-capable type is a hint to the implementation to treat the field as if it were a Second Class Object. But this behavior is not further specified and is not portable.

A portable application must not assign instances of mutable classes to multiple embedded fields, and must not compare values of these fields using Java identity ("`f1==f2`").

The following field declarations are mutually exclusive; only one may be specified:

- `default-fetch-group = "true"`
- `primary-key = "true"`
- `persistence-modifier = "transactional"`
- `persistence-modifier = "none"`

28.4.1 ELEMENT collection

This element specifies the element type of collection typed fields. The default is `Collection` typed fields are persistent, and the element type is `Object`.

The `element-type` attribute specifies the type of the elements. The type name uses Java rules for naming: if no package is included in the name, the package name is assumed to be the same package as the persistence-capable class. Inner classes are identified by the "\$" marker.

The `embedded-element` attribute specifies whether the values of the elements should be stored as part of the containing instance instead of as their own instances in the datastore. It defaults to "false" for persistence-capable types, `Object` types, and interface types; and "true" for other types.

The embedded treatment of the collection instance itself is governed by the `embedded` attribute of the field element.

28.4.2 ELEMENT map

This element specifies the treatment of keys and values of map typed fields. The default is map typed fields are persistent, and the key and value types are `Object`.

The `key-type` and `value-type` attributes specify the types of the key and value, respectively. The type names use Java rules for naming: if no package is included in the name, the package name is assumed to be the same package as the persistence-capable class. Inner classes are identified by the "\$" marker.

The `embedded-key` and `embedded-value` attributes specify whether the key and value should be stored as part of the containing instance instead of as their own instances in the datastore. They

default to "false" for persistence-capable types, Object types, and interface types; and "true" for other types.

The embedded treatment of the map instance itself is governed by the embedded attribute of the field element.

28.4.3 ELEMENT array

This element specifies the treatment of array typed fields. The default persistence-modifier for array typed fields is based on the Java type of the component and modifiers of the field, according to the rules in **18.4 Default persistence-modifier**.

The embedded-element attribute specifies whether the values of the components should be stored as part of the containing instance instead of as their own instances in the datastore. It defaults to "false" for persistence-capable types, Object types, interface types, and concrete implementation classes of map and collection types. It defaults to "true" for other types.

The embedded treatment of the array instance itself is governed by the embedded attribute of the field element.

28.5 ELEMENT extension

This element specifies JDO vendor extensions. The vendor-name attribute is required. The vendor name "JDORI" is reserved for use by the JDO reference implementation. The key and value attributes are optional, and have vendor-specific meanings. They may be ignored by any JDO implementation.

28.6 The Document Type Descriptor

The document type descriptor is referred by the xml, and must be identified with a DOCTYPE so that the parser can validate the syntax of the metadata file. Either the SYSTEM or PUBLIC form of DOCTYPE can be used.

- If SYSTEM is used, the URI must be accessible; a jdo implementation might optimize access for the URI "file:/javax/jdo/jdo.dtd"
- If PUBLIC is used, the public id should be "-//Sun Microsystems, Inc.//DTD Java Data Objects Metadata 1.0//EN"; a jdo implementation might optimize access for this id.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jdo
    PUBLIC "-//Sun Microsystems, Inc.//DTD Java Data Objects Metadata 1.0//EN"
    "http://java.sun.com/dtd/jdo_1_0.dtd">
<!ELEMENT jdo ((package)+, (extension)*)>
<!ELEMENT package ((class)+, (extension)*)>
<!ATTLIST package name CDATA #REQUIRED>
<!ELEMENT class (field|extension)*>
<!ATTLIST class name CDATA #REQUIRED>
<!ATTLIST class identity-type (application|datastore|nondurable) #IMPLIED>
<!ATTLIST class objectid-class CDATA #IMPLIED>
<!ATTLIST class requires-extent (true|false) 'true'>
<!ATTLIST class persistence-capable-superclass CDATA #IMPLIED>
<!ELEMENT field ((collection|map|array)?, (extension)*)?>
<!ATTLIST field name CDATA #REQUIRED>
<!ATTLIST field persistence-modifier (persistent|transactional|none) #IMPLIED>
<!ATTLIST field primary-key (true|false) 'false'>
<!ATTLIST field null-value (exception|default|none) 'none'>
<!ATTLIST field default-fetch-group (true|false) #IMPLIED>
```

```
<!ATTLIST field embedded (true|false) #IMPLIED>
<!ELEMENT collection (extension)*>
<!ATTLIST collection element-type CDATA #IMPLIED>
<!ATTLIST collection embedded-element (true|false) #IMPLIED>
<!ELEMENT map (extension)*>
<!ATTLIST map key-type CDATA #IMPLIED>
<!ATTLIST map embedded-key (true|false) #IMPLIED>
<!ATTLIST map value-type CDATA #IMPLIED>
<!ATTLIST map embedded-value (true|false) #IMPLIED>
<!ELEMENT array (extension)*>
<!ATTLIST array embedded-element (true|false) #IMPLIED>
<!ELEMENT extension (extension)*>
<!ATTLIST extension vendor-name CDATA #REQUIRED>
<!ATTLIST extension key CDATA #IMPLIED>
<!ATTLIST extension value CDATA #IMPLIED>
```

28.7 Example XML file

An example XML file for the query example classes follows. Note that all fields of both classes are persistent, which is the default for fields. The `emps` field in `Department` contains a collection of elements of type `Employee`, with an inverse relationship to the `dept` field in `Employee`.

In directory `com/xyz`, a file named `hr.jdo` contains:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jdo SYSTEM "jdo.dtd">
<jdo>
  <package name="com.xyz.hr">
    <class name="Employee" identity-type="application" objectid-class="IntIdentity">
      <field name="name" primary-key="true">
        <extension vendor-name="sunw" key="index" value="btree"/>
      </field>
      <field name="salary" default-fetch-group="true"/>
      <field name="dept">
        <extension vendor-name="sunw" key="inverse" value="emps"/>
      </field>
      <field name="boss" />
    </class>
    <class name="Department" identity-type="application" objectid-
      class="DepartmentKey">
      <field name="name" primary-key="true"/>
      <field name="emps">
        <collection element-type="Employee">
          <extension vendor-name="sunw" key="element-inverse" value="dept"/>
        </collection>
      </field>
    </class>
  </package>
</jdo>
```

Appendix A: References

- [1] **Enterprise JavaBeans (EJB) specification:**
<http://java.sun.com/products/ejb/docs.html>
- [2] **Java Transaction API (JTA) specification - version 1.0**
<http://java.sun.com/products/jta/>
- [3] **Java 2 Platform Enterprise Edition (J2EE), Platform specification:**
<http://java.sun.com/j2ee/docs.html>
- [4] **Java 2 Platform Enterprise Edition (J2EE), Connector Architecture:**
<http://java.sun.com/j2ee/apidocs/>
<http://java.sun.com/j2ee/download.html#connectorspec>

Appendix B: Design Decisions

This appendix outlines some of the design decisions that were considered and not taken, along with the rationale.

B.1 Enhancer

With JDO 2.0, enhancement is now no longer required. Reflection techniques for examining persistent instances at transaction commit can be used instead, and proxies can be used to fault in referenced instances.

The enhancer could generate code that would delegate to the associated StateManager every access (read or write) for every field. This design was rejected because of several factors.

- Code bloat: the enhanced code would add an extra method call to every access to a persistent field.
- Performance: the calls to the StateManager would add extra cycles to every access to a persistent field, even if the field were already fetched into the persistent instance.

The enhancer could require complete metadata descriptions for all persistence-capable classes and persistent and transactional fields, and further require that all classes be available during enhancement of any class.

This would allow the enhancer to generate the most efficient code, but imposes an extra burden on the user to keep the metadata and class definition absolutely in sync. If a field were declared in a class after the metadata was defined, the user would have to update the metadata to add the new field.

Requiring access to all classes during enhancement of any class was also seen as an extra burden on the user, who would have to execute the enhancement in an environment that did not necessarily reflect the runtime environment. There is also a performance penalty and additional complexity for the enhancer.

The decision that was taken was that the enhancer must be able to determine the persistence-modifier (persistent or none) from the Java modifiers and type of a field. Further, the information needed to enhance a class is only the class file for the class being enhanced, plus the metadata for the class and classes directly reachable (via references or inheritance) from the class.

The java byte codes generated in a class for a field in another class do not contain much information about the modifiers (final or transient) of the field. They do have the field name and the field type, and whether the field is static. There is an implied access control that permits the generated access (package, protected, or public) but no distinction among the choices.

Therefore, a field that is not declared in the metadata must be enhanced to generate an accessor and mutator even though the field is not persistent. For example, for a final int field declared in a class, the field is not persistent, so it is not included in the list of persistent/transactional fields, but an accessor is generated for it. This accessor will be used only by other classes' accesses, and access will not be mediated (the StateManager will never be called). Accesses within the class are not enhanced.

Appendix C: Revision History

This appendix outlines the significant changes during the evolution of the specification.

C.1 Changes since Draft 0.1

- Added Appendix for revision history
- Added Appendix for design decisions not taken

C.2 Changes since Draft 0.2

- Changed the description for the persistent state (cached non-transactional values)
- Added JDO instance state transition diagram and descriptions of state transitions.
- Enhanced description of non-datastore JDO identity.
- Added persistent-new-dirty and persistent-new-clean states to the life cycle.
- Removed the `checkpoint` method from the `Transaction` interface. This functionality is now done by the `TRANSACTION_RETAIN_VALUES` Transaction flag.
- Added `jdoCopy` to the `PersistenceCapable` interface.
- Added `Query` interface.

C.3 Changes since Draft 0.3

- Changed `Query` signatures for `setVars` and `setParams`.
- Changed all “set” `Query` signatures to return `void` instead of “`Query`”.
- Added description of key (JDO identity) change semantics.
- Added life cycle description for `deletePersistent`, a new interrogatory `jdoIsDeleted`, and two new states `persistent-new-deleted` and `persistent-deleted`.
- Added Chapter 6 Persistent Object Model, which specifies the field types for persistent fields, including the required Collection types.
- Added descriptions of enhancement to Chapter 13 JDO Enhancer, including serialization, cloning, and reflection.
- Added multiple object versions of `makePersistent`, `makeTransactional`, `makeNontransactional`.

C.4 Changes since Draft 0.4

C.4.1 PersistenceManager

- Removed flush and `postCompletion` from the API.
- Changed refresh to indicate it is effective only in optimistic transactions.
- Removed `getFlags` and `setFlags`, substituting `getXXX` and `setXXX` for all options.
- Added `getProperties`, which returns `VendorName`, `VersionNumber`, etc.
- Added `get/setUserObject`, which allow a user-specified object to be remembered by the PersistenceManager.
- Required the implementation to support `PersistenceManagerFactory` and specified the interface for it.

Associated the concept of Extent with makePersistent and deletePersistent. Only classes with a managed Extent can be parameters of these methods.

Added getObjectIdClass to allow the application to get the ObjectId class for a class.

C.4.2 **Query**

Added newQuery (Class cls, String filter).

Changed signature of compile to return void. This is not required to do anything but validate query elements.

Made the Query implementation class serializable. A serialized and restored query instance can be bound to a PersistenceManager by newQuery (Object).

Removed execute methods with four, five, and six parameters.

Allowed Date comparisons for equality and range queries.

Allowed String comparisons for equality and range queries.

Added "this" as a valid keyword in filters.

Added a query option to indicate faster queries that don't execute the filter on cached instances.

Clarified that portable applications require all variables to be scoped by a contains clause.

Defined that variables not scoped by a contains clause are scoped by the Extent of the class.

C.4.3 **Object Model**

Changed the name of "Tracked SCO" to "SCO".

Required a transaction to be in effect to execute makePersistent and deletePersistent.

Allowed an implementation to treat all reference types as First Class Objects.

Sharing of SCOs is permitted but the semantics are not guaranteed to be portable.

C.4.4 **Life Cycle**

Removed state persistent-new-clean and changed the name of persistent-new-dirty to persistent-new.

Updated life cycle state diagram to simplify state transition descriptions.

Added section describing optimistic transaction state changes.

C.4.5 **PersistenceCapable**

Removed methods jdoIsReadReady and jdoIsWriteReady. None of the application's business, these.

Changed the semantics of jdoIsTransactional to return `false` if an instance is read in an optimistic transaction. In an optimistic transaction, only new, deleted, modified instances and instances made transactional return `true`.

Added jdoGetPersistenceManager, jdoGetObjectId, and jdoMakeDirty.

C.5 Changes since Draft 0.5

Clarified NontransactionalRead, Optimistic, and RetainValues flag dependencies.

Added a table and diagrams of life cycle transitions.

Changed datastore ObjectId to allow primitive wrapper classes to be used.

