



JPPF Manual

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1 Introduction

1.1 Intended audience

This manual is intended for developers, software engineers and architects who wish to discover, learn or deepen their knowledge of JPPF and how it works. The intent is also to provide enough knowledge to not only write your own applications using JPPF, but also extend it by creating add-ons and connectors to other frameworks.

1.2 Prerequisites

JPPF works on any system that supports Java. There is no operating system requirement, it can be installed on all flavors of Unix, Linux, Windows, Mac OS, and other systems such as zOS or other mainframe systems.

JPPF requires the following installed on your machine:

- Java Standard Edition version 1.5 or later, with the environment variable `JAVA_HOME` pointing to your Java installation root folder
- Apache Ant, version 1.7.0 or later, with the environment variable `ANT_HOME` pointing to the Ant installation root folder
- Entries in the default system `PATH` for `JAVA-HOME/bin` and `ANT_HOME/bin`

1.3 Where to download

All JPPF software can be downloaded from the [JPPF downloads page](#).

We have tried to give each module a name that makes sense. The format is *JPPF-x.y.z-<module-name>.zip*, where:

- x is the major version number
- y is the minor version number
- z is the patch release number - it will not appear if no patch has been released (i.e. if it is equal to 0)
- <module-name> is the name given to the module

1.4 Installation

Each JPPF download is in zip format. To install it, simply unzip it in a directory of your choice.

When unzipped, the content will be under a directory called *JPPF-x.y.z-<module-name>*

1.5 Running the standalone modules

The JPPF distribution includes a number of standalone modules or components, which can be deployed and run independantly from any other on separate machines, and/or from a separate location on each machine

These modules are the following:

- application template: this is the application template to use as starting point for a new JPPF application, file *JPPF-x.y.z-application-template.zip*
- driver: this is the server component, file *JPPF-x.y.z-driver.zip*
- node: this is the node component, file *JPPF-x.y.z-node.zip*
- administration console: this is the management and monitoring user interface, file *JPPF-x.y.z .admin-ui.zip*
- multiplexer: this is the TCP multipler that routes all traffic through a single port, file *JPPF-x.y.z .multiplexer.zip*.

These can be run from either a shell script (except for the multiplexer) or an Ant script. The ant script is always called *"build.xml"* and it always has a default target called *"run"*. To run any of these modules, simply type *"ant"* or *"ant run"* in a command prompt or shell console. The provided shell scripts are named *start<Component>.<ext>* where *Component* is the JPPF component to run (e.g. "Node", "Driver", "Console") and *ext* is the file extension, "bat" for Windows systems, or "sh" for Linux/Unix-like systems.

2 Tutorial : A first taste of JPPF

2.1 Required software

In this tutorial, we will be writing a sample JPPF application, and we will run it on a small grid. To this effect, we will need to download and install the following JPPF components:

- JPPF application template: this is the JPPF-x.y.z-application-template.zip file
- JPPF driver: this is the JPPF-x.y.z-driver.zip file
- JPPF node: this is the JPPF-x.y.z-node.zip file
- JPPF administration console: this is the JPPF-x.y.z-admin-ui.zip file

Note: “x.y.z” designates the latest version of JPPF (major.minor.update). Generally, “x.y.0” is abbreviated into “x.y”.

These files are all available from the JPPF installer and/or from the [JPPF download page](#).

In addition to this, Java 1.6 or later and Apache Ant 1.7.0 or later should already be installed on your machine.

We will assume the creation of a new folder called "JPPF-Tutorial", in which all these components are unzipped. Thus, we should have the following folder structure:

- » JPPF-Tutorial
 - » JPPF-x.y.z-admin-ui
 - » JPPF-x.y.z-application-template
 - » JPPF-x.y.z-driver
 - » JPPF-x.y.z-node

2.2 Overview

2.2.1 Tutorial organization

We will base this tutorial on a pre-existing application template, which is one of the components of the JPPF distribution. The advantage is that most of the low-level wiring is already written for us, and we can thus focus on the steps to put together a JPPF application. The template is a very simple, but fully working, JPPF application, and contains fully commented source code, configuration files and scripts to build and run it.

It is organized with the following directory structure:

- » **root directory**: contains the scripts to build and run the application
 - » **src**: this is where the sources of the application are located
 - » **classes**: the location where the Java compiler will place the built sources
 - » **config**: contains the JPPF and logging configuration files
 - » **lib**: contains the required libraries to build and run the application

2.2.2 Expectations

We will learn how to:

- write a JPPF task
- create a job and execute it
- process the execution results
- manage JPPF jobs
- run a JPPF application

The features of JPPF that we will use:

- JPPF task and job APIs
- local code changes automatically accounted for
- JPPF client APIs
- management and monitoring console
- configuring JPPF

By the end of this tutorial, we will have a full-fledged JPPF application that we can build, run, monitor and manage in a JPPF grid. We will also have gained knowledge of the workings of a typical JPPF application and we will be ready to write real-life, grid-enabled applications.

2.3 Writing a JPPF task

A JPPF task is the smallest unit of code that can be executed on a JPPF grid. From a JPPF perspective, it is thus defined as an *atomic* code unit. A task is always defined as a subclass of the class [JPPFTask](#). JPPFTask is an abstract class that implements the [Runnable](#) interface. The part of a task that will be executed on the grid is whatever is written in its `run()` method.

From a design point of view, writing a JPPF task will comprise 2 major steps:

- create a subclass of `JPPFTask`.
- implement the `run()` method.

From the template application root folder, navigate to the folder `src/org/jppf/application/template`. You will see 2 Java files in this folder: "TemplateApplicationRunner.java" and "TemplateJPPFTask.java". Open the file "TemplateJPPFTask.java" in your favorite text editor.

In the editor you will see a full-fledged JPPF task declared as follows:

```
public class TemplateJPPFTask extends JPPFTask
```

Below this, you will find a `run()` method declared as:

```
public void run()
{
    // write your task code here.
    System.out.println("Hello, this is the node executing a template JPPF task");

    // ...

    // eventually set the execution results
    setResult("the execution was performed successfully");
}
```

We can guess that this task will first print a "Hello ..." message to the console, then set the execution result by calling the `setResult()` method with a string message. The [setResult\(\)](#) method actually takes any object, and is provided as a convenience to store the results of the task execution, for later retrieval.

In this method, to show that we have customized the template, let's replace the line `// ...` with a statement printing a second message, for instance "In fact, this is more than the standard template". The `run()` method becomes:

```
public void run()
{
    // write your task code here.
    System.out.println("Hello, this is the node executing a template JPPF task");
    System.out.println("In fact, this is more than the standard template");

    // eventually set the execution results
    setResult("the execution was performed successfully");
}
```

Do not forget to save the file for this change to be taken into account.

The next step is to create a JPPF job from one or multiple tasks, and execute this job on the grid.

2.4 Creating and executing a job

A job is a grouping of tasks with a common set of characteristics and a common SLA. These characteristics include:

- common data shared between tasks
- a priority
- a maximum number of nodes a job can be executed on
- an execution policy describing which nodes it can run on
- a suspended indicator, that enables submitting a job in suspended state, waiting for an external command to resume or start its execution
- a blocking/non-blocking indicator, specifying whether the job execution is synchronous or asynchronous from the application's point of view

2.4.1 Creating and populating a job

In the JPPF APIs, a job is represented as an instance of the class [JPPFJob](#).

To see how a job is created, let's open the source file "TemplateApplicationRunner.java" in the folder JPPF-x.y.z-application-template/src/org/jppf/application/template. In this file, navigate to the method `createJob()`.

This method is written as follows:

```
public JPPFJob createJob() throws Exception {
    // create a JPPF job
    JPPFJob job = new JPPFJob();

    // give this job a readable unique id that we can use to
    // monitor and manage it.
    job.setName("Template Job Id");

    // add a task to the job.
    job.addTask(new TemplateJPPFTask());

    // add more tasks here ...

    // there is no guarantee on the order of execution of the tasks,
    // however the results are guaranteed to be returned in the same
    // order as the tasks.
    return job;
}
```

We can see that creating a job is done by calling the default constructor of class `JPPFJob`. The call to the method `job.setName(String)` is used to give the job a meaningful and readable name that we can use later to manage it. If this method is not called, an id is automatically generated, as a string of 32 hexadecimal characters.

Adding a task to the job is done by calling the method `addTask(Object task, Object...args)`. The optional arguments are used when we want to execute other forms of tasks, that are not subclasses of `JPPFTask`. We will see their use in the more advanced sections of the JPPF user manual. As we can see, all the work is already done in the template file, so there is no need to modify the `createJob()` method for now.

2.4.2 Executing a job and processing the results

Now that we have learned how to create a job and populate it with tasks, we still need to execute this job on the grid, and process the results of this execution. Still in the source file "TemplateApplicationRunner.java", let's navigate to the `main(String...args)` method. we will first take a closer look at the `try` block, which contains a very important initialization statement:

```
jppfClient = new JPPFClient();
```

This single statement initializes the JPPF framework in your application. When it is executed JPPF will do several things:

- read the configuration file
- establish a connection with one or multiple servers for job execution
- establish a monitoring and management connection with each connected server
- register listeners to monitor the status of each connection

As you can see, the JPPF client has a non-negligible impact on memory and network resources. This is why we

recommend to declare it as a singleton, and always use the same instance throughout your application. This will also ensure a greater scalability, as it is also designed for concurrent use by multiple threads. To this effect, we have declared it as a static variable in `TemplateApplicationRunner.java`:

```
private static JPPFClient jppfClient = null;
```

It is also a good practice to release the resources used by the JPPF client when they are not used anymore. We actually recommend to do this by calling its `close()` method within a `finally{} block`:

```
try {
    jppfClient = new JPPFClient();
    // ...
} finally {
    if (jppfClient != null) jppfClient.close();
}
```

Back to the main method, after initializing the JPPF client, the next steps are to initialize our job runner, create a job and execute it:

```
// create a runner instance.
TemplateApplicationRunner runner = new TemplateApplicationRunner();

// Create a job
JPPFJob job = runner.createJob();

// execute a blocking job
runner.executeBlockingJob(job);
```

The call to `runner.createJob()` is exactly what we saw in the previous section 2.4.1. What remains to do is to execute the job and process the results, which is the intent of the call to `executeBlockingJob(JPPFJob job)`:

```
/**
 * Execute a job in blocking mode. The application will be blocked until the job
 * execution is complete.
 * @param job the JPPF job to execute.
 * @throws Exception if an error occurs while executing the job.
 */
public void executeBlockingJob(JPPFJob job) throws Exception {
    // set the job in blocking mode.
    job.setBlocking(true);

    // Submit the job and wait until the results are returned.
    // The results are returned as a list of JPPFTask instances,
    // in the same order as the one in which the tasks where initially added the job.
    List<JPPFTask> results = jppfClient.submit(job);

    // process the results
    processExecutionResults(results);
}
```

The first statement of this method ensures that the job will be submitted in blocking mode, meaning that the application will block until the job is executed:

```
job.setBlocking(true);
```

This is, in fact, optional since submission in blocking mode is the default behavior in JPPF.

The second statement is the one that will send the job to the server and wait until it has been executed and the results are returned:

```
List<JPPFTask> results = jppfClient.submit(job);
```

We can see that the results are returned as a list of `JPPFTask` objects. It is guaranteed that each task in this list has the same position as the corresponding task that was added to the job. In other words, the results are always in the same order as the tasks in the the job.

The last step is to interpret and process the results. From the JPPF point of view, there are two possible outcomes of the execution of a task: one that raised a `Throwable`, and one that did not. When an uncaught `Throwable` (i.e. generally an

instance of a subclass of `java.lang.Error` or `java.lang.Exception`) is raised, JPPF will catch it and set it as the outcome of the task. To do so, the method `JPPFTask.setException(Exception)` is called. You will note that the parameter is an instance of `Exception` or of one of its subclasses. Thus, any uncaught `Error` will be wrapped in a `JPPFException`. JPPF considers that exception processing is part of the life cycle of a task and provides the means to capture that information accordingly.

This explains why, in our template code, we have separated the result processing of each task in 2 blocks:

```
public void processExecutionResults(List<JPPFTask> results) {  
    // process the results  
    for (JPPFTask task: results) {  
        if (task.getException() != null) {  
            // process the exception here ...  
        } else {  
            // process the result here ...  
        }  
    }  
}
```

The actual results of the computation of a task can be any attribute of the task, or any object accessible from them. The `JPPFTask` API provides two convenience methods to help doing this: `setResult(Object)` and `getResult()`, however it is not mandatory to use them, and you can implement your own result handling scheme, or it could simply be a part of the task's design.

As an example for this tutorial, let's modify this part of the code to display the exception message if an exception was raised, and to display the result otherwise:

```
if (task.getException() != null) {  
    System.out.println("An exception was raised: " + task.getException().getMessage());  
} else {  
    System.out.println("Execution result: " + task.getResult());  
}
```

We can now save the file and close it.

2.5 Running the application

We are now ready to test our JPPF application. To this effect, we will need to first start a JPPF grid, as follows:

Step 1: start a server

Go to the JPPF-x.y.z-driver folder and open a command prompt or shell console. Type "startDriver.bat" on Windows or "./startDriver.sh." on Linux/Unix. You should see the following lines printed to the console:

```
driver process id: 2612
management initialized and listening on port 11191
ClientClassServer initialized
NodeClassServer initialized
ClientServer initialized
TasksServer initialized
Acceptor initialized
- accepting plain connections on port 11111
- accepting secure connections on port 11443
JPPF Driver initialization complete
```

The server is now ready to process job requests.

Step 2: start a node

Go to the JPPF-x.y.z-node folder and open a command prompt or shell console. Type "startNode.bat" on Windows or "./startNode.sh." on Linux/Unix. You will then see the following lines printed to the console:

```
node process id: 3336
Attempting connection to the class server at localhost:11111
Reconnected to the class server
JPPF Node management initialized
Attempting connection to the node server at localhost:11111
Reconnected to the node server
Node successfully initialized
```

Together, this node and the server constitute the smallest JPPF grid that you can have.

Step 3: run the application

Go to the JPPF-x.y.z-application-template folder and open a command prompt or shell console. Type "ant". This time, the Ant script will first compile our application, then run it. You should see these lines printed to the console:

```
[client: driver-1] Attempting connection to the class server at localhost:11111
[client: driver-1] Reconnected to the class server
[client: driver-1] Attempting connection to the JPPF task server at localhost:11111
[client: driver-1] Reconnected to the JPPF task server
Execution result: the execution was performed successfully
```

You will notice that the last printed line is the same message that we used in our task in the `run()` method, to set the result of the execution in the statement:

```
setResult("the execution was performed successfully");
```

Now, if you switch back to the node console, you should see that 2 new messages have been printed:

```
Hello, this is the node executing a template JPPF task
In fact, this is more than the standard template
```

These 2 lines are those that we actually coded at the beginning of the task's `run()` method:

```
System.out.println("Hello, this is the node executing a template JPPF task");
System.out.println("In fact, this is more than the standard template");
```

From these messages, we can conclude that our application was run successfully. Congratulations!

At this point, there is however one aspect that we have not yet addressed: since the node is a separate process from our application, **how does it know to execute our task?** Remember that we have not even attempted to deploy the

application classes to any specific location. We have simply compiled them so that we can execute our application locally. This topic is the object of the next section of this tutorial.

2.6 Dynamic deployment

One of the greatest features of JPPF is its ability to dynamically load the code of an application that was deployed only locally. JPPF extends the standard Java class loading mechanism so that, by simply using the JPPF APIs, the classes of an application are loaded to any remote node that needs them. The benefit is that *no deployment of the application is required to have it run on a JPPF grid*, no matter how many nodes or servers are present in the grid. Furthermore, this mechanism is totally transparent to the application developer.

A second major benefit is that code changes are automatically taken into account, without any need to restart the nodes or the server. This means that, when you change any part of the code executed on a node, all you have to do is recompile the code and run the application again, and the changes will take effect immediately, on all the nodes that execute the application.

We will now demonstrate this by making a small, but visible, code change and running it against the server and node we have already started. If you have stopped them already, just perform again all the steps described in the previous section (2.5), before continuing.

Let's open again the source file "TemplateJPPFTask.java" in `src/org/jppf/application/template/`, and navigate to the `run()` method. Let's replace the first two lines with the following:

```
System.out.println("*** We are now running a modified version of the code ***");
```

The `run()` method should now look like this:

```
public void run() {
    // write your task code here.
    System.out.println("*** We are now running a modified version of the code ***");

    // eventually set the execution results
    setResult("the execution was performed successfully");
}
```

Save the changes to the file, and open or go back to a command prompt or shell console in the JPPF-2.0-application-template folder. From there, type "ant" to run the application again. You should now see the same messages as in the initial run displayed in the console. This is what we expected. On the other hand, if you switch back to the node console, you should now see a new message displayed:

```
[java] *** We are now running a modified version of the code ***
```

Success! We have successfully executed our new code without any explicit redeployment.

2.7 Job Management

Now that we are able to create, submit and execute a job, we can start thinking about monitoring and eventually controlling its life cycle on the grid. To do that, we will use the JPPF administration and monitoring console. The JPPF console is a standalone graphical tool that provides user-friendly interfaces to:

- obtain statistics on server performance
- define, customize and visualize server performance charts
- monitor and control the status and health of servers and nodes
- monitor and control the execution of the jobs on the grid
- manage the workload and load-balancing behavior

2.7.1 Preparing the job for management

In our application template, the job that we execute on the grid has a single task. As we have seen, this task is very short-live, since it executes in no more than a few milliseconds. This definitely will not allow us to monitor or manage it with our bare human reaction time. For the purpose of this tutorial, we will now adapt the template to something more realistic from this perspective.

Step 1: make the tasks last longer

What we will do here is add a delay to each task, before it terminates. It will do nothing during this time, only wait for a specified duration. Let's edit again the source file "TemplateJPPFTask.java" in JPPF-x.y.z-application-template/src/org/jppf/application/template/ and modify the `run()` method as follows:

```
public void run() {
    // write your task code here.
    System.out.println("*** We are now running a modified version of the code ***");
    // simply wait for 3 seconds
    try {
        Thread.sleep(3000L);
    } catch (InterruptedException e) {
        setException(e);
        return;
    }
    // eventually set the execution results
    setResult("the execution was performed successfully");
}
```

Note that here, we make an explicit call to `setException()`, in case an `InterruptedException` is raised. Since the exception would be occurring in the node, capturing it will allow us to know what happened from the application side.

Step 2: add more tasks to the job, submit it as suspended

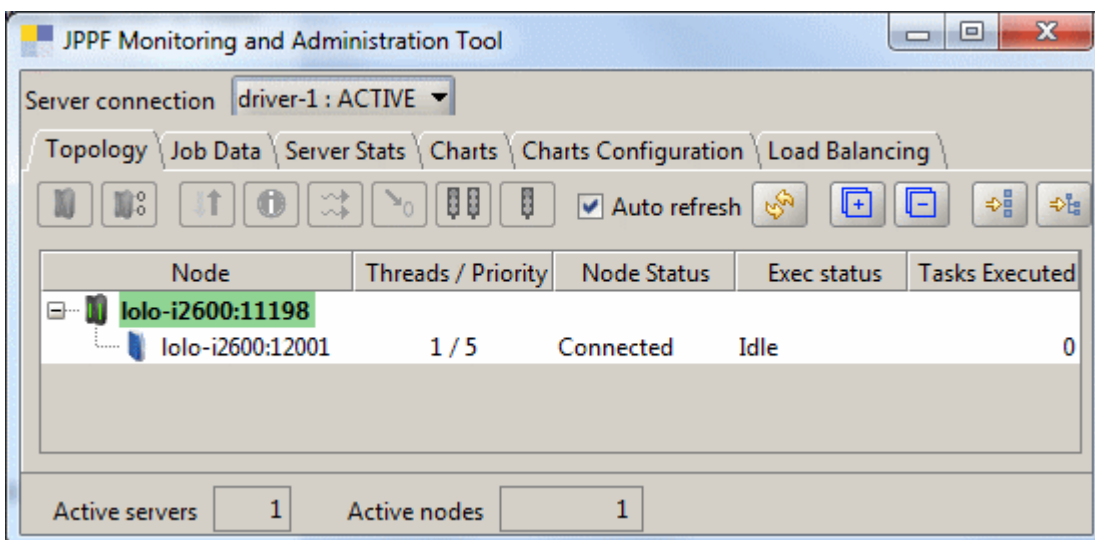
This time, our job will contain more than one task. In order for us to have the time to manipulate it from the administration console, we will also start it in suspended mode. To this effect, we will modify the method `createJob()` of the application runner "TemplateApplicationRunner.java" as follows:

```
public JPPFJob createJob() throws Exception {
    // create a JPPF job
    JPPFJob job = new JPPFJob();
    // give this job a readable unique id that we can use to monitor and manage it.
    job.setName("Template Job Id");
    // add 10 tasks to the job.
    for (int i=0; i<10; i++) job.addTask(new TemplateJPPFTask());
    // start the job in suspended mode
    job.getJobSLA().setSuspended(true);
    return job;
}
```

Step 3: start the JPPF components

If you have stopped the server and node, simply start them again as described in the first two step of section 2.5 of this tutorial.

We will also start the administration console: go to the JPPF-x.y.z-admin-ui folder and open a command prompt or shell console. Type "ant". When the console is started, you will see a panel named "Topology" displaying the servers and the nodes attached to them. It should look like this:



We can see here that a server is started on machine "lolo-quad" and that it has a node attached to it. The color for the server is a health indicator, green meaning that it is running normally and red meaning that it is down.

Let's switch to the "Job Data" panel, which should look like this:



We also see the color-coded driver health information in this panel. There is currently no other element displayed, because we haven't submitted a job yet.

Step 4: start a job


We will now start a job by running our application: go to the JPPF-x.y.z-application-template folder and open a command prompt or shell console. Type "ant". Switch back to the administration console. We should now see some change in the display:



We now see that a job is present in the server's queue, in suspended state (yellow highlighting). Here is an explanation of the columns in the table:

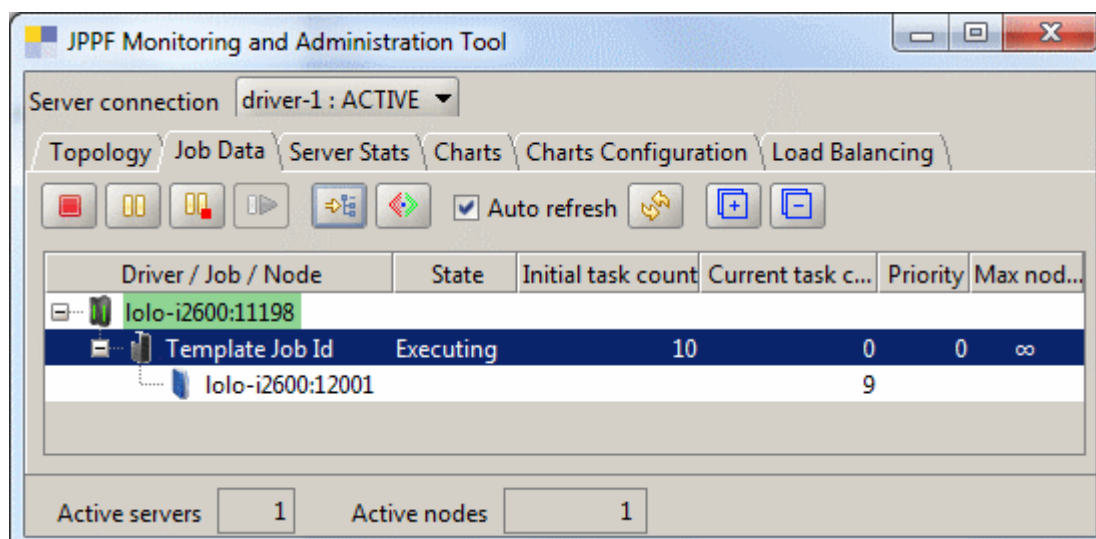
- "Driver / Job / Node" : displays an identifier for a server, for a job submitted to that server, or for a node to which some of the tasks in the job have been dispatched for execution
- "State" : the current state of a job, either "Suspended" or "Executing"
- "Initial task count" : the number of tasks in the job at the time it was submitted by the application
- "Current task count": the number of tasks remaining in the job, that haven't been executed
- "Priority" : this is the priority, of the job, the default value is 0.
- "Max nodes" : the maximum number of nodes a job can be executed on. By default, there is no limit, which is represented as the infinity symbol

Step 5: resuming the job execution

Since the job was submitted in suspended state, we will resume its execution manually from the console. Select the line where the job "Template Job Id" is displayed. You should see that some buttons are now activated. Click on the resume button (marked by the icon ) to resume the job execution, as shown below:



As soon as we resume the job, the server starts distributing tasks to the node, and we can see that the current task count starts decreasing accordingly, and the job status has been changed to "Executing":



You are encouraged to experiment with the tool and the code. For example you can add more tasks to the job, make them last longer, suspend, resume or terminate the job while it is executing, etc...

2.8 Conclusion

In this tutorial, we have seen how to write a JPPF-enabled application from end to end. We have also learned the basic APIs that allow us to write an application made of atomic and independent execution units called tasks, and group them into jobs that can be executed on the grid. We have also learned how jobs can be dynamically managed and monitored while executing. Finally, we also learned that, even though an application can be distributed over any number of nodes, there is no need to explicitly deploy the application code, since JPPF implicitly takes care of it.

