The Neo4j Java Developer Reference v3.0

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This part contains information on advanced usage of Neo4j. Among the topics covered are embedding Neo4j in your own software and writing extensions for the Neo4j Server.

You might want to keep the Neo4j JavaDocs (javadocs/) handy while reading!

Chapter 1. Extending Neo4j

Neo4j provides a pluggable infrastructure for extensions. Procedures extend the capabilities of the Cypher query language. Server extensions allow new surfaces to be created in the REST API. Both require the user to be familiar with the Java programming language and to have an environment set up for compiling Java code.

When running your own code and Neo4j in the same JVM, there are a few things you should keep in mind:

- Don't create or retain more objects than you strictly need to. Large caches in particular tend to promote more objects to the old generation, thus increasing the need for expensive full garbage collections.
- Don't use internal Neo4j APIs. They are internal to Neo4j and subject to change without notice, which may break or change the behavior of your code.
- If possible, avoid using Java object serialization or reflection in your code or in any runtime dependency that you use. Otherwise, if you cannot avoid using Java object serialization and reflection, then ensure that the `-XX:+TrustFinalNonStaticFields` JVM flag is disabled in `neo4j-wrapper.conf`.

1.1. Procedures

User-defined procedures are written in Java, deployed into the database, and called from Cypher.

A *procedure* is a mechanism that allows Neo4j to be extended by writing custom code which can be invoked directly from Cypher. Procedures can take arguments, perform operations on the database, and return results.

Procedures are written in Java and compiled into *jar* files. They can be deployed to the database by dropping a *jar* file into the *$NEO4J_HOME/plugins* directory on each standalone or clustered server. The database must be re-started on each server to pick up new procedures.

Procedures are the preferred means for extending Neo4j. Examples of use cases for procedures are:

1. To provide access to functionality that is not available in Cypher, such as manual indexes and schema introspection.
2. To provide access to third party systems.
3. To perform graph-global operations, such as counting connected components or finding dense nodes.
4. To express a procedural operation that is difficult to express declaratively with Cypher.

1.1.1. Calling procedures

To call a stored procedure, use a Cypher `CALL` clause. The procedure name must be fully qualified, so a procedure named `findDenseNodes` defined in the package `org.neo4j.examples` could be called using:

```
CALL org.neo4j.examples.findDenseNodes(1000)
```

A `CALL` may be the only clause within a Cypher statement or may be combined with other clauses. Arguments can be supplied directly within the query or taken from the associated parameter set. For full details, see the Cypher documentation on the `CALL` clause *(http://neo4j.com/docs/developer-*

manual/3.0/cypher/#query-call).

1.1.2. Built-in procedures

Neo4j comes bundled with a number of built-in procedures. These are listed in the table below:

Procedure name	Command to invoke procedure	What it does
`ListLabels`	`CALL db.labels()`	List all labels in the database.
`ListRelationshipTypes`	`CALL db.relationshipTypes()`	List all relationship types in the database.
`ListPropertyKeys`	`CALL db.propertyKeys()`	List all property keys in the database.
`ListIndexes`	`CALL db.indexes()`	List all indexes in the database.
`ListConstraints`	`CALL db.constraints()`	List all constraints in the database.
`ListProcedures`	`CALL dbms.procedures()`	List all procedures in the DBMS.
`ListComponents`	`CALL dbms.components()`	List DBMS components and their versions.
`QueryJmx`	`CALL dbms.queryJmx(query)`	Query JMX management data by domain and name. For instance, "org.neo4j:*".
`AlterUserPassword`	`CALL dbms.changePassword(query)`	Change the user password.

1.1.3. User-defined procedures

The example discussed below is available as a repository on GitHub *(https://github.com/neo4j-examples/neo4j-procedure-template)*. To get started quickly you can fork the repository and work with the code as you follow along in the guide below.

Custom procedures are written in the Java programming language. Procedures are deployed via a *jar* file that contains the code itself along with any dependencies (excluding Neo4j). These files should be placed into the *plugin* directory of each standalone database or cluster member and will become available following the next database restart.

The example that follows shows the steps to create and deploy a new procedure.

Set up a new project

A project can be set up in any way that allows for compiling a procedure and producing a *jar* file. Below is an example configuration using the Maven *(https://maven.apache.org/)* build system. For readability, only excerpts from the Maven *pom.xml* file are shown here, the whole file is available from the Neo4j Procedure Template *(https://github.com/neo4j-examples/neo4j-procedure-template)* repository.

```
<project xmlns="http://maven.apache.org/POM/4.0.0" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
                     http://maven.apache.org/xsd/maven-4.0.0.xsd">
 <modelVersion>4.0.0</modelVersion>

 <groupId>org.neo4j.example</groupId>
 <artifactId>procedure-template</artifactId>
 <version>1.0.0-SNAPSHOT</version>

 <packaging>jar</packaging>
 <name>Neo4j Procedure Template</name>
 <description>A template project for building a Neo4j Procedure</description>

 <properties>
   <neo4j.version>3.0</neo4j.version>
 </properties>
```

Next, the build dependencies are defined. The following two sections are included in the *pom.xml* between `<dependencies></dependencies>` tags.

The first dependency section includes the procedure API that procedures use at runtime. The scope is set to `provided`, because once the procedure is deployed to a Neo4j instance, this dependency is provided by Neo4j. If non-Neo4j dependencies are added to the project, their scope should normally be `compile`.

```
   <dependency>
     <groupId>org.neo4j</groupId>
     <artifactId>neo4j</artifactId>
     <version>${neo4j.version}</version>
     <scope>provided</scope>
   </dependency>
```

Next, the dependencies necessary for testing the procedure are added:

- Neo4j Harness, a utility that allows for starting a lightweight Neo4j instance. It is used to start Neo4j with a specific procedure deployed, which greatly simplifies testing.
- The Neo4j Java driver, used to send cypher statements that call the procedure.
- JUnit, a common Java test framework.

```
   <dependency>
     <groupId>org.neo4j.test</groupId>
     <artifactId>neo4j-harness</artifactId>
     <version>${neo4j.version}</version>
     <scope>test</scope>
   </dependency>

   <dependency>
     <groupId>org.neo4j.driver</groupId>
     <artifactId>neo4j-java-driver</artifactId>
     <version>1.0-SNAPSHOT</version>
     <scope>test</scope>
   </dependency>

   <dependency>
     <groupId>junit</groupId>
     <artifactId>junit</artifactId>
     <version>4.12</version>
     <scope>test</scope>
   </dependency>
```

Along with declaring the dependencies used by the procedure it is also necessary to define the steps that Maven will go through to build the project. The goal is first to *compile* the source, then to *package* it in a *jar* that can be deployed to a Neo4j instance.

Procedures require at least Java 8, so the version `1.8` should be defined as the *source* and *target version* in the configuration for the Maven compiler plugin.

The Maven Shade *(https://maven.apache.org/plugins/maven-shade-plugin/)* plugin is used to package the compiled procedure. It also includes all dependencies in the package, unless the dependency scope is set to *test* or *provided*.

Once the procedure has been deployed to the *plugins* directory of each Neo4j instance and the instances have restarted, the procedure is available for use.

```
<build>
 <plugins>
   <plugin>
     <artifactId>maven-compiler-plugin</artifactId>
     <configuration>
       <source>1.8</source>
       <target>1.8</target>
     </configuration>
   </plugin>
   <plugin>
     <artifactId>maven-shade-plugin</artifactId>
     <executions>
       <execution>
         <phase>package</phase>
         <goals>
           <goal>shade</goal>
         </goals>
       </execution>
     </executions>
   </plugin>
 </plugins>
</build>
```

Writing integration tests

The test dependencies include *Neo4j Harness* and *JUnit*. These can be used to write integration tests for procedures.

First, we decide what the procedure should do, then we write a test that proves that it does it right. Finally we write a procedure that passes the test.

Below is a template for testing a procedure that accesses Neo4j's full-text indexes from Cypher.

Writing tests for procedures

```java
package example;

import org.junit.Rule;
import org.junit.Test;
import org.neo4j.driver.v1.*;
import org.neo4j.graphdb.factory.GraphDatabaseSettings;
import org.neo4j.harness.junit.Neo4jRule;

import static org.hamcrest.core.IsEqual.equalTo;
import static org.junit.Assert.assertThat;
import static org.neo4j.driver.v1.Values.parameters;

public class ManualFullTextIndexTest
{
    // This rule starts a Neo4j instance for us
    @Rule
    public Neo4jRule neo4j = new Neo4jRule()

            // This is the Procedure we want to test
            .withProcedure( FullTextIndex.class );

    @Test
    public void shouldAllowIndexingAndFindingANode() throws Throwable
    {
        // In a try-block, to make sure we close the driver after the test
        try( Driver driver = GraphDatabase.driver( neo4j.boltURI() , Config.build().withEncryptionLevel(
Config.EncryptionLevel.NONE ).toConfig() ) )
        {

            // Given I've started Neo4j with the FullTextIndex procedure class
            //       which my 'neo4j' rule above does.
            Session session = driver.session();

            // And given I have a node in the database
            long nodeId = session.run( "CREATE (p:User {name:'Brookreson'}) RETURN id(p)" )
                    .single()
                    .get( 0 ).asLong();

            // When I use the index procedure to index a node
            session.run( "CALL example.index({id}, ['name'])", parameters( "id", nodeId ) );

            // Then I can search for that node with lucene query syntax
            StatementResult result = session.run( "CALL example.search('User', 'name:Brook*')" );
            assertThat( result.single().get( "nodeId" ).asLong(), equalTo( nodeId ) );
        }
    }
}
```

Writing a procedure

With the test in place, we write a procedure procedure that fulfils the expectations of the test. The full example is available in the Neo4j Procedure Template *(https://github.com/neo4j-examples/neo4j-procedure-template)* repository.

Particular things to note:

- All procedures are annotated `@Procedure`. Procedures that write to the database are additionally annotated `@PerformsWrites`.
- The *context* of the procedure, which is the same as each resource that the procedure wants to use, is annotated `@Context`.
- The *input* and *output*.

For more details, see the API documentation for procedures *(http://neo4j.com/docs/java-reference/3.0/javadocs/index.html?org/neo4j/procedure/Procedure.html)*.

The correct way to signal an error from within a procedure is to throw a `RuntimeException`.

```java
package example;

import java.util.List;
import java.util.Map;
import java.util.Set;
import java.util.stream.Stream;

import org.neo4j.graphdb.GraphDatabaseService;
import org.neo4j.graphdb.Label;
import org.neo4j.graphdb.Node;
import org.neo4j.graphdb.index.Index;
import org.neo4j.graphdb.index.IndexManager;
import org.neo4j.logging.Log;
import org.neo4j.procedure.Context;
import org.neo4j.procedure.Name;
import org.neo4j.procedure.PerformsWrites;
import org.neo4j.procedure.Procedure;

import static org.neo4j.helpers.collection.MapUtil.stringMap;

/**
 * This is an example showing how you could expose Neo4j's full text indexes as
 * two procedures - one for updating indexes, and one for querying by label and
 * the lucene query language.
 */
public class FullTextIndex
{
    // Only static fields and @Context-annotated fields are allowed in
    // Procedure classes. This static field is the configuration we use
    // to create full-text indexes.
    private static final Map<String,String> FULL_TEXT =
            stringMap( IndexManager.PROVIDER, "lucene", "type", "fulltext" );

    // This field declares that we need a GraphDatabaseService
    // as context when any procedure in this class is invoked
    @Context
    public GraphDatabaseService db;

    // This gives us a log instance that outputs messages to the
    // standard log, `neo4j.log`
    @Context
    public Log log;

    /**
     * This declares the first of two procedures in this class - a
     * procedure that performs queries in a manual index.
     *
     * It returns a Stream of Records, where records are
     * specified per procedure. This particular procedure returns
     * a stream of {@link SearchHit} records.
     *
     * The arguments to this procedure are annotated with the
     * {@link Name} annotation and define the position, name
     * and type of arguments required to invoke this procedure.
     * There is a limited set of types you can use for arguments,
     * these are as follows:
     *
     * <ul>
     *     <li>{@link String}</li>
     *     <li>{@link Long} or {@code long}</li>
     *     <li>{@link Double} or {@code double}</li>
     *     <li>{@link Number}</li>
     *     <li>{@link Boolean} or {@code boolean}</li>
     *     <li>{@link java.util.Map} with key {@link String} and value {@link Object}</li>
     *     <li>{@link java.util.List} of elements of any valid argument type, including {@link
java.util.List}</li>
     *     <li>{@link Object}, meaning any of the valid argument types</li>
     * </ul>
     *
     * @param label the label name to query by
     * @param query the lucene query, for instance `name:Brook*` to
     *              search by property `name` and find any value starting
     *              with `Brook`. Please refer to the Lucene Query Parser
     *              documentation for full available syntax.
     * @return the nodes found by the query
     */
    @Procedure("example.search")
    @PerformsWrites
    public Stream<SearchHit> search( @Name("label") String label,
                                     @Name("query") String query )
    {
        String index = indexName( label );

        // Avoid creating the index, if it's not there we won't be
        // finding anything anyway!
        if( !db.index().existsForNodes( index ))
        {
            // Just to show how you'd do logging
            log.debug( "Skipping index query since index does not exist: `%s`", index );
            return Stream.empty();
        }

        // If there is an index, do a lookup and convert the result
        // to our output record.
        return db.index()
                .forNodes( index )
                .query( query )
                .stream()
                .map( SearchHit::new );
    }

    /**
     * This is the second procedure defined in this class, it is used to update the
     * index with nodes that should be queryable. You can send the same node multiple
     * times, if it already exists in the index the index will be updated to match
     * the current state of the node.
     *
     * This procedure works largely the same as {@link #search(String, String)},
     * with two notable differences. One, it is annotated with {@link PerformsWrites},
     * which is <i>required</i> if you want to perform updates to the graph in your
     * procedure.
     *
     * Two, it returns {@code void} rather than a stream. This is simply a short-hand
     * for saying our procedure always returns an empty stream of empty records.
     *
     * @param nodeId the id of the node to index
     * @param propKeys a list of property keys to index, only the ones the node
     *                 actually contains will be added
     */
    @Procedure("example.index")
    @PerformsWrites
    public void index( @Name("nodeId") long nodeId,
                       @Name("properties") List<String> propKeys )
    {
        Node node = db.getNodeById( nodeId );

        // Load all properties for the node once and in bulk,
        // the resulting set will only contain those properties in `propKeys`
        // that the node actually contains.
        Set<Map.Entry<String,Object>> properties =
                node.getProperties( propKeys.toArray( new String[0] ) ).entrySet();

        // Index every label (this is just as an example, we could filter which labels to index)
        for ( Label label : node.getLabels() )
        {
            Index<Node> index = db.index().forNodes( indexName( label.name() ), FULL_TEXT );

            // In case the node is indexed before, remove all occurrences of it so
            // we don't get old or duplicated data
            index.remove( node );

            // And then index all the properties
            for ( Map.Entry<String,Object> property : properties )
            {
                index.add( node, property.getKey(), property.getValue() );
            }
        }
    }


    /**
     * This is the output record for our search procedure. All procedures
     * that return results return them as a Stream of Records, where the
     * records are defined like this one - customized to fit what the procedure
     * is returning.
     *
     * These classes can only have public non-final fields, and the fields must
     * be one of the following types:
```

```
     *
     * <ul>
     *     <li>{@link String}</li>
     *     <li>{@link Long} or {@code long}</li>
     *     <li>{@link Double} or {@code double}</li>
     *     <li>{@link Number}</li>
     *     <li>{@link Boolean} or {@code boolean}</li>
     *     <li>{@link org.neo4j.graphdb.Node}</li>
     *     <li>{@link org.neo4j.graphdb.Relationship}</li>
     *     <li>{@link org.neo4j.graphdb.Path}</li>
     *     <li>{@link java.util.Map} with key {@link String} and value {@link Object}</li>
     *     <li>{@link java.util.List} of elements of any valid field type, including {@link
java.util.List}</li>
     *     <li>{@link Object}, meaning any of the valid field types</li>
     * </ul>
     */
    public static class SearchHit
    {
        // This records contain a single field named 'nodeId'
        public long nodeId;

        public SearchHit( Node node )
        {
            this.nodeId = node.getId();
        }
    }

    private String indexName( String label )
    {
        return "label-" + label;
    }
}
```

1.2. Unmanaged server extensions

Sometimes you'll want finer grained control over your application's interactions with Neo4j than cypher provides. For these situations you can use the unmanaged extension API.

This is a sharp tool, allowing users to deploy arbitrary JAX-RS *(https://en.wikipedia.org/wiki/JAX-RS)* classes to the server so be careful when using this. In particular it's easy to consume lots of heap space on the server and degrade performance. If in doubt, please ask for help via one of the community channels.