Added failed object array and methods to JDOException, JDOCanRetryException, JDODataStoreException, and JDOUserException.

Added a Chapter on Application Portability Guidelines.

Added a Chapter on XML Metadata.

Added two collection factories to PersistenceManager.

Added connection factory to PersistenceManagerFactory.

C.6 Changes since Draft 0.6 (Participant Review Draft)

Updated life cycle table to match transition descriptions for persistent-nontransactional instances.
Clarified that all data accessed while a datastore transaction is in progress will be transactional.

Added a discussion on inheritance issues for persistence capable classes.

Added class JDOHelper with static methods to avoid calling JDO specific methods on Persistence-Capable classes.

Added a discussion on using the life cycle methods of PersistenceManager to clarify that the correct method must be called if an instance that implements a Collection interface is to be a parameter.

Query use of operator = was extended to include pre- and post-increment and -decrement operators.

Query variables need not be unique; if they need to be unique, then uniqueness can be specified with an additional query term.

Query examples were clarified as to their intent.

The terms persistent, non-persistent, transient were made consistent throughout the document. “Persistent field” and “non-persistent field” refer to fields as declared in the JDO metadata. “Transient field” refers to the field modifiers (orthogonal to persistent/non-persistent) and “transient instance” refers to an instance of a persistence capable class that is not persistent. “Persistent instance” refers to an instance of a persistence capable class that is persistent.

Derived fields were removed. These fields were supposed to be non-persistent fields whose values depended on values of persistent fields. For example, age depends on birthdate. The application will have to have a method age() instead of an instance variable age.

Transactional non-persistent fields were added. These fields have their values saved and restored during rollback transitions along with persistent fields.

More details were added on use of JDO in the EJB environment.

C.7 Changes since Draft 0.7

Binary compatibility table was added to 2.1.1.

Optional features were added to Portability Guidelines.

Section 5.5.2 was clarified to require that the JDO identity instance can be obtained immediately after the transition from transient to persistent-new.

The treatment of marking fields dirty for hidden fields was changed.

A table of arithmetic operators was added to the Query section.

C.8 Changes since Draft 0.8

Query filter defaults to “true” if not specified.

Added java.lang.BigInteger, java.lang.BigDecimal to object model.

Added cast operator (class) to query filter syntax.

Added bitwise invert operator to query filter syntax.

Added unary + to query filter syntax.

Added parentheses to query filter syntax.

Added String methods beginsWith and endsWith to query filter syntax.

Added chapter for StateManager interface.

Rewrote entire chapter on Reference Enhancer.

Updated PersistenceCapable interface to match Reference Enhancer.

Removed PersistenceManager.setObjectId.

Updated XML to conform to xml4j DOM and Apache/Xerces verifying parsers.

Added second-class XML attribute to field element.

Added null-value XML attribute to field element. This attribute specifies the behavior of the runtime system when a null-valued field mapped to a non-nullable datastore element is stored. The user can choose to throw an exception or to convert the null value to a default datastore value.

Changed the description of life cycle states and enhancer to indicate that primary key field access is always permitted, regardless of the life cycle state.

Added Extent chapter. The Extent interface was defined to be the result type of PersistenceManager.getExtent. The interface does not have the methods of Collection, so it can be used only for iteration or for specifying the candidate instances for Query.

Fields in an inherited class may not be managed by a persistence capable class. It is a future objective to allow a class to manage the state of inherited fields if it directly derives from a non-persistence capable class.

Clarified the behavior of null parameters in calls to PersistenceManager. Null values are permitted as parameters for PersistenceCapable instances, and permitted as elements of Collection and Object[] parameters, but are not permitted as parameters for Collection and Object[].

Added JDOPermission class to allow security management to enable jdo implementations without requiring ReflectPermission, which is too permissive.

C.9 Changes since Draft 0.9

Updated XML Metadata

- Added xml version number
- Changed definition of class element to allow multiple field, vendor elements
- Added jdo element, which contains multiple package elements
- Added key-type to field element for Map types.
- Changed key-type in class element to identity-type
- Changed key-class in class element to objectid-class
- Added inverse to field element for managed relationships
- Added has-extent to class element

Fixed missing “static” in generated jdoInheritedFieldCount.

Fixed jdoGetXXX/jdoSetXXX in enhanced code for non-dgf fields. Transient instances would have thrown null pointer exception.

Fixed missing generated method in PersistenceCapable: PersistenceCapable jdoNewInstance(StateManager sm)

Fixed the reference to the Connector Architecture in Appendix A.

Updated ordering to include expressions and restrict the types of ordering expressions to primitives except boolean, wrappers except Boolean, BigDecimal, BigInteger, and Date.

Removed bitwise AND, OR, and XOR from query operators.

Changed signatures of PersistenceManager methods getObjectId and getTransactionalInstance to include a boolean flag indicating whether to validate that the instance exists in the datastore.

Clarified that getObjectId returns the identity as of the beginning of the transaction, in case the identity is being modified in the transaction.

C.10 Changes since draft 0.91

Changed xml has-extent to requires-extent

Corrected the signature of replacingIntField in StateManager.

Corrected the example code generated for PersistenceCapable jdoReplaceField.

Corrected the name of the verify parameter to validate in the signature of getObjectId.

Removed getTransactionalInstance in favor of overloading the meaning of getObjectId.

Changed the requirement to expose the hollow state to the application. A JDO implementation might perform a state transition of a hollow instance as if the application had read a field.

Changed inheritance rules to allow non-persistence-capable classes to have persistence-capable superclasses and subclasses.

Corrected the description of the field name in the markDirty method so an unqualified name refers to the field in the most-derived class.

Corrected the signature of the newInstance method in JDOHelper to return Object.

Updated the instance callback description to include the rationale and environment for callbacks.

Updated makePersistent and deletePersistent to remove the restriction that the class of the instances must have an Extent.

The behavior of failing instances in the life cycle methods was clarified to specify that all instances will be attempted, and all failing instances will be included in the exception.

The newCollectionInstance was modified to include an initialContents parameter.

A new method newMapInstance was created to allow construction of a second class map instance.

Optimistic transaction management was clarified to specify that instances accessed during an optimistic transaction are not enlisted in any datastore transaction until commit.

The ordering specification was modified to include String.

The isEmpty method was added to the allowed Collection methods in query.

The treatment of null-valued collection fields was specified to be identical to fields containing empty collections.

Specified the behavior of the iterator of an Extent if there are deleted or newly persistent instances in the Extent.

The chapter on EJB has been substantially redone.

Exceptions were updated as to the contents of the failed object array.

The meaning of JDOHelper.getObjectId versus PersistenceManager.getObjectId was clarified with regard to change of identity within a transaction.

Fixed (removed) all references to reference parameter in StateManager.

Changed interface in PersistenceCapable for creating new instances, registering the PersistenceCapable class with the runtime, and managing minimal “reflective” metadata for the runtime (managed field names and types).

Added chapters for JDOHelper and JDOImplHelper.

C.11 Changes since draft 0.92

PersistenceManager methods that take a collection or array of instances have been changed to include All in their names.

Text throughout the document has been clarified to refer to the specific exception thrown.

Corrected sample code generated by the enhancer.

Added PersistenceManagerFactory methods getPersistenceManager(String userid, String password).

Static fields for values of jdoFlags were added to the PersistenceCapable interface.

A new ELEMENT array was added to the XML metadata to specify for array types whether the elements are embedded or not.

Clarified the possible treatment of jdoFlags by the StateManager, and the handling of isLoaded.

Added methods PersistenceManager.getTransactionalObjectId, PersistenceCapable.jdoGetTransactionalObjectId, and JDOHelper.getTransactionalObjectId to cover the case of changing primary key in a transaction.

Changed the requirement for a compliant implementation to support all Collection types. The behavior of all Collection types is specified, but only Collection, Set, and HashSet are required.

Clarified the semantics of getObjectId with the validate flag set to true when the instance is in the cache, for the cases of transactional v. nontransactional instances.

Changed failedObjectArray to failedObject, and nestedException to nestedExceptionArray in JDOException.

C.12 Changes since draft 0.93

Removed the requirement for application identity key classes to implement equals for all object types that include the correct name and type fields.

Changed the state transition of persistent-deleted to be unchanged by refresh.

Added a generated constructor jdoNewObjectIdInstance to facilitate key class handling.

Added a generated constructor jdoNewInstance (StateManager sm, Object oid) to facilitate key class handling.

Added generated jdoCopyKeyFieldsToObjectId methods to facilitate key class handling.

Added nested interface ObjectIdFieldManager to facilitate key class handling.

Added PersistenceManagerFactory properties ConnectionFactory2 and ConnectionFactory2Name for application server optimistic transaction support.

Added loadFactor to the newCollectionInstance method.

Clarified handling of getObjectId, getObjectById, and validate.

Added methods close(Iterator) and closeAll() to Extent.

Added methods close (Object queryResult) and closeAll() to Query.

Updated EJB chapter to clarify life cycle changes.

Removed inverse from XML metadata.

Corrected some code examples in reference enhancer.

Added methods to support different query languages: PersistenceManager.newQuery (String language, Object query) and Set supportedQueryLanguages().

Added nested extensions, and package extensions to xml.

C.13 Changes since draft 0.94

Added PersistenceManager and PersistenceManagerFactory methods to support the Multithreaded property. This property indicates that the application is multithreaded (multiple threads will access instances managed by the PersistenceManager).

Removed the PersistenceCapable constructor that takes StateManager as an argument. The helper methods newInstance will use the default constructor instead, and will create protected default constructor if none exists.

Removed jdoVersionUID and replaced it with explicit byte[] jdoFieldFlags and Class jdoPersistenceCapableSuperclass.

Added static fields to define values for jdoFieldFlags elements.

Added a chapter on JDOPermission.

Added optional extension element to xml elements array, collection, and map.

Added Multithreaded property to PersistenceManager, which indicates whether the PersistenceManager must synchronize accesses from multiple application threads.

Added allowNulls parameter to PersistenceManager newMapInstance.

Changed the name of the method getJDOImplHelper to getInstance.

Clarified the handling of abstract classes, which might be PersistenceCapable (for the benefit of concrete subclasses).

Removed the requirement for implementations to track modifications made to arrays.

Removed method getProperties from PersistenceManager. This method now is in PersistenceManagerFactory only.

Removed supportedQuery from PersistenceManager. This method has been replaced by supportedOptions, from which supported query languages should be available.

Added a method supportedOptions to PersistenceManagerFactory for the application to determine which optional features are supported by an implementation.

Added query BNF chapter.

C.14 Changes since draft 0.95 (Proposed Final Draft)

Defined the term “Managed Fields” to mean persistent or transactional fields.

Clarified the treatment of non-managed identity if multiple instances are changed or deleted.

Removed the requirement that a transaction be active to make an instance transactional or nontransactional.

Reorganized the State Transitions table to indicate that some state transitions are impossible (e.g. without a transaction active, there can be no new instances).

Clarified the requirement for a no-args constructor in PersistenceCapable classes and superclasses.

Fixed bug in PersistenceCapable.jdoReplaceStateManager code generation.

Removed properties minPool, maxPool, msWait, and ConnectionDriverName from the interface. These can be specified by PersistenceManagerFactory implementations as needed.

Reorganized sections 20.14 through 20.16 for clarity.

Changed jdoFieldFlags to be independent flags, allowing for identification of non-transient (serializable) fields.

Reworded the transaction synchronization sections for clarity.

Reworded the optimistic transaction section for clarity.

Modified the String concatenation operator (+) to allow only String + String, not String + primitive.

Clarified that String comparisons are lexicographical (not Locale-specific).

Added descriptions of JDOUserException for transaction not active and object deleted.

C.15 Changes since draft 0.96

Changed to specify that String comparisons in queries are based on an ordering not specified by JDO, allowing for locale-specific orderings by JDO implementations.

Added a portability requirement for object id classes to have a `toString()` method and a public constructor that takes a String argument. Added `newObjectIdInstance(Class, String)` to `PersistenceCapable`, `jdoNewObjectIdInstance(String)` to `PersistenceCapable` and `newObjectIdInstance(Class, String)` to `JDOImplHelper`.

Split `PersistenceCapable.ObjectIdFieldManager` into two interfaces: `PersistenceCapable.ObjectIdFieldSupplier` to supply values and `PersistenceCapable.ObjectIdFieldConsumer` to receive values.

Added the ability to construct a `PersistenceManagerFactory` from a `Properties` instance containing keys and values of properties. Added a convenience method to `JDOHelper getPersistenceManagerFactory(Properties)` to call the method in the implementation class.

Changed SCO factory name to `newTrackedInstance`, and removed the simultaneous setting of the field value in the persistence-capable instance. The user must assign the newly created instance to a field directly.