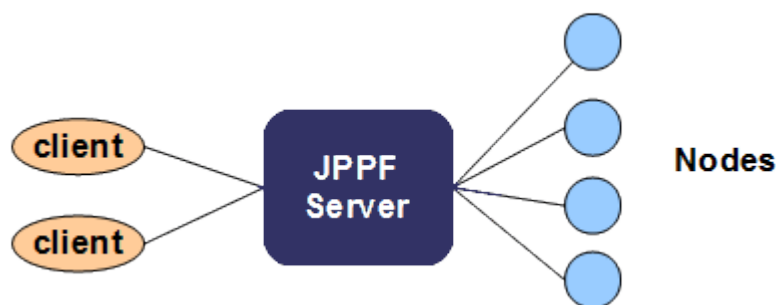
3 JPPF Overview

3.1 Architecture and topology

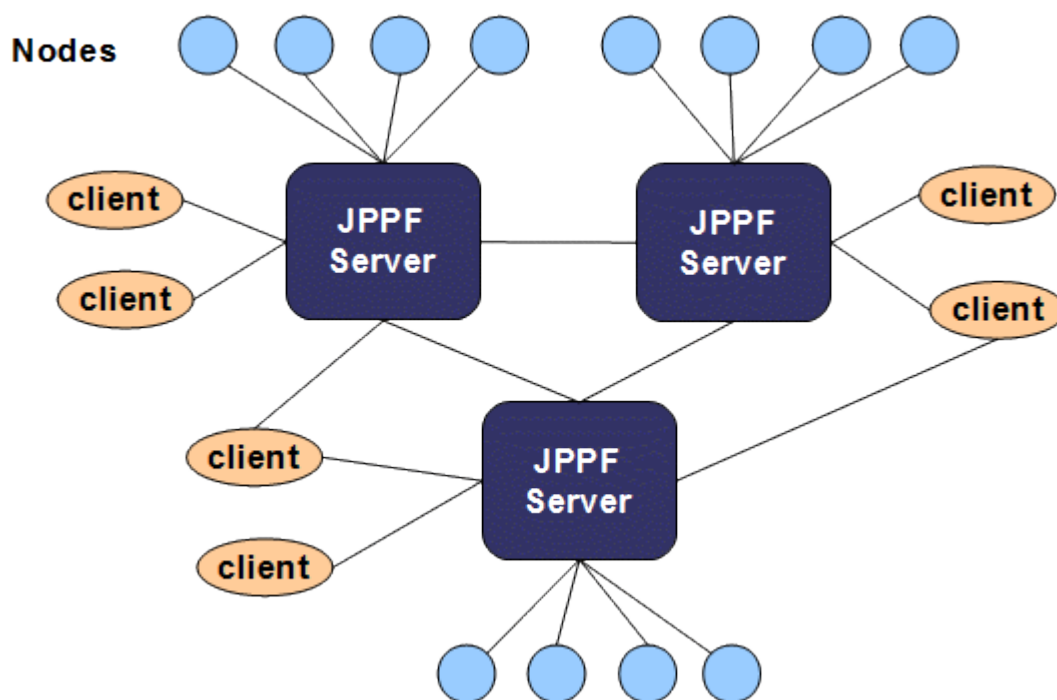
A JPPF grid is made of three different types of components that communicate together:

- **clients** are entry points to the grid and enable developers to submit work via the client APIs
- **servers** are the components that receive work from the clients and dispatch it to the nodes
- **nodes** perform the actual work execution

The figure below shows how all the components are organized together:



From this picture, we can see that the server plays a central role, and its interactions with the nodes define a *master / worker* architecture, where the server (i.e. master) distributes the work to the nodes (i.e. workers). This also represents the most common topology in a JPPF grid, where each client is connected to a single server, and many nodes are attached to the same server. As with any such architecture, this one is facing the risk of a single point of failure. To mitigate this risk, JPPF provides the ability to connect multiple servers together in a peer-to-peer network and additional connectivity options for clients and nodes, as illustrated in this figure:



Note how some of the clients are connected to multiple servers, providing failover as well as load balancing capabilities. In addition, and not visible in the previous figure, the nodes have a failover mechanism that will enable them to attach to a different server, should the one they are attached to fail or die.

The connection between two servers is directional: if server A is connected to server B then A will see B as a client, and B will see A as a node. This relationship can be made bi-directional by also connecting B to A. Note that in this scenario, each server taken locally still acts as a master in a master/worker paradigm.

In short, we can say that the single point of failure issue is addressed by a combination of redundancy and dynamic reconfiguration of the grid topology.

3.2 Work distribution

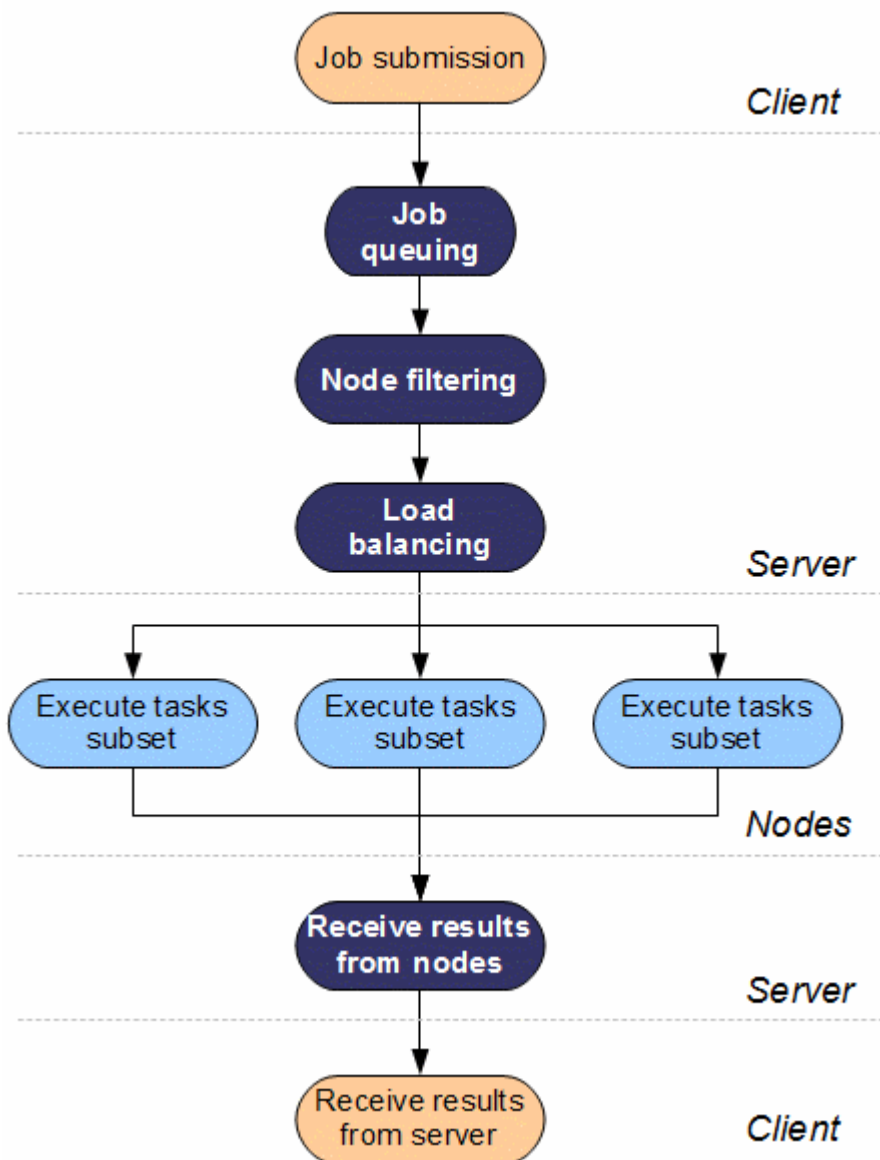
To understand how the work is distributed in a JPPF grid, and what role is played by each component, we will start by defining the two units of work that JPPF handles.

A **task** is the smallest unit of work that can be handled in the grid. From the JPPF perspective, it is considered *atomic*.

A **job** is a logical grouping of tasks that are submitted together, and may define a common service level agreement (SLA) with the JPPF grid. The SLA can have a significant influence on how the job's work will be distributed in the grid, by specifying a number of behavioral characteristics:

- rule-based filtering of nodes, specifying which nodes the work can be distributed to (aka execution policies)
- maximum number of nodes the work can be distributed to
- job priority
- start and expiration schedule
- user-defined metadata which can be used by the load balancer

To illustrate the most common flow of a job's execution, let's take a look at the following flow chart:



This chart shows the different steps involved in the execution of a job, and where each of them takes place with regards to the grid component boundaries.

It also shows that the main source of parallelism is provided by the load balancer, whose role is to split each job into multiple subsets that can be executed on multiple nodes in parallel. There are other sources of parallelism at different levels, and we will describe them in the next sections.

3.3 Networking considerations

3.3.1 Two channels per connection

Each connection between a server and any other component is in fact a grouping of two network channels:

- one channel is used to transport job data
- the other channel is used by the JPPF distributed class loader, that allows Java classes to be deployed on-demand where they are needed, completely transparently from a developer's perspective.

3.3.2 Synchronous networking

In JPPF, all network communications are synchronous and follow a protocol based on a request/response paradigm. The attribution of requester vs. responder role depends on which components communicate and through which channel.

We illustrate this in the following picture:



This communication model has a number of important implications:

- nodes can only process one job at a time; however they can execute multiple tasks in parallel
- in the same way, a single client / server connection can only process one job at a time; however, each client can be connected multiple times to the same server, or multiple times to many servers
- in the case of a server-to-server communication, only one job can be processed at a time, since a server attaches to another server in exactly the same way as a node.

3.3.3 Protocol

JPPF components communicate by exchanging messages. As described in the previous section, each JPPF transaction will be made of a request message, followed by a response message.

Messages all have the same structure, and are made of one or more blocks of data (in fact blocks of bytes), each preceded by its block size. Each block of data represents a serialized object graph. Thus, each message can be represented generically as follows:

Size 1	Serialized Object 1	Size n	Serialized Object n
--------	---------------------	-----------	--------	---------------------

The actual message format is different for each type of communication channel, and may also differ depending on whether it is a request or response message:

Job data channel

A job data request is composed of the following elements:

- a header, which is an object representing information about the job, including the number of tasks in the job, the job SLA, job metadata, and additional information required internally by the JPPF components.
- a data provider, which is a read-only container for data shared among all the tasks
- the tasks themselves

It can be represented as follows:

Header size	Header (nb tasks)	Data provider size	Data provider data	Size ₁	Task ₁	Size _n	Task _n
-------------	-------------------	--------------------	--------------------	-------------------	-------------------	-------	-------------------	-------------------

To read the full message, JPPF has to first read the header and obtain the number of tasks in the job.

The response will be in a very similar format, except that it doesn't have a data provider: being read-only, no change to its content is expected, which removes the need to send it in the response. Thus the response can be represented as:

Header size	Header (nb tasks)	Size ₁	Task ₁	Size _n	Task _n
-------------	-------------------	-------------------	-------------------	-------	-------------------	-------------------

Class loader channel

A class loader message, either request or response, is always made of a single serialized object. Therefore, the message structure is always as follows:

size	Resource request / response
------	-----------------------------

3.4 Sources of parallelism

3.4.1 At the client level

There are three ways JPPF clients can provide parallel processing, which may be used individually or in any combination:

Single client, multiple concurrent jobs

A single client may submit multiple jobs in parallel. This differs from the single client/single job scenario in that the jobs must be submitted in *non-blocking* mode, and their results are retrieved asynchronously. An other difference is that the client must establish multiple connections to the server to enable parallelism, and not just asynchronous submission. When multiple non-blocking jobs are submitted over a single connection, only one at a time will be submitted, and the others will be queued on the client side. The only parallelism is in the submission of the jobs, but not in their execution. To enable parallel execution of multiple jobs, it is necessary to configure a *pool of connections* for the client. The size of the pool determines the number of jobs that can be processed in parallel by the server.

Multiple clients

In this configuration, the parallelism occurs naturally, by letting the different clients work concurrently.

Mixed local and remote execution

Clients have the ability to execute jobs locally, within the same process, rather than remotely. They may also use both capabilities at the same time, in which case a load-balancing mechanism will provide an additional source of parallelism.

3.4.2 At the server level

The server has a number of factors that determine what can be parallelized and how much:

Number of connected clients

The number of connected clients, or more accurately, client connections, has a direct influence on how many jobs can be processed by the grid at any one time.

The relationship is defined as: *maximum number of parallel jobs = total number of client connections*

Number of attached nodes

This determines the maximum number of jobs that can be executed on the grid nodes. With regards to the previous point, we can redefine it as: *maximum number of parallel jobs = min(total number of client connections, total number of nodes)*

Load balancing

This is the mechanism that splits the jobs into multiple subsets of their tasks, and distributes these subsets over the available nodes. Given the synchronous nature of the server to node connections, a node is available only when it is not already executing a job subset. The load balancing also computes how many tasks will be sent to each node, in a way that can be static, dynamic, or even user-defined.

Job SLA

The job Service Level Agreement is used to filter out nodes in which the user does not want to see a job executed. This can be done by specifying an execution policy (rules-based filtering) for the job, or by configuring the maximum number of nodes a job can run on (grid partitioning).

Parallel I/O

Each server maintains internally a pool of threads dedicated to network I/O. The size of this pool determines how many nodes the server can communicate with in parallel, *at any given time*. Furthermore, as communication with the nodes is non-blocking, this pool of I/O threads is part of a mechanism that achieves a preemptive multitasking of the network I/O. This means that, even if you have a limited number of I/O threads, the overall result will be as if the server were communicating with all nodes in parallel.

3.4.3 At the node level

To execute tasks, each node uses a pool of threads that are called "processing threads". The size of the pool determines the maximum number of tasks a single node can execute in parallel. The pool size may be adjusted either statically or dynamically to account for the actual number of processors available to the node, and for the tasks' resource usage profile (i.e. I/O-bound tasks versus CPU-bound tasks).

4 Development Guide

4.1 Task objects

In JPPF terms, a task is the smallest unit of execution that can be handled by the framework. We will say that it is an *atomic* execution unit. A JPPF application creates tasks, groups them into a job, and submits the job for execution on the grid.

4.1.1 JPPFTask

[JPPFTask](#) is the base super class for any task that is run by JPPF. We will see in the next sections that other forms of tasks, that do not inherit from JPPFTask, are still wrapped by the framework in a subclass of JPPFTask.

JPPFTask is defined as follows:

```
public abstract class JPPFTask implements Task<Object> {  
    ...  
}
```

We can see that this class implements the [Task<T>](#) interface, defined as follows:

```
public interface Task<T> extends Runnable, Serializable {  
    ...  
}
```

We have outlined three important keywords that characterize JPPFTask:

- **abstract**: JPPFTask cannot be used directly, it must be extended to construct a real task
- **Runnable**, via Task<T>: when writing a JPPF task, the run() method of `java.lang.Runnable` must be implemented. This is the part of a task that will be executed on a remote node.
- **Serializable** via Task<T>: tasks are sent to servers and nodes over a network. JPPF uses the Java serialization mechanism to transform task objects into a form appropriate for networking

To write a real task in your application, you simply extend JPPFTask to implement your own type:

```
public class MyTask extends JPPFTask {  
    public void run() {  
        // ... your code here ...  
    }  
}
```

We will now review the functionalities that are inherited from JPPFTask.

4.1.1.1 Execution results handling

JPPFTask provides 2 convenience methods to store and retrieve the results of the execution:

- `public void setResult(Object result)` : stores the execution result; the argument must be serializable
- `public Object getResult()` : retrieves the execution result

Here is an example using these methods:

```
public class MyTask extends JPPFTask {  
    public void run() {  
        // ... some code here ...  
        setResult("This is the result");  
    }  
}
```

and later in your application, you would use:

```
String result = (String) myTask.getResult();
```

Using `getResult()` and `setResult()` is not mandatory. As we mentioned earlier, these methods are provided as

conveniences with a meaningful semantics attached to them. There are many other ways to store and retrieve execution results, which can be used to the exclusion of others, or in any combination. These include, but are not limited to:

- using custom attributes in the task class and their accessors
- storing and getting data to/from a database
- using a file system
- using third-party applications or libraries
- etc ...

4.1.1.2 Exception handling - task execution

Exception handling is a very important part of processing a task. In effect, exceptions may arise from many places: in the application code, in the JVM, in third-party APIs, etc... To handle this, JPPF provides both a mechanism to process uncaught exceptions and methods to store and retrieve exceptions that arise while executing a task.

JPPFTask provides 2 methods to explicitly handle exceptions:

- `public void setException(Exception e)` : store an exception for later retrieval
- `public Exception getException()` : retrieve an exception that was thrown during execution

Here is an example of explicit exception handling:

```
public class MyTask extends JPPFTask {
    public void run() {
        try {
            // ... some code here ...
        } catch (Exception e) {
            setException(e);
        }
    }
}
```

Later on, you can retrieve the exception as follows:

```
Exception exception = myTask.getException();
```

JPPF also automatically handles uncaught exceptions. In fact, we should say that it handles uncaught *throwables*. Uncaught throwables are never propagated beyond the scope of a task, as this would cause an unpredictable behavior of the node that executes the task. Instead, they are stored within the task using the `setException()` method. This way, it is always possible for the application to know what happened.

We may wonder what happens when the throwable is not an instance of `Exception`, as the method `setException()` only takes an `Exception` object as argument. In this case, the throwable is wrapped into an instance of `JPPFException` and can be retrieved by calling its `getCause()` method. The following code shows how JPPF handles uncaught exceptions and throwables:

```
JPPFTask task = ...;
try {
    task.run();
} catch (Throwable t) {
    if (t instanceof Exception) task.setException((Exception) t);
    else task.setException(new JPPFException(t));
}
```

Then in the application, you can retrieve the throwable as follows:

```
JPPFTask task = ...;
if (task.getException() != null) {
    Throwable cause = null;
    Exception e = task.getException();
    if (e instanceof JPPFException) cause = e.getCause();
    else cause = e;
}
```


4.1.1.3 Task life cycle

JPPF provides some options to control a task's life cycle once it has been submitted, including the following:

- cancel a task
- task timeout settings

Canceling a task applies whether the task has already started or not. Timeout of a task only applies while the task is executing. In any case, if a task has already completed its execution, it cannot be canceled or timed out anymore.

Apart from timeout settings, controlling the life cycle of a task is normally done externally, using the JPPF remote management facilities. We will see those later, in a dedicated chapter of this user manual.

It is possible to perform a specific processing when a task life cycle event occurs. For this, JPPFTask provides a callback method for each type of event:

```
public void onCancel(): invoked when the task is canceled
public void onTimeout(): invoked when the task times out
```

By default, these methods do not do anything. You can, however, override them to implement any application-specific processing, such as releasing resources used by the task, updating the state of the task, etc.

Here is a code sample illustrating these concepts:

```
public class MyTask extends JPPFTask {
    public MyTask(String taskId) {
        this.setId(taskId); // set the task id
    }

    @Override
    public void run() {
        // task processing here ...
    }

    @Override
    public void onCancel() {
        // process task cancel event ...
    }

    @Override
    public void onTimeout() {
        // process task timeout event ...
    }
}
```

A task timeout can be set by using a [JPPFSchedule](#) object, which is an immutable object that proposes two constructors:

```
// schedule after a specified duration in milliseconds
public JPPFSchedule(final long duration)
// schedule at a specified fixed date/time
public JPPFSchedule(final String date, final String format)
```

Using a JPPFSchedule, we can thus set and obtain a task timeout using the corresponding accessors:

```
public JPPFTask implements Task<Object> {
    // get the timeout schedule
    public JPPFSchedule getTimeoutSchedule();
    // set a new timeout schedule
    public void setTimeoutSchedule(final JPPFSchedule timeoutSchedule);
}
```

For example:

```
// set the task to expire after 5 seconds
myTask.setTimeout(new JPPFSchedule(5000L));
// set the task to expire on 9/30/2012 at 12:08 pm
myTask.setTimeoutSchedule(
    new JPPFSchedule("09/30/2012 12:08 PM", "MM/dd/yyyy hh:mm a"));
```

4.1.2 Exception handling - node processing

It is possible that an error occurs while the node is processing a job or a task, before or after its execution. These error conditions include any instance of Throwable, i.e. any Exception or Error occurring during serialization or deserialization of the tasks, or while sending or receiving data to or from the server.

Depending on when they occur, these errors can be handled in two different ways:

- **When the node is receiving tasks from the server:** if any error is generated, for any task, then all the tasks will be sent back to the client application as they were initially, with only their exception attribute (see [JPPFTask.getException\(\)](#)) set to the captured error.
- **After execution of the tasks:** for each task that generates an error that prevents it from being sent back to the server, the JPPF will substitute an instance of [JPPFExceptionResult](#), which is a JPPF task used solely to describe the error and the object on which it occurred.

4.1.3 Executing code in the client from a task

The JPPFTask API provides two methods that will allow a task to send code for execution on the client, and to determine whether the task is executing within a node or within a client with local execution enabled:

```
public abstract class JPPFTask implements Task<Object> {
    // is the task executing in a node or in the client?
    public boolean isInNode()

    // send a callable for execution on the client side
    public <V> V compute(final JPPFCallable<V> callable)
}
```

The method `compute()` takes a [JPPFCallable](#) as input, which is a `Serializable` extension of the `Callable` interface and will be executed on the client side. The return value is the result of calling `JPPFCallable.call()` on the client side.

This API is a more flexible version of the `ClientDataProvider` facility (see 4.4.2), which will be deprecated in the future.

Example usage:

```
public class MyTask extends JPPFTask {
    @Override
    public void run() {
        String callableResult;
        // if this task is executing in a JPPF node
        if (isInNode()) callableResult = compute(new MyNodeCallable());
        // otherwise if it is executing locally in the JPPF client
        else callableResult = compute(new MyClientCallable());
        // set the callable result as this task's result
        setResult(callableResult);
    }

    public static class MyNodeCallable implements JPPFCallable<String> {
        @Override
        public String call() throws Exception {
            return "executed in the NODE";
        }
    }

    public static class MyClientCallable implements JPPFCallable<String> {
        @Override
        public String call() throws Exception {
            return "executed in the CLIENT";
        }
    }
}
```

4.1.4 JPPF-annotated tasks

Another way to write a JPPF task is to take an existing class and annotate one of its public methods or constructors using [@JPPFRunnable](#).

Here is an example:

```
public class MyClass implements Serializable {
    @JPPFRunnable
    public String myMethod(int intArg, String stringArg) {
        String s = "int arg = " + intArg + ", string arg = \"" + stringArg + "\"";
        System.out.println(s);
        return s;
    }
}
```

We can see that we are simply using a POJO class, for which we annotated the `myMethod()` method with `@JPPFRunnable`. At runtime, the arguments of the method will be passed when the task is added to a job, as illustrated in the following example:

```
JPPFJob job = new JPPFJob();
JPPFTask task = job.addTask(new MyClass(), 3, "string arg");
```

Here we simply add our annotated class as a task, setting the two arguments of the annotated method in the same call. Note also that a `JPPFTask` object is returned. It is generated by a mechanism that wraps the annotated class into a `JPPFTask`, which allows it to use most of the functionalities that come with it.

JPPF-annotated tasks present the following properties and constraints:

- if the annotated element is an *instance* (non-static) method, the annotated class must be serializable
- if the class is already an instance of `JPPFTask`, the annotation will be ignored
- if an annotated method has a return type (i.e. non void), the return value will be set as the task result
- it is possible to annotate a public method or constructor
- an annotated method can be static or non-static
- if the annotated element is a constructor or a static method, the first argument of `JPPFJob.addTask()` must be a Class object representing the class that declares it.
- an annotated method or constructor can have any signature, with no limit on the number of arguments
- through the task-wrapping mechanism, a JPPF-annotated class benefits from the `JPPFTask` facilities described in the previous section 4.1.1, except for the callback methods `onCancel()`, `onRestart()` and `onTimeout()`.

Here is an example using an annotated constructor:

```
public class MyClass implements Serializable {
    @JPPFRunnable
    public MyClass(int intArg, String stringArg) {
        String s = "int arg = " + intArg + ", string arg = \"" + stringArg + "\"";
        System.out.println(s);
    }
}

JPPFJob job = new JPPFJob();
JPPFTask task = job.addTask(MyClass.class, 3, "string arg");
```

Another example using an annotated static method:

```
public class MyClass implements Serializable {
    @JPPFRunnable
    public static String myStaticMethod(int intArg, String stringArg) {
        String s = "int arg = " + intArg + ", string arg = \"" + stringArg + "\"";
        System.out.println(s);
        return s;
    }
}

JPPFJob job = new JPPFJob();
JPPFTask task = job.addTask(MyClass.class, 3, "string arg");
```

Note how, in the last 2 examples, we use `MyClass.class` as the first argument in `JPPFJob.addTask()`.