1.2.1. Introduction to unmanaged extensions

The first step when writing an unmanaged extension is to create a project which includes dependencies to the JAX-RS and Neo4j core jars. In Maven this would be achieved by adding the following lines to the pom file:

```
<dependency>
    <groupId>javax.ws.rs</groupId>
    <artifactId>javax.ws.rs-api</artifactId>
    <version>2.0</version>
    <scope>provided</scope>
</dependency>
```

```
<dependency>
    <groupId>org.neo4j</groupId>
    <artifactId>neo4j</artifactId>
    <version>3.0</version>
    <scope>provided</scope>
</dependency>
```

Now we're ready to write our extension.

In our code we'll interact with the database using `GraphDatabaseService` which we can get access to by using the `@Context` annotation. The following example serves as a template which you can base your extension on:

Unmanaged extension example

```
@Path( "/helloworld" )
public class HelloWorldResource
{
    private final GraphDatabaseService database;

    public HelloWorldResource( @Context GraphDatabaseService database )
    {
        this.database = database;
    }

    @GET
    @Produces( MediaType.TEXT_PLAIN )
    @Path( "/{nodeId}" )
    public Response hello( @PathParam( "nodeId" ) long nodeId )
    {
        // Do stuff with the database
        return Response.status( Status.OK ).entity( UTF8.encode( "Hello World, nodeId=" + nodeId ) ).
build();
    }
}
```

The full source code is found here: HelloWorldResource.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/server-examples/src/main/java/org/neo4j/examples/server/unmanaged/HelloWorldResource.java)*

Having built your code, the resulting jar file (and any custom dependencies) should be placed in the *$NEO4J_SERVER_HOME/plugins* directory. We also need to tell Neo4j where to look for the extension by adding some configuration in *neo4j.conf*:

```
#Comma separated list of JAXRS packages containing JAXRS Resource, one package name for each mountpoint.
dbms.unmanaged_extension_classes=org.neo4j.examples.server.unmanaged=/examples/unmanaged
```

Our hello method will now respond to `GET` requests at the URI: `http://{neo4j_server}:{neo4j_port}/examples/unmanaged/helloworld/{nodeId}`. e.g.

```
curl http://localhost:7474/examples/unmanaged/helloworld/123
```

which results in

```
Hello World, nodeId=123
```

1.2.2. Streaming JSON responses

When writing unmanaged extensions we have greater control over the amount of memory that our Neo4j queries use. If we keep too much state around it can lead to more frequent full Garbage Collection and subsequent unresponsiveness by the Neo4j server.

A common way that state can creep in is the creation of JSON objects to represent the result of a query which we then send back to our application. Neo4j's Transactional Cypher HTTP endpoint streams responses back to the client and we should follow in its footsteps.

For example, the following unmanaged extension streams an array of a person's colleagues:

Unmanaged extension streaming example

```
@Path("/colleagues")
public class ColleaguesResource
{
    private GraphDatabaseService graphDb;
    private final ObjectMapper objectMapper;

    private static final RelationshipType ACTED_IN = RelationshipType.withName( "ACTED_IN" );
    private static final Label PERSON = Label.label( "Person" );

    public ColleaguesResource( @Context GraphDatabaseService graphDb )
    {
        this.graphDb = graphDb;
        this.objectMapper = new ObjectMapper();
    }

    @GET
    @Path("/{personName}")
    public Response findColleagues( final @PathParam("personName") String personName )
    {
        StreamingOutput stream = new StreamingOutput()
        {
            @Override
            public void write( OutputStream os ) throws IOException, WebApplicationException
            {
                JsonGenerator jg = objectMapper.getJsonFactory().createJsonGenerator( os, JsonEncoding
.UTF8 );
                jg.writeStartObject();
                jg.writeFieldName( "colleagues" );
                jg.writeStartArray();

                try ( Transaction tx = graphDb.beginTx();
                      ResourceIterator<Node> persons = graphDb.findNodes( PERSON, "name", personName ) )
                {
                    while ( persons.hasNext() )
                    {
                        Node person = persons.next();
                        for ( Relationship actedIn : person.getRelationships( ACTED_IN, OUTGOING ) )
                        {
                            Node endNode = actedIn.getEndNode();
                            for ( Relationship colleagueActedIn : endNode.getRelationships( ACTED_IN,
INCOMING ) )
                            {
                                Node colleague = colleagueActedIn.getStartNode();
                                if ( !colleague.equals( person ) )
                                {
                                    jg.writeString( colleague.getProperty( "name" ).toString() );
                                }
                            }
                        }
                    }
                    tx.success();
                }

                jg.writeEndArray();
                jg.writeEndObject();
                jg.flush();
                jg.close();
            }
        };

        return Response.ok().entity( stream ).type( MediaType.APPLICATION_JSON ).build();
    }
}
```

The full source code is found here: ColleaguesResource.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/server-examples/src/main/java/org/neo4j/examples/server/unmanaged/ColleaguesResource.java)*

As well as depending on JAX-RS API this example also uses Jackson — a Java JSON library. You'll need to add the following dependency to your Maven POM file (or equivalent):

```
<dependency>
    <groupId>org.codehaus.jackson</groupId>
    <artifactId>jackson-mapper-asl</artifactId>
    <version>1.9.7</version>
</dependency>
```

Our `findColleagues` method will now respond to `GET` requests at the URI:
`http://{neo4j_server}:{neo4j_port}/examples/unmanaged/colleagues/{personName}`. For example:

```
curl http://localhost:7474/examples/unmanaged/colleagues/Keanu%20Reeves
```

which results in

```
{"colleagues":["Hugo Weaving","Carrie-Anne Moss","Laurence Fishburne"]}
```

1.2.3. Using Cypher in an unmanaged extension

You can execute Cypher queries by using the `GraphDatabaseService` that is injected into the extension. For example, the following unmanaged extension retrieves a person's colleagues using Cypher:

Unmanaged extension Cypher execution example

```
@Path("/colleagues-cypher-execution")
public class ColleaguesCypherExecutionResource
{
    private final ObjectMapper objectMapper;
    private GraphDatabaseService graphDb;

    public ColleaguesCypherExecutionResource( @Context GraphDatabaseService graphDb )
    {
        this.graphDb = graphDb;
        this.objectMapper = new ObjectMapper();
    }

    @GET
    @Path("/{personName}")
    public Response findColleagues( final @PathParam("personName") String personName )
    {
        final Map<String, Object> params = MapUtil.map( "personName", personName );

        StreamingOutput stream = new StreamingOutput()
        {
            @Override
            public void write( OutputStream os ) throws IOException, WebApplicationException
            {
                JsonGenerator jg = objectMapper.getJsonFactory().createJsonGenerator( os, JsonEncoding
.UTF8 );
                jg.writeStartObject();
                jg.writeFieldName( "colleagues" );
                jg.writeStartArray();

                try ( Transaction tx = graphDb.beginTx();
                      Result result = graphDb.execute( colleaguesQuery(), params ) )
                {
                    while ( result.hasNext() )
                    {
                        Map<String,Object> row = result.next();
                        jg.writeString( ((Node) row.get( "colleague" )).getProperty( "name" ).toString()
);
                    }
                    tx.success();
                }

                jg.writeEndArray();
                jg.writeEndObject();
                jg.flush();
                jg.close();
            }
        };

        return Response.ok().entity( stream ).type( MediaType.APPLICATION_JSON ).build();
    }

    private String colleaguesQuery()
    {
        return "MATCH (p:Person {name: {personName} })-[:ACTED_IN]->()<-[:ACTED_IN]-(colleague) RETURN
colleague";
    }
}
```

The full source code is found here: ColleaguesCypherExecutionResource.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/server-examples/src/main/java/org/neo4j/examples/server/unmanaged/ColleaguesCypherExecutionResource.java)*

Our `findColleagues` method will now respond to `GET` requests at the URI: `http://{neo4j_server}:{neo4j_port}/examples/unmanaged/colleagues-cypher-execution/{personName}`. e.g.

```
curl http://localhost:7474/examples/unmanaged/colleagues-cypher-execution/Keanu%20Reeves
```

which results in

```
{"colleagues":["Hugo Weaving","Carrie-Anne Moss","Laurence Fishburne"]}
```

1.2.4. Testing your extension

Neo4j provides tools to help you write integration tests for your extensions. You can access this toolkit by adding the following test dependency to your project:

```xml
<dependency>
   <groupId>org.neo4j.test</groupId>
   <artifactId>neo4j-harness</artifactId>
   <version>3.0</version>
   <scope>test</scope>
</dependency>
```

The test toolkit provides a mechanism to start a Neo4j instance with custom configuration and with extensions of your choice. It also provides mechanisms to specify data fixtures to include when starting Neo4j.

Usage example

```
@Path("")
public static class MyUnmanagedExtension
{
    @GET
    public Response myEndpoint()
    {
        return Response.ok().build();
    }
}

@Test
public void testMyExtension() throws Exception
{
    // Given
    try ( ServerControls server = getServerBuilder()
            .withExtension( "/myExtension", MyUnmanagedExtension.class )
            .newServer() )
    {
        // When
        HTTP.Response response = HTTP.GET(
                HTTP.GET( server.httpURI().resolve( "myExtension" ).toString() ).location() );

        // Then
        assertEquals( 200, response.status() );
    }
}

@Test
public void testMyExtensionWithFunctionFixture() throws Exception
{
    // Given
    try ( ServerControls server = getServerBuilder()
            .withExtension( "/myExtension", MyUnmanagedExtension.class )
            .withFixture( new Function<GraphDatabaseService, Void>()
            {
                @Override
                public Void apply( GraphDatabaseService graphDatabaseService ) throws RuntimeException
                {
                    try ( Transaction tx = graphDatabaseService.beginTx() )
                    {
                        graphDatabaseService.createNode( Label.label( "User" ) );
                        tx.success();
                    }
                    return null;
                }
            } )
            .newServer() )
    {
        // When
        Result result = server.graph().execute( "MATCH (n:User) return n" );

        // Then
        assertEquals( 1, count( result ) );
    }
}
```

The full source code of the example is found here: ExtensionTestingDocTest.java
(https://github.com/neo4j/neo4j/blob/3.0/manual/neo4j-harness-test/src/test/java/org/neo4j/harness/doc/ExtensionTestingDocTest.java)

Note the use of `server.httpURI().resolve( "myExtension" )` to ensure that the correct base URI is used.

If you are using the JUnit test framework, there is a JUnit rule available as well.

JUnit example

```
@Rule
public Neo4jRule neo4j = new Neo4jRule()
        .withFixture( "CREATE (admin:Admin)" )
        .withConfig( ServerSettings.certificates_directory.name(),
                getRelativePath( getSharedTestTemporaryFolder(), ServerSettings.certificates_directory ) )
        .withFixture( new Function<GraphDatabaseService, Void>()
        {
            @Override
            public Void apply( GraphDatabaseService graphDatabaseService ) throws RuntimeException
            {
                try (Transaction tx = graphDatabaseService.beginTx())
                {
                    graphDatabaseService.createNode( Label.label( "Admin" ) );
                    tx.success();
                }
                return null;
            }
        } );

@Test
public void shouldWorkWithServer() throws Exception
{
    // Given
    URI serverURI = neo4j.httpURI();

    // When I access the server
    HTTP.Response response = HTTP.GET( serverURI.toString() );

    // Then it should reply
    assertEquals(200, response.status());

    // and we have access to underlying GraphDatabaseService
    try (Transaction tx = neo4j.getGraphDatabaseService().beginTx()) {
        assertEquals( 2, count(neo4j.getGraphDatabaseService().findNodes( Label.label( "Admin" ) ) ));
        tx.success();
    }
}
```

1.3. Installing Procedures and Extensions in Neo4j Desktop

Extensions can be be deployed also when using Neo4j Desktop. Neo4j Desktop will add all jars in *%ProgramFiles%\Neo4j Community\plugins* to the classpath, but please note that nested directories for plugins are not supported.

Otherwise extensions are subject to the same rules as usual. Please note when configuring server extensions that *neo4j.conf* for Neo4j Desktop lives in *%APPDATA%\Neo4j Community*.

Chapter 2. Using Neo4j embedded in Java applications

It's easy to use Neo4j embedded in Java applications. In this chapter you will find everything needed — from setting up the environment to doing something useful with your data.

When running your own code and Neo4j in the same JVM, there are a few things you should keep in mind:

- Don't create or retain more objects than you strictly need to. Large caches in particular tend to promote more objects to the old generation, thus increasing the need for expensive full garbage collections.
- Don't use internal Neo4j APIs. They are internal to Neo4j and subject to change without notice, which may break or change the behavior of your code.
- Don't enable the `-XX:+TrustFinalNonStaticFields` JVM flag when running in embedded mode.

2.1. Include Neo4j in your project

After selecting the appropriate edition for your platform, embed Neo4j in your Java application by including the Neo4j library jars in your build. The following sections will show how to do this by either altering the build path directly or by using dependency management.

2.1.1. Add Neo4j to the build path

Get the Neo4j libraries from one of these sources:

- Extract a Neo4j zip/tarball *(https://neo4j.com/download/)*, and use the *jar* files found in the *lib/* directory.
- Use the *jar* files available from Maven Central Repository *(http://search.maven.org/#search|ga|1|g%3A%22org.neo4j%22)*

Add the jar files to your project:

JDK tools

Append to `-classpath`

Eclipse

- Right-click on the project and then go *Build Path* *Configure Build Path.* In the dialog, choose *Add External JARs*, browse to the Neo4j *lib/* directory and select all of the jar files.
- Another option is to use User Libraries *(http://help.eclipse.org/indigo/index.jsp?topic=/org.eclipse.jdt.doc.user/reference/preferences/java/buildpath/ref-preferences-user-libraries.htm)*.

IntelliJ IDEA

See Libraries, Global Libraries, and the Configure Library dialog *(http://www.jetbrains.com/help/idea/2016.1/configuring-project-and-global-libraries.html)*

NetBeans

- Right-click on the *Libraries* node of the project, choose *Add JAR/Folder*, browse to the Neo4j *lib/* directory and select all of the jar files.
- You can also handle libraries from the project node, see Managing a Project's Classpath *(http://netbeans.org/kb/docs/java/project-setup.html#projects-classpath)*.

2.1.2. Editions

The following table outlines the available editions and their names for use with dependency management tools.

Follow the links in the table for details on dependency configuration with Apache Maven, Apache Buildr, Apache Ivy, Groovy Grape, Grails, Scala SBT!

Table 1. Neo4j editions

Edition	Dependency	Description	License
Community	org.neo4j:neo4j *(http://search.maven.org/#search%7Cgav%7C1%7Cg%3A%22org.neo4j%22%20AND%20a%3A%22neo4j%22)*	a high performance, fully ACID transactional graph database	GPLv3
Enterprise	org.neo4j:neo4j-enterprise *(http://search.maven.org/#search%7Cgav%7C1%7Cg%3A%22org.neo4j%22%20AND%20a%3A%22neo4j-enterprise%22)*	adding advanced monitoring, online backup and High Availability clustering	AGPLv3

The listed dependencies do not contain the implementation, but pulls it in transitively.

For more information regarding licensing, see the Licensing Guide *(https://neo4j.com/licensing)*.

Javadocs can be downloaded packaged in jar files from Maven Central or read at javadocs *(javadocs/)*.

2.1.3. Add Neo4j as a dependency

You can either go with the top-level artifact from the table above or include the individual components directly. The examples included here use the top-level artifact approach.

Maven

Add the dependency to your project along the lines of the snippet below. This is usually done in the *pom.xml* file found in the root directory of the project.

Maven dependency

```
<project>
...
 <dependencies>
  <dependency>
   <groupId>org.neo4j</groupId>
   <artifactId>neo4j</artifactId>
   <version>3.0</version>
  </dependency>
  ...
 </dependencies>
...
</project>
```

Where the `artifactId` is found in the editions table.

Eclipse and Maven

For development in Eclipse *(http://www.eclipse.org)*, it is recommended to install the m2e plugin *(http://www.eclipse.org/m2e/)* and let Maven manage the project build classpath instead, see above. This also adds the possibility to build your project both via the command line with Maven and have a working Eclipse setup for development.

Ivy

Make sure to resolve dependencies from Maven Central, for example using this configuration in your *ivysettings.xml* file:

```
<ivysettings>
  <settings defaultResolver="main"/>
  <resolvers>
    <chain name="main">
      <filesystem name="local">
        <artifact pattern="${ivy.settings.dir}/repository/[artifact]-[revision].[ext]" />
      </filesystem>
      <ibiblio name="maven_central" root="http://repo1.maven.org/maven2/" m2compatible="true"/>
    </chain>
  </resolvers>
</ivysettings>
```

With that in place you can add Neo4j to the mix by having something along these lines to your 'ivy.xml' file:

```
..
<dependencies>
  ..
  <dependency org="org.neo4j" name="neo4j" rev="3.0"/>
  ..
</dependencies>
..
```

Where the `name` is found in the editions table above

Gradle

The example below shows an example gradle build script for including the Neo4j libraries.

```
def neo4jVersion = "3.0"
apply plugin: 'java'
repositories {
   mavenCentral()
}
dependencies {
   compile "org.neo4j:neo4j:${neo4jVersion}"
}
```

Where the coordinates (`org.neo4j:neo4j` in the example) are found in the editions table above.