Added a parameter to `newTrackedInstance` to allow the user to specify a comparator for Collection or Map.

Modified the behavior of `makePersistent` with regard to reachable instances. The newly reachable instances have the characteristics of persistent-new until transaction end, at which time they either become persistent or revert to transient.

Made support for application changes to application object identity an optional feature.

Methods `retrieve` and `retrieveAll` were added to `PersistenceManager` to allow the application to give the implementation a hint that the instances are going to be used by the application, and the implementation can perform some optimized fetching of the instances.

Introduced the notion of provisional persistence. Instances that are reachable by persistent fields from instances made persistent become provisionally persistent. They behave like persistent instances until commit, at which time if they are no longer reachable from persistent instances they revert to transient.

Type-import-on-demand (`import <package-name>.*`) has been added to query `declareImports`. The Java rules for determining the package for an unqualified name are followed by query.

The `newQuery` methods that take both `Extent` and `Class` have been changed to eliminate the `Class` argument. The `Class` is taken from the `Extent`.

The Reference Enhancement chapter was reorganized to make it easier to determine: changes to `PersistenceCapable` root classes; changes to non-root classes; and changes to non-`PersistenceCapable` classes.

Changed the signatures of StateManager interface methods to take PersistenceCapable as the first argument, to avoid a cast operation.

Defined a new method to be enhanced into the least-derived PersistenceCapable class to handle copying key fields from oid into the instance: jdoCopyKeyFieldsFromObjectId (Object oid).

Removed that makeDirty in JDOHelper throws an exception in the case that the instance is not transient and the field is not managed. This is only one case that throws an exception; the other cases silently ignore the condition. To be consistent, this condition will also silently return.

C.16 Changes since draft 0.97

Clarified comparisons in JDOQL for wrapped types and promotion of numeric types.

Made static method getPersistenceManagerFactory(Properties) mandatory for JDO implementations.

Added PersistenceManagerFactory property ConnectionDriverName.

Added vendor-specific global configuration data in the first part of a XXX.jdo file. For this, the DTD was changed from <!ELEMENT jdo (package)+> to <!ELEMENT jdo (package)+ (extension)*>.

Clarified that the class of a persistent instance must be preserved, unless some outside change is made to the datastore.

Clarified that parameters to query must be persistent, associated with the same PersistenceManager as the Query.

Clarified that for portability, the instances in a candidate collection must be persistent, associated with the same PersistenceManager as the Query.

Changed the semantics of retrieve and retrieveAll to require that the PersistenceManager load all fields of the parameter instances, so a subsequent call to makeTransient can operate on a valid instance (all persistent fields loaded).

Added description of class loaders to the PersistenceManager chapter 12.5.

Clarified that there are no default values for flags in getPersistenceManager.

Added transaction flag restoreValues, which determines the treatment of persistent instances at transaction rollback.

Changed the specification of application identity key classes to require (instead of recommend) that the class override the toString method and provide a public constructor that takes only a String parameter.

Clarified query comparisons for persistent and transient parameters and candidate instances.

C.17 Changes since Approved Draft

Changed 3.2.1 to correct the interface name from javax.jdo.PersistenceCapable to javax.jdo.spi.PersistenceCapable.

Fixed typo in 5.5.6. Changed “The instance loses its JDO Identity and its association with the PersistenceManager.” to “The instance retains its JDO Identity and its association with the PersistenceManager.”

In 5.4.1 changed the wording regarding field types of application identity key fields to require portable applications to use only primitive, String, Date, and Number types.

In 5.4.1 added a restriction that application object id instances must not have any key fields with a value of null.

Added to 5.6.1 that the `PersistenceManager` must not hold a strong reference to a persistent-non-transactional instance, so that it may be garbage collected.

In 5.8, clarified that a before image might be created on update depending on the implementation of optimistic verification.

Corrected table 2 for rollback entries; changed the flag that affects the operation from `retainValues` to `restoreValues`.

In Figure 13 Note 23, fixed “A persistent-dirty instance transitions to persistent-nontransactional... at `rollback` when `RestoreValues` set to `true`.”

In Figure 13 Note 18 fixed from “The instance is cleared of values.” to ”No changes are made to the values.”

Clarified 6.3 to discuss the treatment of Second Class Objects embedded in First Class Objects. SCO instances of `PersistenceCapable` types have no standard treatment.

In 8.5, fixed missing property `javax.jdo.option.ConnectionDriverName` in `JDOHelper` list of standard properties for `getPersistenceManagerFactory`.

Added new section 9.5 for new security checking for `StateManager`. The new authorization strategy does not require that the persistence-capable classes be authorized for `JDOPermission`(“`setStateManager`”).

Fixed 10.3 the description of `jdoPreClear` does not include deleted instances, as these instances do not transition to hollow.

Fixed typos in 11.2, 12.6.5: changed “`JDODatastoreException`” to “`JDODataStoreException`”

Inserted new 11.4 to add `PersistenceManagerFactory` close method.

Added to 12.6 “In a non-managed environment, if the current transaction is active, `close()` throws `JDOUserException`.”

In 12.6.1, added new methods `retrieveAll` (`Collection, boolean`) and `retrieveAll` (`Object[], boolean`).

In 12.6.1, clarified the description of `retrieve`.

In 12.6.4, clarified the description of `getExtent` to throw `JDOUserException` if the metadata does not require an extent to be maintained.

In 12.6.5, changed code example from `aPersistenceManager.getObjectById` (`pc.getPersistenceManager().getObjectId(pc), validate`) to `aPersistenceManager.getObjectById` (`JDOHelper.getObjectId(pc), validate`). This avoids using the `PersistenceCapable` interface from user code.

In 12.6.5, changed the exception thrown by `getObjectById` to `JDOObjectNotFoundException`.

In 12.6.6, clarified description of `makeTransient` to make clear that the persistence manager is not responsible for clearing references to parameter instances to avoid making them persistent by reachability at commit.

In 12.6.6, clarified description of `makeTransactional` to include throwing `JDOUnsupportedOptionException` if a parameter is transient but `TransientTransactional` is not supported.

Fixed typo in 13.4.2. Changed “The `retainValues` setting currently active is returned.” to “The `restoreValues` setting currently active is returned.”

Fixed typo in 13.4.2. Changed “If this flag is set to `true`, then restoration of persistent instances does not take place after transaction rollback.” to “If this flag is set to `true`, then restoration of persistent instances takes place after transaction rollback.”

Corrected 13.4.3 to remove the requirement that `Transaction` must implement `javax.transaction.Synchronization`.

In 13.5, changed the behavior of failed optimistic transactions. The commit method throws a JDOOptimisticVerificationException and automatically rolls back the transaction.

Clarified 14.3 that variable declarations each require a type and a name, and there must be separating semicolons only if more than one declaration.

Clarified 14.3 that “candidate instances” are a subset of the candidate collection that are instances of the candidate class or a subset of the candidate class.

Clarified 14.4 that “compile time” refers to “JDOQL-compile time”.

Changed 14.5 to state “If the candidates are not specified, then the candidate extent is the extent of instances in the datastore with subclasses true.”

Clarified 14.6.2 if a cast operation would throw ClassCastException, it is treated the same as a NullPointerException.

Clarified 14.6.5 the semantics of “contains” is “exists”. This clarification is needed to provide a rational meaning if the contains clause is negated.

Clarified in 15 that Extents are not managed for instances of embedded fields.

In 15.3, clarified that the iterator method will throw an exception if NontransactionalRead is not supported.

In 17.1, added `getCause()`, `getFailedObject()` and `getNestedExceptions()` to the description of `JDOException`.

In 17.1, fixed description of `JDOUnsupportedOptionException`: “This class is a derived class of `JDOUserException`. This exception is thrown by an implementation to indicate that it does not implement a JDO optional feature.”

In 17.1.9, added new `JDOObjectNotFoundException` to report instances that cannot be found in the datastore.

In 17.1.10, added new `JDOOptimisticVerificationException` to report optimistic verification failures during commit.

Changed chapter 18 introduction to describe new policy for naming and accessing metadata files.

In 18.3, changed name scoping for persistence-capable-superclass.

Corrected 18.4 to correct an inconsistency with 20.9.6: “null-valued fields throw a `JDOUserException` when the instance is flushed to the datastore and the datastore does not support null values.”

Clarified in 18.4 that Extents are not managed for instances of embedded fields.

Updated 18.4.1 and 18.4.2 to clarify type name scoping: The type names use Java rules for naming: if no package is included in the name, the package name is assumed to be the same package as the persistence-capable class. Inner classes are identified by the “\$” marker.

In 18.6, added DOCTYPE description to describe access to the public DTD at java.sun.com/dtd.

Changed 19.3 to reflect change in portable object identity field types.

Changed 20.9.6 to correct an inconsistency with 18.4: “null-valued fields throw a `JDOUserException` when the instance is flushed to the datastore and the datastore does not support null values.”

Changed 20.17 and 20.20.4 to modify security checking for `JDOPermission`(“`setStateManager`”).

Changed 20.17 to correct the access modifier of `jdoPreSerialize` from private to protected.

Changed 20.20.1 to correct the interface name from `javax.jdo.PersistenceCapable` to `javax.jdo.spi.PersistenceCapable`.

Added new `JDOPermission`(“`closePersistenceManagerFactory`”) to check that the caller of `PersistenceManagerFactory.close()` is authorized.

Corrected Chapter 23 to remove alternative Name (ArgumentList_{opt}) from MethodInvocation non-terminal in the BNF.

Corrected Chapter 23 to remove the exclusive or operator from the BNF.

Removed Appendix B.3 since it no longer reflects reality.

C.18 Changes since 1.0.1

In 5.4, added classes used as an application identity class where there is a single application identity field.

In 6.4.3, added interfaces and classes required to be supported as persistent field types: LinkedHashMap, LinkedHashSet, LinkedList, and Currency.

Added to 7.3 .1 a method to retrieve the version of an instance.

Added to 7.4.6 a method to determine if an instance is detached.

Changed 7.12 to add methods handling SimpleIdentity.

Changed in 8.5 the signature of the getPersistenceManagerFactory from Properties to Map.

Added to 8.5 new helper methods for getting PersistenceManagerFactory.

Added to 8.6 new options to specify the mapping for a PersistenceManagerFactory.

Updated 10 to disaggregate instance callbacks.

Changed in 11.1 and 11.7 the parameter of the getPersistenceManagerFactory from Properties to Map.

Changed 11.6 to add javax.jdo.option.BinaryCompatibility, javax.jdo.option.UnconstrainedQueryVariables, javax.jdo.query.SQL, and javax.jdo.option.GetDataStoreConnection to optional features that can be supported by the implementation.

Added to 11.8 a second level cache management API.

Added to 11.9 life cycle event listeners.

Changed requirements for PersistenceCapable to refer to BinaryCompatibility throughout.

Added new method in 12.6.4 getExtent(Class persistenceCapableClass).

Added to 12.6 a discussion on using interfaces with Extents.

Added to 12.6.1 a new method refreshAll(JDOException ex) to refresh instances after a failed optimistic transaction.

Added to 12.6.5 new methods getObjectsById to retrieve multiple instances based on id.

Added to 12.6.5 a new methods getObjectById to retrieve an instance based on class and key.

Added 12.6.6 newInstance method to create instances of persistence-capable interfaces.

Added 12.6.8 methods to detach and attach instances for multi-tier applications.

Added 12.7 methods to specify how instances are fetched from the datastore.

Added 12.8 a method to explicitly flush changes to the datastore.

Added to 12.11 methods to access multiple User Objects.

Added 12.14 new method getSequence.

Added 12.15 new LifecycleEventListener.

Added 12.16 new method getDataStoreConnection.

Clarified 13.4.4 if a transaction is active when begin is called, or a transaction is not active when commit or rollback is called, JDOUserException is thrown.

Added 13.4.5 get/setRollbackOnly to the Transaction interface.

Added to 14.5 newNamedQuery method.

Added to 14.6.1 setParameters methods to bind parameters to query instances.

Added to 14.6.2 the requirement for support of public final static fields in query filters.

Added to 14.6.2 table with supported methods on Collection, Map, and String.

Added to 14.6.2 static method JDOHelper.getObjectId(Object) to allow use of object id in queries.

Added after 14.6.7 new query elements for uniqueness, result, result class, grouping, and result cardinality limits.

Added after 14.6.12 a table for interactions among new query elements.

Added after 14.6 a new section to describe delete by query.

Added after 14.6 a new section to describe support for SQL native queries.

Changed 14.6.6 to permit ordering on boolean fields as a non-portable extension.

Moved Chapter 15 Extent to Chapter 19.

Added new Chapter 15 with object-relational mapping examples.

Moved Chapter 18 to Chapter 25 for JDO 1.0.1 XML metadata.

Added object-relational mapping metadata to Chapter 18.