4.1.5 Runnable tasks

Classes that implement [java.lang.Runnable](#) can be used as JPPF tasks without any modification. The `run()` method will then be executed as the task's entry point. Here is an example:

```
public class MyRunnableClass implements Runnable, Serializable {
    public void run() {
        System.out.println("Hello from a Runnable task");
    }
}

JPPFJob job = new JPPFJob();
JPPFTask task = job.add(new MyRunnableClass());
```

The following rules apply to Runnable tasks:

- the class must be serializable
- if the class is already an instance of `JPPFTask`, or annotated with `@JPPFRunnable`, it will be processed as such
- through the task-wrapping mechanism, a Runnable task benefits from the `JPPFTask` facilities described in the previous section 4.1.1, except for the callback methods `onCancel()`, `onRestart()` and `onTimeout()`.

4.1.6 Callable tasks

In the same way as Runnable tasks, classes implementing [java.util.concurrent.Callable<V>](#) can be directly used as tasks. In this case, the `call()` method will be used as the task's execution entry point. Here's an example:

```
public class MyCallableClass implements Callable<String>, Serializable {
    public String call() throws Exception {
        String s = "Hello from a Callable task";
        System.out.println(s);
        return s;
    }
}

JPPFJob job = new JPPFJob();
JPPFTask task = job.add(new MyCallableClass());
```

The following rules apply to Callable tasks:

- the Callable class must be serializable
- if the class is already an instance of `JPPFTask`, annotated with `@JPPFRunnable` or implements `Runnable`, it will be processed as such and the `call()` method will be ignored
- the return value of the `call()` method will be set as the task result
- through the task-wrapping mechanism, a callable class benefits from the `JPPFTask` facilities described in the previous section 4.1.1, except for the callback methods `onCancel()`, `onRestart()` and `onTimeout()`.

4.1.7 POJO tasks

The most unintrusive way of defining a task is by simply using an existing POJO class without any modification. This will allow you to use existing classes directly even if you don't have the source code. A POJO task offers the same possibilities as a JPPF annotated task (see section 4.1.4), except for the fact that we need to specify explicitly which method or constructor to use when adding the task to a job. To this effect, we use a different form of the method `JPPFJob.addTask()`, that takes a method or constructor name as its first argument.

Here is a code example illustrating these possibilities:

```
public class MyClass implements Serializable {
    public MyClass() {
    }

    public MyClass(int intArg, String stringArg) {
        String s = "int arg = " + intArg + ", string arg = \"" + stringArg + "\"";
        System.out.println(s);
    }
}
```

```

    public String myMethod(int intArg, String stringArg) {
        String s = "int arg = " + intArg + ", string arg = \"" + stringArg + "\"";
        System.out.println(s);
        return s;
    }

    public static String myStaticMethod(int intArg, String stringArg) {
        String s = "int arg = " + intArg + ", string arg = \"" + stringArg + "\"";
        System.out.println(s);
        return s;
    }
}

JPPFJob job = new JPPFJob();

// add a task using the constructor as entry point
JPPFTask task1 = job.addTask("MyClass", MyClass.class, 3, "string arg");

// add a task using an instance method as entry point
JPPFTask task2 = job.addTask("myMethod", new MyClass(), 3, "string arg");

// add a task using a static method as entry point
JPPFTask task3 = job.addTask("myStaticMethod", MyClass.class, 3, "string arg");

```

POJO tasks present the following properties and constraints:

- if the entry point is an *instance* (non-static) method, the class must be serializable
- if a method has a return type (i.e. non void), the return value will be set as the task result
- it is possible to use a public method or constructor as entry point
- a method entry point can be static or non-static
- A POJO task is added to a job by calling a `JPPFJob.addTask()` method whose first argument is the method or constructor name.
- if the entry point is a constructor or a static method, the second argument of `JPPFJob.addTask()` be a Class object representing the class that declares it.
- an annotated method or constructor can have any signature, with no limit on the number of arguments
- through the task-wrapping mechanism, a JPPF-annotated class benefits from the JPPFTask facilities described in the previous section 4.1.1, except for the callback methods `onCancel()`, `onRestart()` and `onTimeout()`.

4.1.8 Running non-Java tasks: `CommandLineTask`

JPPF has a pre-defined task type that allows you to run an external process from a task. This process can be any executable program (including java), shell script or command. The JPPF API also provides a set of simple classes to access data, whether in-process or outside, local or remote.

The class that will allow you to run a process is [CommandLineTask](#). Like [JPPFTask](#), it is an abstract class that you must extend and whose `run()` method you must override.

This class provides methods to:

Setup the external process name, path, arguments and environment:

```

// list of commands passed to the shell
List<String> getCommandList()
void setCommandList(List<String> commandList)
void setCommandList(String... commands)

// set of environment variables
Map<String,String> getEnv()
void setEnv(Map<String, String> env)

// directory in which the command is executed
String getStartDir()
void setStartDir(String startDir)

```

You can also use the built-in constructors to do this at task initialization time:

```

CommandLineTask(Map<String, String> env, String startDir, String... commands)
CommandLineTask(String... commands)

```

Launch the process:

The process is launched by calling the following method from the `run()` method of the task:

```
// launch the process and return its exit code
int launchProcess()
```

This method will block until the process has completed or is destroyed. The process exit code can also be obtained via the following method:

```
// get the process exit code
int getExitCode()
```

Setup the capture of the process output:

You can specify and determine whether the process output (either standard or error console output) is or should be captured, and obtain the captured output:

```
boolean isCaptureOutput()

void setCaptureOutput(boolean captureOutput)

// corresponds to what is sent to System.out / stdout
String getErrorOutput()

// corresponds to what is sent to System.err / stderr
String getStandardOutput()
```

Here is a sample command line task that lists the content of a directory in the node's file system:

```
import org.jppf.server.protocol.*;

// This task lists the files in a directory of the node's host
public class ListDirectoryTask extends CommandLineTask {
    // Execute the script
    public void run() {
        try {
            // get the name of the node's operating system
            String os = System.getProperty("os.name").toLowerCase();
            // the type of OS determines which command to execute
            if (os.indexOf("linux") >= 0) {
                setCommandList("ls", "-a", "/usr/local");
            } else if (os.indexOf("windows") >= 0) {
                setCommandList("cmd", "/C", "dir", "C:\\Windows");
            }
            // enable the capture of the console output
            setCaptureOutput(true);
            // execute the script/command
            launchProcess();
            // get the resulting console output and set it as a result
            String output = getStandardOutput();
            setResult(output);
        } catch (Exception e) {
            setException(e);
        }
    }
}
```

4.1.9 The Location API

This API allows developers to easily write data to, or read data from various sources: JVM heap, file system or URL. It is based on the interface [Location](#), which provides the following methods:

```
public interface Location<T> {
    // Copy the content at this location to another location
    void copyTo(Location location);
    // Obtain an input stream to read from this location
    InputStream getInputStream();
    // Obtain an output stream to write to this location
    OutputStream getOutputStream();
    // Get this location's path
    T getPath();
    // Get the size of the data this location points to
    long size();
    // Get the content at this location as an array of bytes
    byte[] toByteArray() throws Exception;
}
```

Currently, JPPF provides 3 implementations of this interface:

- [FileLocation](#) represents a path in the file system
- [URLLocation](#) can be used to get data to and from a URL, including HTTP and FTP URLs
- [MemoryLocation](#) represents a block of data in memory that can be copied from or sent to another location

To illustrate the use of this API, let's transform our previous `ListDirectoryTask` in a way such that the output of the command is redirected to a file, instead of the console. We then read the content of this file and set it as the task's result:

```
import org.jppf.server.protocol.*;

// This task lists the files in a directory of the node's host
public class ListDirectoryTask extends CommandLineTask {
    // Execute the script
    public void run() {
        try {
            String os = System.getProperty("os.name").toLowerCase();
            if (os.indexOf("linux") >= 0)
                // equivalent to shell command "ls -a /usr/local > output.txt"
                setCommandList("ls", "-a", "/usr/local", ">", "output.txt");
            else if (os.indexOf("windows") >= 0)
                // equivalent to shell command "dir C:\Windows > output.txt"
                setCommandList("cmd", "/C", "dir", "C:\\Windows", ">", "output.txt");
            // disable the capture of the console output
            setCaptureOutput(false);
            // execute the script or command
            launchProcess();
            // copy the resulting file in memory
            FileLocation fileLoc = new FileLocation("output.txt");
            MemoryLocation memoryLoc = new MemoryLocation((int) fileLoc.size());
            fileLoc.copyTo(memoryLoc);
            // set the file content as a result
            setResult(new String(memoryLoc.toByteArray()));
        } catch (Exception e) {
            setException(e);
        }
    }
}
```


4.2 Dealing with jobs

A job is a grouping of tasks with a common set of characteristics and a common SLA. These characteristics include:

- common data shared between tasks (data provider)
- A common Service Level Agreement (SLA) comprising:
 - the job priority
 - the maximum number of nodes a job can be executed on
 - an optional execution policy describing which nodes the job can run on
 - a suspended indicator, that enables submitting a job in suspended state, waiting for an external command to resume or start its execution
 - an execution start date and time
 - an expiration (timeout) date and time
 - an indicator specifying what the server should do when the application is disconnected
- a blocking/non-blocking indicator, specifying whether the job execution is synchronous or asynchronous from the application's point of view
- a listener to receive notifications of completed tasks when running in non-blocking mode
- the ability to receive notifications when the job execution starts and completes
- a persistence manager, to store the job state during execution, and recover its latest saved state on demand, in particular after an application crash

In the JPPF API, a job is represented by the class [JPPFJob](#). In addition to accessors and mutators for the attributes we have seen above, `JPPFJob` provides methods to add tasks and a set of constructors that make creation of jobs easier.

4.2.1 Job name and identifier

Each job has a unique identifier (UUID), that allows JPPF to manage and monitor the job while distinguishing it from other jobs. If this identifier is not explicitly specified via a dedicated constructor, JPPF will create one as a string of 32 hexadecimal characters. It is very important that all jobs across an entire JPPF grid have a unique distinct uuid, otherwise there is no guarantee that a job will be executed properly.

Additionally, a job can have a name which doesn't need to be unique, and which is used by the JPPF administration console for display purposes only. You may also use it in your application for logging and tracing. If not set by the user, the name will be by default equal to the uuid.

The class `JPPFJob` provides the following APIs for the job name and uuid:

```
public class JPPFJob implements Serializable, JPPFDistributedJob {
    // create a blocking job with the specified uuid
    public JPPFJob(final String jobUuid)

    // get this job's UUID
    public String getUuid()

    // get the user-defined display name for this job
    public String getName()

    // set the user-defined display name for this job
    public void setName(final String name)
}
```

4.2.2 Creating a job

To create a job, the `JPPFJob` class offers a number of constructors, that can be split in 2 groups:

Constructors for blocking jobs

```
// creates a blocking job with no data provider and default SLA values
public JPPFJob()
// creates a blocking job with the specified data provider and default SLA values
public JPPFJob(DataProvider dataProvider)
// creates a blocking job with the specified data provider and SLA
public JPPFJob(DataProvider dataProvider, JPPFJobSLA jobSLA)
```

Constructors for non-blocking jobs

```
// creates a blocking job with the specified execution results listener,
// no data provider and default SLA values
public JPPFJob(TaskResultListener resultsListener)
// creates a blocking job with the specified execution results listener,
// data provider and default SLA values
public JPPFJob(DataProvider dataProvider, TaskResultListener resultsListener)
// creates a blocking job with the specified execution results listener,
// data provider and SLA
public JPPFJob(DataProvider dataProvider, JPPFJobSLA jobSLA,
               TaskResultListener resultsListener)
```

Basically, the distinction for a non-blocking job is made via the presence of a `TaskResultListener`.

Finally, there is a more generic constructor that embraces everything the other constructors do:

```
// creates a job with the specified data provider, SLA, blocking indicator
// and execution results listener
public JPPFJob(DataProvider dataProvider, JPPFJobSLA jobSLA, boolean blocking,
               TaskResultListener resultsListener)
```

No matter which constructor is used, the job id is automatically generated as a pseudo-random string of 32 hexadecimal characters. It can then be obtained or changed with the job's `getId()` and `setId(String)` methods. This mechanism ensures that a job always has an id, and that developers always have the possibility to change it to a more readable one.

4.2.3 Adding tasks to a job

As we have seen in section 4.1 about the various forms of tasks that we can use in JPPF, [JPPFJob](#) provides two methods to add tasks to a job.

Adding a JPPFTask, annotated, Runnable or Callable task

```
public JPPFTask addTask(Object taskObject, Object...args) throws JPPFException
```

The `taskObject` parameter can be one of the following:

- an instance of `JPPFTask`
- an instance of a class with a non-static public method annotated with `@JPPFRunnable`
- a `Class` object representing a class that has a public static method or a constructor annotated with `@JPPFRunnable`
- an instance of a `Runnable` class
- an instance of a `Callable` class

The `args` parameter is optional and is only used to pass the arguments of a method or constructor annotated with `@JPPFRunnable`. It is ignored for all other forms of tasks.

The return value is an instance of (a subclass of) `JPPFTask`, regardless the type of task that is added. In the case of an annotated, `Runnable` or `Callable` task, the original task object, wrapped by this `JPPFTask`, can be retrieved using the method `JPPFTask.getTaskObject()`, as in the following example:

```
JPPFTask task = job.addTask(new MyRunnableTask());
MyRunnableTask runnableTask = (MyRunnableTask) task.getTaskObject();
```

As JPPF is using reflection to properly wrap the task, an eventual exception may be thrown. It will then be wrapped into a `JPPFException`.

Adding a POJO task

```
public JPPFTask addTask(String method, Object taskObject, Object...args)
    throws JPPFException
```

The `method` parameter is the name of the method or of the constructor to execute as the entry point of the task. In the case of a constructor, it must be the same as the name of the class.

The `taskObject` parameter can be one of the following:

- an instance of the POJO class if the entry point is a non-static method
- a `Class` object representing a POJO class that has a public static method or a constructor as entry point

The `args` parameter is optional and is used to pass the arguments of a method or constructor defined as the task's entry point.

As for the other form of this method, the return value is a `JPPFTask`, and the original task object can be retrieved using the method `JPPFTask.getTaskObject()`, as in the following example:

```
JPPFTask task = job.addTask("myMethod", new MyPOJO(), 3, "string");
MyPOJO pojo = (MyPOJO) task.getTaskObject();
// we can also set a timeout on the wrapper
task.setTimeoutSchedule(new JPPFSchedule(5000L));
```

As JPPF is using reflection to properly wrap the task, an eventual exception may be thrown. It will then be wrapped into a `JPPFException`.

4.2.4 Non-blocking jobs

Jobs can be submitted asynchronously from the application's perspective. This means that an asynchronous (or non-blocking) job will not block the application thread from which it is submitted. It also implies that we must have the means to obtain the execution results at a later time. To this effect, it is possible to register a listener with the job, to receive notifications when tasks have been completed and their results were returned to the application.

These listeners are represented by the interface [TaskResultListener](#). It is defined as follows:

```
public interface TaskResultListener extends EventListener {
    void resultsReceived(TaskResultEvent event);
}
```

We will thus be listening for events of type [TaskResultEvent](#). Since JPPF 2.5, the public API for `TaskResultEvent` has two methods, as illustrated below:

```
public class TaskResultEvent extends EventObject {
    // Get the list of tasks whose results have been received from the server
    public List<JPPFTask> getTaskList();

    // Get the throwable eventually raised while receiving the results
    public Throwable getThrowable()
}
```

We can see that each notification is wrapping either a list of `JPPFTask` instances, or a `Throwable` to may be raised while receiving the results, both being mutually exclusive, mean that there is always one of the two methods that returns null..

Note that there is no guarantee the tasks are in the same order as when they were originally submitted. In fact the list is generally only a subset of the tasks that were submitted, and multiple notifications may be necessary to collect all the results. To restore the original ordering, `JPPFTask.getPosition()` should be used. Each task position is automatically calculated by JPPF at the time the job is submitted, as shown in the example below.

When the event's `Throwable` is non-null, this indicates that there was an issue with the connection to the driver. Using the built-in mechanism in the JPPF client, the client will (attempt to) reconnect and resubmit the job. This implies that you need to reset the state of the `TaskResultListener`, as if it were created anew. This is illustrated in the following example:

```

public class MyResultListener implements TaskResultListener {
    // Initial count of tasks in the job
    private int initialCount = 0;
    // Count of results not yet received
    private int pendingCount = 0;
    // Sorted map containing the resulting tasks, ordered by ascending position
    private Map<Integer, JPPFTask> resultMap = new TreeMap<Integer, JPPFTask>();

    // Initialize this collector with a specified number of tasks
    public MyResultListener(int count) {
        initialCount = count;
        pendingCount = count;
    }

    // Notification that the results of a number of tasks have been received
    public void resultsReceived(TaskResultEvent event) {
        if (event.getThrowable() != null) {
            // Insert the tasks in the map, in ascending position order
            for (JPPFTask task: event.getTaskList()) resultMap.put(task.getPosition(), task);
            // Update the number of pending tasks accordingly
            pendingCount -= event.getTaskList().size();
        } else {
            // Reset the state of this listener as if for a new job
            resultMap.clear();
            pendingCount = initialCount;
        }
    }

    // Get the list of results
    public List<JPPFTask> getResults() {
        List<JPPFTask> results = new ArrayList<JPPFTask>();
        // collect all results received so far in ascending position order
        for (Integer n: resultMap.keySet()) results.add(resultMap.get(n));
        return results;
    }

    public boolean isJobComplete() {
        return pendingCount <= 0;
    }
}

```

We can then use our result listener as follows:

```

// create a job
JPPFJob myJob = new JPPFJob();
// add 10 tasks
for (int i=0; i<10; i++) myJob.add(new MyTask(i));
// create a task result listener
MyResultListener myResultListener = new MyResultListener(10);
// register the listener with the job
myJob.setResultListener(myResultListener);
// set the job as non-blocking
myJob.setBlocking(false);

// submit the job
jppfClient.submit(job);

while (!myResultListener.isJobComplete()) {
    // ... do something while the job is executing ...
}

// once the job is complete, process the results
List<JPPFTask> results = myResultListener.getResults();

```

JPPF uses an existing implementation of *TaskResultListener*: the class [JPPFResultCollector](#). It can be used directly, and its implementation is very similar to that of the code sample above, except that it provides a way to synchronize with the job execution through its `waitForResult()` methods, so you don't have to write your own synchronization code. Additionally, `JPPFResultCollector` is also always used for blocking jobs.

4.3 Jobs runtime behavior, recovery and failover

4.3.1 Handling of execution results

As we have seen in the previous section, the results of the tasks executions are handed over by an instance of [TaskResultListener](#). Here, it is important to understand that, while JPPF jobs are submitted to the grid as a whole, the results of the tasks execution may be received in multiple chunks, each chunk being made of one or more tasks holding the results.

We can thus say the `TaskResultListener` is an asynchronous receiver, whose job is to:

- handle and store the execution results of the tasks
- ensure the results are in the same order as the tasks initially submitted
- handle errors occurring while receiving the results from the server
- update the state of the job's execution
- optionally handle the persistence of the job's state for later recovery

To store the execution results, the [JPPFJob](#) class holds an instance of [JobResults](#), which is accessible via the `getResults()` method. `JobResults` provides the following API:

```
public class JobResults {
    // Get the current number of received results
    public synchronized int size()

    // Determine whether the job received a result
    // for the task at the specified position
    public synchronized boolean hasResult(final int position)

    // Add the specified results to the job
    public synchronized void putResults(final List<JPPFTask> tasks)

    // Get all the tasks received as results for the job
    public synchronized Collection<JPPFTask> getAll()
}
```

Since [JPPFResultCollector](#) holds a reference to the job, it will be able to update the execution results each time it receives a `resultsReceived(TaskResultEvent)` notification.

4.3.2 Failover and job re-submission

When the connection with the JPPF server is broken, the client application becomes unable to receive any more results for the jobs it has submitted and which are still executing. When this happens, the default behavior for the JPPF client is to resubmit the job, so that it will either be sent to another available server, or wait in the client's queue until the connection is re-established.

If the job is using a `TaskResultListener` instance, such as [JPPFResultCollector](#), which properly updates the job results via the associated `JobResults` object, then only the tasks for which no result was received will be sent again to the server. This fault-tolerance mechanism minimizes the impact of losing the connection to the server.

There can be some side effects to this behavior, which should be carefully accounted for when designing your tasks. In effect, the fact that a task result was not received by the client doesn't necessarily mean the task was not executed on a node. This implies that a task may be executed more than once on the grid, as the client has no way of knowing this. In particular, if the task performs persistent operations, such as updating a database or writing to a file system, this may lead to unexpected results whenever the task is executed again.

4.3.3 Job persistence and recovery

The entire state of a job can be persisted by associating a *persistence manager* to the job. A persistence manager is an implementation of the [JobPersistence](#) interface, defined as follows:

```
package org.jppf.client.persistence;

public interface JobPersistence<K> {
    // Compute the key for the specified job. All calls to this method
    // with the same job instance should always return the same result.
    K computeKey(JPPFJob job);

    // Get the keys of all jobs in the persistence store
    Collection<K> allKeys() throws JobPersistenceException;

    // Load a job from the persistence store given its key
    JPPFJob loadJob(K key) throws JobPersistenceException;

    // Store the specified tasks of the specified job with the specified key
    // The list of tasks may be used to only store the delta for better performance
    void storeJob(K key, JPPFJob job, List<JPPFTask> tasks)
        throws JobPersistenceException;

    // Delete the job with the specified key from the persistence store
    void deleteJob(K key) throws JobPersistenceException;

    // Close this store and release any used resources
    void close();
}
```

As we can see, the persistence manager relies on keys that will allow it to uniquely identify jobs in the persistent store. The type of store is implementation-dependent, and can be any storage device or facility, for example a file system, a database, a cloud storage facility, a distributed cache, etc...

The [JPPFJob](#) class provides the following getter and setter for the persistence manager:

```
public class JPPFJob implements Serializable, JPPFDistributedJob {
    // Get the persistence manager
    public <T> JobPersistence<T> getPersistenceManager()

    // Set the persistence manager
    public <T> void setPersistenceManager(final JobPersistence<T> persistenceManager)
}
```

JPPF provides a ready-to-use implementation of JobPersistence: the class [DefaultFilePersistenceManager](#). This implementation stores the jobs on the file system. Each job, with its attributes and tasks, is saved in a single file, using Java serialization. The key associated with each job is the job's uuid (see `JPPFJob.getUuid()` method). It can be instantiated using one of the following constructors:

```
public class DefaultFilePersistenceManager implements JobPersistence<String> {
    // Initialize with the specified root path, using default file prefix and extension
    public DefaultFilePersistenceManager(File root)

    // Initialize with the specified root path, file prefix and extension
    public DefaultFilePersistenceManager(File root, String prefix, String ext)

    // Initialize with the specified root path, using default file prefix and extension
    public DefaultFilePersistenceManager(String root)

    // Initialize with the specified root path, file prefix and extension
    public DefaultFilePersistenceManager(String root, String prefix, String ext)
}
```

Note, that [DefaultFilePersistenceManager](#) will use the serializations scheme configured for the client. Finally, this persistence manager is shown in action in the [Job Recovery](#) related sample.

4.3.4 A full TaskResultListener example

To put together everything we have seen in this chapter, here is a `TaskResultListener` that handles receiving the results, updating the job state, and persisting the job state via a persistence manager. This is, in fact, a simplified version of the code for the class `JPPFResultCollector`, which you can also find in the JPPF SVN repository [at this location](#).

```
public class MyResultListener implements TaskResultListener {
    protected int count;
    protected int pendingCount = 0;
    protected final JPPFJob job;

    // Initialize this collector with the specified job
    public JPPFResultCollector(JPPFJob job) {
        this.job = job;
        count = job.getTasks().size() - job.getResults().size();
        pendingCount = count;
    }

    // Called to notify that the results of a number of tasks
    // have been received from the server
    public synchronized void resultsReceived(TaskResultEvent event) {
        if (event.getThrowable() == null) {
            List<JPPFTask> tasks = event.getTaskList();
            // update the job's results
            job.getResults().putResults(tasks);
            pendingCount -= tasks.size();
            // notify the threads waiting in waitForResults()
            notifyAll();
            // store the results if a persistence manager is present
            if (job.getPersistenceManager() != null) {
                JobPersistence pm = job.getPersistenceManager();
                try {
                    pm.storeJob(pm.computeKey(job), job, tasks);
                } catch (JobPersistenceException e) {
                    e.printStackTrace();
                }
            }
        } else {
            // reset this object's state to prepare for job resubmission
            count = job.getTasks().size() - job.getResults().size();
            pendingCount = count;
        }
    }

    // Wait until all results of a request have been collected
    public synchronized List<JPPFTask> waitForResults() {
        while (pendingCount > 0) {
            try {
                wait();
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
        }
        return getResults();
    }

    // Get the list of final results
    public List<JPPFTask> getResults() {
        return new ArrayList<JPPFTask>(job.getResults().getAll());
    }
}
```


4.3.5 Job start and completion notifications

It is possible to receive notifications for when a job is being started (i.e. sent to the server), when its execution is completed (results have been received for all tasks), when a subset of its tasks is dispatched for execution and when a subset of its tasks has returned from execution. This is done by registering instances of the [JobListener](#) interface, which is defined as follows:

```
// Listener interface for receiving job execution event notifications
public interface JobListener extends EventListener {
    // Called when a job is sent to the server, or its execution starts locally
    void jobStarted(JobEvent event);

    // Called when the execution of a job is complete
    void jobEnded(JobEvent event);

    // Called when a job, or a subset of its tasks, is sent to the server,
    // or to the local executor
    void jobDispatched(JobEvent event);

    // Called when the execution of a subset of a job is complete
    void jobReturned(JobEvent event);
}
```

Please note that `jobDispatched()` and `jobReturned()` may be called in parallel by multiple threads, in the case where the JPPF client has multiple connections in its configuration. This happens if the client uses multiple connections to the same server, connections to multiple servers, or a mix of connections to remote servers and a local executor. You will need to synchronize any operations that is not thread-safe within these methods.