2.1.4. Starting and stopping

To create a new database or open an existing one you instantiate a `GraphDatabaseService` `(javadocs/org/neo4j/graphdb/GraphDatabaseService.html)`.

```
graphDb = new GraphDatabaseFactory().newEmbeddedDatabase( DB_PATH );
registerShutdownHook( graphDb );
```

The `GraphDatabaseService` instance can be shared among multiple threads. Note however that you can’t create multiple instances pointing to the same database.

To stop the database, call the `shutdown()` method:

```
graphDb.shutdown();
```

To make sure Neo4j is shut down properly you can add a shutdown hook:

```
private static void registerShutdownHook( final GraphDatabaseService graphDb )
{
    // Registers a shutdown hook for the Neo4j instance so that it
    // shuts down nicely when the VM exits (even if you "Ctrl-C" the
    // running application).
    Runtime.getRuntime().addShutdownHook( new Thread()
    {
        @Override
        public void run()
        {
            graphDb.shutdown();
        }
    } );
}
```

Starting an embedded database with configuration settings

To start Neo4j with configuration settings, a Neo4j properties file can be loaded like this:

```
GraphDatabaseService graphDb = new GraphDatabaseFactory()
    .newEmbeddedDatabaseBuilder( testDirectory.graphDbDir() )
    .loadPropertiesFromFile( pathToConfig + "neo4j.conf" )
    .newGraphDatabase();
```

Configuration settings can also be applied programmatically, like so:

```
GraphDatabaseService graphDb = new GraphDatabaseFactory()
    .newEmbeddedDatabaseBuilder( testDirectory.graphDbDir() )
    .setConfig( GraphDatabaseSettings.pagecache_memory, "512M" )
    .setConfig( GraphDatabaseSettings.string_block_size, "60" )
    .setConfig( GraphDatabaseSettings.array_block_size, "300" )
    .newGraphDatabase();
```

Starting an embedded read-only instance

If you want a *read-only view* of the database, create an instance this way:

```
graphDb = new GraphDatabaseFactory().newEmbeddedDatabaseBuilder( dir )
        .setConfig( GraphDatabaseSettings.read_only, "true" )
        .newGraphDatabase();
```

Obviously the database has to already exist in this case.

Concurrent access to the same database files by multiple (read-only or write) instances is not supported.

2.2. Hello world

Learn how to create and access nodes and relationships. For information on project setup, see Include Neo4j in your project.

Remember that a Neo4j graph consists of:

- Nodes that are connected by

- Relationships, with
- Properties on both nodes and relationships.

All relationships have a type. For example, if the graph represents a social network, a relationship type could be KNOWS. If a relationship of the type KNOWS connects two nodes, that probably represents two people that know each other. A lot of the semantics (that is the meaning) of a graph is encoded in the relationship types of the application. And although relationships are directed they are equally well traversed regardless of which direction they are traversed.

The source code of this example is found here: EmbeddedNeo4j.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/EmbeddedNeo4j.java)*

2.2.1. Prepare the database

Relationship types can be created by using an enum. In this example we only need a single relationship type. This is how to define it:

```
private static enum RelTypes implements RelationshipType
{
    KNOWS
}
```

We also prepare some variables to use:

```
GraphDatabaseService graphDb;
Node firstNode;
Node secondNode;
Relationship relationship;
```

The next step is to start the database server. Note that if the directory given for the database doesn't already exist, it will be created.

```
graphDb = new GraphDatabaseFactory().newEmbeddedDatabase( DB_PATH );
registerShutdownHook( graphDb );
```

Note that starting a database server is an expensive operation, so don't start up a new instance every time you need to interact with the database! The instance can be shared by multiple threads. Transactions are thread confined.

As seen, we register a shutdown hook that will make sure the database shuts down when the JVM exits. Now it's time to interact with the database.

2.2.2. Wrap operations in a transaction

All operations have to be performed in a transaction. This is a conscious design decision, since we believe transaction demarcation to be an important part of working with a real enterprise database. Now, transaction handling in Neo4j is very easy:

```
try ( Transaction tx = graphDb.beginTx() )
{
    // Database operations go here
    tx.success();
}
```

For more information on transactions, see Transaction Management and Java API for Transaction *(javadocs/org/neo4j/graphdb/Transaction.html)*.

For brevity, we do not spell out wrapping of operations in a transaction throughout the manual.

2.2.3. Create a small graph

Now, let's create a few nodes. The API is very intuitive. Feel free to have a look at the Neo4j Javadocs *(javadocs/)*. They're included in the distribution, as well. Here's how to create a small graph consisting of two nodes, connected with one relationship and some properties:

```
firstNode = graphDb.createNode();
firstNode.setProperty( "message", "Hello, " );
secondNode = graphDb.createNode();
secondNode.setProperty( "message", "World!" );

relationship = firstNode.createRelationshipTo( secondNode, RelTypes.KNOWS );
relationship.setProperty( "message", "brave Neo4j " );
```

We now have a graph that looks like this:

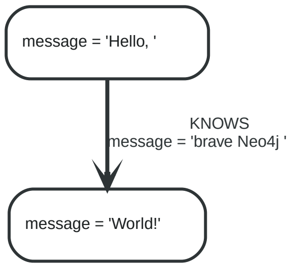


Figure 1. Hello World Graph

2.2.4. Print the result

After we've created our graph, let's read from it and print the result.

```
System.out.print( firstNode.getProperty( "message" ) );
System.out.print( relationship.getProperty( "message" ) );
System.out.print( secondNode.getProperty( "message" ) );
```

Which will output:

Hello, brave Neo4j World!

2.2.5. Remove the data

In this case we'll remove the data before committing:

```
// let's remove the data
firstNode.getSingleRelationship( RelTypes.KNOWS, Direction.OUTGOING ).delete();
firstNode.delete();
secondNode.delete();
```

Note that deleting a node which still has relationships when the transaction commits will fail. This is to make sure relationships always have a start node and an end node.

2.2.6. Shut down the database server

Finally, shut down the database server *when the application finishes:*

```
graphDb.shutdown();
```

2.3. Property values

Both nodes and relationships can have properties.

Properties are named values where the name is a string. Property values can be either a primitive or an array of one primitive type. For example `String`, `int` and `int[]` values are valid for properties.

> `NULL` *is not a valid property value.*
> NULLs can instead be modeled by the absence of a key.

Table 2. Property value types

Type	Description	Value range
`boolean`		true/false
`byte`	8-bit integer	-128 to 127, inclusive
`short`	16-bit integer	-32768 to 32767, inclusive
`int`	32-bit integer	-2147483648 to 2147483647, inclusive
`long`	64-bit integer	-9223372036854775808 to 9223372036854775807, inclusive
`float`	32-bit IEEE 754 floating-point number	
`double`	64-bit IEEE 754 floating-point number	
`char`	16-bit unsigned integers representing Unicode characters	u0000 to uffff (0 to 65535)
`String`	sequence of Unicode characters	

For further details on float/double values, see Java Language Specification *(http://docs.oracle.com/javase/specs/jls/se8/html/jls-4.html#jls-4.2.3)*.

2.4. User database with indexes

You have a user database, and want to retrieve users by name using indexes.

> The source code used in this example is found here: EmbeddedNeo4jWithNewIndexing.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/EmbeddedNeo4jWithNewIndexing.java)*

To begin with, we start the database server:

```
GraphDatabaseService graphDb = new GraphDatabaseFactory().newEmbeddedDatabase( DB_PATH );
```

Then we have to configure the database to index users by name. This only needs to be done once.

Schema changes and data changes are not allowed in the same transaction. Each transaction must either change the schema or the data, but not both.

```
IndexDefinition indexDefinition;
try ( Transaction tx = graphDb.beginTx() )
{
    Schema schema = graphDb.schema();
    indexDefinition = schema.indexFor( Label.label( "User" ) )
            .on( "username" )
            .create();
    tx.success();
}
```

Indexes are populated asynchronously when they are first created. It is possible to use the core API to wait for index population to complete:

```
try ( Transaction tx = graphDb.beginTx() )
{
    Schema schema = graphDb.schema();
    schema.awaitIndexOnline( indexDefinition, 10, TimeUnit.SECONDS );
}
```

It is also possible to query the progress of the index population:

```
try ( Transaction tx = graphDb.beginTx() )
{
    Schema schema = graphDb.schema();
    System.out.println( String.format( "Percent complete: %1.0f%%",
            schema.getIndexPopulationProgress( indexDefinition ).getCompletedPercentage() ) );
}
```

It’s time to add the users:

```
try ( Transaction tx = graphDb.beginTx() )
{
    Label label = Label.label( "User" );

    // Create some users
    for ( int id = 0; id < 100; id++ )
    {
        Node userNode = graphDb.createNode( label );
        userNode.setProperty( "username", "user" + id + "@neo4j.org" );
    }
    System.out.println( "Users created" );
    tx.success();
}
```

Please read Managing resources when using long running transactions on how to properly close `ResourceIterators` returned from index lookups.

And here’s how to find a user by id:

```
Label label = Label.label( "User" );
int idToFind = 45;
String nameToFind = "user" + idToFind + "@neo4j.org";
try ( Transaction tx = graphDb.beginTx() )
{
    try ( ResourceIterator<Node> users =
                  graphDb.findNodes( label, "username", nameToFind ) )
    {
        ArrayList<Node> userNodes = new ArrayList<>();
        while ( users.hasNext() )
        {
            userNodes.add( users.next() );
        }

        for ( Node node : userNodes )
        {
            System.out.println(
                    "The username of user " + idToFind + " is " + node.getProperty( "username" ) );
        }
    }
}
```

When updating the name of a user, the index is updated as well:

```
try ( Transaction tx = graphDb.beginTx() )
{
    Label label = Label.label( "User" );
    int idToFind = 45;
    String nameToFind = "user" + idToFind + "@neo4j.org";

    for ( Node node : loop( graphDb.findNodes( label, "username", nameToFind ) ) )
    {
        node.setProperty( "username", "user" + (idToFind + 1) + "@neo4j.org" );
    }
    tx.success();
}
```

When deleting a user, it is automatically removed from the index:

```
try ( Transaction tx = graphDb.beginTx() )
{
    Label label = Label.label( "User" );
    int idToFind = 46;
    String nameToFind = "user" + idToFind + "@neo4j.org";

    for ( Node node : loop( graphDb.findNodes( label, "username", nameToFind ) ) )
    {
        node.delete();
    }
    tx.success();
}
```

In case we change our data model, we can drop the index as well:

```
try ( Transaction tx = graphDb.beginTx() )
{
    Label label = Label.label( "User" );
    for ( IndexDefinition indexDefinition : graphDb.schema()
            .getIndexes( label ) )
    {
        // There is only one index
        indexDefinition.drop();
    }

    tx.success();
}
```

2.5. User database with manual index

Unless you have specific reasons to use the manual indexing, see User database with indexes instead.

Please read Managing resources when using long running transactions on how to properly close `ResourceIterators` returned from index lookups.

You have a user database, and want to retrieve users by name using the manual indexing system.

The source code used in this example is found here:
EmbeddedNeo4jWithIndexing.java
(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/EmbeddedNeo4jWithIndexing.java)

We have created two helper methods to handle user names and adding users to the database:

```
private static String idToUserName( final int id )
{
    return "user" + id + "@neo4j.org";
}

private static Node createAndIndexUser( final String username )
{
    Node node = graphDb.createNode();
    node.setProperty( USERNAME_KEY, username );
    nodeIndex.add( node, USERNAME_KEY, username );
    return node;
}
```

The next step is to start the database server:

```
graphDb = new GraphDatabaseFactory().newEmbeddedDatabase( DB_PATH );
registerShutdownHook();
```

It’s time to add the users:

```
try ( Transaction tx = graphDb.beginTx() )
{
    nodeIndex = graphDb.index().forNodes( "nodes" );
    // Create some users and index their names with the IndexService
    for ( int id = 0; id < 100; id++ )
    {
        createAndIndexUser( idToUserName( id ) );
    }
```

And here’s how to find a user by Id:

```
int idToFind = 45;
String userName = idToUserName( idToFind );
Node foundUser = nodeIndex.get( USERNAME_KEY, userName ).getSingle();

System.out.println( "The username of user " + idToFind + " is "
    + foundUser.getProperty( USERNAME_KEY ) );
```

2.6. Managing resources when using long running transactions

It is necessary to always open a transaction when accessing the database. Inside a long running transaction it is good practice to ensure that any `org.neo4j.graphdb.ResourceIterator`'s obtained inside the transaction are closed as early as possible. This is either achieved by just exhausting the iterator or by explicitly calling its close method.

What follows is an example of how to work with a `ResourceIterator`. As we don't exhaust the iterator, we will close it explicitly using the `close()` method.

```
Label label = Label.label( "User" );
int idToFind = 45;
String nameToFind = "user" + idToFind + "@neo4j.org";
try ( Transaction tx = graphDb.beginTx();
      ResourceIterator<Node> users = graphDb.findNodes( label, "username", nameToFind ) )
{
    Node firstUserNode;
    if ( users.hasNext() )
    {
        firstUserNode = users.next();
    }
    users.close();
}
```

2.7. Controlling logging

To control logging in Neo4j embedded, use the Neo4j embedded logging framework.

Neo4j embedded provides logging via its own `org.neo4j.logging.Log` `(javadocs/org/neo4j/logging/Log.html)` layer, and does not natively use any existing Java logging framework. All logging events produced by Neo4j have a name, a level and a message. The name is a FQCN (fully qualified class name).

Neo4j uses the following log levels:

`ERROR`	For serious errors that are almost always fatal
`WARN`	For events that are serious, but not fatal
`INFO`	Informational events
`DEBUG`	Debugging events

To enable logging, an implementation of `org.neo4j.logging.LogProvider` `(javadocs/org/neo4j/logging/LogProvider.html)` must be provided to the `GraphDatabaseFactory` `(javadocs/org/neo4j/graphdb/factory/GraphDatabaseFactory.html)`, as follows:

```
LogProvider logProvider = new MyCustomLogProvider( output );
graphDb = new GraphDatabaseFactory().setUserLogProvider( logProvider ).newEmbeddedDatabase( DB_PATH );
```

Neo4j also includes a binding for SLF4J, which is available in the `neo4j-slf4j` library jar. This can be obtained via Maven:

```
<project>
...
 <dependencies>
  <dependency>
   <groupId>org.neo4j</groupId>
   <artifactId>neo4j-slf4j</artifactId>
   <version>3.0</version>
  </dependency>
  <dependency>
    <groupId>org.slf4j</groupId>
    <artifactId>slf4j-api</artifactId>
    <version>${slf4j-version}</version>
  </dependency>
  ...
 </dependencies>
...
</project>
```

To use this binding, simply pass an instance of `org.neo4j.logging.slf4j.Slf4jLogProvider` `(javadocs/org/neo4j/logging/slf4j/Slf4jLogProvider.html)` to the `GraphDatabaseFactory` `(javadocs/org/neo4j/graphdb/factory/GraphDatabaseFactory.html)`, as follows:

```
graphDb = new GraphDatabaseFactory().setUserLogProvider( new Slf4jLogProvider() ).newEmbeddedDatabase(
DB_PATH );
```

All log output can then be controlled via SLF4J configuration.

2.8. Basic unit testing

The basic pattern of unit testing with Neo4j is illustrated by the following example.

To access the Neo4j testing facilities you should have the `neo4j-kernel` 'tests.jar' together with the `neo4j-io` 'tests.jar' on the classpath during tests. You can download them from Maven Central: org.neo4j:neo4j-kernel *(http://search.maven.org/#search|ga|1|g%3A%22org.neo4j%22%20AND%20a%3A%22neo4j-kernel%22)* and org.neo4j:neo4j-io *(http://search.maven.org/#search|ga|1|g%3A%22org.neo4j%22%20AND%20a%3A%22neo4j-io%22)*.