Added 20.10 to discuss Binary Compatibility portability implications.

Renumbered Chapter 20 Reference Enhancer to Chapter 21.

Added new methods to Chapter 21 to support detached instances.

Updated 21.20.7 to correct a bug in the specification and implementation of getManagedFieldCount.

Renumbered Chapter 21 State Manager to Chapter 22.

Added new methods to Chapter 22 to support detached instances.

Updated 24.6 BLOB/CLOB datatype support to reflect that this functionality is part of JDO 2.0.

Updated 24.8 Case-Insensitive Query to reflect that this functionality is part of JDO 2.0.

Updated 24.13 Projections in query to reflect that this functionality is part of JDO 2.0.

Updated 24.16 Distributed object support to reflect that this functionality is part of JDO 2.0.

Updated 24.17 Object-Relational Mapping to reflect that this functionality is part of JDO 2.0.

Removed B.2 which discussed implications of removing PersistenceCapable.

C.19 Changes since Proposed Final Draft

Updated 18.14 to remove serialized attribute from element, key, and value. Removed foreign-key attribute from field element. Added attribute serialized-element to elements collection and array. Added attributes serialized-key and serialized-value to element map.

Removed attribute serialized from orm metadata. Added serialized-element, serialized-key, and serialized-value to jdo metadata.

Removed true/false use of attribute foreign-key in metadata.

Allowed persistence-capable class to be the parameter of PersistenceManager newInstance.

Allowed attribute order in element collection to permit specifying a column to allow duplicates.

Allowed java.lang classes to be used in metadata without importing them.

Added DetachAllOnCommit property to PersistenceManager to facilitate construction of detached instances.

Changed signature of makePersistent to return the persistent instances, and to attach detached instances.

Added attribute element-type to element array in metadata.

Added field-type to element field in metadata.

Specified behavior of null values in aggregates in JDOQL.

Allowed distinct with aggregates in JDOQL.

Allowed constructors or result class in JDOQL.

Allowed setUnique for delete by query in JDOQL.

Required relationships mapped using mapped-by to be consistent after flush.

Replaced fetch-depth by recursion-depth in fetch plan.

Added methods to specify detachment roots in fetch plan.

Automatically import JDOHelper in JDOQL.

Defined behavior of deletePersistent on detached instances.

C.20 Changes since 2.0

In 5.4.1, Compound Identity should be updated to reflect that for key fields of reference types, the type of the key field is the reference type in the class but the oid of the reference type in the oid class.

In Table 2: State Transitions, the transition for a transient-dirty instance during commit with DetachAllOnCommit = true should be to transient-clean. Also, state changes need to be added for detach methods and serialization.

In 5.5.8 and 5.5.9, detachCopy should be removed from the list of methods that throw exceptions if applied to detached-clean or detached-dirty instances.

In 6.4.3, change "Portable JDO applications must not depend on whether instances of these classes are treated as SCOs or FCOs." to "Portable JDO applications must not depend on SCO or FCO unquoting behavior, nor on the storage mechanism in the datastore. Portable applications may use the same instance of these classes as field values in any persistence-capable class instance."

In section 7.5, change "If the class is abstract, null is returned." to "If the class is abstract, JDOFatalInternalException is thrown".

In section 7.5, add public byte fetchByteField(int fieldNumber); to ObjectIdFieldSupplier.

In section 7.5, add public byte storeByteField(int fieldNumber, byte value); to ObjectIdFieldConsumer.

In Chapter 8, add after class JDOHelper {

```
public JDOHelper();
```

For some usage patterns, an instance of JDOHelper on which to invoke methods is preferable to the use of static methods. For this purpose, a public constructor is provided.

In Chapter 8, add a convenience method that returns a PersistenceManager proxy that can be used in web and ejb containers to dynamically bind to the transaction-associated PersistenceManager.

In Chapter 9, add section on managing date formatting for ObjectIdentity constructors.

```
public synchronized void registerDateFormat(java.text.DateFormat df);
```

In 9.4, add method to retrieve persistence-capable classes that have been registered.

public java.util.Collection getRegisteredClasses();

In 9.5, add method to verify that the class is authorized to be a state manager.

public static void checkAuthorizedStateManagerClass(Class smClass);

In 9.5, add method to register multiple state manager classes.

public static void registerAuthorizedStateManagerClasses(java.util.Collection smClasses) throws SecurityException;

In Chapter 11, add properties for configuring PersistenceManagerFactory that are consistent with JPA specification of TransactionType and Persistence Unit Name.

In Chapter 12, specify the behavior of PersistenceManager if it extends Serializable and writeObject is called.

In 12.6.6, clarify that a JDOUserException will be thrown when invoking newInstance: if a class is not persistence-capable, or does not declare a public no-args constructor; if an interface is not persistence-capable or declares methods that are not defined as persistent properties; if an abstract class is not persistence-capable or declares abstract methods that are not defined as persistent properties.

In 12.6.8, section heading Explicit Detach, the sentence "If the parameter instance is detached, then JDOUserException is thrown." should be removed.

In 12.6.8, add a note that serialization for storage using the serialized, serialized-element, serialized-key, or serialized-value metadata attributes does not create a detached instance.

In 12.6.8, clarify the behavior of instances during serialization both with and without an active transaction.

In 12.7.5, change public int setMaxFetchDepth(); to public int getMaxFetchDepth();

In 12.7.5, specify that getFetchGroups returns a read-only copy of the active Fetch Groups.

In 12.7.6, p. 127, change "A recursion-depth of 0 will fetch the whole graph of instances reachable from this field." to "A recursion-depth of -1 will fetch the whole graph of instances reachable from this field."

In 12.7.6 p. 129, change fetch-depth to recursion-depth in the example.

In 14, add subqueries to permit e.g. select from Employee where this.salary > (select avg(salary) from Employee)

In 14.6.2 p. 159, the sectionheading "Methods" is not marked as a sectionheading.

Add to 14.6.9: Projected SCOs are never owned, projected FCOs are always managed. Modifying unowned SCOs never has an effect on the database. Modifying FCOs no matter how you get them always has an effect if the tx commits.

In 15.3, p. 187, the third paragraph, beginning "The field on the other side" and ending "in the next transaction", is duplicated and will be removed.

In 15.3, add text to describe updating the other side of relationships where this side is deleted. This maintains referential integrity for delete as well as update.

Add to 17.1.11

JDOUserCallbackException extends javax.jdo.JDOUserException

In Chapter 18, add an xml element to specify the fetch plan to use for a query.

In 18.15.1, change "(e.g. a field of type Object can specify field-type='Integer')." to "(e.g. an element of type Object can specify element-type='Integer')."

In Chapter 18, add to .jdo metadata:

<!ATTLIST property field-type CDATA #IMPLIED>

Add to 18.15.1 "The default for dependent-element is false."

Add to 18.15.2 "The default for dependent-key is false."

Add to 18.15.2 "The default for dependent-value is false."

Change the last paragraph of 21.6 from "For Detachable classes, the results of restoring a serialized persistent instance graph is a graph of interconnected detached instances that might be attached via the attachCopy methods." to "For Detachable classes, the results of restoring a serialized persistent instance graph is a graph of interconnected detached instances that might be attached via the makePersistent methods."

Change 21.13 from "Some methods require a non-null state manager. In these cases, if the jdoStateManager is null, then IllegalStateException is thrown." to "Some methods require a non-null state manager. In these cases, if the jdoStateManager is null, then JDOFatalInternalException is thrown."

Change 21.21.7 Generated jdoGetManagedFieldCount sample implementation to avoid using the jdoFieldNames field that might be initialized after it is used during initialization of a subclass.

```
protected static int jdoGetManagedFieldCount () {
    return jdoFieldNames.length;
}
to protected static int jdoGetManagedFieldCount () {
    return <enhancer-generated constant>;
}
```

Add to Chapter 23, constants defined in the JDOPermission class:

```
public static final javax.jdo.spi.JDOPermission CLOSE_PERSISTENCE_MANAGER_FACTORY = "closePersistenceManagerFactory";
public static final javax.jdo.spi.JDOPermission GET_METADATA = "getMetadata";
public static final javax.jdo.spi.JDOPermission MANAGE_METADATA = "manageMetadata";
public static final javax.jdo.spi.JDOPermission SET_STATE_MANAGER = "setStateManager";
```

These changes better support JDK 1.5:

Add to 6.3 a section requiring support for enum types, including subclasses of enum types.

Change in 12.6 signatures of the following PersistenceManager methods to use Java SE 5 features including generics and varargs.

Note that these changes are source compatible with existing application programs.

Table 1: Java SE 5 Signature Changes

JDO 2.0	JDO 2.1 Maintenance Release
Object[] getObjectsById (Object[] oids)	Object[] getObjectsById (Object... oids)
Object getObjectById (Class cls, Object key)	<T> T getObjectById (Class<T> cls, Object key)
Object[] getObjectsById (Object[] oids, boolean validate)	Object[] getObjectsById (boolean validate, Object... oids)
Object newInstance(Class persistenceCapable)	<T> T newInstance(Class<T> persistenceCapable)
Object makePersistent (Object pc)	<T> T makePersistent (T pc)

Table 1: Java SE 5 Signature Changes

JDO 2.0	JDO 2.1 Maintenance Release
Object[] makePersistentAll (Object[] pcs)	<T> T[] makePersistentAll (T[] pcs)
Collection makePersistentAll (Collection pcs)	<T> Collection<T> makePersistentAll (Collection<T> pcs)
Object detachCopy(Object pc)	<T> T detachCopy(T pc)
Collection detachCopyAll(Collection pcs)	<T> Collection<T> detachCopyAll(Collection<T> pcs)
Object[] detachCopyAll(Object[] pcs)	<T> T[] detachCopyAll(T[] pcs)
void deletePersistentAll (Object[] pcs)	void deletePersistentAll (Object... pcs)
void evictAll(Object[] pcs)	void evictAll(Object... pcs)
void refreshAll (Object[] pcs)	void refreshAll (Object... pcs)
Extent getExtent (Class persistenceCapableClass, boolean subclasses)	<T> Extent<T> getExtent (Class<T> persistenceCapableClass, boolean subclasses)
Extent getExtent (Class persistenceCapableClass)	<T> Extent<T> getExtent (Class<T> persistenceCapableClass)
void makeTransientAll (Object[] pcs)	void makeTransientAll (Object... pcs)
void makeTransientAll (Object[] pcs, boolean useFetchPlan)	void makeTransientAll (boolean useFetchPlan, Object... pcs)
void makeTransactionalAll (Object[] pcs)	void makeTransactionalAll (Object... pcs)
void makeNontransactionalAll (Object[] pcs)	void makeNontransactionalAll (Object... pcs)
void retrieveAll (Object[] pcs)	void retrieveAll (Object... pcs)
void retrieveAll (Object[] pcs, boolean useFetchPlan)	void retrieveAll (boolean useFetchPlan, Object... pcs)

Add to 15.1 a paragraph describing that mapping an enum to a fixed-precision numeric type uses the ordinal() value for storage; mapping to a character column type (CHAR, VARCHAR, etc.) is the default, and uses the name() value for storage; mapping to any other column type is an error.

Provide in a new chapter a set of annotations that map directly to xml elements as an alternative to using xml metadata. Describe how jdo implementations can use either JDO annotations or JPA annotations to provide metadata.

Provide interfaces that extend both JDO and JPA in order to make it easier to migrate applications from JDO to JPA.

C.21 Changes since 2.2

Added “extensions” property to annotation @Order.

Allow applications to specify that a single object identity names the exact class.

Added an Enhancer API to allow applications to dynamically enhance classes.

- Added a Metadata API to allow applications to query and create metadata for classes.
- Modified the behavior of getObjectId to allow the application to specify the exact class of an instance, thereby avoiding a database access to instantiate a persistent instance with a specific identity.
- Added a datastore timeout that will cancel datastore operations that exceed a user-specified time limit.
- Added a query cancel that allows applications to cancel currently-executing queries.