In a normal execution cycle, `jobStarted()` and `jobEnded()` will be called only once for each job, whereas `jobDispatched()` and `jobReturned()` may be called multiple times, depending on the number of available connections, the load-balancing configuration on the client side, and the job's client-side SLA.

Additionally, the built-in job failover mechanism may cause the `jobStarted()` and `jobEnded()` callbacks to be invoked multiple times, for instance in the case where the connection to the server is lost, causing the job to be re-submitted.

Note: *it is recommended to only change the job SLA or metadata during the `jobStarted()` notification. Making changes in the other notifications will lead to unpredictable results and may cause the job to fail.*

The notifications are sent as instances of [JobEvent](#), which is defined as:

```
// Event emitted by a job when its execution starts or completes
public class JobEvent extends EventObject {
    // Get the job source of this event
    public JPPFJob getJob()

    // Get the tasks that were dispatched or returned
    public List<JPPFTask> getTasks()
}
```

Note that the `getTasks()` method is only useful for `jobDispatched()` and `jobReturned()` notifications. In all other cases, it will return `null`.

To add or remove listeners, use the related methods in `JPPFJob`:

```
public class JPPFJob implements Serializable, JPPFDistributedJob {
    // Add a job listener
    public void addJobListener(JobListener listener)

    // Remove a job listener
    public void removeJobListener(JobListener listener)
}
```

A possible use of these listeners is to “intercept” a job before it is sent to the server, and adjust some of its attributes, such as the SLA specifications, which may vary depending on the time at which the job is started or on an application-dependent context.

4.4 Sharing data among tasks : the *DataProvider* API

After a job is submitted, the server will distribute the tasks in the job among the nodes of the JPPF grid. Generally, more than one task may be sent to each node. Given the communication and serialization protocols implemented in JPPF, objects referenced by multiple tasks at submission time will be deserialized as multiple distinct instances at the time of execution in the node. This means that, if n tasks reference object A at submission time, the node will actually deserialize multiple copies of A , with $Task_1$ referencing A_1 , ... , $Task_n$ referencing A_n . We can see that, if the shared object is very large, we will quickly face memory issues.

To resolve this problem, JPPF provides a mechanism called *data provider* that enables sharing common objects among tasks in the same job. A data provider is an instance of a class that implements the interface [DataProvider](#). Here is the definition of this interface:

```
public interface DataProvider extends Serializable {
    Object getValue(Object key) throws Exception;

    void setValue(Object key, Object value) throws Exception;
}
```

This is indeed a basic object map interface: you can store objects and associate them with a key, then retrieve these objects using the associated key.

Here is an example of using a data provider:

In the application:

```
MyLargeObject myLargeObject = ...;
// create a data provider backed by a HashMap
DataProvider dataProvider = new MemoryMapDataProvider();
// store the shared object in the data provider
dataProvider.setValue("myKey", myLargeObject);
// associate the dataProvider with the job
JPPFJob = new JPPFJob(dataProvider);
job.add(new MyTask());
```

In the task:

```
public class MyTask extends JPPFTask {
    public void run() {
        // get a reference to the data provider
        DataProvider dataProvider = getDataProvider();
        // retrieve the shared data
        MyLargeObject myLargeObject = (MyLargeObject) dataProvider.getValue("myKey");
        // ... use the data ...
    }
}
```

Note 1: the association of a data provider to each task is done automatically by JPPF and is totally transparent to the application.

Note 2: from each task's perspective, the data provider should be considered read-only. Modifications to the data provider such as adding or modifying values, will NOT be propagated beyond the scope of the node. Hence, a data provider cannot be used as a common data store for the tasks. Its only goal is to avoid excessive memory consumption.

In the next sub-sections, we will detail the existing implementations of `DataProvider` that exist in the JPPF API.

4.4.1 `MemoryMapDataProvider`: map-based provider

[MemoryMapDataProvider](#) is a very simple implementation of the `DataProvider` interface. It is backed by a `java.util.HashMap<Object, Object>`. The `getValue()` method is equivalent to a call to `HashMap.get()`, and the `setValue()` is equivalent to `HashMap.put()`.

4.4.2 ClientDataProvider: computing data in the client (deprecated)

Note: as of JPPF 3.2, this feature has been deprecated, and may be removed in a future version. It is replaced with the `JPPFTask.compute(JPPFCallable)` and `JPPFTask.isInNode()` APIs, as described in “4.1.3 Executing code in the client from a task”. These APIs resolve a limitation of `ClientDataProvider` which does not work when a task is executing locally with regards to the JPPF client.

JPPF provides a way for a task to send a piece of code to be executed on the client and get the resulting data objects. This functionality is available through the use of a new `DataProvider`: [ClientDataProvider](#), which extends `MemoryMapDataProvider` and adds one method:

```
public <V> Object computeValue(Object key, JPPFCallable<V> callable)
```

Here, `callable` is the equivalent of a callback that is sent to the client for execution, and whose result is stored in the `DataProvider` on the node side. The interface [JPPFCallable<V>](#) is defined as follows:

```
public interface JPPFCallable<V> extends Callable<V>, Serializable {  
}
```

Example use:

```
public class DataProviderTestTask extends JPPFTask {  
    public void run() {  
        System.out.println("this should be on the node side");  
        ClientDataProvider dataProvider = (ClientDataProvider) getDataProvider();  
        // compute a value on the client side and store in the data provider  
        Object o = dataProvider.computeValue("result", new MyCallable());  
        System.out.println("Result of client-side execution:\n" + o);  
        setResult(o);  
        // retrieve the value without re-computing it  
        Object o2 = dataProvider.getValue("result");  
    }  
  
    // A callable that simply prints a message on the client side  
    // and returns the message to the node.  
    public static class MyCallable implements JPPFCallable<String> {  
        public String call() {  
            String s = "this should be on the client side";  
            System.out.println(s);  
            return s;  
        }  
    }  
}
```

Here is the sequence of steps performed when calling the method `ClientDataProvider.computeValue()`:

- the `JPPFCallable` instance is sent to the client application
- the resulting value is computed as the return value of `JPPFCallable.call()`
- the resulting value is sent back to the node
- the value is stored in the data provider by calling `ClientDataProvider.setValue(key, value)`
- the value is returned as the result of `ClientDataProvider.computeValue()`

Once the value has been computed, it can be retrieved, without being computed again, by calling the method `ClientDataProvider.getValue()`. To compute a new value, `ClientDataProvider.computeValue()` should be called again.

4.4.3 Data provider for non-JPPF tasks

By default, tasks whose class does not extend [JPPFTask](#) do not have access to the [DataProvider](#) that is set on the a job. This includes tasks that implement `Runnable` or `Callable` (including those submitted with a [JPPFExecutorService](#)), annotated with [@JPPFRunnable](#), and POJO tasks.

JPPF now provides a mechanism which enables non JPPF tasks to gain access to the `DataProvider`. To this effect, the task must implement the interface [DataProviderHolder](#), defined as follows:

```
package org.jppf.client.taskwrapper;
import org.jppf.task.storage.DataProvider;

// This interface must be implemented by tasks that are not subclasses
// of JPPFTask when they need access to the job's DataProvider
public interface DataProviderHolder {
    // Set the data provider for the task
    void setDataProvider(DataProvider dataProvider);
}
```

Here is an example implementation:

```
public class MyTask
    implements Callable<String>, Serializable, DataProviderHolder {

    // DataProvider set onto this task
    private transient DataProvider dataProvider;

    @Override
    public String call() throws Exception {
        String result = (String) dataProvider.getValue("myKey");
        System.out.println("got value " + result);
        return result;
    }

    @Override
    public void setDataProvider(final DataProvider dataProvider) {
        this.dataProvider = dataProvider;
    }
}
```

Note that the “dataProvider” attribute is set as transient, to prevent the `DataProvider` from being serialized along with the task when it is sent back to the server after execution. Another way to achieve this would be to set it to `null` at the end of the `call()` method, for instance in a `try {} finally {}` block.

4.5 Job Service Level Agreement

A job service level agreement (SLA) defines the terms and conditions in which a job will be processed. A job carries two distinct SLAs, one which defines a contract between the job and the JPPF server, the other defining a different contract between the job and the JPPF client.

Server and client SLAs have common attributes, which specify:

- the characteristics of the nodes it can run on (server side), or of the channels it can be sent through (client side): the job execution policy
- the time at which a job is scheduled to start
- an expiration date for the job

The attributes specific to the server side SLA are:

- the priority of a job
- whether it is submitted in suspended state
- the maximum number of nodes it can run on
- whether the job is a standard or broadcast job
- whether the server should immediately cancel the job, if the client that submitted it is disconnected

The attributes specific to the client side SLA are:

- the maximum number of channels it can be sent through

A job SLA is represented by the interface [JobSLA](#) for the server side SLA, and by the interface [JobClientSLA](#) for the client side SLA. It can be accessed from a job using the related getters and setters:

```
public class JPPFJob implements Serializable, JPPFDistributedJob {
    // The job's server-side SLA
    public JobSLA getSLA()
    public void setSLA(final JobSLA jobSLA)

    // The job's client-side SLA
    public JobClientSLA getClientSLA()
    public void setClientSLA(final JobClientSLA jobClientSLA)
}
```

Example usage:

```
JPPFJob myJob = new JPPFJob();
myJob.getClientSLA().setMaxChannels(2);
myJob.getSLA().setPriority(1000);
```

Also note that both interfaces extend the common interface [JobCommonSLA](#). We will go into the details of these interfaces in the following sections.

4.5.1 Attributes common to server and client side SLAs

As seen previously, the common attributes for server and client side SLAs are defined by the [JobCommonSLA](#) interface:

```
public interface JobCommonSLA extends Serializable {
    // The execution policy
    ExecutionPolicy getExecutionPolicy();
    void setExecutionPolicy(ExecutionPolicy executionPolicy);

    // The job start schedule
    JPPFSchedule getJobSchedule();
    void setJobSchedule(JPPFSchedule jobSchedule);

    // The job expiration schedule
    JPPFSchedule getJobExpirationSchedule();
    void setJobExpirationSchedule(JPPFSchedule jobExpirationSchedule);
}
```

4.5.1.1 Execution policy

An execution policy is an object that determines whether a particular set of JPPF tasks can be executed on a JPPF node (for the server-side SLA) or if it can be sent via a communication channel (for the client-side). It does so by applying the set of rules (or tests) it is made of, against a set of properties associated with the node or channel.

These properties include:

- JPPF configuration properties
- System properties (including -D*=* properties specified on the JVM command line)
- Environment variables (e.g. PATH, JAVA_HOME, etc.)
- Networking: list of ipv4 and ipv6 addresses with corresponding host name when it can be resolved
- Runtime information such as maximum heap memory, number of available processors, etc...
- Disk space and storage information (JDK 1.6 or later only)
- A special boolean property named "jppf.channel.local" which indicates whether a node (server-side) or communication channel (client-side) is local to the JPPF server or client, respectively.

The kind of tests that can be performed apply to the value of a property, and include:

- Binary comparison operators: ==, <, <=, >, >= ; for instance: "property_value <= 15"
- Range operators (intervals): "property_value in" [a,b] , [a,b[,]a,b] ,]a,b[
- "One of" operator (discrete sets): "property_value in { a1, ... , aN }"
- "Contains string" operator: "property_value contains "substring""
- Regular expressions: " property_value matches 'regexp' "
- Custom, user-defined tests

The tests can also be combined into complex expressions using the boolean operators NOT, AND, OR and XOR.

Using this mechanism, it is possible to write execution policies such as:

"Execute on a node only if the node has at least 256 MB of memory and at least 2 CPUs available"

"Execute the job only in the client's local executor"

In the context of a server-side SLA, an execution policy is sent along with the tasks to the JPPF driver, and evaluated by the driver. It does not need to be sent to the nodes.

For a detailed and complete description of all policy elements, operators and available properties, please refer to the chapter **Appendix B: Execution policy reference**.

4.5.1.1.1 Creating and using an execution policy

An execution policy is an object whose type is a subclass of [ExecutionPolicy](#). It can be built in 2 ways:

By API, using the classes in the [org.jppf.node.policy](#) package.

Example:

```
// define a policy allowing only nodes with 2 processing threads or more
ExecutionPolicy atLeast2ThreadsPolicy = new AtLeast("processing.threads", 2);
// define a policy allowing only nodes that are part of the "mydomain.com"
// internet domain (case ignored)
ExecutionPolicy myDomainPolicy =
    new Contains("ipv4.addresses", true, "mydomain.com");
// define a policy that requires both of the above to be satisfied
ExecutionPolicy myPolicy = atLeast2ThreadsPolicy.and(myDomainPolicy);
```

Alternatively, this could be written in a single statement:

```
// define the same policy in one statement
ExecutionPolicy myPolicy = new AtLeast("processing.threads", 2).and(
    new Contains("ipv4.addresses", true, "mydomain.com"));
```

Using an XML policy document:

Example XML policy:

```
<ExecutionPolicy>
  <!-- define a policy that requires both rules to be satisfied -->
  <AND>
    <!-- define a policy allowing only nodes with 2 processing threads or more -->
    <AtLeast>
      <Property>processing.threads</Property>
      <Value>2</Value>
    </AtLeast>
    <!-- allow only nodes in the "mydomain.com" internet domain (case ignored) -->
    <Contains ignoreCase="true">
      <Property>ipv4.addresses</Property>
      <Value>mydomain.com</Value>
    </Contains>
  </AND>
</ExecutionPolicy>
```

As you can see, this is the exact equivalent of the policy we constructed programmatically before.

To transform this XML policy into an `ExecutionPolicy` object, we will have to parse it using the [PolicyParser](#) API, by the means of one of the following methods:

```
static ExecutionPolicy parsePolicy(String)           // parse from a string
static ExecutionPolicy parsePolicyFile(String)       // parse from a file
static ExecutionPolicy parsePolicy(File)            // parse from a file
static ExecutionPolicy parsePolicy(Reader)          // parse from a Reader
static ExecutionPolicy parsePolicy(InputStream)     // parse from an InputStream
```

Example use:

```
// parse the specified XML file into an ExecutionPolicy object
ExecutionPolicy myPolicy = PolicyParser.parsePolicyFile("../policies/MyPolicy.xml");
```

It is also possible to validate an XML execution policy against the [JPPF Execution Policy schema](#) using one of the `validatePolicy()` methods of `PolicyParser`:

```
static ExecutionPolicy validatePolicy(String)        // validate from a string
static ExecutionPolicy validatePolicyFile(String)    // validate from a file
static ExecutionPolicy validatePolicy(File)          // validate from a file
static ExecutionPolicy validatePolicy(Reader)        // validate from a Reader
static ExecutionPolicy validatePolicy(InputStream)   // validate from an InputStream
```

To enable validation, the document's namespace must be specified in the root element:

```
<jppf:ExecutionPolicy xmlns:jppf="http://www.jppf.org/schemas/ExecutionPolicy.xsd">
  ...
</jppf:ExecutionPolicy>
```

Example use:

```
public ExecutionPolicy createPolicy(String policyPath) {
  try {
    // validate the specified XML file
    PolicyParser.validatePolicyFile(policyPath);
  } catch (Exception e) {
    // the validation and parsing errors are in the exception message
    System.err.println("The execution policy " + policyPath +
      " is not valid: " + e.getMessage());
    return null;
  }
  // the policy is valid, we can parse it safely
  return PolicyParser.parsePolicyFile(policyPath);
}
```

4.5.1.1.2 Creating custom policies

It is possible to apply user-defined policies. When you do so, a number of constraints must be respected:

- the custom policy class must extend [CustomPolicy](#)
- the custom policy class must be deployed in the JPPF server classpath as well as the client's

Here is a sample custom policy code:

```
package my.package;
import org.jppf.management.JPPFSystemInformation;
import org.jppf.node.policy.CustomPolicy;

// define a policy allowing only nodes with 2 processing threads or more
public class MyCustomPolicy extends CustomPolicy {
    public boolean accepts(JPPFSystemInformation info) {
        // get the value of the "processing.threads" property
        String s = this.getProperty(info, "processing.threads");
        int n = -1;
        try { n = Integer.valueOf(s); }
        catch(NumberFormatException e) { // process the exception }
        // node is accepted only if number of threads >= 2
        return n >= 2;
    }
}
```

Now, let's imagine that we want our policy to be more generic, and to accept nodes with at least a parametrized number of threads given as argument to the policy.

Our `accepts()` method becomes then:

```
public boolean accepts(JPPFSystemInformation info) {
    // get the value to compare with, passed as the first argument to this policy
    String s1 = getArgs()[0];
    int param = -1;
    try { param = Integer.valueOf(s1); }
    catch(NumberFormatException e) { }
    String s2 = getProperty(info, "processing.thread");
    int n = -1;
    try { n = Integer.valueOf(s2); }
    catch(NumberFormatException e) { }
    // node is accepted only if number of threads >= param
    return n >= param;
}
```

Here we use the `getArgs()` method which returns an array of strings, corresponding to the arguments passed in the XML representation of the policy.

To illustrate how to use a custom policy in an XML policy document, here is an example XML representation of the custom policy we created above:

```
<CustomRule class="my.package.MyCustomPolicy">
  <Arg>3</Arg>
</CustomRule>
```

The "class" attribute is the fully qualified name of the custom policy class. There can be any number of `<Arg>` elements, these are the parameters that will then be accessible through `CustomPolicy.getArgs()`.

When the XML descriptor is parsed, an execution policy object will be created exactly as in this code snippet:

```
MyCustomPolicy policy = new MyCustomPolicy();
policy.setArgs( "3" );
```

Finally, to enable the use of this custom policy, you will need to deploy the corresponding class(es) to both the server's and the client's classpath.

4.5.1.2 Job start and expiration scheduling

It is possible to schedule a job for a later start, and also to set a job for expiration at a specified date/time. The job SLA allows this by providing the following methods:

```
// job start schedule
public JPPFSchedule getJobSchedule()
public void setJobSchedule(JPPFSchedule schedule)

// job expiration schedule
public JPPFSchedule getJobExpirationSchedule()
public void setJobExpirationSchedule(JPPFSchedule schedule)
```

As we can see, this is all about getting and setting an instance of [JPPFSchedule](#). A schedule is normally defined through one of its constructors:

As a fixed length of time

```
public JPPFSchedule(long duration)
```

The semantics is that the job will start *duration* milliseconds after the job is received by the server. Here is an example:

```
JPPFJob myJob = new Job();
// set the job to start 5 seconds after being received
JPPFSchedule mySchedule = new JPPFSchedule(5000L);
myJob.getSLA().setJobSchedule(mySchedule);
```

As a specific date/time

```
public JPPFSchedule(String date, String dateFormat)
```

Here the date format is specified as a pattern for a [SimpleDateFormat](#) instance.

Here is an example use of this constructor:

```
JPPFJob myJob = new Job();
String dateFormat = "MM/dd/yyyy hh:mm a z";
// set the job to expire on September 30, 2010 at 12:08 PM in the CEDT time zone
JPPFSchedule schedule = new JPPFSchedule("09/30/2010 12:08 PM CEDT", dateFormat);
myJob.getSLA().setJobExpirationSchedule(mySchedule);
```

4.5.2 Server side SLA attributes

A server-side SLA is described by the [JobSLA](#) interface, defined as:

```
public interface JobSLA extends JobCommonSLA {
    // Job priority
    int getPriority();
    void setPriority(int priority);

    // Maximum number of nodes the job can run on
    int getMaxNodes();
    void setMaxNodes(int maxNodes);

    // Whether the job is initially suspended
    boolean isSuspended();
    void setSuspended(boolean suspended);

    // Whether the job is a broadcast job
    boolean isBroadcastJob();
    void setBroadcastJob(boolean broadcastJob);

    // Determine whether the job should be canceled by the server
    // if the client gets disconnected
    boolean isCancelUponClientDisconnect();
    void setCancelUponClientDisconnect(boolean cancelUponClientDisconnect);
}
```

4.5.2.1 Job priority

The priority of a job determines the order in which the job will be executed by the server. It can be any integer value, such that if `jobA.getPriority() > jobB.getPriority()` then `jobA` will be executed before `jobB`. There are situations where both jobs may be executed at the same time, for instance if there remain any available nodes for `jobB` after `jobA` has been dispatched. Two jobs with the same priority will have an equal share (as much as is possible) of the available grid nodes.

The priority attribute is also manageable, which means that it can be dynamically updated, while the job is still executing, using the JPPF administration console or the related management APIs.

4.5.2.2 Maximum number of nodes

The maximum number of nodes attribute determines how many grid nodes a job can run on, at any given time. This is an upper bound limit, and does not guarantee that always this number of nodes will be used, only that no more than this number of nodes will be assigned to the job. This attribute is also non-distinctive, in that it does not specify which nodes the job will run on.

The resulting assignment of nodes to the job is influenced by other attributes, especially the job priority and an eventual execution policy.

The maximum number of nodes is a manageable attribute, which means it can be dynamically updated, while the job is still executing, using the JPPF administration console or the related management APIs.

4.5.2.3 Initial suspended state

A job can be initially suspended. In this case, it will remain in the server's queue until it is explicitly resumed or canceled, or if it expires (if a timeout was set), whichever happens first. A job can be resumed and suspended again any number of times via the JPPF administration console or the related management APIs.

4.5.2.4 Broadcast jobs

A broadcast job is a specific type of job, for which each task will be executed on all the nodes currently present in the grid. This opens new possibilities for grid applications, such as performing maintenance operations on the nodes or drastically reducing the size of a job that performs identical tasks on each node.

With regards to the job SLA, a job is set in broadcast mode via a boolean indicator, for which the interface [JobSLA](#) provides the following accessors:

```
public boolean isBroadcastJob()
public void setBroadcastJob(boolean broadcastJob)
```

To set a job in broadcast mode:

```
JPPFJob myJob = new JPPFJob();
myJob.getSLA().setBroadcastJob(true);
```

With respect to the dynamic aspect of a JPPF grid, the following behavior is enforced:

- a broadcast job is only executed on the nodes active at the time the job is received by the JPPF driver
- if a node dies or disconnects while the job is executing on it, the job is canceled for this node
- if a new node connects while the job is executing, the broadcast job will not execute on it
- a broadcast job does not return any results, i.e. it returns the tasks in the same state as they were submitted

Additionally, if local execution of jobs is enabled for the JPPF client, a broadcast job will not be executed locally. In other words, a broadcast job is only executed on remote nodes.

4.5.2.5 Canceling a job upon client disconnection

By default, if the JPPF client is disconnected from the server while a job is executing, the server will automatically attempt to cancel the job's execution on all nodes it was dispatched to, and remove the job from the server queue. You may disable this behavior on a per-node basis, for example if you want to let the job execute until completion but do not need the execution results.

This property is set once for each job, and cannot be changed once the job has been submitted to the server, i.e. it is not dynamically manageable.

4.5.3 Client side SLA attributes

A client-side SLA is described by the interface [JobClientSLA](#), defined as:

```
public interface JobClientSLA extends JobCommonSLA {
    // The maximum number of channels the job can be sent through,
    // including the local executor if any is configured
    int getMaxChannels();
    void setMaxChannels(int maxChannels);
}
```

Note: since JPPF clients do not have a management interface, none of the client-side SLA attributes are manageable.

4.5.3.1 Maximum number of execution channels

The maximum number of channels attribute determines how many server connections a job can be sent through, at any given time. This is an upper bound limit, and does not guarantee that this number of channels will always be used. This attribute is also non-specific, since it does not specify which channels will be used.

Note 1: when the JPPF client is configured with a single server connection, this attribute has no effect.

Note 2: when local execution is enabled in the JPPF client, the local executor counts as one (additional) channel.

Note 3: the resulting assignment of channels to the job is influenced by other attributes, especially the execution policy.

4.6 Job Metadata

It is possible to attach user-defined metadata to a job, to describe the characteristics of the job and its tasks. This additional data can then be reused by customized load-balancing algorithms, to perform load balancing based on knowledge about the jobs. For instance, the metadata could provide information about the memory footprint of the tasks and about their duration, which can be critical data for the server, in order to determine on which nodes the job or tasks should be executed.

The job metadata is encapsulated in a specific interface: [JobMetadata](#), and can be accessed from the job as follows:

```
JPPFJob job = ...;
JobMetadata metaData = job.getMetadata();
```

[JobMetadata](#) provides the following methods:

```
public interface JobMetadata extends Serializable {
    // Set a parameter in the metadata
    public void setParameter(Object key, Object value)
    // Retrieve a parameter in the metadata
    public Object getParameter(Object key)
    // Retrieve a parameter in the metadata
    public Object getParameter(Object key, Object defaultValue)
    // Remove a parameter from the metadata
    public Object removeParameter(Object key)
    // Get a copy of the metadata map
    public Map<Object, Object> getAll()
}
```

Here is an example use:

```
JPPFJob job = ...;
JobMetadata metaData = job.getMetadata();
// set the memory footprint of each task to 10 KB
metaData.setParameter("task.footprint", "" + (10 * 1024));
// set the duration of each task to 80 milliseconds
metaData.setParameter("task.duration", "80");
```

Related sample: ["CustomLoadBalancer"](#) in the JPPF samples pack.