Using Maven as a dependency manager you would typically add this dependency together with JUnit and Hamcrest like so:

Maven dependency

```xml
<project>
...
 <dependencies>
  <dependency>
   <groupId>org.neo4j</groupId>
   <artifactId>neo4j-kernel</artifactId>
   <version>3.0</version>
   <type>test-jar</type>
   <scope>test</scope>
  </dependency>
  <dependency>
   <groupId>org.neo4j</groupId>
   <artifactId>neo4j-io</artifactId>
   <version>3.0</version>
   <type>test-jar</type>
   <scope>test</scope>
  </dependency>
  <dependency>
   <groupId>junit</groupId>
   <artifactId>junit</artifactId>
   <version>4.12</version>
   <scope>test</scope>
  </dependency>
  <dependency>
   <groupId>org.hamcrest</groupId>
   <artifactId>hamcrest-all</artifactId>
   <version>1.3</version>
   <scope>test</scope>
  </dependency>
  ...
 </dependencies>
...
</project>
```

Observe that the `<type>test-jar</type>` is crucial. Without it you would get the common `neo4j-kernel` jar, not the one containing the testing facilities.

With that in place, we're ready to code our tests.

For the full source code of this example see: Neo4jBasicDocTest.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/test/java/org/neo4j/examples/Neo4jBasicDocTest.java)*

Before each test, create a fresh database:

```java
@Before
public void prepareTestDatabase()
{
    graphDb = new TestGraphDatabaseFactory().newImpermanentDatabase();
}
```

After the test has executed, the database should be shut down:

```java
@After
public void destroyTestDatabase()
{
    graphDb.shutdown();
}
```

During a test, create nodes and check to see that they are there, while enclosing write operations in a transaction.

```
Node n = null;
try ( Transaction tx = graphDb.beginTx() )
{
    n = graphDb.createNode();
    n.setProperty( "name", "Nancy" );
    tx.success();
}

// The node should have a valid id
assertThat( n.getId(), is( greaterThan( -1L ) ) );

// Retrieve a node by using the id of the created node. The id's and
// property should match.
try ( Transaction tx = graphDb.beginTx() )
{
    Node foundNode = graphDb.getNodeById( n.getId() );
    assertThat( foundNode.getId(), is( n.getId() ) );
    assertThat( (String) foundNode.getProperty( "name" ), is( "Nancy" ) );
}
```

If you want to set configuration parameters at database creation, it's done like this:

```
GraphDatabaseService db = new TestGraphDatabaseFactory()
    .newImpermanentDatabaseBuilder()
    .setConfig( GraphDatabaseSettings.pagecache_memory, "512M" )
    .setConfig( GraphDatabaseSettings.string_block_size, "60" )
    .setConfig( GraphDatabaseSettings.array_block_size, "300" )
    .newGraphDatabase();
```

2.9. Traversal

For reading about traversals, see The traversal framework.

2.9.1. The Matrix

This is the first graph we want to traverse into:

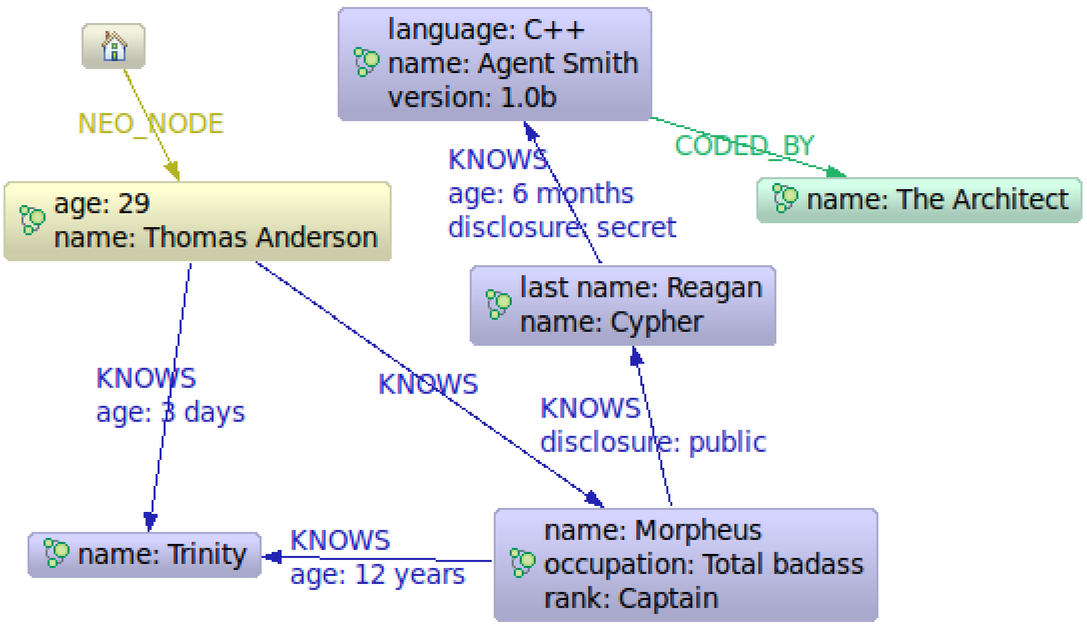


Figure 2. Matrix node space view

The source code of this example is found here: NewMatrix.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/NewMatrix.java)*

Friends and friends of friends

```
private Traverser getFriends(
        final Node person )
{
    TraversalDescription td = graphDb.traversalDescription()
            .breadthFirst()
            .relationships( RelTypes.KNOWS, Direction.OUTGOING )
            .evaluator( Evaluators.excludeStartPosition() );
    return td.traverse( person );
}
```

Let’s perform the actual traversal and print the results:

```
int numberOfFriends = 0;
String output = neoNode.getProperty( "name" ) + "'s friends:\n";
Traverser friendsTraverser = getFriends( neoNode );
for ( Path friendPath : friendsTraverser )
{
    output += "At depth " + friendPath.length() + " => "
              + friendPath.endNode()
                      .getProperty( "name" ) + "\n";
    numberOfFriends++;
}
output += "Number of friends found: " + numberOfFriends + "\n";
```

Which will give us the following output:

```
Thomas Anderson's friends:
At depth 1 => Morpheus
At depth 1 => Trinity
At depth 2 => Cypher
At depth 3 => Agent Smith
Number of friends found: 4
```

Who coded the Matrix?

```
private Traverser findHackers( final Node startNode )
{
    TraversalDescription td = graphDb.traversalDescription()
            .breadthFirst()
            .relationships( RelTypes.CODED_BY, Direction.OUTGOING )
            .relationships( RelTypes.KNOWS, Direction.OUTGOING )
            .evaluator(
                    Evaluators.includeWhereLastRelationshipTypeIs( RelTypes.CODED_BY ) );
    return td.traverse( startNode );
}
```

Print out the result:

```
String output = "Hackers:\n";
int numberOfHackers = 0;
Traverser traverser = findHackers( getNeoNode() );
for ( Path hackerPath : traverser )
{
    output += "At depth " + hackerPath.length() + " => "
              + hackerPath.endNode()
                      .getProperty( "name" ) + "\n";
    numberOfHackers++;
}
output += "Number of hackers found: " + numberOfHackers + "\n";
```

Now we know who coded the Matrix:

```
Hackers:
At depth 4 => The Architect
Number of hackers found: 1
```

Walking an ordered path

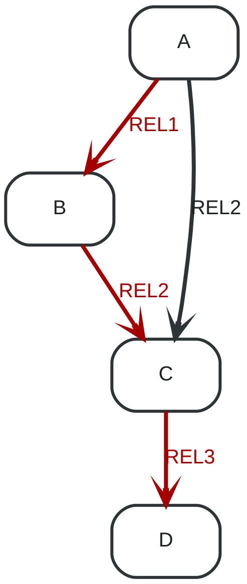
This example shows how to use a path context holding a representation of a path.

The source code of this example is found here: OrderedPath.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/orderedpath/OrderedPath.java)*

Create a toy graph

```
Node A = db.createNode();
Node B = db.createNode();
Node C = db.createNode();
Node D = db.createNode();

A.createRelationshipTo( C, REL2 );
C.createRelationshipTo( D, REL3 );
A.createRelationshipTo( B, REL1 );
B.createRelationshipTo( C, REL2 );
```



Now, the order of relationships (`REL1` □ `REL2` □ `REL3`) is stored in an `ArrayList`. Upon traversal, the `Evaluator` can check against it to ensure that only paths are included and returned that have the predefined order of relationships:

Define how to walk the path

```
final ArrayList<RelationshipType> orderedPathContext = new ArrayList<RelationshipType>();
orderedPathContext.add( REL1 );
orderedPathContext.add( withName( "REL2" ) );
orderedPathContext.add( withName( "REL3" ) );
TraversalDescription td = db.traversalDescription()
        .evaluator( new Evaluator()
        {
            @Override
            public Evaluation evaluate( final Path path )
            {
                if ( path.length() == 0 )
                {
                    return Evaluation.EXCLUDE_AND_CONTINUE;
                }
                RelationshipType expectedType = orderedPathContext.get( path.length() - 1 );
                boolean isExpectedType = path.lastRelationship()
                        .isType( expectedType );
                boolean included = path.length() == orderedPathContext.size() && isExpectedType;
                boolean continued = path.length() < orderedPathContext.size() && isExpectedType;
                return Evaluation.of( included, continued );
            }
        } )
        .uniqueness( Uniqueness.NODE_PATH );
```

Note that we set the uniqueness to `Uniqueness.NODE_PATH` (javadocs/org/neo4j/graphdb/traversal/Uniqueness.html#NODE_PATH) as we want to be able to revisit the same node dureing the traversal, but not the same path.

Perform the traversal and print the result

```
Traverser traverser = td.traverse( A );
PathPrinter pathPrinter = new PathPrinter( "name" );
for ( Path path : traverser )
{
    output += Paths.pathToString( path, pathPrinter );
}
```

Which will output:

```
(A)--[REL1]-->(B)--[REL2]-->(C)--[REL3]-->(D)
```

In this case we use a custom class to format the path output. This is how it’s done:

```
static class PathPrinter implements Paths.PathDescriptor<Path>
{
    private final String nodePropertyKey;

    public PathPrinter( String nodePropertyKey )
    {
        this.nodePropertyKey = nodePropertyKey;
    }

    @Override
    public String nodeRepresentation( Path path, Node node )
    {
        return "(" + node.getProperty( nodePropertyKey, "" ) + ")";
    }

    @Override
    public String relationshipRepresentation( Path path, Node from, Relationship relationship )
    {
        String prefix = "--", suffix = "--";
        if ( from.equals( relationship.getEndNode() ) )
        {
            prefix = "<--";
        }
        else
        {
            suffix = "-->";
        }
        return prefix + "[" + relationship.getType().name() + "]" + suffix;
    }
}
```

2.9.2. Uniqueness of Paths in traversals

This example is demonstrating the use of node uniqueness. Below an imaginary domain graph with Principals that own pets that are descendant to other pets.

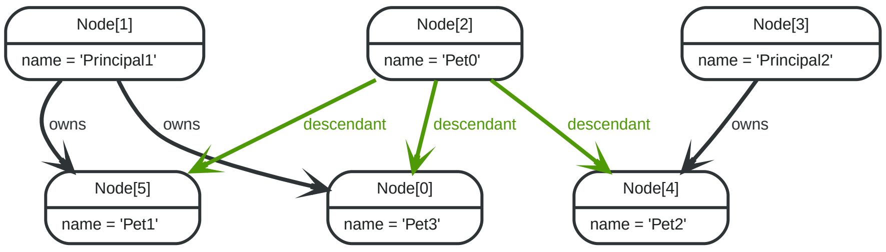


Figure 3. Descendants Example Graph

In order to return all descendants of `Pet0` which have the relation `owns` to `Principal1` (`Pet1` and `Pet3`), the Uniqueness of the traversal needs to be set to `NODE_PATH` rather than the default `NODE_GLOBAL`. This way nodes can be traversed more that once, and paths that have different nodes but can have some nodes in common (like the start and end node) can be returned.

```
final Node target = data.get().get( "Principal1" );
TraversalDescription td = db.traversalDescription()
        .uniqueness( Uniqueness.NODE_PATH )
        .evaluator( new Evaluator()
{
    @Override
    public Evaluation evaluate( Path path )
    {
        boolean endNodeIsTarget = path.endNode().equals( target );
        return Evaluation.of( endNodeIsTarget, !endNodeIsTarget );
    }
} );

Traverser results = td.traverse( start );
```

This will return the following paths:

```
(2)--[descendant,2]-->(0)<--[owns,5]--(1)
(2)--[descendant,0]-->(5)<--[owns,3]--(1)
```

In the default `path.toString()` implementation, `(1)--[knows,2]- (4)` denotes a node with ID=1 having a relationship with ID 2 or type `knows` to a node with ID-4.

Let's create a new `TraversalDescription` from the old one, having `NODE_GLOBAL` uniqueness to see the difference.

TIP:

The `TraversalDescription` object is immutable, so we have to use the new instance returned with the new uniqueness setting.

```
TraversalDescription nodeGlobalTd = td.uniqueness( Uniqueness.NODE_GLOBAL );
results = nodeGlobalTd.traverse( start );
```

Now only one path is returned:

```
(2)--[descendant,2]-->(0)<--[owns,5]--(1)
```

2.9.3. Social network

The following example uses the new enhanced traversal API.

Social networks (know as social graphs out on the web) are natural to model with a graph. This example shows a very simple social model that connects friends and keeps track of status updates.

The source code of the example is found here: socnet *(https://github.com/neo4j/neo4j/tree/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/socnet)*

Simple social model

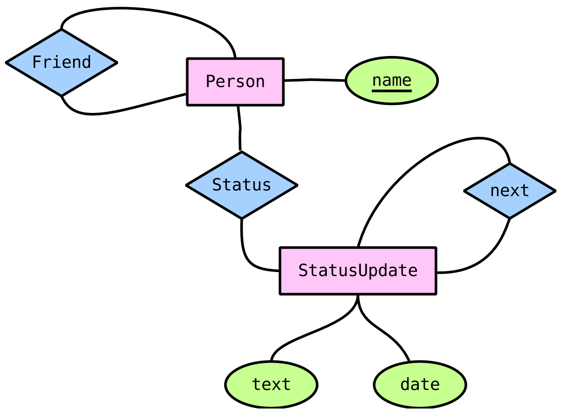


Figure 4. Social network data model

The data model for a social network is pretty simple: Persons with names and StatusUpdates with timestamped text. These entities are then connected by specific relationships.

- Person
  - friend: relates two distinct Person instances (no self-reference)

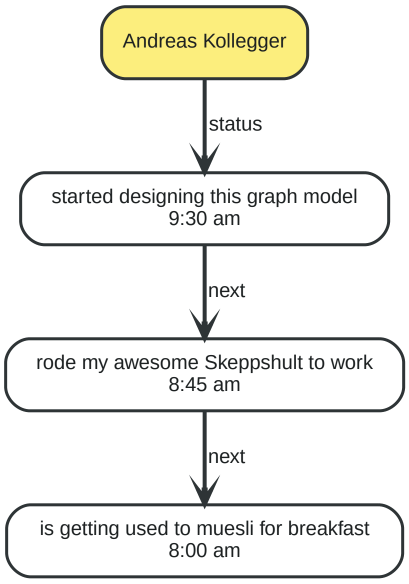
    - status: connects to the most recent StatusUpdate

- StatusUpdate
    - next: points to the next StatusUpdate in the chain, which was posted before the current one

Status graph instance

The StatusUpdate list for a Person is a linked list. The head of the list (the most recent status) is found by following status. Each subsequent StatusUpdate is connected by next.

Here’s an example where Andreas Kollegger micro-blogged his way to work in the morning:


Andreas Kollegger
status
started designing this graph model
9:30 am
next
rode my awesome Skeppshult to work
8:45 am
next
is getting used to muesli for breakfast
8:00 am

To read the status updates, we can create a traversal, like so:

```
TraversalDescription traversal = graphDb().traversalDescription()
        .depthFirst()
        .relationships( NEXT );
```

This gives us a traverser that will start at one StatusUpdate, and will follow the chain of updates until they run out. Traversers are lazy loading, so it’s performant even when dealing with thousands of statuses — they are not loaded until we actually consume them.

Activity stream

Once we have friends, and they have status messages, we might want to read our friends status' messages, in reverse time order — latest first. To do this, we go through these steps:

1. Gather all friend’s status update iterators in a list — latest date first.
2. Sort the list.
3. Return the first item in the list.
4. If the first iterator is exhausted, remove it from the list. Otherwise, get the next item in that iterator.
5. Go to step 2 until there are no iterators left in the list.

Animated, the sequence looks like this *(http://www.slideshare.net/systay/pattern-activity-stream)*.

The code looks like:

```
PositionedIterator<StatusUpdate> first = statuses.get(0);
StatusUpdate returnVal = first.current();

if ( !first.hasNext() )
{
    statuses.remove( 0 );
}
else
{
    first.next();
    sort();
}

return returnVal;
```

2.10. Domain entities

This page demonstrates one way to handle domain entities when using Neo4j. The principle at use is to wrap the entities around a node (the same approach can be used with relationships as well).