Appendix D: XML Schema for jdoconfig.xml

```

<?xml version="1.0" encoding="UTF-8"?>
<xss:schema
    targetNamespace="http://java.sun.com/xml/ns/jdo/jdoconfig"
    xmlns="http://java.sun.com/xml/ns/jdo/jdoconfig"
    xmlns:xss="http://www.w3.org/2001/XMLSchema"
    xmlns:jdoconfig="http://java.sun.com/xml/ns/jdo/jdoconfig"
    elementFormDefault="qualified"
    attributeFormDefault="unqualified"
    version="3.0">
    <xss:annotation>
        <xss:documentation>
            This is the XML Schema for the JDO configuration file.
        </xss:documentation>
    </xss:annotation>

    <xss:element name="jdoconfig">
        <xss:complexType>
            <xss:annotation>
                <xss:documentation>
                    The root configuration element for JDO.
                </xss:documentation>
            </xss:annotation>
            <xss:sequence>
                <xss:element name="persistence-manager-factory" minOccurs="1"
                            maxOccurs="unbounded">
                    <xss:complexType>
                        <xss:annotation>
                            <xss:documentation>
                                Standard JDO PersistenceManagerFactory configuration properties.
                                Vendor-specific properties are set using additional
                                vendor-specific attributes and/or property elements.
                            </xss:documentation>
                        </xss:annotation>
                    </xss:complexType>
                    <xss:sequence minOccurs="0" maxOccurs="1">
                        <xss:element name="property" minOccurs="0"
                                    maxOccurs="unbounded">
                            <xss:complexType>
                                <xss:annotation>
                                    <xss:documentation>
                                        Vendor-specific properties.
                                    </xss:documentation>
                                </xss:annotation>
                                <xss:attributeGroup ref="attlist.property"/>
                            </xss:complexType>
                        </xss:element>
                    </xss:sequence>
                <xss:element name="instance-lifecycle-listener"
                            minOccurs="0" maxOccurs="unbounded">
                    <xss:complexType>
                        <xss:annotation>
                            <xss:documentation>
                                javax.jdo.listener.InstanceLifecycleListener instance
                                configuration. There is one instance-lifecycle-listener
                                element per listener instance. Only one instance of the
                                listener class is supported in this configuration file.
                                If multiple instances of the same listener class is
                                required, then the API
                                PersistenceManagerFactory.addInstanceLifecycleListener(....)
                                must be used.
                            </xss:documentation>
                        </xss:annotation>
                    </xss:complexType>
                </xss:element>
            </xss:sequence>
        </xss:complexType>
    </xss:element>

```

```
If attribute "classes" is missing, all persistence-capable
instances are observed; otherwise it is a comma- or
whitespace-delimited list of persistence-capable
classes whose instances will be observed.
</xs:documentation>
</xs:annotation>
<xs:attributeGroup
    ref="attlist.instance-lifecycle-listener"/>
</xs:complexType>
</xs:element>
</xs:sequence>
<xs:attributeGroup
    ref="attlist.persistence-manager-factory"/>
</xs:complexType>
</xs:element>
</xs:sequence>
<xs:attributeGroup ref="attlist.jdoconfig"/>
</xs:complexType>
</xs:element>

<xs:attributeGroup name="attlist.jdoconfig"/>

<xs:attributeGroup name="attlist.persistence-manager-factory">
    <xs:annotation>
        <xs:documentation>
            These are attributes corresponding to the standard properties
            defined in JDO.
            Any other attributes present, if unrecognized by a JDO
            implementation, may be silently ignored.
        </xs:documentation>
    </xs:annotation>

    <!-- Corresponds to standard JDO property
javax.jdo.PersistenceManagerFactoryClass. -->
    <xs:attribute name="class" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.Name.
        The absence of this attribute implies the anonymous PMF. -->
    <xs:attribute name="name" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.PersistenceUnitName.
-->
    <xs:attribute name="persistence-unit-name" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.Optimistic. -->
    <xs:attribute name="optimistic" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.ReadOnly. -->
    <xs:attribute name="readonly" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.RetainValues. -->
    <xs:attribute name="retain-values" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.RestoreValues. -->
    <xs:attribute name="restore-values" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.IgnoreCache. -->
    <xs:attribute name="ignore-cache" use="optional"/>
    <!-- Corresponds to standard JDO property
javax.jdo.option.NontransactionalRead. -->
    <xs:attribute name="nontransactional-read" use="optional"/>
    <!-- Corresponds to standard JDO property
javax.jdo.option.NontransactionalWrite. -->
    <xs:attribute name="nontransactional-write" use="optional"/>
    <!-- Corresponds to standard JDO property javax.jdo.option.Multithreaded. -->
    <xs:attribute name="multithreaded" use="optional"/>
```

```

<!-- Corresponds to standard JDO property
javax.jdo.option.TransactionIsolationLevel. -->
<xs:attribute name="transaction-isolation-level" use="optional"/>
<!-- Corresponds to standard JDO property
javax.jdo.option.ConnectionDriverName. -->
<xs:attribute name="connection-driver-name" use="optional"/>
<!-- Corresponds to standard JDO property javax.jdo.option.ConnectionUserName.
-->
<xs:attribute name="connection-user-name" use="optional"/>
<!-- Corresponds to standard JDO property javax.jdo.option.ConnectionPassword.
-->
<xs:attribute name="connection-password" use="optional"/>
<!-- Corresponds to standard JDO property javax.jdo.option.ConnectionURL. -->
<xs:attribute name="connection-url" use="optional"/>
<!-- Corresponds to standard JDO property
javax.jdo.option.ConnectionFactoryName. -->
<xs:attribute name="connection-factory-name" use="optional"/>
<!-- Corresponds to standard JDO property
javax.jdo.option.ConnectionFactory2Name. -->
<xs:attribute name="connection-factory2-name" use="optional"/>
<!-- Corresponds to standard JDO property javax.jdo.option.Mapping. -->
<xs:attribute name="mapping" use="optional"/>
<!-- Corresponds to standard JDO property javax.jdo.option.DetachAllOnCommit.
-->
<xs:attribute name="detach-all-on-commit" use="optional"/>
<!-- Corresponds to standard JDO property javax.jdo.option.ServerTimeZoneID. --
->
<xs:attribute name="server-time-zone-id" use="optional"/>
<!-- Corresponds to standard JDO property
javax.jdo.option.DatastoreReadTimeoutMillis. -->
<xs:attribute name="datastore-read-timeout-millis" use="optional"/>
<!-- Corresponds to standard JDO property
javax.jdo.option.DatastoreWriteTimeoutMillis. -->
<xs:attribute name="datastore-write-timeout-millis" use="optional"/>
<!-- Any other vendor-specific attributes are allowed and passed literally
to the underlying implementation. -->
<xs:anyAttribute processContents="lax"/>
</xs:attributeGroup>

<xs:attributeGroup name="attlist.property">
<!-- The name of the vendor-specific property. -->
<xs:attribute name="name" use="required"/>
<!-- The value of the vendor-specific property. -->
<xs:attribute name="value" use="optional"/>
</xs:attributeGroup>

<xs:attributeGroup name="attlist.instance-lifecycle-listener">
<!-- The name of the listener class to instantiate. -->
<xs:attribute name="listener" use="required"/>
<!-- Comma- or whitespace-delimited list of persistence-capable classes
whose instances to observe. The absence of this attribute means
to observe all. -->
<xs:attribute name="classes" use="optional"/>
</xs:attributeGroup>

</xs:schema>

```

Appendix E: XML Schema for jdo.xml

```

<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://java.sun.com/xml/ns/jdo/jdo"
    xmlns="http://java.sun.com/xml/ns/jdo/jdo"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    version="3.0">
    <xs:element name="jdo">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="package"/>
                <xs:element ref="query"/>
                <xs:element ref="fetch-plan"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.jdo"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.jdo">
        <xs:attribute name="catalog"/>
        <xs:attribute name="schema"/>
    </xs:attributeGroup>
    <xs:element name="fetch-plan">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="fetch-group"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.fetch-plan"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.fetch-plan">
        <xs:attribute name="name" default="" />
        <xs:attribute name="max-fetch-depth" default="1" />
        <xs:attribute name="fetch-size" default="0" />
    </xs:attributeGroup>
    <xs:element name="package">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="interface"/>
                <xs:element ref="class"/>
                <xs:element ref="sequence"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.package"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.package">
        <xs:attribute name="name" default="" />
        <xs:attribute name="catalog"/>
        <xs:attribute name="schema"/>
    </xs:attributeGroup>
    <xs:element name="interface">
        <xs:complexType>
            <xs:choice minOccurs="0" maxOccurs="unbounded">
                <xs:annotation><xs:documentation>
                    Please note,
                    the following subelements must not occur more than once:
                    - datastore-identity
                    - primary-key
                    - inheritance
                </xs:documentation>
            </xs:choice>
        </xs:complexType>
    </xs:element>

```

```
        - version
    </xs:documentation></xs:annotation>
    <xs:element ref="extension"/>
    <xs:element ref="datastore-identity"/>
    <xs:element ref="primary-key"/>
    <xs:element ref="inheritance"/>
    <xs:element ref="version"/>
    <xs:element ref="join"/>
    <xs:element ref="foreign-key"/>
    <xs:element ref="index"/>
    <xs:element ref="unique"/>
    <xs:element ref="property"/>
    <xs:element ref="query"/>
    <xs:element ref="fetch-group"/>
</xs:choice>
<xs:attributeGroup ref="attlist.interface"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.interface">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="table"/>
    <xs:attribute name="identity-type">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="datastore"/>
                <xs:enumeration value="application"/>
                <xs:enumeration value="nondurable"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="objectid-class"/>
    <xs:attribute name="requires-extent" default="true">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="detachable" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="embedded-only">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="catalog"/>
    <xs:attribute name="schema"/>
    <xs:attribute name="cacheable" default="true">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
```

```
        <xs:enumeration value="false"/>
    </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="serialize-read" default="false">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="property">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of array, collection and map,
                - join
                - embedded
                - key
                - value
                - order
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice minOccurs="0" maxOccurs="1">
                <xs:element ref="array"/>
                <xs:element ref="collection"/>
                <xs:element ref="map"/>
            </xs:choice>
            <xs:element ref="join"/>
            <xs:element ref="embedded"/>
            <xs:element ref="element"/>
            <xs:element ref="key"/>
            <xs:element ref="value"/>
            <xs:element ref="order"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.property"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.property">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="persistence-modifier">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="persistent"/>
                <xs:enumeration value="transactional"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="default-fetch-group">
```

```
<xs:simpleType>
  <xs:restriction base="xs:token">
    <xs:enumeration value="true"/>
    <xs:enumeration value="false"/>
  </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="load-fetch-group"/>
<xs:attribute name="null-value" default="none">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="default"/>
      <xs:enumeration value="exception"/>
      <xs:enumeration value="none"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="dependent">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="embedded">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="primary-key" default="false">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="value-strategy"/>
<xs:attribute name="sequence"/>
<xs:attribute name="serialized">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="field-type"/>
<xs:attribute name="table"/>
<xs:attribute name="column"/>
<xs:attribute name="delete-action">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="restrict"/>
      <xs:enumeration value="cascade"/>
      <xs:enumeration value="null"/>
      <xs:enumeration value="default"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
```

```
        <xs:enumeration value="none" />
    </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true" />
            <xs:enumeration value="false" />
            <xs:enumeration value="unique" />
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true" />
            <xs:enumeration value="false" />
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by" />
<xs:attribute name="recursion-depth" />
<xs:attribute name="field-name" />
<xs:attribute name="cacheable" default="true">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true" />
            <xs:enumeration value="false" />
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="class">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - datastore-identity
                - primary-key
                - inheritance
                - version
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="implements"/>
            <xs:element ref="datastore-identity"/>
            <xs:element ref="primary-key"/>
            <xs:element ref="inheritance"/>
            <xs:element ref="version"/>
            <xs:element ref="join"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
            <xs:element ref="column"/>
            <xs:element ref="field"/>
            <xs:element ref="property"/>
            <xs:element ref="query"/>
            <xs:element ref="fetch-group"/>
        </xs:choice>
    <xs:attributeGroup ref="attlist.class" />
```

```
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.class">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="identity-type">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="application"/>
                <xs:enumeration value="datastore"/>
                <xs:enumeration value="nondurable"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="objectid-class"/>
    <xs:attribute name="table"/>
    <xs:attribute name="requires-extent" default="true">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="persistence-capable-superclass"/>
    <xs:attribute name="detachable" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="embedded-only">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="persistence-modifier">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="persistence-capable"/>
                <xs:enumeration value="persistence-aware"/>
                <xs:enumeration value="non-persistent"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="catalog"/>
    <xs:attribute name="schema"/>
    <xs:attribute name="cacheable" default="true">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="serialize-read" default="false">
        <xs:simpleType>
```

```
<xs:restriction base="xs:token">
    <xs:enumeration value="true"/>
    <xs:enumeration value="false"/>
</xs:restriction>
</xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="primary-key">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.primary-key"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.primary-key">
    <xs:attribute name="name"/>
    <xs:attribute name="column"/>
</xs:attributeGroup>
<xs:element name="join">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - primary-key
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="primary-key"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.join"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.join">
    <xs:attribute name="table"/>
    <xs:attribute name="column"/>
    <xs:attribute name="outer" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>

```

```
</xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="version">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - index
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
            <xs:element ref="index"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.version"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.version">
    <xs:attribute name="strategy"/>
    <xs:attribute name="column"/>
    <xs:attribute name="indexed">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
                <xs:enumeration value="unique"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="datastore-identity">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.datastore-identity"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.datastore-identity">
    <xs:attribute name="column"/>
    <xs:attribute name="strategy" default="native"/>
    <xs:attribute name="sequence"/>