4.7 The JPPFClient API

A JPPF client is an object that will handle the communication between the application and the server. Its role is to:

- manage one or multiple connections with the server
- submit jobs and get their results
- handle notifications of job results
- manage each connection's life cycle events
- provide the low-level machinery on the client side for the distributed class loading mechanism
- provide an access point for the management and monitoring of each server

A JPPF client is represented by the class `JPPFClient`. We will detail its functionalities in the next sub-sections.

4.7.1 Creating and closing a JPPFClient

A JPPF client is a Java object, and is created via one of the constructors of the class `JPPFClient`. Each JPPF client has a unique identifier that is always transported along with any job that is submitted by this client. This identifier is what allows JPPF to know from where the classes used in the tasks should be loaded. In effect, each node in the grid will have a map of each client identifier with a unique class loader, creating the class loader when needed. The implication is that, if a new client identifier is specified, the classes used in any job / task submitted by this client will be dynamically reloaded. This is what enables the immediate dynamic redeployment of code changes in the application. On the other hand, if a previously existing identifier is reused, then no dynamic redeployment occurs, and code changes will be ignored (i.e. the classes already loaded by the node will be reused), even if the application is restarted between 2 job submissions.

There are two forms of constructors for `JPPFClient`, each with a specific corresponding semantics:

Generic constructor with automatic identifier generation

```
public JPPFClient()
```

When using this constructor, JPPF will automatically create a universal unique identifier (uuid) that is guaranteed to be unique on the grid. The first submission of a job will cause the classes it uses to be dynamically loaded by any node that executes the job.

Constructor specifying a user-defined client identifier

```
public JPPFClient(String uuid)
```

In this case, the classes used by a job will be loaded only the first time they are used, including if the application has been restarted in the meantime, or if the JPPF client is created from a separate application. This behavior is more adapted to an application deployed in production, where the client identifier would only change when a new version of the application is deployed on the grid. It is a good practice to include a version number in the identifier.

As a `JPPFClient` uses a number of system and network resources, it is recommended to use it as a singleton. It is designed for concurrent use by multiple threads, which makes it safe for use with a singleton pattern. It is also recommended to release these resources when they are no longer needed, via a call to the `JPPFClient.close()` method. The following code sample illustrates what is considered a best practice for using a `JPPFClient`:

```
public class MyApplication {
    // singleton instance of the JPPF client
    private static JPPFClient jppfClient = new JPPFClient();
    // allows access to the client from any other class
    public static JPPFClient getJPPFClient() {
        return jppfClient;
    }

    public static void main(String...args) {
        // enclosed in a try / catch to ensure resources are properly released
        try {
            jppfClient = new JPPFClient();
            // ... application-specific code here ...
        } finally {
            // close the client to release its resources
            if (jppfClient != null) jppfClient.close();
        }
    }
}
```

4.7.2 Submitting a job

To submit a job, JPPFClient provides a single method:

```
public List<JPPFTasks> submit(JPPFJob job)
```

This method has two different behaviors, depending on whether the job is blocking or non-blocking:

- blocking job: the `submit()` method blocks until the job execution is complete. The return value is a list of tasks with their results, in the same order as the tasks that were added to the job.
- non-blocking job: `submit()` returns immediately with a null value. It is up to the developer to collect the execution results by the means of a `TaskResultListener` set onto the job (see section 4.2.4).

4.7.3 Cancelling a job

The ability to cancel a job is provided by JPPFClient's superclass [AbstractGenericClient](#), which provides a `cancelJob()` method, defined as follows:

```
// superclass of JPPFClient
public abstract class AbstractGenericClient extends AbstractJPPFClient {
    // cancel the job with the specified UUID
    public boolean cancelJob(final String jobId) throws Exception;
}
```

This method will work even if the client is connected to multiple drivers. In this case, it will send the cancel request to all the drivers.

4.7.4 Exploring the server connections

The JPPF client handles one or more connections to one or multiple servers. Each individual connection is represented as an instance of the interface [JPPFClientConnection](#). It is possible to explore these connections using the following methods in JPPFClient:

```
// Get all the client connections handled by this JPPFClient
public List<JPPFClientConnection> getAllConnections()
// Get the names of all the client connections handled by this JPPFClient
public List<String> getAllConnectionNames()
// Get a connection given its name
public JPPFClientConnection getClientConnection(String name)
```

4.7.5 Receiving notifications for new connections

The JPPF client emits an event each time a new connection is established with a server. It is possible to receive these events by registering an implementation of the listener interface [ClientListener](#) with the client. Since the connections are generally established during the initialization of the client, i.e. when calling its constructor, JPPFClient provides a different form of the two constructors we have seen in section 4.7.1:

```
// Initialize with the specified listeners and a generated uuid
public JPPFClient(ClientListener...listeners)
// Initialize with the specified listeners and user-defined uuid
public JPPFClient(String uuid, ClientListener...clientListeners)
```

It is also possible to add and remove listeners using these two more "conventional" methods:

```
// register a listener with this client
public void addClientListener(ClientListener listener)
// remove a listener from the registered listeners
public synchronized void removeClientListener(ClientListener listener)
```

Here is a sample `ClientListener` implementation:

```
public class MyClientListener implements ClientListener {
    public void newConnection(ClientEvent event) {
        // the new connection is the source of the event
        JPPFClientConnection connection = event.getConnection();
        System.out.println("New connection with name " + connection.getName());
    }
}
```

```

ClientListener myClientListener = new MyClientListener();
// initialize the client and register the listener
JPPFClient jppfClient = new JPPFClient(myClientListener);

```

4.7.6 Status notifications for existing connections

Each individual server connection has a status that depends on the state of its network connection to the server and whether it is executing a job request. A connection status is represented by the enum [JPPFClientConnectionStatus](#), and has the following possible values: NEW, DISCONNECTED, CONNECTING, ACTIVE, EXECUTING or FAILED.

JPPFConnection extends the interface ClientConnectionStatusHandler, which provides the following methods to handle the connection status and register or remove listeners:

```

public interface ClientConnectionStatusHandler {
    // Get the status of this connection
    JPPFClientConnectionStatus getStatus();
    // Set the status of this connection
    void setStatus(JPPFClientConnectionStatus status);
    // Register a connection status listener with this connection
    void addClientConnectionStatusListener(ClientConnectionStatusListener listener);
    // Remove a connection status listener from the registered listeners
    void removeClientConnectionStatusListener(ClientConnectionStatusListener listener);
}

```

Here is a sample status listener implementation:

```

public class MyStatusListener extends ClientConnectionStatusListener {
    public void statusChanged(ClientConnectionStatusEvent event) {
        // obtain the client connection from the event
        JPPFClientConnection connection =
            (JPPFClientConnection) event.getClientConnectionStatusHandler();
        // get the new status
        JPPFClientConnectionStatus status = connection.getStatus();
        System.out.println("Connection " + connection.getName() + " status changed to "
            + status);
    }
}

```

To put all of this together, let's take the sample listener from the previous section 4.7.5 and modify it to add a status listener to each new connection:

```

public MyClientListener implements ClientListener {
    public void newConnection(ClientEvent event) {
        // the new connection is the source of the event
        JPPFClientConnection connection = event.getConnection();
        System.out.println("New connection with name " + connection.getName());
        // register to receive status event on the new connection
        connection.addClientConnectionStatusListener(new MyStatusListener());
    }
}

```

4.7.7 Switching local execution on or off

The JPPFClient API allows users to dynamically turn the local (in the client JVM) execution of jobs on or off, and determine whether it is active or not. This is done via these two methods:

```

// Determine whether local execution is enabled on this client
public boolean isLocalExecutionEnabled()

// Specify whether local execution is enabled on this client
public void setLocalExecutionEnabled(boolean localExecutionEnabled)

```

Turning local execution on or off will affect the next job to be executed, but not any that is currently executing.

4.8 JPPF Executor Services

4.8.1 Basic usage

JPPF 2.2 introduced a new API, that serves as an [ExecutorService](#) facade to the JPPF client API. This API consists in a simple class: [JPPFExecutorService](#), implementing the interface `java.util.concurrent.ExecutorService`.

A `JPPFExecutorService` is obtained via its constructor, to which a `JPPFClient` must be passed:

```
JPPFClient jppfClient = new JPPFClient();
ExecutorService executor = new JPPFExecutorService(jppfClient);
```

The behavior of the resulting executor will depend largely on the configuration of the `JPPFClient` and on which `ExecutorService` method you invoke to submit tasks. In effect, each time you invoke an `invokeAll(...)`, `invokeAny(...)`, `submit(...)` or `execute(...)` method of the executor, a new `JPPFJob` will be created and sent for execution on the grid. This means that, if the executor method you invoke only takes a single task, then a job with only one task will be sent to the JPPF server.

Here is an example use:

```
JPPFClient jppfClient = new JPPFClient();
ExecutorService executor = new JPPFExecutorService(jppfClient);

try {
    // submit a single task
    Runnable myTask = new MyRunnable(0);
    Future<?> future = executor.submit(myTask);
    // wait for the results
    future.get();
    // process the results
    ...

    // submit a list of tasks
    List<Runnable> myTaskList = new ArrayList<Runnable>;
    for (int i=0; i<10; i++) myTaskList.add(new MyRunnable(i));
    List<Future<?>> futureList = executor.invokeAll(myTaskList);
    // wait for the results
    for (Future<?> future: futureList) future.get();
    // process the results for the list of tasks
    ...
} finally {
    // clean up after use
    executor.shutdown();
    jppfClient.close();
}

// !!! it is important that this task is Serializable !!!
public static class MyRunnable implements Runnable, Serializable {
    private int id = 0;

    public MyRunnable(int id) {
        this.id = id;
    }

    public void run() {
        System.out.println("Running task id " + id);
    }
}
```

4.8.2 Batch modes

The executor's behavior can be modified by using one of the batch modes of the `JPPFExecutorService`. By batch mode, we mean the ability to group tasks into batches, in several different ways. This enables tasks to be sent together, even if they are submitted individually, and allows them to benefit from the parallel features inherent to JPPF. This will also dramatically improve the throughput of individual tasks sent via an executor service.

Using a batch size: specifying a batch size via the method `JPPFExecutorService.setBatchSize(int limit)` causes the executor to only send tasks when at least that number of tasks have been submitted. When using this mode, you must be cautious as to how many tasks you send via the executor: if you send less than the batch size, these tasks will remain pending and un-executed. Sometimes, the executor will send more than the specified number of tasks in the same batch: this will happen in the case where one of the `JPPFExecutorService.invokeXXX()` method is called with n tasks, such that $\text{current batch size} + n > \text{limit}$. The behavior is to send all tasks included in the `invokeXXX()` call together.

Here is an example:

```
JPPFExecutorService executor = new JPPFExecutorService(jppfClient);
// the executor will send jobs with at least 5 tasks each
executor.setBatchSize(5);
List<Future<?>> futures = new ArrayList<Future<?>>();
// we submit 10 = 2 * 5 tasks, this will cause the client to send 2 jobs
for (int i=0; i<10; i++) futures.add(executor.submit(new MyTask(i)));
for (Future<?> f: futures) f.get();
```

Using a batch timeout: this is done via the method `JPPFExecutorService.setBatchTimeout(long timeout)` and causes the executor to send the tasks at regular intervals, specified as the timeout. The timeout value is expressed in milliseconds. Once the timeout has expired, the counter is reset to zero. If no task has been submitted between two timeout expirations, then nothing happens.

Example:

```
JPPFExecutorService executor = new JPPFExecutorService(jppfClient);
// the executor will send a job every second (if any task is submitted)
executor.setBatchTimeout(1000L);
List<Future<?>> futures = new ArrayList<Future<?>>();
// we submit 5 tasks
for (int i=0; i<5; i++) futures.add(executor.submit(new MyTask(i)));
// we wait 1.5 second, during that time a job with 5 tasks will be submitted
Thread.sleep(1500L);
// we submit 6 more tasks, they will be sent in a different job
for (int i=5; i<11; i++) futures.add(executor.submit(new MyTask(i)));
// here we get the results for tasks sent in 2 different jobs!
for (Future<?> f: futures) f.get();
```

Using both batch size and timeout: it is possible to use a combination of batch size and timeout. In this case, a job will be sent whenever the batch limit is reached or the timeout expires, whichever happens first. In any case, the timeout counter will be reset each time a job is sent. Using a timeout is also an efficient way to deal with the possible blocking behavior of the batch size mode. In this case, just use a timeout that is sufficiently large for your needs.

Example:

```
JPPFExecutorService executor = new JPPFExecutorService(jppfClient);
executor.setBatchTimeout(1000L);
executor.setBatchSize(5);
List<Future<?>> futures = new ArrayList<Future<?>>();
// we submit 3 tasks
for (int i=0; i<3; i++) futures.add(executor.submit(new MyTask(i)));
// we wait 1.5 second, during that time a job with 3 tasks will be submitted,
// even though the batch size is set to 5
Thread.sleep(1500L);
for (Future<?> f: futures) f.get();
```


4.8.3 Configuring jobs and tasks

There is a limitation in the `JPPFExecutorService`, in that if you use only the `ExecutorService` interface which it extends, it does not provide a way to use JPPF-specific features, such as job SLA, metadata or persistence, or task timeout, `onTimeout()` and `onCancel()`.

To overcome this limitation without breaking the semantics of `ExecutorService`, `JPPFExecutorService` provides a way to specify the configuration of the jobs and tasks that will be submitted subsequently.

This can be done via the [ExecutorServiceConfiguration](#) interface, which can be accessed from a [JPPFExecutorService](#) instance via the following accessor methods:

```
// Get the configuration for this executor service
public ExecutorServiceConfiguration getConfiguration();

// Reset the configuration for this executor service to a blank state
public ExecutorServiceConfiguration resetConfiguration();
```

[ExecutorServiceConfiguration](#) provides the following API:

```
// Get the configuration to use for the jobs submitted by the executor service
JobConfiguration getJobConfiguration();

// Get the configuration to use for the tasks submitted by the executor service
TaskConfiguration getTaskConfiguration();
```

4.8.3.1 Job configuration

The [JobConfiguration](#) interface is defined as follows:

```
public interface JobConfiguration {
    // Get the service level agreement between the jobs and the server
    JobSLA getSLA();

    // Get the service level agreement between the jobs and the client
    JobClientSLA getClientSLA();

    // Get the user-defined metadata associated with the jobs
    JobMetadata getMetadata();

    // Get/set the persistence manager that enables saving and restoring
    // the state of the jobs
    <T> JobPersistence<T> getPersistenceManager();
    <T> void setPersistenceManager(final JobPersistence<T> persistenceManager);

    // Get/set the job's data provider
    DataProvider getDataProvider();
    void setDataProvider(DataProvider dataProvider);

    // Add or remove a listener to/from the list of job listeners
    void addJobListener(JobListener listener);
    void removeJobListener(JobListener listener);
}
```

As we can see, this provides a way to set the properties normally available to [JPPFJob](#) instances, even though the jobs submitted by a `JPPFExecutorService` are not visible. Any change to the `JobConfiguration` will apply to the next job that will be submitted by the executor and all subsequent jobs.

Here is an example usage:

```
JPPFExecutorService executor = ...;
// get the executor configuration
ExecutorServiceConfiguration config = executor.getConfiguration();
// get the job configuration
JobConfiguration jobConfig = config.getJobConfiguration();
// set all jobs to expire after 5 seconds
jobConfig.getSLA().setJobExpirationSchedule(new JPPFSchedule(5000L));
```

4.8.3.2 Task configuration

The [TaskConfiguration](#) interface can be used to set JPPF-specific properties onto executor service tasks that do not extend [JPPFTask](#). It is defined as follows:

```
public interface TaskConfiguration {
    // Get/set the delegate for the onCancel() method
    JPPFTaskCallback getOnCancelCallback();
    void setOnCancelCallback(final JPPFTaskCallback cancelCallback);

    // Get/set the delegate for the onTimeout() method
    JPPFTaskCallback getOnTimeoutCallback();
    void setOnTimeoutCallback(final JPPFTaskCallback timeoutCallback);

    // Get/set the task timeout schedule
    JPPFSchedule getTimeoutSchedule();
    void setTimeoutSchedule(final JPPFSchedule timeoutSchedule);
}
```

This API introduces the concept of a callback delegate, which is used in lieu of the “standard” [JPPFTask](#) callback methods, [JPPFTask.onCancel\(\)](#) and [JPPFTask.onTimeout\(\)](#). This is done by providing a subclass of [JPPFTaskCallback](#), which is defined as follows:

```
public abstract class JPPFTaskCallback implements Runnable, Serializable {
    // Get the task this callback is associated with
    public final JPPFTask getTask();
}
```

Here is a task configuration usage example:

```
JPPFExecutorService executor = ...;
// get the executor configuration
ExecutorServiceConfiguration config = executor.getConfig();
// get the task configuration
TaskConfiguration taskConfig = config.getTaskConfiguration();
// set the task to timeout after 5 seconds
taskConfig.setTimeoutSchedule(new JPPFSchedule(5000L));
// set the onTimeout() callback
taskConfig.setOnTimeoutCallback(new MyTaskCallback());
// A callback that sets a timeout message as the task result
static class MyTaskCallback extends JPPFTaskCallback {
    @Override
    public void run() {
        getTask().setResult("this task has timed out");
    }
}
```

4.8.4 JPPFCompletionService

The JDK package [java.util.concurrent](#) provides the interface [CompletionService](#), which represents “a service that decouples the production of new asynchronous tasks from the consumption of the results of completed tasks”. The JDK also provides a concrete implementation with the class [ExecutorCompletionService](#). Unfortunately, this class does not work with a [JPPFExecutorService](#), as it was not designed with distributed execution in mind.

As a convenience, the JPPF API provides a specific implementation of [CompletionService](#) with the class [JPPFCompletionService](#), which respects the contract and semantics defined by the [CompletionService](#) interface and which can be used as follows:

```
JPPFExecutorService executor = ...;
JPPFCompletionService<String> completionService =
    new JPPFCompletionService<String>(executor);
MyCallable<String> task = new MyCallable<String>();
Future<String> future = completionService.submit(task);

// ... later on ...
// block until a result is available
future = completionService.take();
String result = future.get();
```

4.9 The JPPF configuration API

The JPPF configuration properties are accessible at runtime, via a static method call: [JPPFConfiguration.getProperties\(\)](#). This method returns an object of type [TypedProperties](#), which is an extension of [java.util.Properties](#) with additional methods to handle properties with primitive values: boolean, int, long, float and double.

Here is a summary of the API provided by [TypedProperties](#):

```
public class TypedProperties extends Properties {
    // constructors
    public TypedProperties()
    // initialize with existing key/value pairs from a map
    public TypedProperties(Map<Object, Object> map)
    // string properties
    public String getString(String key)
    public String getString(String key, String defValue)
    // int properties
    public int getInt(String key)
    public int getInt(String key, int defValue)
    // long properties
    public long getLong(String key)
    public long getLong(String key, long defValue)
    // float properties
    public float getFloat(String key)
    public float getFloat(String key, float defValue)
    // double properties
    public double getDouble(String key)
    public double getDouble(String key, double defValue)
    // boolean properties
    public boolean getBoolean(String key)
    public boolean getBoolean(String key, boolean defValue)
    // properties that are the path to another properties file
    public TypedProperties getProperties(String key)
    public TypedProperties getProperties(String key, TypedProperties defValue)
}
```

As you can see, each `getXXX()` method has a corresponding method that takes a default value, to be returned if the property is not defined for the specified key.

You will also notice the last two methods `getProperties(...)`, which are special in the sense that they do not handle simple value types, but rather specify the path to another properties file, whose content is returned as a [TypedProperties](#) instance. They are convenience methods that allow an easy navigation into a hierarchy of configuration files. The lookup mechanism for the specified properties file is described in the Javadoc for [TypedProperties.getProperties\(String\)](#).

It is possible to alter the JPPF configuration, via a call to the method `setProperty(String, String)` of [java.util.Properties](#). Notes that in this case, the value must be specified as a string. If you wish to programmatically change one or more JPPF configuration properties, then it should be done before they are used. For instance, in a client application, it should be done before the JPPF client is initialized, as in this sample code:

```
// get the configuration
TypedProperties props = JPPFConfiguration.getProperties();
// set the connection properties programmatically
props.setProperty("jppf.discovery.enabled", "false");
props.setProperty("jppf.drivers", "driver1");
props.setProperty("driver1.jppf.server.host", "www.myhost.com");
props.setProperty("driver1.jppf.server.port", "11111");

// now our configuration will be used
JPPFClient client = new JPPFClient();
```

5 Configuration guide

A JPPF grid is composed of many distributed components interacting with each other, often in different environments. While JPPF will work in most environments, the default behavior may not be appropriate or adapted to some situations. Much of the behavior in JPPF components can thus be modified, fine-tuned or sometimes even disabled, via numerous configuration properties. These properties apply to many mechanisms and behaviors in JPPF, including:

- network communication
- management and monitoring
- performance / load-balancing
- failover and recovery

Any configuration property has a default value that is used when the property is not specified, and which should work in most environments. In practice, this means that JPPF can work without any explicitly specified configuration at all.

For a full list of the JPPF configuration properties, do not hesitate to read the chapter **Appendix A: configuration properties reference** of this manual.

5.1 Configuration file specification and lookup

All JPPF components work with a set of configuration properties. The format of these properties is as specified in the [Java Properties class](#). To enable a JPPF component to retrieve these properties file, their source must be specified using one of the two, mutually exclusive, system properties:

- `jppf.config.plugin = class_name`, where *class_name* is the fully qualified name of a class implementing the interface [JPPFConfiguration.ConfigurationSource](#), enabling a configuration source from any origin, such as a URL, a distributed file system, a remote storage facility, a database, etc.
- `jppf.config = path`, where *path* is the location of the configuration file, either on the file system, or relative to the JVM's classpath root. If this system property is not specified, JPPF will look for a default file named "jppf.properties" in the current directory or in the classpath root.

Example use:

```
java -Djppf.config.plugin=my.own.Configuration ...
```

or

```
java -Djppf.config=my/folder/myFile.properties ...
```

The configuration file lookup mechanism is as follows:

1. if `jppf.plugin.config` is specified
 - a) instantiate an object of the specified class name and read the properties via the stream provided by this object's `getPropertyStream()` method.
 - b) if, for any reason, the stream cannot be obtained or reading the properties from it fails, go to 3.
2. else if `jppf.config` is specified
 - a) look for the file in the file system
 - b) if not found in the file system, look in the classpath
 - c) if not found in the classpath use default configuration values
3. if `jppf.config` is not specified
 - a) use default file "jppf.properties"
 - b) look for "jppf.properties" in the file system
 - c) if not found in the file system, look for it in the classpath
 - d) if not found in the classpath use default configuration values

A practical side effect of this mechanism is that it allows us to place a configuration file in the classpath, for instance packaged in a jar file, and override it if needed with an external file, since the file system is always looked up first.