The source code of the examples is found here: Person.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/socnet/Person.java)*

First off, store the node and make it accessible inside the package:

```
private final Node underlyingNode;

Person( Node personNode )
{
    this.underlyingNode = personNode;
}

protected Node getUnderlyingNode()
{
    return underlyingNode;
}
```

Delegate attributes to the node:

```
public String getName()
{
    return (String)underlyingNode.getProperty( NAME );
}
```

Make sure to override these methods:

```
@Override
public int hashCode()
{
    return underlyingNode.hashCode();
}

@Override
public boolean equals( Object o )
{
    return o instanceof Person &&
            underlyingNode.equals( ( (Person)o ).getUnderlyingNode() );
}

@Override
public String toString()
{
    return "Person[" + getName() + "]";
}
```

2.11. Graph algorithm examples

For details on the graph algorithm usage, see the Javadocs *(javadocs/org/neo4j/graphalgo/GraphAlgoFactory.html)*.

The source code used in the example is found here: PathFindingDocTest.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/test/java/org/neo4j/examples/PathFindingDocTest.java)*

Calculating the shortest path (least number of relationships) between two nodes:

```
Node startNode = graphDb.createNode();
Node middleNode1 = graphDb.createNode();
Node middleNode2 = graphDb.createNode();
Node middleNode3 = graphDb.createNode();
Node endNode = graphDb.createNode();
createRelationshipsBetween( startNode, middleNode1, endNode );
createRelationshipsBetween( startNode, middleNode2, middleNode3, endNode );

// Will find the shortest path between startNode and endNode via
// "MY_TYPE" relationships (in OUTGOING direction), like f.ex:
//
// (startNode)-->(middleNode1)-->(endNode)
//
PathFinder<Path> finder = GraphAlgoFactory.shortestPath(
    PathExpanders.forTypeAndDirection( ExampleTypes.MY_TYPE, Direction.OUTGOING ), 15 );
Iterable<Path> paths = finder.findAllPaths( startNode, endNode );
```

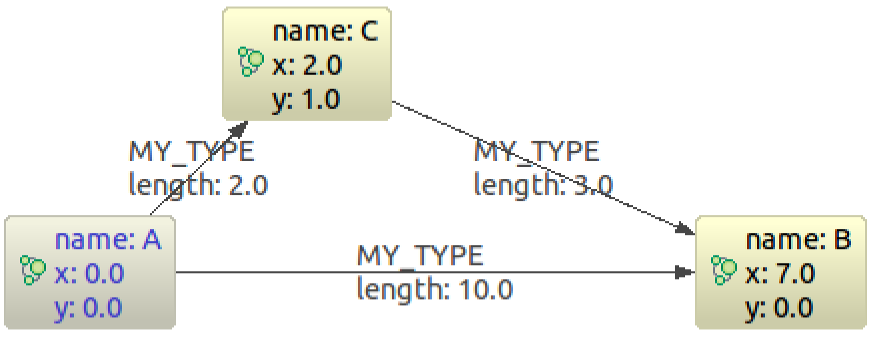
Using Dijkstra's algorithm *(https://en.wikipedia.org/wiki/Dijkstra%27s_algorithm)* to calculate cheapest path between node A and B where each relationship can have a weight (i.e. cost) and the path(s) with least cost are found.

```
PathFinder<WeightedPath> finder = GraphAlgoFactory.dijkstra(
    PathExpanders.forTypeAndDirection( ExampleTypes.MY_TYPE, Direction.BOTH ), "cost" );

WeightedPath path = finder.findSinglePath( nodeA, nodeB );

// Get the weight for the found path
path.weight();
```

Using A* *(https://en.wikipedia.org/wiki/A*_search_algorithm)* to calculate the cheapest path between node A and B, where cheapest is for example the path in a network of roads which has the shortest length between node A and B. Here's our example graph:



```
Node nodeA = createNode( "name", "A", "x", 0d, "y", 0d );
Node nodeB = createNode( "name", "B", "x", 7d, "y", 0d );
Node nodeC = createNode( "name", "C", "x", 2d, "y", 1d );
Relationship relAB = createRelationship( nodeA, nodeC, "length", 2d );
Relationship relBC = createRelationship( nodeC, nodeB, "length", 3d );
Relationship relAC = createRelationship( nodeA, nodeB, "length", 10d );

EstimateEvaluator<Double> estimateEvaluator = new EstimateEvaluator<Double>()
{
    @Override
    public Double getCost( final Node node, final Node goal )
    {
        double dx = (Double) node.getProperty( "x" ) - (Double) goal.getProperty( "x" );
        double dy = (Double) node.getProperty( "y" ) - (Double) goal.getProperty( "y" );
        double result = Math.sqrt( Math.pow( dx, 2 ) + Math.pow( dy, 2 ) );
        return result;
    }
};
PathFinder<WeightedPath> astar = GraphAlgoFactory.aStar(
        PathExpanders.allTypesAndDirections(),
        CommonEvaluators.doubleCostEvaluator( "length" ), estimateEvaluator );
WeightedPath path = astar.findSinglePath( nodeA, nodeB );
```

2.12. Reading a management attribute

The JmxUtils *(javadocs/org/neo4j/jmx/JmxUtils.html)* class includes methods to access Neo4j management beans. The common JMX service can be used as well, but from your code you probably rather want to use the approach outlined here.

The source code of the example is found here: JmxDocTest.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/test/java/org/neo4j/examples/JmxDocTest.java)*

This example shows how to get the start time of a database:

```
private static Date getStartTimeFromManagementBean(
        GraphDatabaseService graphDbService )
{
    ObjectName objectName = JmxUtils.getObjectName( graphDbService, "Kernel" );
    Date date = JmxUtils.getAttribute( objectName, "KernelStartTime" );
    return date;
}
```

Depending on which Neo4j edition you are using different sets of management beans are available.

- For all editions, see the org.neo4j.jmx *(javadocs/org/neo4j/jmx/package-summary.html)* package.
- For the Enterprise Edition, see the org.neo4j.management *(javadocs/org/neo4j/management/package-summary.html)* package as well.

2.13. How to create unique nodes

This section is about how to ensure uniqueness of a property when creating nodes. For an overview of the topic, see Creating unique nodes.

2.13.1. Get or create unique node using Cypher and unique constraints

Create a unique constraint

```
try ( Transaction tx = graphdb.beginTx() )
{
    graphdb.schema()
            .constraintFor( Label.label( "User" ) )
            .assertPropertyIsUnique( "name" )
            .create();
    tx.success();
}
```

Use MERGE to create a unique node

```
Node result = null;
ResourceIterator<Node> resultIterator = null;
try ( Transaction tx = graphDb.beginTx() )
{
    String queryString = "MERGE (n:User {name: {name}}) RETURN n";
    Map<String, Object> parameters = new HashMap<>();
    parameters.put( "name", username );
    resultIterator = graphDb.execute( queryString, parameters ).columnAs( "n" );
    result = resultIterator.next();
    tx.success();
    return result;
}
```

2.13.2. Get or create unique node using a manual index

While this is a working solution, please consider using the preferred solution at Get or create unique node using Cypher and unique constraints instead.

By using put-if-absent *(javadocs/org/neo4j/graphdb/index/Index.html#putIfAbsent-T-java.lang.String-java.lang.Object-)* functionality, entity uniqueness can be guaranteed using an index.

Here the index acts as the lock and will only lock the smallest part needed to guarantee uniqueness across threads and transactions. To get the more high-level `get-or-create` functionality make use of UniqueFactory *(javadocs/org/neo4j/graphdb/index/UniqueFactory.html)* as seen in the example below.

Create a factory for unique nodes at application start

```
try ( Transaction tx = graphDb.beginTx() )
{
    UniqueFactory.UniqueNodeFactory result = new UniqueFactory.UniqueNodeFactory( graphDb, "users" )
    {
        @Override
        protected void initialize( Node created, Map<String, Object> properties )
        {
            created.addLabel( Label.label( "User" ) );
            created.setProperty( "name", properties.get( "name" ) );
        }
    };
    tx.success();
    return result;
}
```

Use the unique node factory to get or create a node

```
try ( Transaction tx = graphDb.beginTx() )
{
    Node node = factory.getOrCreate( "name", username );
    tx.success();
    return node;
}
```

2.13.3. Pessimistic locking for node creation

> ❗ While this is a working solution, please consider using the preferred solution at Get or create unique node using Cypher and unique constraints instead.

One might be tempted to use Java synchronization for pessimistic locking, but this is dangerous. By mixing locks in Neo4j and in the Java runtime, it is easy to produce deadlocks that are not detectable by Neo4j. As long as all locking is done by Neo4j, all deadlocks will be detected and avoided. Also, a solution using manual synchronization doesn't ensure uniqueness in an HA environment.

This example uses a single "lock node" for locking. We create it only as a place to put locks, nothing else.

Create a lock node at application start

```
try ( Transaction tx = graphDb.beginTx() )
{
    final Node lockNode = graphDb.createNode();
    tx.success();
    return lockNode;
}
```

Use the lock node to ensure nodes are not created concurrently

```
try ( Transaction tx = graphDb.beginTx() )
{
    Index<Node> usersIndex = graphDb.index().forNodes( "users" );
    Node userNode = usersIndex.get( "name", username ).getSingle();
    if ( userNode != null )
    {
        return userNode;
    }

    tx.acquireWriteLock( lockNode );
    userNode = usersIndex.get( "name", username ).getSingle();
    if ( userNode == null )
    {
        userNode = graphDb.createNode( Label.label( "User" ) );
        usersIndex.add( userNode, "name", username );
        userNode.setProperty( "name", username );
    }
    tx.success();
    return userNode;
}
```

Note that finishing the transaction will release the lock on the lock node.

2.14. Accessing Neo4j embedded via the Bolt protocol

Open a Bolt connector to your embedded instance to get GUI administration and other benefits.

The Neo4j Browser and the official Neo4j Drivers use the Bolt database protocol to communicate with Neo4j. By default, Neo4j Embedded does not expose a Bolt connector, but you can enable one. Doing so allows you to connect the services Neo4j Browser to your embedded instance.

It also gives you a way to incrementally transfer an existing Embedded application to use Neo4j Drivers instead. Migrating to Neo4j Drivers means you become free to choose to run Neo4j Embedded or Neo4j Server, without changing your application code.

To add a Bolt Connector to your embedded database, you need to add the Bolt extension to your class path. This is done by adding an additional dependency to your project.

```
<project>
...
 <dependencies>

  <dependency>
    <groupId>org.neo4j</groupId>
    <artifactId>neo4j-bolt</artifactId>
    <version>{neo4j-version}</version>
  </dependency>
  ...
 </dependencies>
...
</project>
```

With this dependency in place, you can configure Neo4j to enable a Bolt connector.

```
GraphDatabaseSettings.BoltConnector bolt = GraphDatabaseSettings.boltConnector( "0" );

GraphDatabaseService graphDb = new GraphDatabaseFactory()
        .newEmbeddedDatabaseBuilder( DB_PATH )
        .setConfig( bolt.enabled, "true" )
        .setConfig( bolt.address, "localhost:7687" )
        .newGraphDatabase();
```

2.15. Terminating a running transaction

Sometimes you may want to terminate (abort) a long running transaction from another thread.

The source code used in this example is found here: TerminateTransactions.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/embedded-examples/src/main/java/org/neo4j/examples/TerminateTransactions.java)*

To begin with, we start the database server:

```
GraphDatabaseService graphDb = new GraphDatabaseFactory().newEmbeddedDatabase( DB_PATH );
```

Now we start creating an infinite binary tree of nodes in the database, as an example of a long running transaction.

```
RelationshipType relType = RelationshipType.withName( "CHILD" );
Queue<Node> nodes = new LinkedList<>();
int depth = 1;

try ( Transaction tx = graphDb.beginTx() )
{
    Node rootNode = graphDb.createNode();
    nodes.add( rootNode );

    for (; true; depth++) {
        int nodesToExpand = nodes.size();
        for (int i = 0; i < nodesToExpand; ++i) {
            Node parent = nodes.remove();

            Node left = graphDb.createNode();
            Node right = graphDb.createNode();

            parent.createRelationshipTo( left, relType );
            parent.createRelationshipTo( right, relType );

            nodes.add( left );
            nodes.add( right );
        }
    }
}
catch ( TransactionTerminatedException ignored )
{
    return String.format( "Created tree up to depth %s in 1 sec", depth );
}
```

After waiting for some time, we decide to terminate the transaction. This is done from a separate thread.

```
tx.terminate();
```

Running this will execute the long running transaction for about one second and prints the maximum depth of the tree that was created before the transaction was terminated. No changes are actually made to the data — because the transaction has been terminated, the end result is as if no operations were performed.

Example output

```
Created tree up to depth 16 in 1 sec
```

Finally, let’s shut down the database again.

```
graphDb.shutdown();
```

2.16. Execute Cypher Queries from Java

The full source code of the example: JavaQuery.java *(https://github.com/neo4j/neo4j/blob/3.0/manual/cypher/cypher-docs/src/test/java/org/neo4j/cypher/example/JavaQuery.java)*

In Java, you can use the Cypher query language *(http://neo4j.com/docs/developer-manual/3.0/cypher/)* as per the example below. First, let’s add some data.

```
GraphDatabaseService db = new GraphDatabaseFactory().newEmbeddedDatabase( DB_PATH );

try ( Transaction tx = db.beginTx())
{
    Node myNode = db.createNode();
    myNode.setProperty( "name", "my node" );
    tx.success();
}
```

Execute a query:

```
try ( Transaction ignored = db.beginTx();
      Result result = db.execute( "match (n {name: 'my node'}) return n, n.name" ) )
{
    while ( result.hasNext() )
    {
        Map<String,Object> row = result.next();
        for ( Entry<String,Object> column : row.entrySet() )
        {
            rows += column.getKey() + ": " + column.getValue() + "; ";
        }
        rows += "\n";
    }
}
```

In the above example, we also show how to iterate over the rows of the link:javadocs/org/neo4j/graphdb/Result.html[Result].

The code will generate:

```
n.name: my node; n: Node[0];
```

When using an `Result`, you should consume the entire result (iterate over all rows using `next()`, iterating over the iterator from `columnAs()` or calling for example `resultAsString()`). Failing to do so will not properly clean up resources used by the `Result` object, leading to unwanted behavior, such as leaking transactions. In case you don't want to iterate over all of the results, make sure to invoke `close()` as soon as you are done, to release the resources tied to the result.

Using a try-with-resources statement *(http://docs.oracle.com/javase/tutorial/essential/exceptions/tryResourceClose.html)* will make sure that the result is closed at the end of the statement. This is the recommended way to handle results.

You can also get a list of the columns in the result like this:

```
List<String> columns = result.columns();
```

This gives us:

```
[n, n.name]
```

To fetch the result items from a single column, do like below. In this case we'll have to read the property from the node and not from the result.

```
Iterator<Node> n_column = result.columnAs( "n" );
for ( Node node : Iterators.asIterable( n_column ) )
{
    nodeResult = node + ": " + node.getProperty( "name" );
}
```

In this case there's only one node in the result:

```
Node[0]: my node
```

Only use this if the result only contains a single column, or you are only interested in a single column of the result.

> `resultAsString()`, `writeAsStringTo()`, `columnAs()` cannot be called more than once on the same `Result` object, as they consume the result. In the same way, part of the result gets consumed for every call to `next()`. You should instead use only one and if you need the facilities of the other methods on the same query result instead create a new `Result`.

For more information on the Java interface to Cypher, see the Java API *(javadocs/index.html)*.

For more information and examples for Cypher, see Developer Manual Cypher *(http://neo4j.com/docs/developer-manual/3.0/cypher/)*.

2.17. Query Parameters

For more information on parameters see the Developer Manual *(http://neo4j.com/docs/developer-manual/3.0/cypher/#cypher-parameters)*.

Below follows example of how to use parameters when executing Cypher queries from Java.