```

```
</xs:attributeGroup>
<xs:element name="implements">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:element ref="extension"/>
            <xs:element ref="property"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.implements"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.implements">
    <xs:attribute name="name" use="required"/>
</xs:attributeGroup>
<xs:element name="inheritance">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - join
                - discriminator
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="join"/>
            <xs:element ref="discriminator"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.inheritance"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.inheritance">
    <xs:attribute name="strategy"/>
</xs:attributeGroup>
<xs:element name="discriminator">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - index
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
            <xs:element ref="index"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.discriminator"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.discriminator">
    <xs:attribute name="column"/>
    <xs:attribute name="value"/>
    <xs:attribute name="strategy"/>
    <xs:attribute name="indexed">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
                <xs:enumeration value="unique"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
```

```
<xs:element name="column">
  <xs:complexType>
    <xs:sequence>
      <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
    </xs:sequence>
    <xs:attributeGroup ref="attlist.column"/>
  </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.column">
  <xs:attribute name="name"/>
  <xs:attribute name="target"/>
  <xs:attribute name="target-field"/>
  <xs:attribute name="jdbc-type"/>
  <xs:attribute name="sql-type"/>
  <xs:attribute name="length"/>
  <xs:attribute name="scale"/>
  <xs:attribute name="allows-null">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="true"/>
        <xs:enumeration value="false"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
  <xs:attribute name="default-value"/>
  <xs:attribute name="insert-value"/>
</xs:attributeGroup>
<xs:element name="field">
  <xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
      <xs:annotation><xs:documentation>
        Please note,
        the following subelements must not occur more than once:
        - the choice of array, collection, and map
        - join
        - embedded
        - key
        - value
        - order
        - foreign-key
        - index
        - unique
      </xs:documentation></xs:annotation>
      <xs:element ref="extension"/>
      <xs:choice minOccurs="0" maxOccurs="1">
        <xs:element ref="array"/>
        <xs:element ref="collection"/>
        <xs:element ref="map"/>
      </xs:choice>
      <xs:element ref="join"/>
      <xs:element ref="embedded"/>
      <xs:element ref="element"/>
      <xs:element ref="key"/>
      <xs:element ref="value"/>
      <xs:element ref="order"/>
      <xs:element ref="column"/>
      <xs:element ref="foreign-key"/>
      <xs:element ref="index"/>
      <xs:element ref="unique"/>
    </xs:choice>
  <xs:attributeGroup ref="attlist.field"/>
```

```
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.field">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="persistence-modifier">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="persistent"/>
                <xs:enumeration value="transactional"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="field-type"/>
    <xs:attribute name="table"/>
    <xs:attribute name="column"/>
    <xs:attribute name="primary-key" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="null-value" default="none">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="exception"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="default-fetch-group">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="embedded">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="serialized">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="dependent">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
```

```
        <xs:enumeration value="false"/>
    </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="value-strategy"/>
<xs:attribute name="delete-action">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="restrict"/>
            <xs:enumeration value="cascade"/>
            <xs:enumeration value="null"/>
            <xs:enumeration value="default"/>
            <xs:enumeration value="none"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="sequence"/>
<xs:attribute name="load-fetch-group"/>
<xs:attribute name="recursion-depth"/>
<xs:attribute name="mapped-by"/>
<xs:attribute name="cacheable" default="true">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="foreign-key">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of columns, fields and properties
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice minOccurs="0" maxOccurs="1">
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="column"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="field"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="property"/>
            </xs:choice>
        </xs:choice>
    </xs:complexType>

```

```
        <xs:attributeGroup ref="attlist.foreign-key"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.foreign-key">
    <xs:attribute name="table"/>
    <xs:attribute name="deferred">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="delete-action" default="restrict">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="update-action" default="restrict">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="unique">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="name"/>
</xs:attributeGroup>
<xs:element name="collection">
    <xs:complexType>
        <xs:sequence>
            <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
        </xs:sequence>
        <xs:attributeGroup ref="attlist.collection"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.collection">
    <xs:attribute name="element-type"/>
    <xs:attribute name="embedded-element">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
```

```
</xs:simpleType>
</xs:attribute>
<xs:attribute name="dependent-element">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="serialized-element">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="map">
    <xs:complexType>
        <xs:sequence>
            <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
        </xs:sequence>
        <xs:attributeGroup ref="attlist.map"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.map">
    <xs:attribute name="key-type"/>
    <xs:attribute name="embedded-key">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="dependent-key">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="serialized-key">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="value-type"/>
    <xs:attribute name="embedded-value">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
```

```
</xs:attribute>
<xs:attribute name="dependent-value">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="serialized-value">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="key">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - embedded
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="embedded"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.key"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.key">
    <xs:attribute name="column"/>
    <xs:attribute name="table"/>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="update-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
```

```
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="value">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - embedded
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="embedded"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.value"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.value">
    <xs:attribute name="column"/>
    <xs:attribute name="table"/>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="update-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>

```

```
        <xs:enumeration value="cascade"/>
        <xs:enumeration value="null"/>
        <xs:enumeration value="default"/>
        <xs:enumeration value="none"/>
    </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="array">
    <xs:complexType>
        <xs:sequence>
            <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
        </xs:sequence>
        <xs:attributeGroup ref="attlist.array"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.array">
    <xs:attribute name="element-type"/>
    <xs:attribute name="embedded-element">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="dependent-element">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="serialized-element">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
```

```
<xs:element name="element">
  <xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
      <xs:annotation><xs:documentation>
        Please note,
        the following subelements must not occur more than once:
        - embedded
        - foreign-key
        - index
        - unique
      </xs:documentation></xs:annotation>
      <xs:element ref="extension"/>
      <xs:element ref="embedded"/>
      <xs:element ref="column"/>
      <xs:element ref="foreign-key"/>
      <xs:element ref="index"/>
      <xs:element ref="unique"/>
    </xs:choice>
    <xs:attributeGroup ref="attlist.element"/>
  </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.element">
  <xs:attribute name="column"/>
  <xs:attribute name="table"/>
  <xs:attribute name="delete-action">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="restrict"/>
        <xs:enumeration value="cascade"/>
        <xs:enumeration value="null"/>
        <xs:enumeration value="default"/>
        <xs:enumeration value="none"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
  <xs:attribute name="update-action">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="restrict"/>
        <xs:enumeration value="cascade"/>
        <xs:enumeration value="null"/>
        <xs:enumeration value="default"/>
        <xs:enumeration value="none"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
  <xs:attribute name="indexed">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="true"/>
        <xs:enumeration value="false"/>
        <xs:enumeration value="unique"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
  <xs:attribute name="unique">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="true"/>
        <xs:enumeration value="false"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
```

```
</xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="order">
<xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:annotation><xs:documentation>
            Please note,
            the following subelements must not occur more than once:
            - index
        </xs:documentation></xs:annotation>
        <xs:element ref="extension"/>
        <xs:element ref="column"/>
        <xs:element ref="index"/>
    </xs:choice>
    <xs:attributeGroup ref="attlist.order"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.order">
    <xs:attribute name="column"/>
    <xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="fetch-group">
<xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:element ref="extension"/>
        <xs:element ref="fetch-group"/>
        <xs:element ref="field"/>
        <xs:element ref="property"/>
    </xs:choice>
    <xs:attributeGroup ref="attlist.fetch-group"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.fetch-group">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="post-load">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="embedded">
<xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:element ref="extension"/>
        <xs:element ref="field"/>
        <xs:element ref="property"/>
    </xs:choice>
    <xs:attributeGroup ref="attlist.embedded"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.embedded">
    <xs:attribute name="owner-field"/>
    <xs:attribute name="null-indicator-column"/>
    <xs:attribute name="null-indicator-value"/>
</xs:attributeGroup>
<xs:element name="sequence">
```

```

<xs:complexType>
    <xs:sequence>
        <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
    </xs:sequence>
    <xs:attributeGroup ref="attlist.sequence"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.sequence">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="datastore-sequence"/>
    <xs:attribute name="factory-class"/>
    <xs:attribute name="strategy" use="required">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="nontransactional"/>
                <xs:enumeration value="contiguous"/>
                <xs:enumeration value="noncontiguous"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="index">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of columns, fields or properties
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="column"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="field"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="property"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.index"/>
        </xs:choice>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.index">
    <xs:attribute name="name"/>
    <xs:attribute name="table"/>
    <xs:attribute name="unique" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="query">
    <xs:complexType mixed="true">
        <xs:sequence>
            <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
        </xs:sequence>
        <xs:attributeGroup ref="attlist.query"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.query">
    <xs:attribute name="name" use="required"/>

```

```
<xs:attribute name="language"/>
<xs:attribute name="unmodifiable" default="false">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="result-class"/>
<xs:attribute name="fetch-plan"/>
</xs:attributeGroup>
<xs:element name="unique">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of columns, fields or properties
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="column"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="field"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="property"/>
            </xs:choice>
            <xs:choice>
                <xs:attributeGroup ref="attlist.unique"/>
            </xs:choice>
        </xs:choice>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.unique">
    <xs:attribute name="name"/>
    <xs:attribute name="table"/>
    <xs:attribute name="deferred" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="extension">
    <xs:complexType>
        <xs:complexContent>
            <xs:extension base="any">
                <xs:attributeGroup ref="attlist.extension"/>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.extension">
    <xs:attribute name="vendor-name" use="required"/>
```

```
<xs:attribute name="key"/>
<xs:attribute name="value"/>
</xs:attributeGroup>
<xs:complexType name="any" mixed="true">
    <xs:sequence>
        <xs:any minOccurs="0" maxOccurs="unbounded" processContents="skip"/>
    </xs:sequence>
</xs:complexType>
</xs:schema>
```

Appendix F: XML Schema for orm.xml

```

<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://java.sun.com/xml/ns/jdo/orm"
            xmlns="http://java.sun.com/xml/ns/jdo/orm"
            xmlns:xs="http://www.w3.org/2001/XMLSchema"
            version="3.0">
    <xs:element name="orm">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="package"/>
                <xs:element ref="query"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.orm"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.orm">
        <xs:attribute name="catalog"/>
        <xs:attribute name="schema"/>
    </xs:attributeGroup>
    <xs:element name="package">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="interface"/>
                <xs:element ref="class"/>
                <xs:element ref="sequence"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.package"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.package">
        <xs:attribute name="name" default="" />
        <xs:attribute name="catalog"/>
        <xs:attribute name="schema"/>
    </xs:attributeGroup>
    <xs:element name="interface">
        <xs:complexType>
            <xs:choice minOccurs="0" maxOccurs="unbounded">
                <xs:annotation><xs:documentation>
                    Please note,
                    the following subelements must not occur more than once:
                    - datastore-identity
                    - primary-key
                    - inheritance
                    - version
                </xs:documentation></xs:annotation>
                <xs:element ref="extension"/>
                <xs:element ref="datastore-identity"/>
                <xs:element ref="primary-key"/>
                <xs:element ref="inheritance"/>
                <xs:element ref="version"/>
                <xs:element ref="join"/>
                <xs:element ref="foreign-key"/>
                <xs:element ref="index"/>
                <xs:element ref="unique"/>
                <xs:element ref="property"/>
                <xs:element ref="query"/>
            </xs:choice>
        </xs:complexType>
    </xs:element>