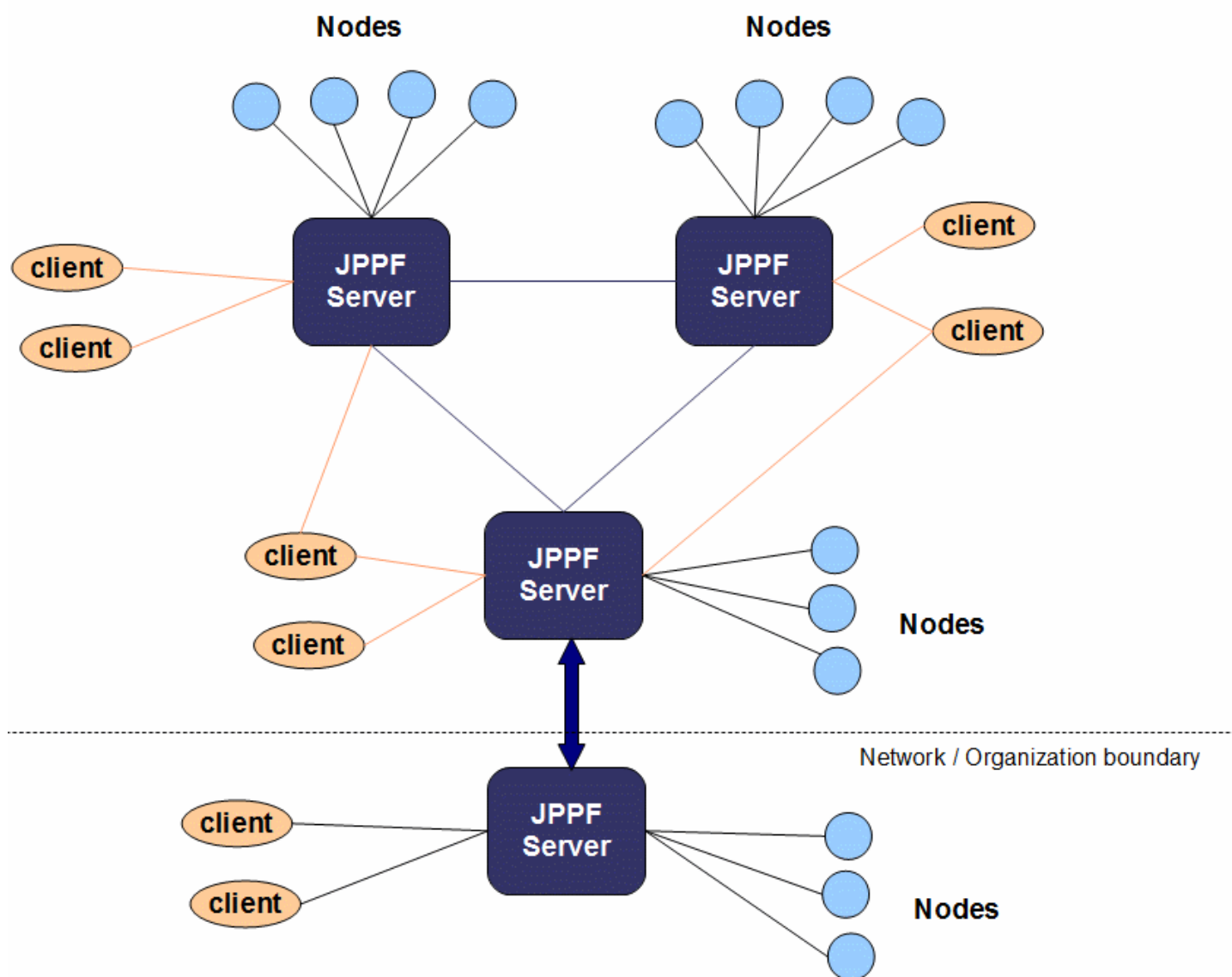
5.2 Reminder: JPPF topology

Before reviewing the details of each configuration property, it is useful to have the big picture of what we are configuring exactly. In a few words, a JPPF grid is made of clients (instances of your applications), servers and nodes. An application submits jobs to a server, and a server distributes the tasks in each job to its attached nodes. The simplest configuration you can have would be as illustrated in this picture:



We can see here that we have a single client communicating with one server, to which a single node is attached. In practice, there will be many nodes attached to the server, and many clients will be able to communicate with the server concurrently. It is also possible to link servers together, forming a peer-to-peer network of JPPF servers, allowing servers to delegate a part of their workload to other servers.

We could effectively build a much more complex JPPF network, such as the one in this picture:



The role of the configuration will be essentially to determine where each component can find the others, and how their interactions will be processed.

5.3 Configuring a JPPF server

5.3.1 Basic network configuration

The server network communication mechanism uses TCP/IP. To do its basic work of receiving jobs and dispatching them for execution, one TCP port is required:

In the configuration file, this property would be defined as follows, with its default value:

```
# JPPF server port
jppf.server.port = 11111
```

Notes:

- not defining this property is equivalent to assigning it its default value.
- dynamic port allocation: when the port number is set to 0, JPPF will dynamically allocate a valid port number. Note that this feature is mostly useful when server discovery is enabled.

Backward compatibility with JPPF v2.x: *To avoid too much disruption in applications configured for JPPF v2.x, JPPF will use the server port defined with the "old" property "class.server.port" if "jppf.server.port" is not defined.*

5.3.2 Server discovery

By default, JPPF nodes and clients are configured to automatically discover active servers on the network. This is made possible because, by default, a JPPF server will broadcast the required information (i.e. host address and port numbers) using the [UDP multicast](#) mechanism. This mechanism itself is configurable, by setting the following properties:

```
# Enable or disable automatic discovery of JPPF drivers
jppf.discovery.enabled = true
# UDP multicast group to which drivers broadcast their connection parameters
jppf.discovery.group = 230.0.0.1
# UDP multicast port to which drivers broadcast their connection parameters
jppf.discovery.port = 11111
# How long a driver should wait between 2 broadcasts, in milliseconds
jppf.discovery.broadcast.interval = 1000

# IPv4 address inclusion patterns
jppf.discovery.broadcast.include.ipv4 =
# IPv4 address exclusion patterns
jppf.discovery.broadcast.exclude.ipv4 =
# IPv6 address inclusion patterns
jppf.discovery.broadcast.include.ipv6 =
# IPv6 address exclusion patterns
jppf.discovery.broadcast.exclude.ipv6 =
```

The values indicated above are the default values. Note that, given the nature of the UDP protocol, the broadcast data is transient, and has to be re-sent at regular intervals to allow new nodes or clients to find the information. The broadcast interval property allows some control over the level of network traffic ("chattyness") thus generated.

The last four properties define inclusion and exclusion patterns for IPv4 and IPv6 addresses. Each of them defines a list of comma- or semicolon- separated patterns. For the syntax of the IPv4 patterns, please refer to the Javadoc for the class [IPv4AddressPattern](#), and to [IPv6AddressPattern](#) for IPv6 patterns syntax. This allows restricting the network interfaces on which to broadcast the server information: the server will only broadcast from the host's addresses that are included and not excluded.

5.3.3 Connecting to other servers

We have seen in section 5.2 that servers can connect to each other, up to a full-fledged peer-to-peer topology. When a server A connects to another server B, A will act as a node attached to B (from B's perspective). Based on this, there are 4 possible kinds of connectivity between 2 servers:

- A and B are not connected at all
- A is connected to B (i.e. A acts as a node attached to B)
- B is connected to A (i.e. B acts as a node attached to A)
- A and B are connected to each other

There are 2 ways to define a connection from a server to other servers on the network:

Using automatic discovery

In this scenario, we must enable the discovery of peer servers:

```
# Enable or disable auto-discovery of other peer servers (defaults to false)
jppf.peer.discovery.enabled = true
```

For this to work, the server broadcast must be enabled on the peer server(s), and the properties defined in the previous section 5.3.2 will be used, hence they must be set to the same values on the other server(s). A server can discover other servers without having to broadcast its own connection information (i.e. without being "discoverable").

Please note that the default value for the above property is "false". Setting the default to "true" would imply that each server would connect to all other servers accessible on the network, with a high risk of unwanted side effects.

Manual connection to peer servers

This will be best illustrated with an example configuration:

```
# define a space-separated list of peers to connect to
jppf.peers = server_1 server_2

# connection to server_1
jppf.peer.server_1.server.host = host_1
jppf.peer.server_1.server.port = 11111
# connection to server_2
jppf.peer.server_2.server.host = host_2
jppf.peer.server_2.server.port = 11111
```

To connect to each peer, we must define its IP address or host name as well as a port number. Please note that the value we have defined for "jppf.peer.server_1.server.port" must be the same as the one defined for "jppf.server.port" in server_1's configuration, and the value for "jppf.peer.server_1.server.port" must be equal to that of "jppf.server.port" in server_1's configuration.

Backward compatibility with JPPF v2.x: To avoid too much disruption in applications configured for JPPF v2.x, JPPF will use the server port defined with the "old" property "driver-1.class.server.port" if "driver-1.jppf.server.port" is not defined..

Using manual configuration and server discovery together

It is possible to use the manual configuration simultaneously with the discovery, by adding a special driver name, "jppf_discovery", to the list of manually configured peers:

```
# enable auto-discovery of other peer servers
jppf.peer.discovery.enabled = true
# specify both discovery and manually configured drivers
jppf.peers = jppf_discovery server_1
# connection to server_1
jppf.peer.server_1.server.host = host_1
jppf.peer.server_1.server.port = 11111
```

5.3.4 Socket connections idle timeout

In some environments, a firewall may be configured to automatically close socket connections that have been idle for more than a specified time. This may lead to a situation where a server may be unaware that a node or client was disconnected, and cause one or more jobs to never return. To remedy to that situation, it is possible to configure an idle timeout on either side of the connection, so that the connection can be closed cleanly and grid operations can continue unhindered. This is done via the following property:

```
jppf.socket.max-idle = timeout_in_seconds
```

If the timeout value is less than 10 seconds, then it is considered as no timeout. The default value is -1.

5.3.5 JMX management configuration

JPPF uses JMX to provide remote management capabilities for the servers, and uses the default JMXMP connector for communication.

The management features are enabled by default; this behavior can be changed by setting the following property:

```
# Enable or disable management of this server
jppf.management.enabled = true
```

When management is enabled, the following properties must be defined:

```
# JMX management host IP address. If not specified (recommended), the first non-local
# IP address (i.e. neither 127.0.0.1 nor localhost) on this machine will be used.
# If no non-local IP is found, localhost will be used.
jppf.management.host = localhost

# JMX management port, used by the remote JMX connector
jppf.management.port = 11198
```

Let's see in more details the usage of each of these properties:

- **jppf.management.host**: defines the host name or IP address for the remote management and monitoring of the servers and nodes. It represents the host where an RMI registry is running. When this property is not defined explicitly, JPPF will automatically fetch the first non-local IP address (meaning not the loopback address) it can find on the current host. If none is found, "localhost" will be used. This provides a way to use an identical configuration for all the servers on a network.
- **jppf.management.port**: defines the port number for connecting to the remote Mbean server. The default value for this property is "11198". If 2 nodes, 2 drivers or a driver and a node run on the same host, they must have a different value for this property.

Note: if a management port is already in use by another JPPF component or application, JPPF will automatically increment it, until it finds an available port number. This means that you can in fact leave the port numbers to their default values (or not specify them at all), as JPPF will automatically ensure that valid unique port numbers are used.

5.3.6 Load-balancing

The distribution of the tasks to the nodes is performed by the JPPF driver. This work is actually the main factor of the observed performance of the framework. It consists essentially in determining how many tasks will go to each node for execution, out of a set of tasks sent by the client application. Each set of tasks sent to a node is called a "bundle", and the role of the load balancing (or task scheduling) algorithm is to optimize the performance by adjusting the number of task sent to each node.

The algorithm to use is configured with the following property:

```
jppf.load.balancing.algorithm = <algorithm_name>
```

The algorithm name can be one of those predefined in JPPF, or a user-defined one. We will see how to define a custom algorithm in **Chapter 6 Extending JPPF** of this manual. JPPF now has 4 predefined load-balancing algorithms to compute the distribution of tasks to the nodes, each with its own configuration parameters. These algorithms are:

- "manual" : each bundle has a fixed number of tasks, meaning that each will receive at most this number of tasks
- "autotuned" : adaptive heuristic algorithm based on the [Monte Carlo](#) algorithm
- "proportional" : an adaptive deterministic algorithm based on the contribution of each node to the overall mean task execution time
- "rl" : adaptive algorithm based on an artificial intelligence technique called "[reinforcement learning](#)"
- "nodethreads" : each bundle will have at most $n * m$ tasks, where n is the number of threads in the node to which the bundle is sent, and m is a user-defined parameter

The predefined possible values for the property `jppf.load.balancing.algorithm` are thus: manual, autotuned, proportional, rl and nodethreads. If not specified, the algorithm defaults to manual. For example:

```
jppf.load.balancing.algorithm = proportional
```

In addition to the pre-defined algorithms, it is possible to define your own, as described in section **Extending and Customizing JPPF > Creating a custom load-balancer**.

Each algorithm uses its own set of parameters, which define together a *strategy* for the algorithm, It is also called a performance profile or simply profile, and we will use these terms interchangeably. A strategy has a name that serves to identify a group of parameters and their values, using the following pattern:


```
jppf.load.balancing.strategy = <profile_name>

strategy.<profile_name>.<parameter_1> = <value_1>
...
strategy.<profile_name>.<parameter_n> = <value_n>
```

Using this, you can define multiple profiles and easily switch from one to the other, by simple changing the value of `jppf.load.balancing.strategy`. It is also possible to mix, in a single profile, the parameters for multiple algorithms, however it is not recommended, as there may be name collisions.

To illustrate this, we will give a sample profile for each of the predefined algorithms:

“manual” algorithm

```
# algorithm name
jppf.load.balancing.algorithm = manual

# name of the set of parameter values or profile for the algorithm
jppf.load.balancing.strategy = manual_profile

# "manual" profile
strategy.manual_profile.size = 1
```

“autotuned” algorithm

```
# algorithm name
jppf.load.balancing.algorithm = autotuned

# name of the set of parameter values or profile for the algorithm
jppf.load.balancing.strategy = autotuned_profile

# "autotuned" profile
strategy.autotuned_profile.size = 5
strategy.autotuned_profile.minSamplesToAnalyse = 100
strategy.autotuned_profile.minSamplesToCheckConvergence = 50
strategy.autotuned_profile.maxDeviation = 0.2
strategy.autotuned_profile.maxGuessToStable = 50
strategy.autotuned_profile.sizeRatioDeviation = 1.5
strategy.autotuned_profile.decreaseRatio = 0.2
```

“proportional” algorithm

```
# algorithm name
jppf.load.balancing.algorithm = proportional

# name of the set of parameter values or profile for the algorithm
jppf.load.balancing.strategy = proportional_profile

# "proportional" profile
strategy.proportional_profile.initialSize = 5
strategy.proportional_profile.performanceCacheSize = 1000
strategy.proportional_profile.proportionalityFactor = 1
```

“rl” algorithm

```
# algorithm name
jppf.load.balancing.algorithm = rl

# name of the set of parameter values or profile for the algorithm
jppf.load.balancing.strategy = rl_profile

# "rl" profile
strategy.rl_profile.performanceCacheSize = 3000
strategy.rl_profile.performanceVariationThreshold = 0.001
```

“nodethreads” algorithm

```
# algorithm name
jppf.load.balancing.algorithm = nodethreads

# name of the set of parameter values or profile for the algorithm
jppf.load.balancing.strategy = nodethreads_profile

# means that multiplier * nbThreads tasks will be sent to each node
strategy.nodethreads_profile.multiplier = 1
```

5.3.7 Server process configuration

A JPPF server is in fact made of two processes: a “controller” process and a “server” process. The controller launches the server as a separate process and watches its exit code. If the exit code has a pre-defined value of 2, then it will restart the server process, otherwise it will simply terminate. This mechanism allows the remote (eventually delayed) restart of a server using the management APIs or the management console. It is also made such that, if any of the two processes dies unexpectedly, then the other process will die as well, leaving no lingering Java process in the OS.

The server process inherits the following parameters from the controller process:

- location of jppf configuration (-Djppf.config or -Djppf.config.plugin)
- current directory
- environment variables
- Java class path

It is possible to specify additional JVM parameters for the server process, using the configuration property jppf.jvm.options, as in this example:

```
jppf.jvm.options = -Xms64m -Xmx512m
```

Here is another example with remote debugging options:

```
jppf.jvm.options = -Xmx512m -server \  
-Xrunjdwp:transport=dt_socket,address=localhost:8000,server=y,suspend=n
```

It is possible to specify additional class path elements through this property, by adding one or more “-cp” or “-classpath” options (unlike the Java command which only accepts one). For example:

```
jppf.jvm.options = -cp lib/myJar1.jar:lib/myJar1.jar -Xmx512m \  
-classpath lib/external/externalJar.jar
```

5.3.8 Configuring a local node

Each JPPF driver is able to run a single node in its own JVM, called “local node”. The main advantage is that the communication between server and node is much faster, since the network overhead is removed. This is particularly useful if you intend to create a pure P2P topology, where all servers communicate with each other and only one node is attached to each server.

To enable a local node in the driver, use the following configuration property, which defaults to “false”:

```
jppf.local.node.enabled = true
```

Please note:

- the local node can be configured using the same properties as described in the [Node Configuration](#) section, except for the network-related properties, since no network is involved between driver and local node
- for the same reason, the SSL configuration does not apply to a local node

5.3.9 Recovery from hardware failures of nodes

Network disconnections due to hardware failures are notoriously difficult to detect, let alone recover from. JPPF implements a configurable mechanism that enables detecting such failures, and recover from them, in a reasonable time frame. This mechanism works as follows:

- the node establishes a specific connection to the server, dedicated to failure detection
- at connection time, a handshake protocol takes place, where the node communicates a unique id (UUID) to the server, that can be correlated to other connections for this node (i.e. job server and distributed class loader)

- at regular intervals (heartbeats), the server will send a very short message to the node, which it expects the node to acknowledge by sending a short response of its own
- if the node's response is not received in a specified time frame, and this, a specified number of times in a row, the server will consider the connection to the node broken, will close it cleanly, close the associated connections, and handle the recovery, such as requeuing tasks that were being executed by the node for execution on another node

In practice, the polling of the nodes is performed by a “reaper” object that will handle the querying of the nodes, using a pool of dedicated threads rather than one thread per node. This enables a higher scalability with a large number of nodes. The ability to specify multiple attempts at getting a response from the node is useful to handle situations where the network is slow, or when the node or server is busy with a high CPU utilization level. On the server side, the parameters of this mechanism are configurable via the following properties:

```
# Enable recovery from hardware failures on the nodes.
# Default value is false (disabled).
jppf.recovery.enabled = false
# Maximum number of attempts to get a response from the node before the
# connection is considered broken. Default value is 3.
jppf.recovery.max.retries = 3
# Maximum time in milliseconds allowed for each attempt to get a response
# from the node. Default value is 6000 (6 seconds).
jppf.recovery.read.timeout = 3000
# Dedicated port number for the detection of node failure.
# Default value is 22222.
jppf.recovery.server.port = 22222
# Interval in milliseconds between two runs of the connection reaper.
# Default value is 60000 (1 minute).
jppf.recovery.reaper.run.interval = 60000
# Number of threads allocated to the reaper.
# Default value is the number of available CPUs.
jppf.recovery.reaper.pool.size = 8
```

Note: if server discovery is active for a node, then the port number specified for the driver will override the one specified in the node's configuration.

5.3.10 Parallel I/O

The JPPF driver uses 2 pools of threads to perform network I/O with the nodes in parallel. One pool is dedicated to sending and receiving job data, the other is dedicated to the distributed class loader. There is a single configuration property that specifies the size of each of these pools:

```
transition.thread.pool.size = <number_of_io_threads>
```

When left unspecified, this property will take a default value equal to the number of processors available to the JVM (equivalent to `Runtime.getRuntime().availableProcessors()`).

5.3.11 Full server configuration file (default values)

To link all the parts together, here is a sample server configuration file that can be reused as is:

```
# port number for the server listens to for connections
jppf.server.port = 11111

# Enabling JMX features
jppf.management.enabled = true
# JMX management host IP address
#jppf.management.host = localhost
# JMX management port
jppf.management.port = 11198

# Enable/Disable automatic discovery of JPPF drivers
jppf.discovery.enabled = true
# UDP multicast group to which drivers broadcast their connection parameters
jppf.discovery.group = 230.0.0.1
# UDP multicast port to which drivers broadcast their connection parameters
jppf.discovery.port = 11111
# How long a driver should wait between 2 broadcasts, in milliseconds
jppf.discovery.broadcast.interval = 1000
# Enable/disable auto-discovery for peer-to-peer communication between drivers
jppf.peer.discovery.enabled = false
```

```
# Load-balancing algorithm
jppf.load.balancing.algorithm = proportional
# parameters profile name
jppf.load.balancing.strategy = proportional_profile

# "manual" profile
strategy.manual_profile.size = 1

# "proportional" profile
strategy.proportional_profile.initialSize = 5
strategy.proportional_profile.performanceCacheSize = 3000
strategy.proportional_profile.proportionalityFactor = 2

# "rl" profile
strategy.rl_profile.performanceCacheSize = 3000
strategy.rl_profile.performanceVariationThreshold = 0.001

# Other JVM options added to the java command line when the server is started
# as a subprocess. Multiple options are separated by spaces
jppf.jvm.options = -server -Xmx256m

# local node configuration
# enable the local (in-JVM) node
jppf.local.node.enabled = true
# number of processing threads for the local node
processing.threads = 4
```

5.4 Node configuration

5.4.1 Server discovery

By default, JPPF nodes are configured to automatically discover active servers on the network. As we have seen in 5.3.2, this is possible thanks to the UDP broadcast mechanism of the server. On the other end, the node needs to join the same UDP group to subscribe to the broadcasts from the server, which is done by configuring the following properties:

```
# Enable or disable automatic discovery of JPPF drivers
jppf.discovery.enabled = true

# UDP multicast group to which drivers broadcast their connection parameters
jppf.discovery.group = 230.0.0.1

# UDP multicast port to which drivers broadcast their connection parameters
jppf.discovery.port = 11111

# How long in milliseconds the node will attempt to automatically discover a driver
# before falling back to the manual configuration parameters
jppf.discovery.timeout = 5000
# IPv4 address inclusion patterns
jppf.discovery.include.ipv4 =
# IPv4 address exclusion patterns
jppf.discovery.exclude.ipv4 =
# IPv6 address inclusion patterns
jppf.discovery.include.ipv6 =
# IPv6 address exclusion patterns
jppf.discovery.exclude.ipv6 =
```

For the node to actually find a server on the network, the values for the group and port must be the same for a node and at least one server. If multiple servers are found on the network, the node will arbitrarily pick one.

Note the property `jppf.discovery.timeout`: it defines a fall back strategy that will cause the node to connect to the server defined in the manual configuration parameters (see 5.4.2) after the specified time.

The last four properties define inclusion and exclusion patterns for IPv4 and IPv6 addresses. Each of them defines a list of comma- or semicolon- separated patterns. For the syntax of the IPv4 patterns, please refer to the Javadoc for the class [IPv4AddressPattern](#), and to [IPv6AddressPattern](#) for IPv6 patterns syntax.

This enables filtering out unwanted IP addresses: the discovery mechanism will only allow addresses that are included and not excluded.

Let's take for instance the following pattern specifications:

```
jppf.discovery.include.ipv4 = 192.168.1.
jppf.discovery.exclude.ipv4 = 192.168.1.100-
```

The inclusion pattern only allows IP addresses in the range 192.168.1.0 ... 192.168.1.255

The exclusion pattern filters out IP addresses in the range 192.168.1.100 ... 192.168.1.255

Thus, we actually defined a filter that only accepts addresses in the range 192.168.1.0 ... 192.168.1.100

Instead of these 2 patterns, we could have simply defined the following equivalent inclusion pattern:

```
jppf.discovery.include.ipv4 = 192.168.1.0-99
```

5.4.2 Manual network configuration

If server discovery is disabled, network access to a server must be configured manually. To this effect, the node requires the address of host on which the server is running, and a TCP port, as shown in this example:

```
# IP address or host name of the server
jppf.server.host = my_host
# JPPF server port
jppf.server.port = 11111
```

Not defining these properties is equivalent to assigning them their default value (i.e. "localhost" for the host address, 11111 for the port number).

Backward compatibility with JPPF v2.x: To avoid too much disruption in applications configured for JPPF v2.x, JPPF will use the server port defined with the "old" property `class.server.port` if `jppf.server.port` is not defined.

5.4.3 Socket connections idle timeout

In some environments, a firewall may be configured to automatically close socket connections that have been idle for more than a specified time. This may lead to a situation where a server may be unaware that a node or client was disconnected, and cause one or more jobs to never return. To remedy to that situation, it is possible to configure an idle timeout on either side of the connection, so that the connection can be closed cleanly and grid operations can continue unhindered. This is done via the following property:

```
jppf.socket.max-idle = timeout_in_seconds
```

If the timeout value is less than 10 seconds, then it is considered as no timeout. The default value is -1.

5.4.4 JMX management configuration

JPPF uses JMX to provide remote management capabilities for the nodes, and uses the JMXMP connector for communication.

The management features are enabled by default; this behavior can be changed by setting the following property:

```
# Enable or disable management of this node
jppf.management.enabled = true
```

When management is enabled, the following properties must be defined:

```
# JMX management host IP address. If not specified (recommended), the first non-local
# IP address (i.e. neither 127.0.0.1 nor localhost) on this machine will be used.
# If no non-local IP is found, localhost will be used.
jppf.management.host = localhost

# JMX management port, used by the remote JMX connector
jppf.management.port = 11198
```

These properties have the same meaning and usage as for a server, as described in the [driver JMX configuration section](#).

5.4.5 Recovery and failover

When the connection to a server is interrupted, the node will automatically attempt, for a given length of time, and at regular intervals, to reconnect to the same server. These properties are configured as follows, with their default values:

```
# number of seconds before the first reconnection attempt
reconnect.initial.delay = 1

# time after which the system stops trying to reconnect, in seconds
# a value of zero or less means it never stops
reconnect.max.time = 60

# time between two connection attempts, in seconds
reconnect.interval = 1
```

With these values, we have configured the recovery mechanism such that it will attempt to reconnect to the server after a 1 second delay, for 60 seconds and with connection attempts at 1 second intervals.

5.4.6 Interaction of failover and server discovery

When discovery is enabled for the node (`jppf.discovery.enabled = true`) and the maximum reconnection time is not infinite (`reconnect.max.time = <strictly_positive_value>`), a sophisticated failover mechanism takes place, following the sequence of steps below:

- the node attempts to reconnect to the driver to which it was previously connected (or attempted to connect), during a maximum time specified by the configuration property `"reconnect.max.time"`
- during this maximum time, it will make multiple attempts to connect to the same driver. This covers the case when the driver is restarted in the mean time.
- after this maximum time has elapsed, it will attempt to auto-discover another driver, during a maximum time, specified via the configuration property `"jppf.discovery.timeout"` (in milliseconds)

- if the node still fails to reconnect after this timeout has expired, it will fall back to the driver manually specified in the node's configuration file
- the cycle starts again

5.4.7 Recovery from hardware failures

The mechanism to recover from hardware failure has its counterpart on each node, which works as follows:

- the node establishes a specific connection to the server, dedicated to failure detection
- at connection time, a handshake protocol takes place, where the node communicates a unique id (UUID) to the server
- the node will then attempt to get a message from the server (“check” message).
- if the message from the server is not received in a specified time frame, and this, a specified number of times in a row, the node will consider the connection to the server broken, will close it cleanly, and let the recovery and failover mechanism take over, as described in the [previous section](#).