Node id

```
Map<String, Object> params = new HashMap<>();
params.put( "id", 0 );
String query = "MATCH (n) WHERE id(n) = {id} RETURN n.name";
Result result = db.execute( query, params );
```

Node object

```
Map<String, Object> params = new HashMap<>();
params.put( "node", andreasNode );
String query = "MATCH (n) WHERE n = {node} RETURN n.name";
Result result = db.execute( query, params );
```

Multiple node ids

```
Map<String, Object> params = new HashMap<>();
params.put( "ids", Arrays.asList( 0, 1, 2 ) );
String query = "MATCH (n) WHERE id(n) in {ids} RETURN n.name";
Result result = db.execute( query, params );
```

String literal

```
Map<String, Object> params = new HashMap<>();
params.put( "name", "Johan" );
String query = "MATCH (n) WHERE n.name = {name} RETURN n";
Result result = db.execute( query, params );
```

Index value

```
Map<String, Object> params = new HashMap<>();
params.put( "value", "Michaela" );
String query = "START n=node:people(name = {value}) RETURN n";
Result result = db.execute( query, params );
```

Index query

```
Map<String, Object> params = new HashMap<>();
params.put( "query", "name:Andreas" );
String query = "START n=node:people({query}) RETURN n";
Result result = db.execute( query, params );
```

Numeric parameters for SKIP and LIMIT

```
Map<String, Object> params = new HashMap<>();
params.put( "s", 1 );
params.put( "l", 1 );
String query = "MATCH (n) RETURN n.name SKIP {s} LIMIT {l}";
Result result = db.execute( query, params );
```

Regular expression

```
Map<String, Object> params = new HashMap<>();
params.put( "regex", ".*h.*" );
String query = "MATCH (n) WHERE n.name =~ {regex} RETURN n.name";
Result result = db.execute( query, params );
```

Create node with properties

```
Map<String, Object> props = new HashMap<>();
props.put( "name", "Andres" );
props.put( "position", "Developer" );

Map<String, Object> params = new HashMap<>();
params.put( "props", props );
String query = "CREATE ({props})";
db.execute( query, params );
```

Create multiple nodes with properties

```
Map<String, Object> n1 = new HashMap<>();
n1.put( "name", "Andres" );
n1.put( "position", "Developer" );
n1.put( "awesome", true );

Map<String, Object> n2 = new HashMap<>();
n2.put( "name", "Michael" );
n2.put( "position", "Developer" );
n2.put( "children", 3 );

Map<String, Object> params = new HashMap<>();
List<Map<String, Object>> maps = Arrays.asList( n1, n2 );
params.put( "props", maps );
String query = "UNWIND {props} AS properties CREATE (n:Person) SET n = properties RETURN n";
db.execute( query, params );
```

Setting all properties on node

```
Map<String, Object> n1 = new HashMap<>();
n1.put( "name", "Andres" );
n1.put( "position", "Developer" );

Map<String, Object> params = new HashMap<>();
params.put( "props", n1 );

String query = "MATCH (n) WHERE n.name='Michaela' SET n = {props}";
db.execute( query, params );
```

Chapter 3. The traversal framework

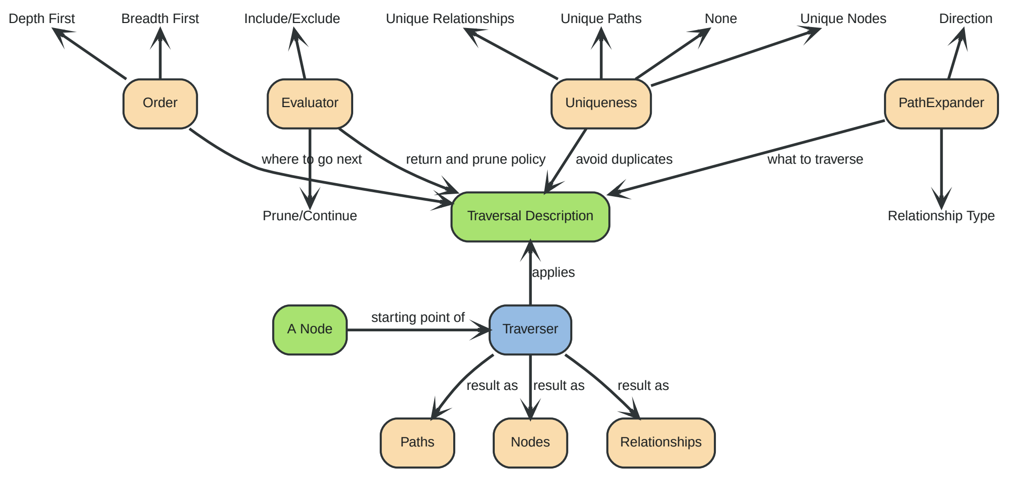
The Neo4j Traversal API *(javadocs/org/neo4j/graphdb/traversal/package-summary.html)* is a callback based, lazily executed way of specifying desired movements through a graph in Java. Some traversal examples are collected under Traversal.

You can also use the Cypher query language *(http://neo4j.com/docs/developer-manual/3.0/cypher/)* as a powerful declarative way to query the graph.

3.1. Main concepts

Here follows a short explanation of all different methods that can modify or add to a traversal description.

- *Pathexpanders* — define what to traverse, typically in terms of relationship direction and type.
- *Order* — for example depth-first or breadth-first.
- *Uniqueness* — visit nodes (relationships, paths) only once.
- *Evaluator* — decide what to return and whether to stop or continue traversal beyond the current position.
- *Starting nodes* where the traversal will begin.



See Traversal framework Java API for more details.

3.2. Traversal framework Java API

The traversal framework consists of a few main interfaces in addition to `Node` and `Relationship`: `TraversalDescription`, `Evaluator`, `Traverser` and `Uniqueness` are the main ones. The `Path` interface also has a special purpose in traversals, since it is used to represent a position in the graph when evaluating that position. Furthermore the `PathExpander` (replacing `RelationshipExpander` and `Expander`) interface is central to traversals, but users of the API rarely need to implement it. There are also a set of interfaces for advanced use, when explicit control over the traversal order is required: `BranchSelector`, `BranchOrderingPolicy` and `TraversalBranch`.

3.2.1. TraversalDescription

The TraversalDescription *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html)* is the main interface used for defining and initializing traversals. It is not meant to be implemented by users of the traversal framework, but rather to be provided by the implementation of the traversal framework as a way for the user to describe traversals. `TraversalDescription` instances are immutable and its methods returns a new `TraversalDescription` that is modified compared to the object the method was invoked on with the arguments of the method.

Relationships

Adds a relationship type to the list of relationship types to traverse. By default that list is empty and it means that it will traverse *all relationships*, regardless of type. If one or more relationships are added to this list *only the added* types will be traversed. There are two methods, one including direction *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#relationships-org.neo4j.graphdb.RelationshipType-org.neo4j.graphdb.Direction-)* and another one excluding direction *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#relationships-org.neo4j.graphdb.RelationshipType-)*, where the latter traverses relationships in both directions *(javadocs/org/neo4j/graphdb/Direction.html#BOTH)*.

3.2.2. Evaluator

Evaluator *(javadocs/org/neo4j/graphdb/traversal/Evaluator.html)*s are used for deciding, at each position (represented as a `Path`): should the traversal continue, and/or should the node be included in the result. Given a `Path`, it asks for one of four actions for that branch of the traversal:

- `Evaluation.INCLUDE_AND_CONTINUE`: Include this node in the result and continue the traversal
- `Evaluation.INCLUDE_AND_PRUNE`: Include this node in the result, but don't continue the traversal
- `Evaluation.EXCLUDE_AND_CONTINUE`: Exclude this node from the result, but continue the traversal
- `Evaluation.EXCLUDE_AND_PRUNE`: Exclude this node from the result and don't continue the traversal

More than one evaluator can be added. Note that evaluators will be called for all positions the traverser encounters, even for the start node.

3.2.3. Traverser

The Traverser *(javadocs/org/neo4j/graphdb/traversal/Traverser.html)* object is the result of invoking traverse() *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#traverse-org.neo4j.graphdb.Node-)* of a TraversalDescription object. It represents a traversal positioned in the graph, and a specification of the format of the result. The actual traversal is performed lazily each time the `next()`-method of the iterator of the `Traverser` is invoked.

3.2.4. Uniqueness

Sets the rules for how positions can be revisited during a traversal as stated in Uniqueness *(javadocs/org/neo4j/graphdb/traversal/Uniqueness.html)*. Default if not set is NODE_GLOBAL *(javadocs/org/neo4j/graphdb/traversal/Uniqueness.html#NODE_GLOBAL)*.

A Uniqueness can be supplied to the TraversalDescription to dictate under what circumstances a traversal may revisit the same position in the graph. The various uniqueness levels that can be used in Neo4j are:

- `NONE`: Any position in the graph may be revisited.
- `NODE_GLOBAL` uniqueness: No node in the entire graph may be visited more than once. This could potentially consume a lot of memory since it requires keeping an in-memory data structure remembering all the visited nodes.
- `RELATIONSHIP_GLOBAL` uniqueness: no relationship in the entire graph may be visited more than once. For the same reasons as `NODE_GLOBAL` uniqueness, this could use up a lot of memory. But since graphs typically have a larger number of relationships than nodes, the memory overhead of this uniqueness level could grow even quicker.
- `NODE_PATH` uniqueness: A node may not occur previously in the path reaching up to it.

- `RELATIONSHIP_PATH` uniqueness: A relationship may not occur previously in the path reaching up to it.
- `NODE_RECENT` uniqueness: Similar to `NODE_GLOBAL` uniqueness in that there is a global collection of visited nodes each position is checked against. This uniqueness level does however have a cap on how much memory it may consume in the form of a collection that only contains the most recently visited nodes. The size of this collection can be specified by providing a number as the second argument to the TraversalDescription.uniqueness()-method along with the uniqueness level.
- `RELATIONSHIP_RECENT` uniqueness: Works like `NODE_RECENT` uniqueness, but with relationships instead of nodes.

Depth first / Breadth first

These are convenience methods for setting preorder depth-first *(https://en.wikipedia.org/wiki/Depth-first_search)*/ breadth-first *(https://en.wikipedia.org/wiki/Breadth-first_search)* `BranchSelector`|`ordering` policies. The same result can be achieved by calling the order *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#order-org.neo4j.graphdb.traversal.BranchOrderingPolicy-)* method with ordering policies from BranchOrderingPolicies *(javadocs/org/neo4j/graphdb/traversal/BranchOrderingPolicies.html)*, or to write your own BranchSelector/BranchOrderingPolicy and pass in.

3.2.5. Order — How to move through branches?

A more generic version of depthFirst/breadthFirst methods in that it allows an arbitrary BranchOrderingPolicy *(javadocs/org/neo4j/graphdb/traversal/BranchOrderingPolicy.html)* to be injected into the description.

3.2.6. BranchSelector

A `BranchSelector`/`BranchOrderingPolicy` is used for selecting which branch of the traversal to attempt next. This is used for implementing traversal orderings. The traversal framework provides a few basic ordering implementations:

- `BranchOrderingPolicies.PREORDER_DEPTH_FIRST`: Traversing depth first, visiting each node before visiting its child nodes.
- `BranchOrderingPolicies.POSTORDER_DEPTH_FIRST`: Traversing depth first, visiting each node after visiting its child nodes.
- `BranchOrderingPolicies.PREORDER_BREADTH_FIRST`: Traversing breadth first, visiting each node before visiting its child nodes.
- `BranchOrderingPolicies.POSTORDER_BREADTH_FIRST`: Traversing breadth first, visiting each node after visiting its child nodes.

> Please note that breadth first traversals have a higher memory overhead than depth first traversals.

`BranchSelector`s carries state and hence needs to be uniquely instantiated for each traversal. Therefore it is supplied to the `TraversalDescription` through a `BranchOrderingPolicy` interface, which is a factory of `BranchSelector` instances.

A user of the Traversal framework rarely needs to implement his own `BranchSelector` or `BranchOrderingPolicy`, it is provided to let graph algorithm implementors provide their own traversal orders. The Neo4j Graph Algorithms package contains for example a `BestFirst` order `BranchSelector` /`BranchOrderingPolicy` that is used in BestFirst search algorithms such as A* and Dijkstra.

BranchOrderingPolicy

A factory for creating `BranchSelector`s to decide in what order branches are returned (where a branch's position is represented as a Path *(javadocs/org/neo4j/graphdb/Path.html)* from the start node to the current node). Common policies are depth-first *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#depthFirst--)* and breadth-first *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#breadthFirst--)* and that's why there are convenience methods for those. For example, calling TraversalDescription#depthFirst() *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html#depthFirst--)* is equivalent to:

```
description.order( BranchOrderingPolicies.PREORDER_DEPTH_FIRST );
```

TraversalBranch

An object used by the BranchSelector to get more branches from a certain branch. In essence these are a composite of a Path and a RelationshipExpander that can be used to get new TraversalBranch *(javadocs/org/neo4j/graphdb/traversal/TraversalBranch.html)*es from the current one.

3.2.7. Path

A Path *(javadocs/org/neo4j/graphdb/Path.html)* is a general interface that is part of the Neo4j API. In the traversal API of Neo4j the use of Paths are twofold. Traversers can return their results in the form of the Paths of the visited positions in the graph that are marked for being returned. Path objects are also used in the evaluation of positions in the graph, for determining if the traversal should continue from a certain point or not, and whether a certain position should be included in the result set or not.

3.2.8. PathExpander/RelationshipExpander

The traversal framework use `PathExpander`s (replacing `RelationshipExpander`) to discover the relationships that should be followed from a particular path to further branches in the traversal.

3.2.9. Expander

A more generic version of relationships where a `RelationshipExpander` is injected, defining all relationships to be traversed for any given node.

The `Expander` interface is an extension of the `RelationshipExpander` interface that makes it possible to build customized versions of an `Expander`. The implementation of `TraversalDescription` uses this to provide methods for defining which relationship types to traverse, this is the usual way a user of the API would define a `RelationshipExpander` — by building it internally in the `TraversalDescription`.

All the RelationshipExpanders provided by the Neo4j traversal framework also implement the Expander interface. For a user of the traversal API it is easier to implement the PathExpander/RelationshipExpander interface, since it only contains one method — the method for getting the relationships from a path/node, the methods that the Expander interface adds are just for building new Expanders.

3.2.10. How to use the Traversal framework

A traversal description *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html)* is built using a fluent interface and such a description can then spawn traversers *(javadocs/org/neo4j/graphdb/traversal/Traverser.html)*.

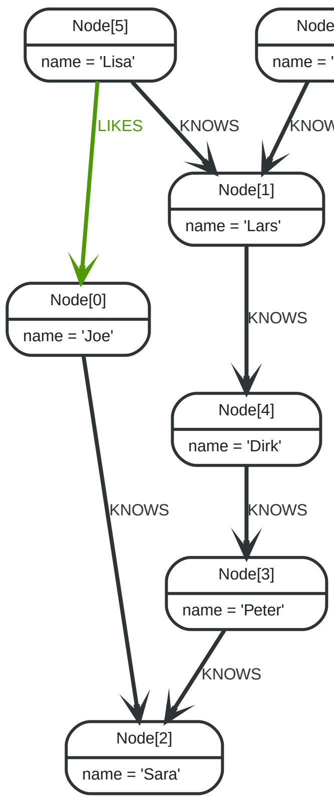


Figure 5. Traversal example graph

With the definition of the `RelationshipTypes` as

```
private enum Rels implements RelationshipType
{
    LIKES, KNOWS
}
```

The graph can be traversed with for example the following traverser, starting at the ``Joe'' node:

```
for ( Path position : db.traversalDescription()
        .depthFirst()
        .relationships( Rels.KNOWS )
        .relationships( Rels.LIKES, Direction.INCOMING )
        .evaluator( Evaluators.toDepth( 5 ) )
        .traverse( node ) )
{
    output += position + "\n";
}
```

The traversal will output:

```
(0)
(0)<--[LIKES,1]--(5)
(0)<--[LIKES,1]--(5)--[KNOWS,6]-->(1)
(0)<--[LIKES,1]--(5)--[KNOWS,6]-->(1)<--[KNOWS,5]--(6)
(0)<--[LIKES,1]--(5)--[KNOWS,6]-->(1)--[KNOWS,4]-->(4)
(0)<--[LIKES,1]--(5)--[KNOWS,6]-->(1)--[KNOWS,4]-->(4)--[KNOWS,3]-->(3)
(0)<--[LIKES,1]--(5)--[KNOWS,6]-->(1)--[KNOWS,4]-->(4)--[KNOWS,3]-->(3)--[KNOWS,2]-->(2)
```

Since TraversalDescription *(javadocs/org/neo4j/graphdb/traversal/TraversalDescription.html)*s are immutable it is also useful to create template descriptions which holds common settings shared by different traversals. For example, let's start with this traverser:

```
friendsTraversal = db.traversalDescription()
        .depthFirst()
        .relationships( Rels.KNOWS )
        .uniqueness( Uniqueness.RELATIONSHIP_GLOBAL );
```

This traverser would yield the following output (we will keep starting from the ``Joe'' node):

```
(0)
(0)--[KNOWS,0]-->(2)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)<--[KNOWS,4]--(1)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)<--[KNOWS,4]--(1)<--[KNOWS,6]--(5)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)<--[KNOWS,4]--(1)<--[KNOWS,5]--(6)
```

Now let's create a new traverser from it, restricting depth to three:

```
for ( Path path : friendsTraversal
        .evaluator( Evaluators.toDepth( 3 ) )
        .traverse( node ) )
{
    output += path + "\n";
}
```

This will give us the following result:

```
(0)
(0)--[KNOWS,0]-->(2)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)
```

Or how about from depth two to four? That's done like this:

```
for ( Path path : friendsTraversal
        .evaluator( Evaluators.fromDepth( 2 ) )
        .evaluator( Evaluators.toDepth( 4 ) )
        .traverse( node ) )
{
    output += path + "\n";
}
```

This traversal gives us:

```
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)
(0)--[KNOWS,0]-->(2)<--[KNOWS,2]--(3)<--[KNOWS,3]--(4)<--[KNOWS,4]--(1)
```

For various useful evaluators, see the Evaluators *(javadocs/org/neo4j/graphdb/traversal/Evaluators.html)* Java API or simply implement the Evaluator *(javadocs/org/neo4j/graphdb/traversal/Evaluator.html)* interface yourself.