```

```
        <xs:attributeGroup ref="attlist.interface"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.interface">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="table"/>
    <xs:attribute name="catalog"/>
    <xs:attribute name="schema"/>
</xs:attributeGroup>
<xs:element name="property">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - join
                - embedded
                - key
                - value
                - order
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="join"/>
            <xs:element ref="embedded"/>
            <xs:element ref="element"/>
            <xs:element ref="key"/>
            <xs:element ref="value"/>
            <xs:element ref="order"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.property"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.property">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="value-strategy"/>
    <xs:attribute name="sequence"/>
    <xs:attribute name="serialized">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="table"/>
    <xs:attribute name="column"/>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
```

```
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
<xs:attribute name="recursion-depth"/>
<xs:attribute name="field-name"/>
</xs:attributeGroup>
<xs:element name="class">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - datastore-identity
                - primary-key
                - inheritance
                - version
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="datastore-identity"/>
            <xs:element ref="primary-key"/>
            <xs:element ref="inheritance"/>
            <xs:element ref="version"/>
            <xs:element ref="join"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
            <xs:element ref="column"/>
            <xs:element ref="field"/>
            <xs:element ref="property"/>
            <xs:element ref="query"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.class"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.class">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="table"/>
    <xs:attribute name="catalog"/>
    <xs:attribute name="schema"/>
</xs:attributeGroup>
<xs:element name="primary-key">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
```

```
<xs:element ref="extension"/>
<xs:element ref="column"/>
</xs:choice>
<xs:attributeGroup ref="attlist.primary-key"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.primary-key">
    <xs:attribute name="name"/>
    <xs:attribute name="column"/>
</xs:attributeGroup>
<xs:element name="join">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - primary-key
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="primary-key"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.join"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.join">
    <xs:attribute name="table"/>
    <xs:attribute name="column"/>
    <xs:attribute name="outer" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="indexed">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
                <xs:enumeration value="unique"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
```

```
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
</xs:attributeGroup>
<xs:element name="version">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - index
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
            <xs:element ref="index"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.version"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.version">
    <xs:attribute name="strategy"/>
    <xs:attribute name="column"/>
    <xs:attribute name="indexed">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
                <xs:enumeration value="unique"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="datastore-identity">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.datastore-identity"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.datastore-identity">
    <xs:attribute name="column"/>
    <xs:attribute name="strategy" default="native"/>
    <xs:attribute name="sequence"/>
</xs:attributeGroup>
<xs:element name="implements">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:element ref="extension"/>
            <xs:element ref="property"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.implements"/>
    </xs:complexType>
</xs:element>
```

```
<xs:attributeGroup name="attlist.implements">
    <xs:attribute name="name" use="required"/>
</xs:attributeGroup>
<xs:element name="inheritance">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - join
                - discriminator
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="join"/>
            <xs:element ref="discriminator"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.inheritance"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.inheritance">
    <xs:attribute name="strategy"/>
</xs:attributeGroup>
<xs:element name="discriminator">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - index
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
            <xs:element ref="index"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.discriminator"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.discriminator">
    <xs:attribute name="column"/>
    <xs:attribute name="value"/>
    <xs:attribute name="strategy"/>
    <xs:attribute name="indexed">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
                <xs:enumeration value="unique"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="column">
    <xs:complexType>
        <xs:sequence>
            <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
        </xs:sequence>
        <xs:attributeGroup ref="attlist.column"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.column">
    <xs:attribute name="name"/>
```

```
<xs:attribute name="target"/>
<xs:attribute name="target-field"/>
<xs:attribute name="jdbc-type"/>
<xs:attribute name="sql-type"/>
<xs:attribute name="length"/>
<xs:attribute name="scale"/>
<xs:attribute name="allows-null">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="default-value"/>
<xs:attribute name="insert-value"/>
</xs:attributeGroup>
<xs:element name="field">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - join
                - embedded
                - key
                - value
                - order
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="join"/>
            <xs:element ref="embedded"/>
            <xs:element ref="element"/>
            <xs:element ref="key"/>
            <xs:element ref="value"/>
            <xs:element ref="order"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.field"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.field">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="table"/>
    <xs:attribute name="column"/>
    <xs:attribute name="value-strategy"/>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
```

```
</xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="sequence"/>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="foreign-key">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of columns, fields and properties
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice minOccurs="0" maxOccurs="1">
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="column"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="field"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="property"/>
            </xs:choice>
        </xs:choice>
        <xs:attributeGroup ref="attlist.foreign-key"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.foreign-key">
    <xs:attribute name="table"/>
    <xs:attribute name="deferred">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="delete-action" default="restrict">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
```

```
<xs:attribute name="update-action" default="restrict">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="restrict"/>
      <xs:enumeration value="cascade"/>
      <xs:enumeration value="null"/>
      <xs:enumeration value="default"/>
      <xs:enumeration value="none"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="name"/>
</xs:attributeGroup>
<xs:element name="key">
  <xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
      <xs:annotation><xs:documentation>
        Please note,
        the following subelements must not occur more than once:
        - embedded
        - foreign-key
        - index
        - unique
      </xs:documentation></xs:annotation>
      <xs:element ref="extension"/>
      <xs:element ref="embedded"/>
      <xs:element ref="column"/>
      <xs:element ref="foreign-key"/>
      <xs:element ref="index"/>
      <xs:element ref="unique"/>
    </xs:choice>
    <xs:attributeGroup ref="attlist.key"/>
  </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.key">
  <xs:attribute name="column"/>
  <xs:attribute name="table"/>
  <xs:attribute name="delete-action">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="restrict"/>
        <xs:enumeration value="cascade"/>
        <xs:enumeration value="null"/>
        <xs:enumeration value="default"/>
        <xs:enumeration value="none"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
  <xs:attribute name="update-action">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="restrict"/>
        <xs:enumeration value="cascade"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
```

```
        <xs:enumeration value="null"/>
        <xs:enumeration value="default"/>
        <xs:enumeration value="none"/>
    </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="value">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - embedded
                - foreign-key
                - index
                - unique
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="embedded"/>
            <xs:element ref="column"/>
            <xs:element ref="foreign-key"/>
            <xs:element ref="index"/>
            <xs:element ref="unique"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.value"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.value">
    <xs:attribute name="column"/>
    <xs:attribute name="table"/>
    <xs:attribute name="delete-action">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="restrict"/>
                <xs:enumeration value="cascade"/>
                <xs:enumeration value="null"/>
                <xs:enumeration value="default"/>
                <xs:enumeration value="none"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="update-action">
```

```
<xs:simpleType>
  <xs:restriction base="xs:token">
    <xs:enumeration value="restrict"/>
    <xs:enumeration value="cascade"/>
    <xs:enumeration value="null"/>
    <xs:enumeration value="default"/>
    <xs:enumeration value="none"/>
  </xs:restriction>
</xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
      <xs:enumeration value="unique"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
  <xs:simpleType>
    <xs:restriction base="xs:token">
      <xs:enumeration value="true"/>
      <xs:enumeration value="false"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="element">
  <xs:complexType>
    <xs:choice minOccurs="0" maxOccurs="unbounded">
      <xs:annotation><xs:documentation>
        Please note,
        the following subelements must not occur more than once:
        - embedded
        - foreign-key
        - index
        - unique
      </xs:documentation></xs:annotation>
      <xs:element ref="extension"/>
      <xs:element ref="embedded"/>
      <xs:element ref="column"/>
      <xs:element ref="foreign-key"/>
      <xs:element ref="index"/>
      <xs:element ref="unique"/>
    </xs:choice>
    <xs:attributeGroup ref="attlist.element"/>
  </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.element">
  <xs:attribute name="column"/>
  <xs:attribute name="table"/>
  <xs:attribute name="delete-action">
    <xs:simpleType>
      <xs:restriction base="xs:token">
        <xs:enumeration value="restrict"/>
        <xs:enumeration value="cascade"/>
        <xs:enumeration value="null"/>
        <xs:enumeration value="default"/>
        <xs:enumeration value="none"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
</xs:attributeGroup>
```

```
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="update-action">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="restrict"/>
            <xs:enumeration value="cascade"/>
            <xs:enumeration value="null"/>
            <xs:enumeration value="default"/>
            <xs:enumeration value="none"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="indexed">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
            <xs:enumeration value="unique"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="unique">
    <xs:simpleType>
        <xs:restriction base="xs:token">
            <xs:enumeration value="true"/>
            <xs:enumeration value="false"/>
        </xs:restriction>
    </xs:simpleType>
</xs:attribute>
<xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="order">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - index
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:element ref="column"/>
            <xs:element ref="index"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.order"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.order">
    <xs:attribute name="column"/>
    <xs:attribute name="mapped-by"/>
</xs:attributeGroup>
<xs:element name="embedded">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:element ref="extension"/>
            <xs:element ref="field"/>
            <xs:element ref="property"/>
        </xs:choice>
        <xs:attributeGroup ref="attlist.embedded"/>
    </xs:complexType>
```

```

</xs:element>
<xs:attributeGroup name="attlist.embedded">
    <xs:attribute name="owner-field"/>
    <xs:attribute name="null-indicator-column"/>
    <xs:attribute name="null-indicator-value"/>
</xs:attributeGroup>
<xs:element name="sequence">
    <xs:complexType>
        <xs:sequence>
            <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
        </xs:sequence>
        <xs:attributeGroup ref="attlist.sequence"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.sequence">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="datastore-sequence"/>
    <xs:attribute name="factory-class"/>
    <xs:attribute name="strategy" use="required">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="nontransactional"/>
                <xs:enumeration value="contiguous"/>
                <xs:enumeration value="noncontiguous"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="index">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of columns, fields or properties
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="column"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="field"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="property"/>
            </xs:choice>
        </xs:choice>
        <xs:attributeGroup ref="attlist.index"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.index">
    <xs:attribute name="name"/>
    <xs:attribute name="table"/>
    <xs:attribute name="unique" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="query">
    <xs:complexType mixed="true">
        <xs:sequence>

```

```
        <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
    </xs:sequence>
    <xs:attributeGroup ref="attlist.query"/>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.query">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="language"/>
    <xs:attribute name="unmodifiable" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="unique">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="result-class"/>
</xs:attributeGroup>
<xs:element name="unique">
    <xs:complexType>
        <xs:choice minOccurs="0" maxOccurs="unbounded">
            <xs:annotation><xs:documentation>
                Please note,
                the following subelements must not occur more than once:
                - the choice of columns, fields or properties
            </xs:documentation></xs:annotation>
            <xs:element ref="extension"/>
            <xs:choice>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="column"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="field"/>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="property"/>
            </xs:choice>
        </xs:choice>
        <xs:attributeGroup ref="attlist.unique"/>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.unique">
    <xs:attribute name="name"/>
    <xs:attribute name="table"/>
    <xs:attribute name="deferred" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:attributeGroup>
<xs:element name="extension">
    <xs:complexType>
        <xs:complexContent>
            <xs:extension base="any">
                <xs:attributeGroup ref="attlist.extension"/>

```

```
        </xs:extension>
    </xs:complexContent>
</xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.extension">
    <xs:attribute name="vendor-name" use="required"/>
    <xs:attribute name="key"/>
    <xs:attribute name="value"/>
</xs:attributeGroup>
<xs:complexType name="any" mixed="true">
    <xs:sequence>
        <xs:any minOccurs="0" maxOccurs="unbounded" processContents="skip"/>
    </xs:sequence>
</xs:complexType>
</xs:schema>
```

Appendix G: XML Schema for jdoquery.xml

```

<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://java.sun.com/xml/ns/jdo/jdoquery"
            xmlns="http://java.sun.com/xml/ns/jdo/jdoquery"
            xmlns:xs="http://www.w3.org/2001/XMLSchema"
            version="3.0">
    <xs:element name="jdoquery">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="package"/>
                <xs:element ref="query"/>
            </xs:choice>
        </xs:complexType>
    </xs:element>
    <xs:element name="package">
        <xs:complexType>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="interface"/>
                <xs:element ref="class"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.package"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.package">
        <xs:attribute name="name" default="" />
    </xs:attributeGroup>
    <xs:element name="interface">
        <xs:complexType>
            <xs:choice minOccurs="0" maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="query"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.interface"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.interface">
        <xs:attribute name="name" use="required"/>
    </xs:attributeGroup>
    <xs:element name="class">
        <xs:complexType>
            <xs:choice minOccurs="0" maxOccurs="unbounded">
                <xs:element ref="extension"/>
                <xs:element ref="query"/>
            </xs:choice>
            <xs:attributeGroup ref="attlist.class"/>
        </xs:complexType>
    </xs:element>
    <xs:attributeGroup name="attlist.class">
        <xs:attribute name="name" use="required"/>
    </xs:attributeGroup>
    <xs:element name="query">
        <xs:complexType mixed="true">
            <xs:sequence>
                <xs:element minOccurs="0" maxOccurs="unbounded" ref="extension"/>
            </xs:sequence>
            <xs:attributeGroup ref="attlist.query"/>
        </xs:complexType>
    </xs:element>

```

```
</xs:element>
<xs:attributeGroup name="attlist.query">
    <xs:attribute name="name" use="required"/>
    <xs:attribute name="language"/>
    <xs:attribute name="unmodifiable" default="false">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="unique">
        <xs:simpleType>
            <xs:restriction base="xs:token">
                <xs:enumeration value="true"/>
                <xs:enumeration value="false"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
    <xs:attribute name="result-class"/>
    <xs:attribute name="datastore-read-timeout-millis"/>
    <xs:attribute name="datastore-write-timeout-millis"/>
</xs:attributeGroup>
<xs:element name="extension">
    <xs:complexType>
        <xs:complexContent>
            <xs:extension base="any">
                <xs:attributeGroup ref="attlist.extension"/>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
</xs:element>
<xs:attributeGroup name="attlist.extension">
    <xs:attribute name="vendor-name" use="required"/>
    <xs:attribute name="key"/>
    <xs:attribute name="value"/>
</xs:attributeGroup>
<xs:complexType name="any" mixed="true">
    <xs:sequence>
        <xs:any minOccurs="0" maxOccurs="unbounded" processContents="skip"/>
    </xs:sequence>
</xs:complexType>
</xs:schema>
```