The following configuration properties are those required by the nodes' hardware failure recovery mechanism implemented by the server:

```
# Enable recovery from hardware failures on the node. Default is false (disabled).
jppf.recovery.enabled = false

# Dedicated port number for the detection of node failure, must be the same as
# the value specified in the server configuration. Default value is 22222.
jppf.recovery.server.port = 22222

# Maximum number of attempts to get a message from the server before the
# connection is considered broken. Default value is 2.
jppf.recovery.max.retries = 2

# Maximum time in milliseconds allowed for each attempt to get a message
# from the server. Default value is 60000 (1 minute).
jppf.recovery.read.timeout = 60000
```

Note: if server discovery is active for a node, then the port number specified for the driver will override the one specified in the node's configuration.

5.4.8 Processing threads

A node can process multiple tasks concurrently, using a pool of threads. The size of this pool is configured as follows:

```
# number of threads running tasks in this node
processing.threads = 4
```

If this property is not defined, its value defaults to the number of processors or cores available to the JVM.

5.4.9 Node process configuration

In the same way as for a server (see 5.3.7 Server process configuration), the node is made of 2 processes. In addition to the properties and environment inherited from the controller process, it is possible to specify other JVM options via the following configuration property:

```
jppf.jvm.options = -Xms64m -Xmx512m
```

As for the server, it is possible to specify additional class path elements through this property, by adding one or more “-cp” or “-classpath” options (unlike the Java command which only accepts one). For example:

```
jppf.jvm.options = -cp lib/myJar1.jar:lib/myJar1.jar -Xmx512m
```

5.4.10 Class loader cache

Each node creates a specific class loader for each new client whose tasks are executed in that node. The cache itself is managed as a bounded queue, and the oldest class loader will be evicted from the cache whenever the maximum size is reached. The evicted class loader then becomes unreachable and can be garbage collected. In most modern JDKs, this also results in the classes being unloaded.

If the class loader cache size is too large, this can lead to an out of memory condition in the node, especially in these 2 scenarios:

- if too many classes are loaded, the space reserved to the class definitions (permanent generation in Oracle JDK) will fill up and cause an “OutOfMemoryError: PermGen space”
- if the classes hold a large amount of static data (via static fields and static initializers), an “OutOfMemoryError: Heap Space” will be thrown

To mitigate this, the size of the class loader cache can be configured in the node as follows:

```
jppf.classloader.cache.size = 50
```

The default value for this property is 50, and the value must be at least equal to 1.

5.4.11 Security policy

To limit what the nodes can do on the machine that hosts them, It is possible to specify what permissions are granted to them on their host. These permissions are based on the Java security policy model.

To implement security, nodes require a security policy file. The syntax of this file is similar to that of Java security policy files, except that it only accepts permission entries (no grant or security context entries).

Some examples of permission entries:

```
// permission to read, write, delete node log file in current directory
permission java.io.FilePermission "${user.dir}/jppf-node.log", "read,write,delete";
// permission to read all log4j system properties
permission java.util.PropertyPermission "log4j.*", "read";
// permission to connect to a MySQL database on the default port on localhost
permission java.net.SocketPermission "localhost:3306", "connect,listen";
```

To enable the security policy, the node configuration file must contain the following property definition:

```
# Path to the security file, relative to the current directory or classpath
jppf.policy.file = jppf.policy
```

When this property is not defined, or the policy file cannot be found, security is disabled.

The policy file does not have to be local to the node. If it is not present locally, the node will download it from the server. In this case it has to be locally accessible by the server, and the path to the policy file will be interpreted as path on the server's file system. This feature, combined with the ability to remotely restart the nodes, allows to easily update and propagate changes to the security policy for all the nodes.

5.4.12 Full node configuration file (default values)

```
# Host name, or ip address, of the host the JPPF driver is running on
jppf.server.host = localhost

# JPPF server port number
jppf.server.port = 11111

# Enabling JMX features
jppf.management.enabled = true

# JMX management host IP address
#jppf.management.host = localhost

# JMX management port
jppf.management.port = 12001

# path to the JPPF security policy file
#jppf.policy.file = config/jppf.policy

# Enable/Disable automatic discovery of JPPF drivers
jppf.discovery.enabled = true

# UDP multicast group to which drivers broadcast their connection parameters
jppf.discovery.group = 230.0.0.1
# UDP multicast port to which drivers broadcast their connection parameters
jppf.discovery.port = 11111
# How long the node will attempt to automatically discover a driver before
# falling back to the parameters specified in this configuration file
jppf.discovery.timeout = 5000

# Automatic recovery: number of seconds before the first reconnection attempt
reconnect.initial.delay = 1

# Time after which the system stops trying to reconnect, in seconds
reconnect.max.time = 5

# Automatic recovery: time between two connection attempts, in seconds
reconnect.interval = 1

# Processing Threads: number of threads running tasks in this node
#processing.threads = 1

# Other JVM options added to the java command line when the node is started as
# a subprocess. Multiple options are separated by spaces
jppf.jvm.options = -server -Xmx256m

# size of the node's class loader cache
jppf.classloader.cache.size = 10
```

5.5 Client and administration console configuration

5.5.1 Server discovery

By default, JPPF clients are configured to automatically discover active servers on the network. This mechanism works in the same way as for the nodes, and uses the same configuration properties, except for the discovery timeout:

```
# Enable or disable automatic discovery of JPPF drivers
jppf.discovery.enabled = true

# UDP multicast group to which drivers broadcast their connection parameters
jppf.discovery.group = 230.0.0.1

# UDP multicast port to which drivers broadcast their connection parameters
jppf.discovery.port = 11111

# IPv4 address inclusion patterns
jppf.discovery.include.ipv4 =

# IPv4 address exclusion patterns
jppf.discovery.exclude.ipv4 =

# IPv6 address inclusion patterns
jppf.discovery.include.ipv6 =

# IPv6 address exclusion patterns
jppf.discovery.exclude.ipv6 =
```

A major difference is that, when discovery is enabled, the client does not stop attempting to find one or more servers. A client can also connect to multiple servers, and will effectively connect to every server it discovers on the network.

A client can also create multiple connections to each discovered server, effectively creating a connection pool that can be used for concurrent job submissions. The size of the connection pools is configured with the following property:

```
# connection pool size for each discovered server; defaults to 1 (single connection)
jppf.pool.size = 5
```

Each server connection has an assigned name, following the pattern: “driver-<n>[-<p>]”, where n is a driver number, in order of discovery, and the optional p is the connection number, if the defined connection pool size is greater than 1.

For instance:

- if we defined `jppf.pool.size = 1`, the first discovered driver will have 1 connection named “driver-1”
- if we defined `jppf.pool.size = 2`, the first discovered driver will have 2 connections named “driver-1-1” and “driver-1-2”

The inclusion and exclusion pattern definitions work exactly in the same way as for the node configuration. Please refer to section 5.4.1 for more details.

Additionally, it is possible to specify the behavior to adopt, when a driver broadcasts its connection information for multiple network interfaces. In this case, the client may end up creating multiple connections to the same driver, but with different IP addresses. This default behavior can be disabled by setting the following property:

```
# enable or disable multiple network interfaces for each driver
jppf.pool.acceptMultipleInterfaces = false
```

This property is set to `false` by default, meaning that only the first discovered interface for a driver will be taken into account.

5.5.2 Manual network configuration

As we have seen, a JPPF client can connect to multiple drivers. The first step will this be to name these drivers:

```
# space-separated list of drivers this client may connect to
# defaults to "default-driver"
jppf.drivers = driver-1 driver-2
```

Then for each driver, we will define the connection and behavior attributes, including:

Connection to the JPPF server

```
# host name, or ip address, of the host the JPPF driver is running on
driver-1.jppf.server.host = localhost
# port number for the on which the driver accepts connections
driver-1.jppf.server.port = 11111
```

Here, `driver-1.class.server.port` and `driver-1.app.server.port` must have the same value as the corresponding properties `class.server.port` and `app.server.port` defined in the server configuration.

Backward compatibility with JPPF v2.x: *To avoid too much disruption in applications configured for JPPF v2.x, JPPF will use the server port defined with the “old” property “driver-1.class.server.port” if “driver-1.jppf.server.port” is not defined.*

Connection pool size

```
# size of the pool of connections to this driver
driver-1.jppf.pool.size = 5
```

This allows the creation of a connection pool with a specific size for each server we connect to, whereas all pools would have the same size when server discovery is enabled.

Priority

```
# assigned driver priority
driver-1.priority = 10
```

The priority assigned to a server connection enables the definition of a fallback strategy for the client. In effect, the client will always use connections that have the highest priority. If the connection with the server is interrupted, then the client we use connections with the next highest priority in the remaining accessible server connection pools.

Connection to the management server

```
# management host for this driver
driver-1.jppf.management.host = localhost
# management port for this driver
driver-1.jppf.management.port = 11198
```

This will allow direct access to the driver's JMX server using the client APIs, unless the client configuration property `jppf.management.enabled` is set to `false`.

5.5.3 Using manual configuration and server discovery together

It is possible to use the manual server configuration simultaneously with the server discovery, by adding a special driver name, “`jppf_discovery`” to the list of manually configured drivers:

```
# enable discovery
jppf.discovery.enabled = true
# specify both discovery and manually configured drivers
jppf.drivers = jppf_discovery driver-1
# host for this driver
driver-1.jppf.server.host = my_host
# port for this driver
driver-1.jppf.server.port = 11111
```

5.5.4 Recovery and failover

As for the nodes, when the connection to a server is interrupted, the client will automatically attempt to reconnect to the same server. This is configured as follows, with the default values:

```
# number of seconds before the first reconnection attempt
reconnect.initial.delay = 1

# time after which the system stops trying to reconnect, in seconds
# a value of zero or less means it never stops
```

```
reconnect.max.time = 60

# time between two connection attempts, in seconds
reconnect.interval = 1
```

With these values, we have configured the recovery mechanism such that it will attempt to reconnect to the server after a 1 second delay, for 60 seconds and with connection attempts at 1 second intervals.

5.5.5 Socket connections idle timeout

In some environments, a firewall may be configured to automatically close socket connections that have been idle for more than a specified time. This may lead to a situation where a server may be unaware that a node or client was disconnected, and cause one or more jobs to never return. To remedy to that situation, it is possible to configure an idle timeout on either side of the connection, so that the connection can be closed cleanly and grid operations can continue unhindered. This is done via the following property:

```
jppf.socket.max-idle = timeout_in_seconds
```

If the timeout value is less than 10 seconds, then it is considered as no timeout. The default value is -1.

5.5.6 Local and remote execution

It is possible for a client to execute jobs locally (i.e. in the client JVM) rather than by submitting them to a server. This feature allows taking advantage of multiple CPUs or cores on the client machine, while using the exact same APIs as for a distributed remote execution. It can also be used for local testing and debugging before performing the “real-life” execution of a job.

Local execution is disabled by default. To enable it, set the following configuration property:

```
# enable local job execution; defaults to false
jppf.local.execution.enabled = true
```

Local execution uses a pool of threads, whose size is configured as follows:

```
# number of threads to use for local execution
# the default value is the number of CPUs or cores available to the JVM
jppf.local.execution.threads = 4
```

It is also possible to mix local and remote execution. This will happen whenever the client is connected to a server and has local execution enabled. In this case, the JPPF client uses an adaptive load-balancing algorithm to balance the workload between local execution and node-side execution.

Finally, the JPPF client also provides the ability to disable remote execution. This can be useful if you want to test the execution of jobs purely locally, even if the server discovery is enabled or the server connection properties would otherwise point to a live JPPF server. To achieve this, simply configure the following:

```
# enable remote job execution; defaults to true
jppf.remote.execution.enabled = false
```

5.5.7 Local execution flow

You can specify how frequently you wish to receive notification of locally executed tasks, using either or both of the following parameters:

```
# specifies for how many completed tasks to wait until a notification is sent
jppf.local.execution.accumulation.size = 4

# specifies how long to wait before a notification is sent
# (if any task has completed)
jppf.local.execution.accumulation.time = 100
# Specifies the time unit:
#   n = nanoseconds      M = minutes
#   m = milliseconds     h = hours
#   s = seconds          d = days
jppf.local.execution.accumulation.unit = m
```

If both accumulation time and size are used at the same time, a notification will be sent whenever the size is reached, or the time is reached, whichever happens first. If neither is specified, the tasks will be returned all at once.

5.5.8 Load-balancing in the client

The JPPF client allows load balancing between local and remote execution. The load balancing configuration is exactly the same as for the driver, which means it uses exactly the same configuration properties, algorithms, parameters, etc... Please refer to the [driver load-balancing configuration](#) section for the configuration details. The default configuration, if none is provided, is equivalent to the following:

```
# name of the load balancing algorithm
jppf.load.balancing.algorithm = proportional
# name of the set of parameter values (aka profile) to use for the algorithm
jppf.load.balancing.strategy = test
# "proportional" profile
strategy.test.performanceCacheSize = 2000
strategy.test.proportionalityFactor = 1
strategy.test.initialSize = 10
strategy.test.initialMeanTime = 1e9
```

Also note that the load balancing is active even if only remote execution is available. This has an impact on how tasks within a job will be sent to the server. For instance, if the “manual” algorithm is configured, with a size of 1, this means the tasks in a job will be sent one at a time.

5.5.9 Full client configuration file (default values)

```
# list of drivers this client may connect to
jppf.drivers = driver-1 driver-2

# host name, or ip address, of the host the JPPF driver is running on
driver-1.jppf.server.host = localhost
# port number for the class server that performs remote class loading
driver-1.jppf.server.port = 11111
# priority given to the driver connection
driver-1.priority = 0
# connection pool size
driver-1.jppf.pool.size = 1

# host name for the management server
driver-1.jppf.management.host = localhost
# port number for the management server
driver-1.jppf.management.port = 11198

# configuration for driver-2
driver-2.jppf.server.host = my.host.com
driver-2.jppf.server.port = 11121
driver-2.jppf.management.port = 12003
driver-2.priority = 10
driver-2.jppf.pool.size = 1

# enable/disable automatic discovery of JPPF drivers
jppf.discovery.enabled = true
# UDP multicast group to which drivers broadcast their connection parameters
jppf.discovery.group = 230.0.0.1
# UDP multicast port to which drivers broadcast their connection parameters
jppf.discovery.port = 11111

# automatic recovery: number of seconds before the first reconnection attempt
reconnect.initial.delay = 1
# time after which the system stops trying to reconnect, in seconds
reconnect.max.time = 5
# automatic recovery: time between two connection attempts, in seconds
reconnect.interval = 1

# enable/disable local job execution; defaults to false
jppf.local.execution.enabled = false
# number of threads to use for local execution
jppf.local.execution.threads = 4
# specifies for how many completed tasks to wait before a notification is sent
jppf.local.execution.accumulation.size = 4
# how long to wait before a notification is sent
```

```
jppf.local.execution.accumulation.time = 100
# the time unit
jppf.local.execution.accumulation.unit = m

# name of the load balancing algorithm
jppf.load.balancing.algorithm = proportional
# name of the set of parameter values (aka profile) to use for the algorithm
jppf.load.balancing.strategy = test
# "proportional" profile
strategy.test.performanceCacheSize = 2000
strategy.test.proportionalityFactor = 1
strategy.test.initialSize = 10
strategy.test.initialMeanTime = 1e9
```

5.6 Configuring SSL/TLS communications

A JPPF grid has the ability to use secure connections between its components. This is done by using the SSL/TLS protocols over network connections, and provides security services such as peer authentication, data encryption and data integrity. This documentation aims at describing how to configure secure connections between JPPF servers, nodes and clients. If you wish to learn details of the SSL/TLS protocols in Java, our recommendation is to read about this in the [Java Secure Socket Extension \(JSSE\) Reference Guide](#).

Additionally, all downloadable JPPF components now come with a predefined set of SSL configuration files, which can be used *as-is for testing purposes*. These files notably include a truststore and a keystore containing self-signed certificates and private keys. For real-world secure connectivity in JPPF, you will have to provide your own key- and trust- stores, with the proper certificate chains, validated by trusted certificate authorities.

5.6.1 Enabling secure connectivity

5.6.1.1 In the nodes and clients

Nodes and clients use either secure connections, or non-secure connections, but not both at the same time. Thus, this is determined from a single configuration property in their respective configuration file:

```
# Enable SSL. Default value is false (disabled).
# If enabled, only SSL/TLS connections are established
jppf.ssl.enabled = true
```

For a node, this also means that its embedded JMX server will only accept secure connections. Apart from the SSL configuration itself, no other properties are required to enable secure connections: the hosts and ports defined in the configuration or via server discovery will be assumed to be secure. If they are not, no connection will be possible.

5.6.1.2 In the servers

A JPPF server has the ability to accept both secure and non-secure connections, i.e. this is not a single on/off switch as for nodes and clients. Additionally, there are 3 areas of a JPPF server that can be configured separately: “standard” connections from nodes and clients (grid jobs handling and distributed class loader), connections to other servers and embedded JMX server. These are configured via the following properties in the server's configuration file:

```
# Port number to which the server listens for secure connections, defaults to 11443
# A negative value indicates that no secure connection is accepted
jppf.ssl.server.port = 11443

# toggle to enable secure connections to remote peer servers, defaults to false
jppf.peer.ssl.enabled = true

# Enabling JMX features via secure connections, defaults to false
jppf.management.ssl.enabled = true
```

Please note that `jppf.ssl.server.port` (secure port) comes in addition to `jppf.server.port` (non secure) and that both can be used together. For instance, if you wish to only accept secure connections, you will have to disable the non-secure connection by specifying a negative port number:

```
# disable non-secure connections
jppf.server.port = -1
# enable secure connections
jppf.ssl.server.port = 11443
```

As for the non-secure port, assigning a value of 0 will cause JPPF to dynamically allocate a valid port number.

In a similar way you can use either JMX secure or non-secure connections, or both:

```
# Enabling JMX via non-secure connections, defaults to true
jppf.management.enabled = false
# Enabling JMX via secure connections, defaults to false
jppf.management.ssl.enabled = true
# Secure JMX server port
jppf.management.ssl.port = 11193
```

5.6.2 Locating the SSL configuration

The SSL configuration is loaded separately from the JPPF configuration itself. The effect of this is that it is harder to find for a remote application, and it will not appear in the JPPF monitoring tools and APIs, the goal being to avoid providing information about how JPPF is secured, which would defeat the purpose of securing it in the first place.

5.6.2.1 Configuration as a file or classpath resource

To specify the location of the SSL configuration as a file, you can use the `jppf.ssl.configuration.file` property in the JPPF configuration file of the driver, node or client:

```
# location of the SSL configuration in the file system or classpath
jppf.ssl.configuration.file = config/ssl/ssl.properties
```

The lookup for the specified file or resource is performed first in the file system, then in the classpath. This allows you for instance to embed a configuration file in a jar file, with the possibility to override it with another file.

Relative paths are relative to the current working directory as specified by `System.getProperty("user.dir")`.

5.6.2.2 Configuration as an external source

JPPF provides a more sophisticated way to locate its SSL configuration, which requires the implementation of a specific plugin. This is useful in situations where a configuration file is not considered secure enough, or if you need to load the configuration from a centralized location, for instance if you run JPPF in a cloud environment and want to fetch the configuration via a cloud storage facility such as Amazon's S3.

This is done via the `jppf.ssl.configuration.source` property:

```
# SSL configuration as an arbitrary source. Value is the fully qualified name
# of an implementation of java.util.concurrent.Callable<InputStream> with optional
# space-separated arguments
jppf.ssl.configuration.source = implementation_of_Callable<InputStream> arg1 ... argN
```

where `implementation_of_Callable<InputStream>` is the fully qualified name of a class which implements the interface [Callable<InputStream>](#) and which must have either a noarg constructor, or a (String...args) vararg constructor.

For example, the predefined JPPF plugin [FileStoreSource](#) is implemented as follows:

```
package org.jppf.ssl;

import java.io.InputStream;
import java.util.concurrent.Callable;
import org.jppf.utils.FileUtils;

// A secure store source that uses a file as source
public class FileStoreSource implements Callable<InputStream> {

    // Optional arguments that may be specified in the configuration
    private final String[] args;

    public FileStoreSource(final String... args) throws Exception {
        this.args = args;
        if ((args == null) || (args.length == 0))
            throw new SSLConfigurationException("missing parameter: file path");
    }

    @Override
    public InputStream call() throws Exception {
        // lookup in the file system, then in the classpath
        InputStream is = FileUtils.getFileInputStream(args[0]);
        if (is == null)
            throw new SSLConfigurationException("could not find file " + args[0]);
        return is;
    }
}
```

We can then use it in the configuration:

```
jppf.ssl.configuration.source = org.jppf.ssl.FileStoreSource config/ssl/ssl.properties
```


which is in fact equivalent to:

```
jppf.ssl.configuration.file = config/ssl/ssl.properties
```

5.6.3 SSL configuration properties

These properties are defined in the SSL configuration file and represent the information required to create and initialize [SSLContext](#), [SSLSocket](#) and [SSLEngine](#) objects.

5.6.3.1 SSLContext protocol

This is the protocol name used in [SSLContext.getInstance\(String protocol\)](#). It is defined as:

```
# SSLContext protocol, defaults to SSL
jppf.ssl.context.protocol = SSL
```

A list of valid protocol names is available [here](#).

5.6.3.2 Enabled protocols

This is the list of supported protocol versions, such as returned by [SSLEngine.getEnabledProtocols\(\)](#). It is defined as a list of space-separated names:

```
# list of space-separated enabled protocols
jppf.ssl.protocols = SSLv2Hello SSLv3
```

A list of valid protocol versions is available [here](#).

5.6.3.3 Enabled cipher suites

This is the list of supported protocol versions, such as returned by [SSLEngine.getEnabledCipherSuites\(\)](#). It is defined as a list of space-separated names:

```
# enabled cipher suites as a list of space-separated values
jppf.ssl.cipher.suites = SSL_RSA_WITH_RC4_128_MD5 SSL_RSA_WITH_RC4_128_SHA
```

A list of supported cipher suites is available [here](#).

5.6.3.4 Client authentication

The client authentication mode is determined by calling the methods [SSLEngine.getWantClientAuth\(\)](#) and [SSLEngine.getNeedClientAuth\(\)](#). It is defined as:

```
# client authentication mode
# possible values: none | want | need
jppf.ssl.client.auth = none
```

5.6.3.5 Key store and associated password

As for the location of the SSL configuration, there are two ways to specify the location of a keystore:

```
# path to the key store on the file system
jppf.ssl.keystore.file = config/ssl/keystore.ks
# an implementation of Callable<InputStream> with optional space-separated arguments
jppf.ssl.keystore.source = org.jppf.ssl.FileStoreSource config/ssl/keystore.ks
```

Note that, if both properties are defined, JPPF will first attempt to load the key store from the defined source, then from the specified file path.

In a similar fashion, there are two ways to specify the key store's password: either as a clear text password, or as a password source. This can be done as follows:

```
# keystore password in clear text
jppf.ssl.keystore.password = password
# keystore password from an arbitrary source
# the source is an implementation of Callable<char[]> with optional parameters
jppf.ssl.keystore.password.source = org.jppf.ssl.PlainTextPassword password
```

5.6.3.6 Trust store and associated password

The trust store and its password are defined in the same way as for the key store:

```
# path to the trust store on the file system
jppf.ssl.truststore.file = config/ssl/truststore.ks
# an implementation of Callable<InputStream> with optional space-separated arguments
jppf.ssl.truststore.source = org.jppf.ssl.FileStoreSource config/ssl/truststore.ks

# keystore password in clear text
jppf.ssl.truststore.password = password
# keystore password from an arbitrary source
# the source is an implementation of Callable<char[]> with optional parameters
jppf.ssl.truststore.password.source = org.jppf.ssl.PlainTextPassword password
```

5.6.4 Full SSL configuration example

```
# SSLContext protocol, defaults to SSL
jppf.ssl.context.protocol = SSL
# list of space-separated enabled protocols
jppf.ssl.protocols = SSLv2Hello SSLv3
# enabled cipher suites as a list of space-separated values
jppf.ssl.cipher.suites = SSL_RSA_WITH_RC4_128_MD5 SSL_RSA_WITH_RC4_128_SHA
# client authentication mode; possible values: none | want | need
jppf.ssl.client.auth = none

# path to the key store on the file system.
jppf.ssl.keystore.file = config/ssl/keystore.ks
# keystore password in clear text
jppf.ssl.keystore.password = password

# the trust store location as an arbitrary source:
# an implementation of Callable<InputStream> with optional space-separated arguments
jppf.ssl.truststore.source = org.jppf.ssl.FileStoreSource config/ssl/truststore.ks
# truststore password as an arbitrary source:
# an implementation of Callable<char[]> with optional space-separated arguments
jppf.ssl.truststore.password.source = org.jppf.ssl.PlainTextPassword password
```

6 Management and monitoring

Management and monitoring are important parts of a grid platform. With these features it is possible to observe the health and status of the grid components, and directly or remotely transform their behavior.