If you're not interested in the Path *(javadocs/org/neo4j/graphdb/Path.html)*s, but the Node *(javadocs/org/neo4j/graphdb/Node.html)*s you can transform the traverser into an iterable of nodes *(javadocs/org/neo4j/graphdb/traversal/Traverser.html#nodes--)* like this:

```
for ( Node currentNode : friendsTraversal
        .traverse( node )
        .nodes() )
{
    output += currentNode.getProperty( "name" ) + "\n";
}
```

In this case we use it to retrieve the names:

```
Joe
Sara
Peter
Dirk
Lars
Lisa
Ed
```

Relationships *(javadocs/org/neo4j/graphdb/traversal/Traverser.html#relationships--)* are fine as well, here's how to get them:

```
for ( Relationship relationship : friendsTraversal
        .traverse( node )
        .relationships() )
{
    output += relationship.getType().name() + "\n";
}
```

Here the relationship types are written, and we get:

```
KNOWS
KNOWS
KNOWS
KNOWS
KNOWS
KNOWS
```

The source code for the traversers in this example is available at: TraversalExample.java *(https://github.com/neo4j/neo4j/blob/3.0/community/embedded-examples/src/main/java/org/neo4j/examples/TraversalExample.java)*

Chapter 4. Manual indexing

This chapter focuses on how to use the Manual Indexes. As of Neo4j 2.0, this is not the favored method of indexing data in Neo4j, instead we recommend defining indexes in the database schema.

However, support for manual indexes remains, because certain features, such as full-text search, are not yet handled by the new indexes.

4.1. Introduction

Manual indexing operations are part of the Neo4j index API *(javadocs/org/neo4j/graphdb/index/package-summary.html)*.

Each index is tied to a unique, user-specified name (for example "first_name" or "books") and can index either nodes *(javadocs/org/neo4j/graphdb/Node.html)* or relationships *(javadocs/org/neo4j/graphdb/Relationship.html)*.

The default index implementation is provided by the `neo4j-lucene-index` component, which is included in the standard Neo4j download. It can also be downloaded separately from http://repo1.maven.org/maven2/org/neo4j/neo4j-lucene-index/ . For Maven users, the `neo4j-lucene-index` component has the coordinates `org.neo4j:neo4j-lucene-index` and should be used with the same version of `org.neo4j:neo4j-kernel`. Different versions of the index and kernel components are not compatible in the general case. Both components are included transitively by the `org.neo4j:neo4j:pom` artifact which makes it simple to keep the versions in sync.

Transactions

All modifying index operations must be performed inside a transaction, as with any modifying operation in Neo4j.

4.2. Create

An index is created if it doesn't exist when you ask for it. Unless you give it a custom configuration, it will be created with default configuration and backend.

To set the stage for our examples, let's create some indexes to begin with:

```
IndexManager index = graphDb.index();
Index<Node> actors = index.forNodes( "actors" );
Index<Node> movies = index.forNodes( "movies" );
RelationshipIndex roles = index.forRelationships( "roles" );
```

This will create two node indexes and one relationship index with default configuration. See Relationship indexes for more information specific to relationship indexes.

See Configuration and fulltext indexes for how to create *fulltext* indexes.

You can also check if an index exists like this:

```
IndexManager index = graphDb.index();
boolean indexExists = index.existsForNodes( "actors" );
```

4.3. Delete

Indexes can be deleted. When deleting, the entire contents of the index will be removed as well as its associated configuration. An index can be created with the same name at a later point in time.

```
IndexManager index = graphDb.index();
Index<Node> actors = index.forNodes( "actors" );
actors.delete();
```

Note that the actual deletion of the index is made during the commit of *the surrounding transaction*. Calls made to such an index instance after delete() *(javadocs/org/neo4j/graphdb/index/Index.html#delete--)* has been called are invalid inside that transaction as well as outside (if the transaction is successful), but will become valid again if the transaction is rolled back.

4.4. Add

Each index supports associating any number of key-value pairs with any number of entities (nodes or relationships), where each association between entity and key-value pair is performed individually. To begin with, let's add a few nodes to the indexes:

```
// Actors
Node reeves = graphDb.createNode();
reeves.setProperty( "name", "Keanu Reeves" );
actors.add( reeves, "name", reeves.getProperty( "name" ) );
Node bellucci = graphDb.createNode();
bellucci.setProperty( "name", "Monica Bellucci" );
actors.add( bellucci, "name", bellucci.getProperty( "name" ) );
// multiple values for a field, in this case for search only
// and not stored as a property.
actors.add( bellucci, "name", "La Bellucci" );
// Movies
Node theMatrix = graphDb.createNode();
theMatrix.setProperty( "title", "The Matrix" );
theMatrix.setProperty( "year", 1999 );
movies.add( theMatrix, "title", theMatrix.getProperty( "title" ) );
movies.add( theMatrix, "year", theMatrix.getProperty( "year" ) );
Node theMatrixReloaded = graphDb.createNode();
theMatrixReloaded.setProperty( "title", "The Matrix Reloaded" );
theMatrixReloaded.setProperty( "year", 2003 );
movies.add( theMatrixReloaded, "title", theMatrixReloaded.getProperty( "title" ) );
movies.add( theMatrixReloaded, "year", 2003 );
Node malena = graphDb.createNode();
malena.setProperty( "title", "Malèna" );
malena.setProperty( "year", 2000 );
movies.add( malena, "title", malena.getProperty( "title" ) );
movies.add( malena, "year", malena.getProperty( "year" ) );
```

Note that there can be multiple values associated with the same entity and key.

Next up, we'll create relationships and index them as well:

```
// we need a relationship type
RelationshipType ACTS_IN = RelationshipType.withName( "ACTS_IN" );
// create relationships
Relationship role1 = reeves.createRelationshipTo( theMatrix, ACTS_IN );
role1.setProperty( "name", "Neo" );
roles.add( role1, "name", role1.getProperty( "name" ) );
Relationship role2 = reeves.createRelationshipTo( theMatrixReloaded, ACTS_IN );
role2.setProperty( "name", "Neo" );
roles.add( role2, "name", role2.getProperty( "name" ) );
Relationship role3 = bellucci.createRelationshipTo( theMatrixReloaded, ACTS_IN );
role3.setProperty( "name", "Persephone" );
roles.add( role3, "name", role3.getProperty( "name" ) );
Relationship role4 = bellucci.createRelationshipTo( malena, ACTS_IN );
role4.setProperty( "name", "Malèna Scordia" );
roles.add( role4, "name", role4.getProperty( "name" ) );
```

After these operations, our example graph looks like this:

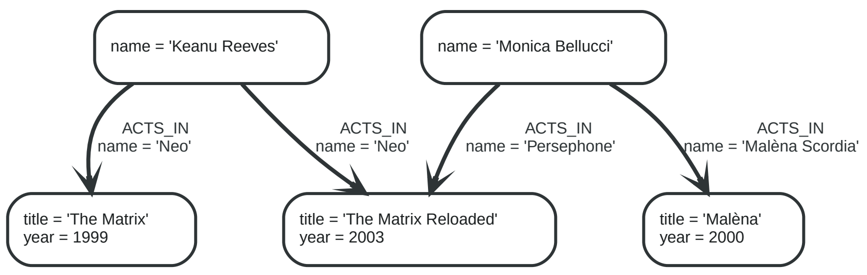


Figure 6. Movie and Actor Graph

4.5. Remove

Removing *(javadocs/org/neo4j/graphdb/index/Index.html#remove-T-java.lang.String-java.lang.Object-)* from an index is similar to adding, but can be done by supplying one of the following combinations of arguments:

- entity
- entity, key
- entity, key, value

```
// completely remove bellucci from the actors index
actors.remove( bellucci );
// remove any "name" entry of bellucci from the actors index
actors.remove( bellucci, "name" );
// remove the "name" -> "La Bellucci" entry of bellucci
actors.remove( bellucci, "name", "La Bellucci" );
```

4.6. Update

To update an index entry, the old one must be removed and a new one added. For details on removing index entries, see Remove.

Remember that a node or relationship can be associated with any number of key-value pairs in an index. This means that you can index a node or relationship with many key-value pairs that have the same key. In the case where a property value changes and you'd like to update the index, it's not enough to just index the new value — you'll have to remove the old value as well.

Here's a code example that demonstrates how it's done:

```
// create a node with a property
// so we have something to update later on
Node fishburn = graphDb.createNode();
fishburn.setProperty( "name", "Fishburn" );
// index it
actors.add( fishburn, "name", fishburn.getProperty( "name" ) );
// update the index entry
// when the property value changes
actors.remove( fishburn, "name", fishburn.getProperty( "name" ) );
fishburn.setProperty( "name", "Laurence Fishburn" );
actors.add( fishburn, "name", fishburn.getProperty( "name" ) );
```

4.7. Search

An index can be searched in two ways, get *(javadocs/org/neo4j/graphdb/index/ReadableIndex.html#get-java.lang.String-java.lang.Object-)* and query *(javadocs/org/neo4j/graphdb/index/ReadableIndex.html#query-java.lang.Object-)*. The `get` method will return exact matches to the given key-value pair, whereas `query` exposes querying capabilities directly from the backend used by the index. For example the Lucene query syntax *(http://lucene.apache.org/core/5_4_0/queryparser/org/apache/lucene/queryparser/classic/package-summary.html#package_description)* can be used directly with the default indexing backend.

4.7.1. Get

This is how to search for a single exact match:

```
IndexHits<Node> hits = actors.get( "name", "Keanu Reeves" );
Node reeves = hits.getSingle();
```

IndexHits *(javadocs/org/neo4j/graphdb/index/IndexHits.html)* is an `Iterable` with some additional useful methods. For example getSingle() *(javadocs/org/neo4j/graphdb/index/IndexHits.html#getSingle--)* returns the first and only item from the result iterator, or `null` if there isn't any hit.

Here's how to get a single relationship by exact matching and retrieve its start and end nodes:

```
Relationship persephone = roles.get( "name", "Persephone" ).getSingle();
Node actor = persephone.getStartNode();
Node movie = persephone.getEndNode();
```

Finally, we can iterate over all exact matches from a relationship index:

```
for ( Relationship role : roles.get( "name", "Neo" ) )
{
    // this will give us Reeves twice
    Node reeves = role.getStartNode();
}
```

In case you don't iterate through all the hits, IndexHits.close() *(javadocs/org/neo4j/graphdb/index/IndexHits.html#close--)* must be called explicitly.

4.7.2. Query

There are two query methods, one which uses a key-value signature where the value represents a query for values with the given key only. The other method is more generic and supports querying for more than one key-value pair in the same query.

Here's an example using the key-query option:

```
for ( Node actor : actors.query( "name", "*e*" ) )
{
    // This will return Reeves and Bellucci
}
```

In the following example the query uses multiple keys:

```
for ( Node movie : movies.query( "title:*Matrix* AND year:1999" ) )
{
    // This will return "The Matrix" from 1999 only.
}
```

Beginning a wildcard search with "*" or "?" is discouraged by Lucene, but will nevertheless work.

You can't have *any whitespace* in the search term with this syntax. See Querying with Lucene query objects for how to do that.

4.8. Relationship indexes

An index for relationships is just like an index for nodes, extended by providing support to constrain a search to relationships with a specific start and/or end nodes These extra methods reside in the RelationshipIndex *(javadocs/org/neo4j/graphdb/index/RelationshipIndex.html)* interface which extends Index<Relationship> *(javadocs/org/neo4j/graphdb/index/Index.html)*.

Example of querying a relationship index:

```
// find relationships filtering on start node
// using exact matches
IndexHits<Relationship> reevesAsNeoHits;
reevesAsNeoHits = roles.get( "name", "Neo", reeves, null );
Relationship reevesAsNeo = reevesAsNeoHits.iterator().next();
reevesAsNeoHits.close();
// find relationships filtering on end node
// using a query
IndexHits<Relationship> matrixNeoHits;
matrixNeoHits = roles.query( "name", "*eo", null, theMatrix );
Relationship matrixNeo = matrixNeoHits.iterator().next();
matrixNeoHits.close();
```

And here's an example for the special case of searching for a specific relationship type:

```
// find relationships filtering on end node
// using a relationship type.
// this is how to add it to the index:
roles.add( reevesAsNeo, "type", reevesAsNeo.getType().name() );
// Note that to use a compound query, we can't combine committed
// and uncommitted index entries, so we'll commit before querying:
tx.success();
tx.close();

// and now we can search for it:
try ( Transaction tx = graphDb.beginTx() )
{
    IndexHits<Relationship> typeHits = roles.query( "type:ACTS_IN AND name:Neo", null, theMatrix );
    Relationship typeNeo = typeHits.iterator().next();
    typeHits.close();
```

Such an index can be useful if your domain has nodes with a very large number of relationships between them, since it reduces the search time for a relationship between two nodes. A good example where this approach pays dividends is in time series data, where we have readings represented as a relationship per occurrence.

4.9. Scores

The `IndexHits` interface exposes scoring *(javadocs/org/neo4j/graphdb/index/IndexHits.html#currentScore--)* so that the index can communicate scores for the hits. Note that the result is not sorted by the score unless you explicitly specify that. See Sorting for how to sort by score.

```
IndexHits<Node> hits = movies.query( "title", "The*" );
for ( Node movie : hits )
{
    System.out.println( movie.getProperty( "title" ) + " " + hits.currentScore() );
}
```

4.10. Configuration and fulltext indexes

At the time of creation extra configuration can be specified to control the behavior of the index and which backend to use. For example to create a Lucene fulltext index:

```
IndexManager index = graphDb.index();
Index<Node> fulltextMovies = index.forNodes( "movies-fulltext",
        MapUtil.stringMap( IndexManager.PROVIDER, "lucene", "type", "fulltext" ) );
fulltextMovies.add( theMatrix, "title", "The Matrix" );
fulltextMovies.add( theMatrixReloaded, "title", "The Matrix Reloaded" );
// search in the fulltext index
Node found = fulltextMovies.query( "title", "reloAdEd" ).getSingle();
```

Here's an example of how to create an exact index which is case-insensitive:

```
Index<Node> index = graphDb.index().forNodes( "exact-case-insensitive",
        stringMap( "type", "exact", "to_lower_case", "true" ) );
Node node = graphDb.createNode();
index.add( node, "name", "Thomas Anderson" );
assertContains( index.query( "name", "\"Thomas Anderson\"" ), node );
assertContains( index.query( "name", "\"thoMas ANDerson\"" ), node );
```

In order to search for tokenized words, the `query` method has to be used. The `get` method will only match the full string value, not the tokens.

The configuration of the index is persisted once the index has been created. The `provider` configuration key is interpreted by Neo4j, but any other configuration is passed onto the backend index (e.g. Lucene) to interpret.

Table 3. Lucene indexing configuration parameters

Parameter	Possible values	Effect
`type`	`exact`, `fulltext`	`exact` is the default and uses a Lucene keyword analyzer *(http://lucene.apache.org/core/5_4_0/analyzers-common/org/apache/lucene/analysis/core/KeywordAnalyzer.html)*. `fulltext` uses a white-space tokenizer in its analyzer.
`to_lower_case`	`true`, `false`	This parameter goes together with `type`: `fulltext` and converts values to lower case during both additions and querying, making the index case insensitive. Defaults to `true`.
`analyzer`	the full class name of an Analyzer *(http://lucene.apache.org/core/5_4_0/core/org/apache/lucene/analysis/Analyzer.html)*	Overrides the `type` so that a custom analyzer can be used. Note: `to_lower_case` still affects lowercasing of string queries. If the custom analyzer uppercases the indexed tokens, string queries will not match as expected.

4.11. Extra features for Lucene indexes

4.11.1. Numeric ranges

Lucene supports smart indexing of numbers, querying for ranges and sorting such results, and so does its backend for Neo4j. To mark a value so that it is indexed as a numeric value, we can make use of the ValueContext *(javadocs/org/neo4j/index/lucene/ValueContext.html)* class, like this:

```
movies.add( theMatrix, "year-numeric", new ValueContext( 1999 ).indexNumeric() );
movies.add( theMatrixReloaded, "year-numeric", new ValueContext( 2003 ).indexNumeric() );
movies.add( malena, "year-numeric", new ValueContext( 2000 ).indexNumeric() );

int from = 1997;
int to = 1999;
hits = movies.query( QueryContext.numericRange( "year-numeric", from, to ) );
```

The same type must be used for indexing and querying. That is, you can't index a value as a Long and then query the index using an Integer.