Index

A

accessDeclaredMembers 339
 addInstanceLifecycleListener 111, 145
 addRegisterClassListener 92
 addStateInterrogation 95
 afterCompletion 51, 153
 all 138
 allows-null 225
 application 43
 ApplicationIdentity 107
 Array 108
 ArrayList 108
 Arrays 75
 associated object 140
 AttachCallback 98
 AttachLifecycleListener 144
 ATTRIBUTE deferred 230
 ATTRIBUTE delete-action 230
 ATTRIBUTE update-action 230

B

basic 138
 beforeCompletion 51, 153
 begin 154
 Binary Compatibility 28
 Binary compatibility 306
 BinaryCompatibility 108
 ByteIdentity 48

C

Cache management 118
 Change of identity 46
 ChangeApplicationIdentity 108
 char literals 168
 CharIdentity 48
 ClearCallback 97
 ClearLifecycleListener 143
 clone 314
 Cloning 314
 Closing Query results 174
 Collection 74, 117
 commit 154, 155
 compile 164
 compound Identity 47
 Conflicting changes 198
 Connection 29, 34, 100
 connection 25, 33, 35, 148
 Connection Management 149

ConnectionFactory 105
 copyKeyFieldsToObjectId 94
 Correlated subqueries 171
 CreateLifecycleListener 142
 Currency 74

D

datastore connection 146
 DataStoreCache 110
 DatastoreIdentity 108
 DateFormat 94
 DateTime 109
 declareImports 163
 declareParameters 163
 declareVariables 163
 default 138
 default fetch group 131
 default-value 225
 Delete persistent instances 125
 DeleteCallback 97
 DeleteLifecycleListener 143
 deletePersistent 125
 DETACH_LOAD_FIELDS 129, 130
 DETACH_UNLOAD_FIELDS 129
 Detachable 83, 311
 DetachAllOnCommit 54, 127, 128
 DetachCallback 97
 detachCopy 128
 detachCopyAll 128
 Detached 79
 Detached-clean 54
 Detached-dirty 54
 detachedState 314
 DetachLifecycleListener 144
 DirtyLifecycleListener 144
 Document Type Descriptor 239, 356

E

ELEMENT array 235, 356
 ELEMENT class 353
 ELEMENT collection 229, 230, 234, 355
 ELEMENT column 223
 ELEMENT discriminator 229
 ELEMENT element 237
 ELEMENT embedded 236
 ELEMENT extension 238, 356
 ELEMENT field 230, 354
 ELEMENT implements 229

ELEMENT inheritance 229
 ELEMENT interface 222
 ELEMENT jdo 222, 353
 ELEMENT join 228
 ELEMENT key 236
 ELEMENT map 235, 355
 ELEMENT orm 238, 239
 ELEMENT package 222, 353
 ELEMENT primary-key 228
 ELEMENT property 230
 ELEMENT query 237
 ELEMENT sequence 238
 ELEMENT value 237
 ELEMENT version 227
 enum 193
 Enums 75
 equals 44
 evict 118
 Evicting objects from the cache 111
 exceptions 216
 exclude subclasses 179, 180
 execute 165
 executeWithArray 166
 executeWithMap 166
 Extent 120, 301
 Extent iterator 301

F

Fetch Groups 131
 fetch plan 119, 130
 fetch size 130
 FETCH_SIZE_GREEDY 134
 FETCH_SIZE_OPTIMAL 134
 FetchGroup 138
 fetch-group 135
 FetchPlan 133
 FGOOnly 119
 Field Numbering 312
 First Class Objects 71
 flush 197
 for... operator 300
 from 179

G

Generated fields 319
 Generated methods 319
 Generated static initializer 319
 getDataStoreCache 110
 GetDataStoreConnection 108

getDataStoreConnection 146
 getDetachAllOnCommit 127, 128
 getDetachmentOptions 134
 getFetchPlan 301
 getFieldNames 91
 getFieldTypes 91
 getIgnoreCache 120, 164
 GetJDBCConnection 108
 getJDOImplHelper 339
 getKey 48
 getKeyAsObject 48
 getMultithreaded 140
 getNativeConnection 146, 147
 getObjectById 121, 123
 getObjectId 86, 122
 getObjectIdClass 141
 getObjectIds 86
 getObjectsById 123
 GetPersistenceManager 77
 getPersistenceManager 105, 106, 150, 162
 getPersistenceManagerFactory 141
 getSynchronization 153
 getTargetClass 48
 getTargetClassName 48
 getTransactionalObjectId 123
 getUserObject 140
 getVersion 86
 group by 179

H

hashCode 44
 HeterogeneousInterfaceType 109
 HeterogeneousObjectType 109
 Hollow 52

I

IgnoreCache 164
 Inheritance 75, 312
 inheritance 226, 353
 Inner class 221, 353
 insert-value 225
 Instance life cycle management 124
 InstanceCallbacks 96
 InstanceLifecycleEvent 145
 InstanceLifecycleListener 111, 142
 IntIdentity 48
 into 179
 Introspection (Java core reflection) 314
 isActive 151

isClosed 117
 isDetached 87
 Isolation Level 100
 isUnmodifiable 164

J

java.sql.Connection 146
 javax.jdo.mapping.Catalog 102
 javax.jdo.mapping.Schema 102
 javax.jdo.option.ChangeApplicationIdentity 130
 javax.jdo.option.Mapping 102, 220
 jdbc-type 224
 JDO Identity 44, 51, 71, 78, 86, 121, 169, 304, 335
 JDO identity 47
 JDO option 42, 43, 54
 jdoconfig 103
 JDOConnection 146, 147
 jdoCopyFields 330
 jdoCopyKeyFieldsToObjectId 321, 322, 332
 JDODetachedFieldAccessException 129, 323
 jdoDetachedState 84, 319
 JDOEntityManagerFactory 299
 jdoFieldFlags 318
 jdoFieldNames 319, 325
 jdoFieldTypes 319, 325
 jdoFlags 317, 325
 jdoGetField 311, 316, 328
 jdoGetManagedFieldCount 327
 jdoGetObjectId 78, 86, 320
 jdoGetPersistenceManager 77
 jdoGetTransactionalObjectId 320
 jdoGetVersion 320
 JDOHelper 77, 85
 JDOImplHelper 91
 jdoInheritedFieldCount 319, 325
 jdoIsDeleted 79, 87, 320
 jdoIsDetached 320
 jdoIsDirty 79, 320
 jdoIsNew 79, 87, 320
 jdoIsPersistent 79, 87, 320
 jdoIsTransactional 79, 87, 320
 jdoMakeDirty 78, 320
 jdoNewInstance 80, 322, 327
 jdoNewObjectIdInstance 81
 JDONullIdentityException 49, 82
 JDOPermission("getMetadata") 339
 JDOPermission("setStateManager") 339
 jdoPersistenceCapableSuperclass 319
 JDOPostAttach 128

jdoPostAttach 98
 jdoPostDetach 97
 jdoPostLoad 96
 jdoPreAttach 98
 jdoPreClear 97
 jdoPreDelete 97
 jdoPreDetach 97
 jdoPreSerialize 313, 331
 jdoPreStore 96
 jdoProvideField 330
 jdoProvideFields 330
 JDOQL 110
 jdoReplaceDetachedState 84, 322
 jdoReplaceField 329
 jdoReplaceFields 329
 jdoReplaceStateManager 326, 327
 jdoSetField 311, 316, 328, 329, 330
 jdoStateManager 325
 JDOUnsupportedOptionException 100
 JoinedTablePerClass 109
 JoinedTablePerConcreteClass 109

L

length 225
 LinkedHashMap 74
 LinkedHashSet 74
 LinkedList 108
 List 108
 LoadCallback 96
 LoadLifecycleListener 143
 Locale 74
 LongIdentity 48

M

Make instances nontransactional 127
 Make instances persistent 124
 Make instances transactional 126
 Make instances transient 126
 makeNontransactional 127
 makePersistent 124, 125, 127
 makeTransactional 126
 makeTransient 126
 mapped-by 197
 MaxFetchDepth 132
 Membership 185
 Message-driven Beans 29
 META 103
 Multithreaded 140
 multivalued 138

N

Namespaces in queries 159
 newInstance 92
 newObjectIdInstance 94
 newQuery 160
 NonDurableIdentity 108
 NonJoinedTablePerConcreteClass 109
 Nontransactional 54
 NontransactionalRead 107, 151
 NontransactionalWrite 107
 NullCollection 108, 170

O

Object Class type 74
 Object Database 35
 object database 27, 28, 157
 object equality 44
 object identity 44, 310
 ObjectId class management 141
 ObjectIdentity 49
 ObjectIdFieldConsumer 83
 ObjectIdFieldManager 83
 ObjectIdFieldSupplier 83
 Optimistic 107, 150, 151, 155
 Optimistic transaction 58
 order by 179
 Ordering 174
 overhead 128

P

parameters 179, 180
 parseXXX 49
 persistence 104
 persistence by reachability 51
 PersistenceCapable 77
 Persistence-capable 70
 PersistenceManager 115
 PersistenceManagerFactory 99
 Persistent-clean 53
 Persistent-deleted 53
 Persistent-dirty 52
 Persistent-new 51
 Persistent-nontransactional 56
 Persistent-nontransactional-dirty 56
 Pinning objects in the cache 111
 Portability Guidelines 300
 postAttach 128
 post-load 135, 138
 PreDirtyEvent 109

primary key 45

Properties 107
 provisionally persistent 124

Q

Query factory 120

R

range 179
 Recursion-depth 132
 recursion-depth 139
 ReflectPermission 339
 refresh 118
 registerClass 92, 325
 registerDateFormat 94
 relational 24, 27, 28, 35, 41, 157, 317
 relationship 138
 RelationSubclassTable 109
 removeInstanceLifecycleListener 112, 146
 removeRegisterClassListener 93
 removeStateInterrogation 95
 restoreValue 51
 RestoreValues 54, 55, 152, 165
 result 179
 result-class-name 179
 RetainValues 107, 151, 152, 165
 retrieve 119
 retrieveAll 119
 rollback 154

S

scale 225
 Second Class Objects 71
 Second-level cache management 110
 select 179
 Sequence 141
 Serialization 313
 Serializing Persistent Instances 128
 setCandidates 162
 setClass 162
 setDetachAllOnCommit 127, 128
 setDetachmentOptions 133
 setFilter 163
 setGrouping 163
 setIgnoreCache 120, 164
 setMultithreaded 140
 setNontransactionalRead 151
 setNontransactionalWrite 151
 setOptimistic 151

setOrdering 163
 setRange 163
 setResult 163
 setResultClass 163
 setRetainValues 152
 setStateManager 339
 setSynchronization 153
 setUnique 163
 setUnmodifiable 164
 setUserObject 140
 ShortIdentity 48
 single field identity 48, 82, 322
 Single-String Query 179
 SQL 109, 157
 SQL Portability 147
 sql-type 225
 State interrogation 79
 StateImage 109
 StateInterrogation 95
 static initialization 319
 static initializer 325
 StoreCallback 96
 StoreLifecycleListener 143
 StringIdentity 48
 subclasses 179, 180
 supported query languages 107
 supportedOptions 107
 suppressAccessChecks 339
 Synchronization 140, 153

T

Threading 116
 Transaction factory 120
 Transaction Isolation Level 100
 Transient 51, 57
 Transient Transactional 57
 Transient-clean 57
 Transient-dirty 58
 TransientTransactional 107
 TreeMap 108
 TreeSet 108

U

UnconstrainedQueryVariables 109
 unique 179
 unmodifiable 139
 Unpinning objects in the cache 111

V

validate 121
 variables 179, 180
 Vector 108

W

web application 128
 where 179
 writeObject 331

4140 Network Circle
Santa Clara, CA 95404

For U.S. Sales Office locations, call:

800 821-4643

In California:

800 821-4642

Australia: (02) 844 5000

Belgium: 32 2 716 7911

Canada: 416 477-6745

Finland: +358-0-525561

France: (1) 30 67 50 00

Germany: (0) 89-46 00 8-0

Hong Kong: 852 802 4188

Italy: 039 60551

Japan: (03) 5717-5000

Korea: 822-563-8700

Latin America: 415 688-9464

The Netherlands: 033 501234

New Zealand: (04) 499 2344

Nordic Countries: +46 (0) 8 623 90 00

PRC: 861-849 2828

Singapore: 224 3388

Spain: (91) 5551648

Switzerland: (1) 825 71 11

Taiwan: 2-514-0567

UK: 0276 20444

Elsewhere in the world,

call Corporate Headquarters:

415 960-1300

Intercontinental Sales: 415 688-9000