By giving `null` as from/to argument, an open ended query is created. In the following example we are doing that, and have added sorting to the query as well:

```
hits = movies.query(
        QueryContext.numericRange( "year-numeric", from, null )
                .sortNumeric( "year-numeric", false ) );
```

From/to in the ranges defaults to be *inclusive*, but you can change this behavior by using two extra parameters:

```
movies.add( theMatrix, "score", new ValueContext( 8.7 ).indexNumeric() );
movies.add( theMatrixReloaded, "score", new ValueContext( 7.1 ).indexNumeric() );
movies.add( malena, "score", new ValueContext( 7.4 ).indexNumeric() );

// include 8.0, exclude 9.0
hits = movies.query( QueryContext.numericRange( "score", 8.0, 9.0, true, false ) );
```

4.11.2. Sorting

Lucene performs sorting very well, and that is also exposed in the index backend, through the QueryContext *(javadocs/org/neo4j/index/lucene/QueryContext.html)* class:

```
hits = movies.query( "title", new QueryContext( "*" ).sort( "title" ) );
for ( Node hit : hits )
{
    // all movies with a title in the index, ordered by title
}
// or
hits = movies.query( new QueryContext( "title:*" ).sort( "year", "title" ) );
for ( Node hit : hits )
{
    // all movies with a title in the index, ordered by year, then title
}
```

We sort the results by relevance (score) like this:

```
hits = movies.query( "title", new QueryContext( "The*" ).sortByScore() );
for ( Node movie : hits )
{
    // hits sorted by relevance (score)
}
```

4.11.3. Querying with Lucene query objects

Instead of passing in Lucene query syntax queries, you can instantiate such queries programmatically and pass in as argument, for example:

```
// a TermQuery will give exact matches
Node actor = actors.query( new TermQuery( new Term( "name", "Keanu Reeves" ) ) ).getSingle();
```

Note that the TermQuery *(http://lucene.apache.org/core/5_4_0/core/org/apache/lucene/search/TermQuery.html)* is basically the same thing as using the `get` method on the index.

This is how to perform *wildcard* searches using Lucene query objects:

```
hits = movies.query( new WildcardQuery( new Term( "title", "The Matrix*" ) ) );
for ( Node movie : hits )
{
    System.out.println( movie.getProperty( "title" ) );
}
```

Note that this allows for whitespace in the search string.

4.11.4. Compound queries

Lucene supports querying for multiple terms in the same query, like so:

```
hits = movies.query( "title:*Matrix* AND year:1999" );
```

Compound queries can't search across committed index entries and those who haven't got committed yet at the same time.

4.11.5. Default operator

The default operator (that is whether `AND` or `OR` is used in between different terms) in a query is `OR`. Changing that behavior is also done via the QueryContext *(javadocs/org/neo4j/index/lucene/QueryContext.html)* class:

```
QueryContext query = new QueryContext( "title:*Matrix* year:1999" )
        .defaultOperator( Operator.AND );
hits = movies.query( query );
```

Chapter 5. Transaction Management

In order to fully maintain data integrity and ensure good transactional behavior, Neo4j supports the ACID properties:

- atomicity: If any part of a transaction fails, the database state is left unchanged.
- consistency: Any transaction will leave the database in a consistent state.
- isolation: During a transaction, modified data cannot be accessed by other operations.
- durability: The DBMS can always recover the results of a committed transaction.

Specifically:

- All database operations that access the graph, indexes, or the schema must be performed in a transaction.
- The default isolation level is `READ_COMMITTED`.
- Data retrieved by traversals is not protected from modification by other transactions.
- Non-repeatable reads may occur (i.e., only write locks are acquired and held until the end of the transaction).
- One can manually acquire write locks on nodes and relationships to achieve higher level of isolation (`SERIALIZABLE`).
- Locks are acquired at the Node and Relationship level.
- Deadlock detection is built into the core transaction management.

5.1. Interaction cycle

All database operations that access the graph, indexes, or the schema must be performed in a transaction. Transactions are thread confined and can be nested as “flat nested transactions”. Flat nested transactions means that all nested transactions are added to the scope of the top level transaction. A nested transaction can mark the top level transaction for rollback, meaning the entire transaction will be rolled back. To only rollback changes made in a nested transaction is not possible.

The interaction cycle of working with transactions looks like this:

1. Begin a transaction.
2. Perform database operations.
3. Mark the transaction as successful or not.
4. Finish the transaction.

It is very important to finish each transaction. The transaction will not release the locks or memory it has acquired until it has been finished. The idiomatic use of transactions in Neo4j is to use a try-finally block, starting the transaction and then try to perform the graph operations. The last operation in the try block should mark the transaction as successful while the finally block should finish the transaction. Finishing the transaction will perform commit or rollback depending on the success status.

All modifications performed in a transaction are kept in memory. This means that very large updates have to be split into several top level transactions to avoid running out of memory. It must be a top level transaction since splitting up the work in many nested transactions will just add all the work to the top level transaction.

In an environment that makes use of *thread pooling* other errors may occur when failing to finish a transaction properly. Consider a leaked transaction that did not get finished properly. It will be tied to a thread and when that thread gets scheduled to perform work starting a new (what looks to be a) top level transaction it will actually be a nested transaction. If the leaked transaction state is “marked for rollback” (which will happen if a deadlock was detected) no more work can be performed on that transaction. Trying to do so will result in error on each call to a write operation.

5.2. Isolation levels

Transactions in Neo4j use a read-committed isolation level, which means they will see data as soon as it has been committed and will not see data in other transactions that have not yet been committed. This type of isolation is weaker than serialization but offers significant performance advantages whilst being sufficient for the overwhelming majority of cases.

In addition, the Neo4j Java API enables explicit locking of nodes and relationships. Using locks gives the opportunity to simulate the effects of higher levels of isolation by obtaining and releasing locks explicitly. For example, if a write lock is taken on a common node or relationship, then all transactions will serialize on that lock — giving the effect of a serialization isolation level.

5.2.1. Lost Updates in Cypher

In Cypher it is possible to acquire write locks to simulate improved isolation in some cases. Consider the case where multiple concurrent Cypher queries increment the value of a property. Due to the limitations of the read-committed isolation level, the increments might not result in a deterministic final value. If there is a direct dependency, Cypher will automatically acquire a write lock before reading. A direct dependency is when the right-hand side of a `SET` has a dependent property read in the expression, or in the value of a key-value pair in a literal map.

For example, the following query, if run by one hundred concurrent clients, will very likely not increment the property `n.prop` to 100, unless a write lock is acquired before reading the property value. This is because all queries would read the value of `n.prop` within their own transaction, and would not see the incremented value from any other transaction that has not yet committed. In the worst case scenario the final value would be as low as 1, if all threads perform the read before any has committed their transaction.

Requires a write lock, and Cypher automatically acquires one.

```
MATCH (n:X {id: 42})
SET n.prop = n.prop + 1
```

Also requires a write lock, and Cypher automatically acquires one.

```
MATCH (n)
SET n += { prop: n.prop + 1 }
```

Due to the complexity of determining such a dependency in the general case, Cypher does not cover any of the below example cases:

Variable depending on results from reading the property in an earlier statement.

```
MATCH (n)
WITH n.prop as p
// ... operations depending on p, producing k
SET n.prop = k + 1
```

Circular dependency between properties read and written in the same query.

```
MATCH (n)
SET n += { propA: n.propB + 1, propB: n.propA + 1 }
```

To ensure deterministic behavior also in the more complex cases, it is necessary to explicitly acquire a write lock on the node in question. In Cypher there is no explicit support for this, but it is possible to work around this limitation by writing to a temporary property.

Acquires a write lock for the node by writing to a dummy property before reading the requested value.

```
MATCH (n:X {id: 42})
SET n._LOCK_ = true
WITH n.prop as p
// ... operations depending on p, producing k
SET n.prop = k + 1
REMOVE n._LOCK_
```

The existence of the `SET n.LOCK` statement before the read of the `n.prop` read ensures the lock is acquired before the read action, and no updates will be lost due to enforced serialization of all concurrent queries on that specific node.

5.3. Default locking behavior

- When adding, changing or removing a property on a node or relationship a write lock will be taken on the specific node or relationship.
- When creating or deleting a node a write lock will be taken for the specific node.
- When creating or deleting a relationship a write lock will be taken on the specific relationship and both its nodes.

The locks will be added to the transaction and released when the transaction finishes.

5.4. Deadlocks

5.4.1. Understanding deadlocks

Since locks are used it is possible for deadlocks to happen. Neo4j will however detect any deadlock (caused by acquiring a lock) before they happen and throw an exception. Before the exception is thrown the transaction is marked for rollback. All locks acquired by the transaction are still being held but will be released when the transaction is finished (in the finally block as pointed out earlier). Once the locks are released other transactions that were waiting for locks held by the transaction causing the deadlock can proceed. The work performed by the transaction causing the deadlock can then be retried by the user if needed.

Experiencing frequent deadlocks is an indication of concurrent write requests happening in such a way that it is not possible to execute them while at the same time live up to the intended isolation and consistency. The solution is to make sure concurrent updates happen in a reasonable way. For example given two specific nodes (A and B), adding or deleting relationships to both these nodes in random order for each transaction will result in deadlocks when there are two or more transactions doing that concurrently. One solution is to make sure that updates always happens in the same order (first A then B). Another solution is to make sure that each thread/transaction does not have any conflicting writes to a node or relationship as some other concurrent transaction. This can for example be achieved by letting a single thread do all updates of a specific type.

Deadlocks caused by the use of other synchronization than the locks managed by Neo4j can still happen. Since all operations in the Neo4j API are thread safe unless specified otherwise, there is no need for external synchronization. Other code that requires synchronization should be synchronized in such a way that it never performs any Neo4j operation in the synchronized block.

5.4.2. Deadlock handling example code

Below you'll find examples of how deadlocks can be handled in procedures, server extensions or when using Neo4j embedded.

The full source code used for the code snippets can be found at DeadlockDocTest.java *(https://github.com/neo4j/neo4j/blob/3.0/community/kernel/src/test/java/examples/DeadlockDocTest.java)*.

When dealing with deadlocks in code, there are several issues you may want to address:

- Only do a limited amount of retries, and fail if a threshold is reached.
- Pause between each attempt to allow the other transaction to finish before trying again.
- A retry-loop can be useful not only for deadlocks, but for other types of transient errors as well.

In the following sections you'll find example code in Java which shows how this can be implemented.

Handling deadlocks using TransactionTemplate

If you don't want to write all the code yourself, there is a class called link:javadocs/org/neo4j/helpers/TransactionTemplate.html[TransactionTemplate] that will help you achieve what's needed. Below is an example of how to create, customize, and use this template for retries in transactions.

First, define the base template:

```
TransactionTemplate template = new TransactionTemplate(  ).retries( 5 ).backoff( 3, TimeUnit.SECONDS );
```

Next, specify the database to use and a function to execute:

```
Object result = template.with(graphDatabaseService).execute( transaction -> {
    Object result1 = null;
    return result1;
} );
```

The operations that could lead to a deadlock should go into the `apply` method.

The `TransactionTemplate` uses a fluent API for configuration, and you can choose whether to set everything at once, or (as in the example) provide some details just before using it. The template allows setting a predicate for what exceptions to retry on, and also allows for easy monitoring of events that take place.

Handling deadlocks using a retry loop

If you want to roll your own retry-loop code, see below for inspiration. Here's an example of what a retry block might look like:

```
Throwable txEx = null;
int RETRIES = 5;
int BACKOFF = 3000;
for ( int i = 0; i < RETRIES; i++ )
{
    try ( Transaction tx = graphDatabaseService.beginTx() )
    {
        Object result = doStuff(tx);
        tx.success();
        return result;
    }
    catch ( Throwable ex )
    {
        txEx = ex;

        // Add whatever exceptions to retry on here
        if ( !(ex instanceof DeadlockDetectedException) )
        {
            break;
        }
    }

    // Wait so that we don't immediately get into the same deadlock
    if ( i < RETRIES - 1 )
    {
        try
        {
            Thread.sleep( BACKOFF );
        }
        catch ( InterruptedException e )
        {
            throw new TransactionFailureException( "Interrupted", e );
        }
    }
}

if ( txEx instanceof TransactionFailureException )
{
    throw ((TransactionFailureException) txEx);
}
else if ( txEx instanceof Error )
{
    throw ((Error) txEx);
}
else if ( txEx instanceof RuntimeException )
{
    throw ((RuntimeException) txEx);
}
else
{
    throw new TransactionFailureException( "Failed", txEx );
}
```

The above is the gist of what such a retry block would look like, and which you can customize to fit your needs.

5.5. Delete semantics

When deleting a node or a relationship all properties for that entity will be automatically removed but the relationships of a node will not be removed.

Neo4j enforces a constraint (upon commit) that all relationships must have a valid start node and end node. In effect this means that trying to delete a node that still has relationships attached to it will throw an exception upon commit. It is however possible to choose in which order to delete the node and the attached relationships as long as no relationships exist when the transaction is committed.

The delete semantics can be summarized in the following bullets:

- All properties of a node or relationship will be removed when it is deleted.

- A deleted node can not have any attached relationships when the transaction commits.
- It is possible to acquire a reference to a deleted relationship or node that has not yet been committed.
- Any write operation on a node or relationship after it has been deleted (but not yet committed) will throw an exception
- After commit trying to acquire a new or work with an old reference to a deleted node or relationship will throw an exception.

5.6. Creating unique nodes

In many use cases, a certain level of uniqueness is desired among entities. You could for instance imagine that only one user with a certain e-mail address may exist in a system. If multiple concurrent threads naively try to create the user, duplicates will be created. There are three main strategies for ensuring uniqueness, and they all work across High Availability and single-instance deployments.

5.6.1. Single thread

By using a single thread, no two threads will even try to create a particular entity simultaneously. On High Availability, an external single-threaded client can perform the operations on the cluster.

5.6.2. Get or create

The preferred way to get or create a unique node is to use unique constraints and Cypher. See Get or create unique node using Cypher and unique constraints for more information.

By using put-if-absent *(javadocs/org/neo4j/graphdb/index/Index.html#putIfAbsent-T-java.lang.String-java.lang.Object-)* functionality, entity uniqueness can be guaranteed using a manual index. Here the manual index acts as the lock and will only lock the smallest part needed to guaranteed uniqueness across threads and transactions.

See Get or create unique node using a manual index for how to do this using the core Java API. When using the REST API, see REST Documentation ▯ Uniqueness *(http://neo4j.com/docs/rest-docs/3.0/#rest-api-unique-indexes)*.

5.6.3. Pessimistic locking

While this is a working solution, please consider using the preferred method method outlined above instead.

By using explicit, pessimistic locking, unique creation of entities can be achieved in a multi-threaded environment. It is most commonly done by locking on a single or a set of common nodes.

See Pessimistic locking for node creation for how to do this using the core Java API.

5.7. Transaction events

A transaction event handler can be registered to receive Neo4j transaction events. Once it has been registered at a `GraphDatabaseService` instance it receives events for transactions before they are committed. Handlers get notified about transactions that have performed any write operation, and that will be committed. If `Transaction#success()` has not been called or the transaction has been marked as failed `Transaction#failure()` it will be rolled back, and no events are sent to the Handler.

Before a transaction is committed the Handler’s `beforeCommit` method is called with the entire diff of modifications made in the transaction. At this point the transaction is still running, so changes can still be made. The method may also throw an exception, which will prevent the transaction from being committed. If the transaction is rolled back, a call to the handler’s `afterRollback` method will follow.

> The order in which handlers are executed is undefined — there is no guarantee that changes made by one handler will be seen by other handlers.

If `beforeCommit` is successfully executed in all registered handlers the transaction is committed and the `afterCommit` method is called with the same transaction data. This call also includes the object returned from `beforeCommit`.

In `afterCommit` the transaction has been closed and access to anything outside `TransactionData` requires a new transaction to be opened. A `TransactionEventHandler` gets notified about transactions that have any changes accessible via `TransactionData` so some indexing and schema changes will not be triggering these events.

Chapter 6. Online Backup from Java

In order to programmatically backup your data full or subsequently incremental from a JVM based program, you need to write Java code like the following:

```
OnlineBackup backup = OnlineBackup.from( "127.0.0.1" );
backup.full( backupPath.getPath() );
assertTrue( "Should be consistent", backup.isConsistent() );
backup.incremental( backupPath.getPath() );
```

For more information, please see the Javadocs for OnlineBackup *(javadocs/org/neo4j/backup/OnlineBackup.html)*.