JPPF provides a comprehensive set of monitoring and management functionalities, based on the [Java Management Extensions \(JMX\)](#) standard. In addition to this, a set of APIs enables a simplified access to the management functions, whether locally or remotely.

Management and monitoring functions are available for JPPF servers and nodes and provided as MBeans. We will see these MBeans in detail and then look at the APIs to access them.

All JPPF MBeans are standard MBeans registered with the [platform MBean server](#). This means, among other things, that they can be accessed through external JMX-based applications or APIs, such as [VisualVM](#).

6.1 Node management

Out of the box in JPPF, each node provides 2 MBeans that can be accessed remotely using a JMXMP remote connector with the JMX URL “`service:jmx:jmxmp://host:port`”, where *host* is the host name or IP address of the machine where the node is running (value of “`jppf.management.host`” in the node configuration file), and *port* is the value of the property “`jppf.management.port`” specified in the node's configuration file.

6.1.1 Node-level management and monitoring MBean

MBean name: “**org.jppf:name=admin,type=node**”

This is also the value of the constant [JPPFNodeAdminMBean.MBEAN_NAME](#).

This MBean's role is to perform management and monitoring at the node level, however we will see that it also has (for historical reasons) some task-level management functions. It exposes the [JPPFNodeAdminMBean](#) interface, which provides the functionalities described hereafter.

6.1.1.1 Getting a snapshot of the node's state

This is done by invoking the following method on the MBean:

```
public interface JPPFNodeAdminMBean extends JPPFAdminMBean {
    // Get the latest state information from the node.
    public JPPFNodeState state() throws Exception;
}
```

This method returns a [JPPFNodeState](#) object, which provides the following information on the node:

```
public class JPPFNodeState implements Serializable {
    // the status of the connection with the server
    public String getConnectionStatus()

    // the current task execution status
    public String getExecutionStatus()

    // the cpu time consumed by the node's execution threads
    // this includes the tasks cpu time and some JPPF processing overhead
    public long getCpuTime()

    // the total number of tasks executed
    public int getNbTasksExecuted()

    // the current size of the pool of threads used for tasks execution
    public int getThreadPoolSize()

    // the current priority assigned to the execution threads
    public int getThreadPriority()
}
```

6.1.1.2 Updating the execution thread pool properties

```
public interface JPPFNodeAdminMBean extends JPPFAdminMBean {
    // Set the size of the node's execution thread pool.
    public void updateThreadPoolSize(Integer size) throws Exception;

    // Update the priority of all execution threads.
    public void updateThreadsPriority(Integer newPriority) throws Exception;
}
```

6.1.1.3 Shutting down and restarting the node

```
public interface JPPFNodeAdminMBean extends JPPFAdminMBean {
    // Restart the node.
    public void restart() throws Exception;

    // Shutdown the node.
    public void shutdown() throws Exception;
}
```

These two methods should be used with precautions. Please note that, once `shutdown()` has been invoked, it is not possible anymore to restart the node remotely.

When any of these methods is invoked, the tasks that were being executed, if any, are automatically resubmitted to the server queue.

6.1.1.4 Updating the executed tasks counter

```
public interface JPPFNodeAdminMBean extends JPPFAdminMBean {
    // Reset the node's executed tasks counter to zero.
    public void resetTaskCounter() throws Exception;

    // Reset the node's executed tasks counter to the specified value.
    public void setTaskCounter(Integer n) throws Exception;
}
```

Please note that `resetTaskCounter()` is equivalent to `setTaskCounter(0)`.

6.1.1.5 Getting information about the node's host

```
public interface JPPFAdminMBean extends Serializable {
    // Get detailed information about the node's JVM properties, environment variables,
    // memory usage, available processors and available storage space.
    JPPFSystemInformation systemInformation() throws Exception;
}
```

This method returns an object of type [JPPFSystemInformation](#), which is a snapshot of the environment of the JPPF node, the JVM and the host they run on. The properties defined in this object are also those used by execution policies, as we have seen in section 3.4.1 of this manual.

`JPPFSystemInformation` provides information about 6 different aspects of the environment:

```
public class JPPFSystemInformation implements Serializable {
    // get the system properties
    public TypedProperties getSystem\(\)
    // get runtime information about JVM memory and available processors
    public TypedProperties getRuntime\(\)
    // get the host environment variables
    public TypedProperties getEnv\(\)
    // get IPV4 and IPV6 addresses assigned to the host
    public TypedProperties getNetwork\(\)
    // get the JPPF configuration properties
    public TypedProperties getJppf\(\)
    // get information on available disk storage
    public TypedProperties getStorage\(\)
}
```

We encourage the reader to follow the links to the above methods' Javadoc, to obtain details on each set of information,

and how the information is formatted and named.

Each of the methods in `JPPFSystemInformation` returns a [TypedProperties](#) object. `TypedProperties` is a subclass of the standard [java.util.Properties](#) that provides convenience methods to read property values as primitive types other than String.

6.1.1.6 Canceling a job

```
public interface JPPFAdminMBean extends Serializable {
    // Cancel the job with the specified uuid. The requeue parameters determines
    // whether the job should be requeued on the server side or not.
    public void cancelJob(String jobId, Boolean requeue) throws Exception;
}
```

This MBean method is used to cancel a job currently running in the node. The job is identified by its `jobId`. The `requeue` parameter is used to notify the server that the canceled job should be requeued on the server and executed again, possibly on an other node. If `requeue` is false, the job is simply terminated and any remaining task will not be executed.

This method should normally only be used by the JPPF server, in the case where a user requested that the server terminates a job. In effect, a job can contain several tasks, with each task potentially executed concurrently on a separate node. When the server receives a job termination request, it will handle the termination of “sub-jobs” (i.e. subsets of the tasks in the job) by notifying each corresponding node.

6.1.1.7 Updating the node's configuration properties

```
public interface JPPFAdminMBean extends Serializable {
    // Update the configuration properties of the node. The reconnect parameter
    // specifies whether the node should disconnect then reconnect to the driver
    // after updating the properties.
    void updateConfiguration(Map<String, String> config, Boolean reconnect)
        throws Exception;
}
```

This method sends a set of configuration properties to the node, that will override those defined in the node's configuration file. The `reconnect` parameter will allow the node to take the changes into account, especially in the case where the server connection or discovery properties have been changed, for instance to force the node to connect to another server without having to stop it.

6.1.2 Task-level monitoring

MBean name : “`org.jppf:name=task.monitor,type=node`”.

This is also the value of the constant [JPPFNodeTaskMonitorMBean.MBEAN_NAME](#)

This MBean monitors the task activity within a node. It exposes the interface [JPPFNodeTaskMonitorMBean](#) and also emits JMX notifications of type [TaskExecutionNotification](#).

6.1.2.1 Snapshot of the tasks activity

The interface [JPPFNodeTaskMonitorMBean](#) provides access to aggregated statistics on the tasks executed within a node:

```
public interface JPPFNodeTaskMonitorMBean extends NotificationEmitter {
    // The total number of tasks executed by the node
    Integer getTotalTasksExecuted();

    // The total number of tasks that ended in error
    Integer getTotalTasksInError();

    // The total number of tasks that executed successfully
    Integer getTotalTasksSuccessful();

    // The total cpu time used by the tasks in milliseconds
    Long getTotalTaskCpuTime();

    // The total elapsed time used by the tasks in milliseconds
    Long getTotalTaskElapsedTime();
}
```

6.1.2.2 Notification of tasks execution

Each time a task completes its execution in a node, the task monitor MBean will emit a JMX notification of type [TaskExecutionNotification](#) defined as follows:

```
public class TaskExecutionNotification extends Notification {
    // Get the object encapsulating information about the task
    public TaskInformation getTaskInformation();
}
```

This notification essentially encapsulates an object of type [TaskInformation](#), which provides the following information about each executed task:

```
public class TaskInformation implements Serializable {
    // Get the task id
    public String getId()

    // Get the uuid of the job this task belongs to
    public String getJobId()

    // Get the cpu time used by the task
    public long getCpuTime()

    // Get the wall clock time used by the task
    public long getElapsedTime()

    // Determines whether the task had an exception
    public boolean hasError()

    // Get the timestamp for the task completion. Caution: this value is related
    // to the node's system time, not to the time of the notification receiver
    public long getTimestamp()
}
```

6.1.3 Accessing and using the node MBeans

JPPF provides an API that simplifies access to the JMX-based management features of a node, by abstracting most of the complexities of JMX programming. This API is represented by the class [JMXNodeConnectionWrapper](#), which provides a simplified way of connecting to the node's MBean server, along with a set of convenience methods to easily access the MBeans' exposed methods and attributes.

6.1.3.1 Connecting to an MBean server

Connection to a node MBean server is done in two steps:

a. Create an instance of JMXNodeConnectionWrapper

To connect to a **local** (same JVM, no network connection involved) MBean server, use the no-arg constructor:

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper();
```

To connect to a **remote** MBean server, use the constructor specifying the management host and port:

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
```

Here `host` and `port` represent the node's configuration properties "jppf.management.host" and "jppf.management.port"

b. Initiate the connection to the MBean server and wait until it is established

There are two ways to do this:

Synchronously:

```
// connect and wait for the connection to be established
// choose a reasonable value for the timeout, or 0 for no timeout
wrapper.connectAndWait(timeout);
```

Asynchronously:

```
// initiate the connection; this method returns immediately
wrapper.connect();
```

```
// ... do something else ...

// check if we are connected
if (wrapper.isConnected()) ...;
else ...;
```

6.1.3.2 Direct use of the JMX wrapper

JMXNodeConnectionWrapper implements directly the interface JPPFNodeAdminMBean. This means that all the methods of this interface can be used directly from the JMX wrapper. For example:

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);

// get the number of tasks executed since the last reset
int nbTasks = wrapper.state().getNbTasksExecuted();
// stop the node
wrapper.shutdown();
```

6.1.3.3 Use of the JMX wrapper's invoke() method

[JMXConnectionWrapper.invoke\(\)](#) is a generic method that allows invoking any exposed method of an MBean.

Here is an example:

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);

// equivalent to JPPFNodeState state = wrapper.state();
JPPFNodeState state = (JPPFNodeState) wrapper.invoke(
    JPPFNodeAdminMBean.MBEAN_NAME, "state", (Object[]) null, (String[]) null);
int nbTasks = state.getNbTasksExecuted();
// get the total CPU time used
long cpuTime = (Long) wrapper.invoke(JPPFNodeTaskMonitorMBean.MBEAN_NAME,
    "getTotalTaskCpuTime", (Object[]) null, (String[]) null);
```

6.1.3.4 Use of an MBean proxy

A proxy is a dynamically created object that implements an interface specified at runtime.

The standard JMX API provides a way to create a proxy to a remote or local MBeans. This is done as follows:

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);

// create the proxy instance
JPPFNodeTaskMonitorMBean proxy = wrapper.getProxy(
    JPPFNodeTaskMonitorMBean.MBEAN_NAME, JPPFNodeTaskMonitorMBean.class);

// get the total CPU time used
long cpuTime = proxy.getTotalTaskCpuTime();
```

6.1.3.5 Subscribing to MBean notifications

We have seen that the task monitoring MBean represented by the JPPFNodeTaskMonitorMBean interface is able to emit notifications of type TaskExecutionNotification. There are 2 ways to subscribe to these notifications:

a. Using a proxy to the MBean

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);
JPPFNodeTaskMonitorMBean proxy = wrapper.getProxy(
    JPPFNodeTaskMonitorMBean.MBEAN_NAME, JPPFNodeTaskMonitorMBean.class);

// subscribe to all notifications from the MBean
proxy.addNotificationListener(myNotificationListener, null, null);
```

b. Using the MBeanServerConnection API

```
JMXNodeConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);
MBeanServerConnection mbsc = wrapper.getMbeanConnection();
ObjectName objectName =
    new ObjectName(JPPFNodeTaskMonitorMBean.MBEAN_NAME);

// subscribe to all notifications from the MBean
mbsc.addNotificationListener(objectName, myNotificationListener, null, null);
```

Here is an example notification listener implementing the [NotificationListener](#) interface:

```
// this class counts the number of tasks executed, along with
// the total cpu time and wall clock time used by the node
public class MyNotificationListener implements NotificationListener {
    AtomicInteger taskCount = new AtomicInteger(0);
    AtomicLong cpuTime = new AtomicLong(0L);
    AtomicLong elapsedTime = new AtomicLong(0L);

    // Handle an MBean notification
    public void handleNotification(Notification notification, Object handback) {
        TaskExecutionNotification jppfNotif = (TaskExecutionNotification) notification;
        TaskInformation info = jppfNotif.getTaskInformation();
        int n = taskCount.incrementAndGet();
        long cpu = cpuTime.addAndGet(info.getCpuTime());
        long elapsed = elapsedTime.addAndGet(info.getElapsedTime());
        // display the statistics for every 50 tasks executed
        if (n % 50 == 0) {
            System.out.println("nb tasks = " + n + ", cpu time = " + cpu
                + " ms, elapsed time = " + elapsed + " ms");
        }
    }
};

NotificationListener myNotificationListener = new MyNotificationListener();
```

6.1.4 Remote logging

It is possible to receive logging messages from a node as JMX notifications. Specific implementation are available for Log4j and JDK logging.

To configure Log4j for emitting JMX notifications, edit the log4j configuration files of the node and add the following:

```
### direct messages to the JMX Logger ###
log4j.appender.JMX=org.jppf.logging.log4j.JmxAppender
log4j.appender.JMX.layout=org.apache.log4j.PatternLayout
log4j.appender.JMX.layout.ConversionPattern=%d [%-5p] [%c.%M(%L)]: %m\n

### set log levels - for more verbose logging change 'info' to 'debug' ###
log4j.rootLogger=INFO, JPPF, JMX
```

To configure the JDK logging to send JMX notifications, edit the JDK logging configuration file of the node and add the following:

```
# list of handlers
handlers= java.util.logging.FileHandler, org.jppf.logging.jdk.JmxHandler

# Write log messages as JMX notifications.
org.jppf.logging.jdk.JmxHandler.level = FINEST
org.jppf.logging.jdk.JmxHandler.formatter = org.jppf.logging.jdk.JPPFLogFormatter
```


To receive the logging notifications from a remote application, you can use the following code:

```
// get a JMX connection to the node MBean server
JMXNodeConnectionWrapper jmxNode = new JMXNodeConnectionWrapper(host, port);
jmxNode.connectAndWait(5000L);
// get a proxy to the MBean
JmxLogger nodeProxy = jmxNode.getProxy(JmxLogger.DEFAULT_MBEAN_NAME, JmxLogger.class);

// use a handback object so we know where the log messages come from
String source = "node " + jmxNode.getHost() + ":" + jmxNode.getPort();
// subscribe to all notifications from the MBean
NotificationListener listener = new MyLoggingHandler();
nodeProxy.addNotificationListener(listener, null, source);

// Logging notification listener that prints remote log messages
// to the console
public class MyLoggingHandler implements NotificationListener {
    // handle the logging notifications
    public void handleNotification(Notification notification, Object handback) {
        String message = notification.getMessage();
        String toDisplay = handback.toString() + ": " + message;
        System.out.println(toDisplay);
    }
}
```

6.2 Server management

Out of the box in JPPF, each server provides 2 MBeans that can be accessed remotely using a JMXMP remote connector with the JMX URL “`service:jmx:jmxmp://host:port`”, where *host* is the host name or IP address of the machine where the server is running (value of “`jppf.management.host`” in the server configuration file), and *port* is the value of the property “`jppf.management.port`” specified in the server's configuration file.

6.2.1 Server-level management and monitoring

MBean name: “**org.jppf:name=admin,type=driver**”

This is also the value of the constant `JPPFDriverAdminMBean.MBEAN_NAME`.

This MBean's role is to perform management and monitoring of the server. It exposes the `JPPFDriverAdminMBean` interface, which provides the functionalities described hereafter.

6.2.1.1 Server statistics

You can get a snapshot of the server's state by invoking the following method, which provides statistics on execution performance, network overhead, server queue behavior, number of connected nodes and clients:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {
    // Get the latest statistics snapshot from the JPPF driver
    public JPPFStats statistics() throws Exception;
}
```

This method returns an object of type `JPPFStats`. We invite you to read the Javadoc for this class to learn how to navigate the various statistics-related data structures.

Additionally, you can reset the server statistics using the following method:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {
    // Reset the JPPF driver statistics
    public void resetStatistics() throws Exception;
}
```

6.2.1.2 Stopping and restarting the server

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {
    // Perform a shutdown or restart of the server. The server stops after
    // the specified shutdown delay, and restarts after the specified restart delay
    public String restartShutdown(Long shutdownDelay, Long restartDelay)
        throws Exception;
}
```

This method allows you to remotely shut down the server, and eventually to restart it after a specified delay. This can be useful when an upgrade or maintenance of the server must take place within a limited time window. The server will only restart after the restart delay if it is at least equal to zero, otherwise it simply shuts down and cannot be restarted remotely anymore.

6.2.1.3 Managing the nodes attached to the server

The driver MBean allows monitoring and managing the nodes attached to the driver with the following two methods:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {
    // Request the JMX connection information for all nodes attached to the server.
    public Collection<JPPFManagementInfo> nodesInformation() throws Exception;

    // Get the number of nodes currently attached to the server.
    public Integer nbNodes() throws Exception;
}
```

The `JPPFManagementInfo` objects returned in the resulting collection encapsulate enough information to connect to the corresponding node's MBean server:

```
public class JPPFManagementInfo
    implements Serializable, Comparable<JPPFManagementInfo> {
    // the host on which the node is running
    public String getHost()
```

```
// the port on which the node's JMX server is listening
public int getPort()
}
```

For example, based on what we saw in the section about nodes management, we could write code that gathers connection information for each node attached to a server, and then performs some management request on them:

```
// Obtain connection information for all attached nodes
Collection<JPPFManagementInfo> nodesInfo = myDriverMBeanProxy.nodesInformation();
// for each node
for (JPPFManagementInfo info: nodesInfo) {
    // create a JMX connection wrapper based on the node information
    JMXNodeConnectionWrapper wrapper =
        new JMXNodeConnectionWrapper(info.getHost(), info.getPort());
    // connect to the node's MBean server
    wrapper.connectAndWait(5000);
    // restart the node
    wrapper.restart();
}
```

Additionally, if all you need is the number of nodes attached to the server, then simply calling the `nbNodes()` method will be much more efficient in terms of CPU usage and network traffic.

6.2.1.4 Monitoring idle nodes

The JPPF driver MBean provides two methods to gather information on idle nodes:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {
    // Request the JMX connection information for the
    // currently idle nodes attached to the server.
    public Collection<JPPFManagementInfo> idleNodesInformation() throws Exception;

    // Get the number of currently idle nodes attached to the server.
    public Integer nbIdleNodes() throws Exception;
}
```

`idleNodesInformation()` is similar to `nodesInformation()` except that it provides information only for the nodes that are currently idle. If all you need is the number of idle nodes, then it is much less costly to call `nbIdleNodes()` instead.

6.2.1.5 Load-balancing settings

The driver management MBean provides two methods to dynamically obtain and change the server's load balancing settings:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {
    // Obtain the current load-balancing settings.
    public LoadBalancingInformation loadBalancerInformation() throws Exception;
}
```

This method returns an object of type [LoadBalancingInformation](#), defined as follows:

```
public class LoadBalancingInformation implements Serializable {
    // Get the name of the algorithm
    public String getAlgorithm()
    // Get the algorithm's parameters
    public TypedProperties getParameters()
    // Get the names of all available algorithms
    public List<String> getAlgorithmNames()
}
```

Notes:

- the value of `algorithm` is included in the list of algorithm names
- `parameters` contains a mapping of the algorithm parameters names to their current value. Unlike what we have seen in the configuration guide chapter, the parameter names are expressed without suffix. This means that instead of `strategy.<profile_name>.<parameter_name>`, they will just be named as `<parameter_name>`.

It is also possible to dynamically change the load-balancing algorithm used by the server, and / or its parameters:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {  
    // Change the load-balancing settings.  
    public String changeLoadBalancerSettings(String algorithm, Map parameters)  
        throws Exception;  
}
```

Where:

- `algorithm` is the name of the algorithm to use. If it is not known to the server, no change occurs.
- `parameters` is a map of algorithm parameter names to their value. Similarly to what we saw above, the parameter names must be expressed without suffix. Internally, the JPPF server will use the profile name “jppf”.

6.2.1.6 Testing an execution policy

This feature allows you to compute the number of nodes that match a specific [execution policy](#). This enables testing whether a job, holding this execution policy as part of its SLA, would be executed, before submitting it:

```
public interface JPPFDriverAdminMBean extends JPPFAdminMBean {  
    // Compute the number of nodes matching the specified policy.  
    public Integer matchingNodes(ExecutionPolicy policy) throws Exception;  
}
```

6.2.2 Job-level management and monitoring

MBean name: “**org.jppf:name=jobManagement,type=driver**”

This is also the value of the constant `DriverJobManagementMBean.MBEAN_NAME`.

The role of this MBean is to control and monitor the life cycle of all jobs submitted to the server. It exposes the `DriverJobManagementMBean` interface, defined as follows:

```
public interface DriverJobManagementMBean extends NotificationEmitter {
    // Cancel the job with the specified id
    public void cancelJob(String jobUuid) throws Exception;
    // Suspend the job with the specified id
    public void suspendJob(String jobUuid, Boolean requeue) throws Exception;
    // Resume the job with the specified id
    public void resumeJob(String jobUuid) throws Exception;
    // Update the maximum number of nodes a job can run on
    public void updateMaxNodes(String jobUuid, Integer maxNodes) throws Exception;
    // Update the priority of a job
    void updatePriority(String jobUuid, Integer newPriority);
    // Get the set of ids for all the jobs currently queued or executing
    public String[] getAllJobIds() throws Exception;
    // Get an object describing the job with the specified id
    public JobInformation getJobInformation(String jobUuid) throws Exception;
    // Get a list of objects describing the nodes to which the whole
    // or part of a job was dispatched
    public NodeJobInformation[] getNodeInformation(String jobUuid) throws Exception;
    // Update the priority of a job
    void updatePriority(String jobUuid, Integer newPriority);
}
```

Reminder:

A job can be made of multiple tasks. These tasks may not be all executed on the same node. Instead, the set of tasks may be split in several subsets, and these subsets can in turn be dispatched to different nodes to allow their execution in parallel. In the remainder of this section we will call each subset a “sub-job”, to distinguish them from actual jobs at the server level. Thus a job is associated with a server, whereas a sub-job is associated with a node.

6.2.2.1 Controlling a job's life cycle

It is possible to terminate, suspend and resume a job using the following methods:

```
public interface DriverJobManagementMBean extends NotificationEmitter {
    // Cancel the job with the specified id.
    public void cancelJob(String jobUuid) throws Exception;
}
```

This will terminate the job with the specified `jobId`. Any sub-job running in a node will be terminated as well. If a sub-job was partially executed (i.e. at least one task execution was completed), the results are discarded. If the job was still waiting in the server queue, is simply removed from the queue, and the enclosed tasks are returned in their original state to the client.

```
public interface DriverJobManagementMBean extends NotificationEmitter {
    // Suspend the job with the specified uuid
    public void suspendJob(String jobUuid, Boolean requeue) throws Exception;
}
```

This method will suspend the job with the specified `jobId`. The `requeue` parameter specifies how the currently running sub-jobs will be processed:

- if **true**, then the sub-job is canceled and inserted back into the server queue, for execution at a later time
- if **false**, JPPF will let the sub-job finish executing in the node, then suspend the rest of the job still in the server queue

If the job is already suspended, then calling this method has no effect.

```
public interface DriverJobManagementMBean extends NotificationEmitter {
    // Resume the job with the specified uuid
    public void resumeJob(String jobUuid) throws Exception;
}
```

```
}
```

This method resumes the execution of a suspended job with the specified `jobId`. If the job was not suspended, this method has no effect.

6.2.2.2 Number of nodes assigned to a job

```
public interface DriverJobManagementMBean extends NotificationEmitter {  
    // Update the maximum number of nodes a job can run on.  
    public void updateMaxNodes(String jobId, Integer maxNodes) throws Exception;  
}
```

This method specifies the maximum number of nodes a job with the specified `jobId` can run on in parallel. It does not guarantee that this number of nodes will be used: the nodes may already be assigned to other jobs, or the job may not be splitted into that many sub-jobs (depending on the load-balancing algorithm). However it does guarantee that no more than `maxNodes` nodes will be used to execute the job.

6.2.2.3 Updating the priority of a job

```
public interface DriverJobManagementMBean extends NotificationEmitter {  
    // Update the priority of a job  
    void updatePriority(String jobId, Integer newPriority);  
}
```

This method dynamically updates the priority of job specified via its uuid. The update takes effect immediately

6.2.2.4 Job introspection

The management features allow users to query and inspect the jobs currently queued or executing in the server. This can be done using two related methods of the jobs management MBean:

```
public interface DriverJobManagementMBean extends NotificationEmitter {  
    // Get the set of uuids for all the jobs currently queued or executing  
    public String[] getAllJobIds() throws Exception;  
    // Get an object describing the job with the specified uuid  
    public JobInformation getJobInformation(String jobId) throws Exception;  
    // Get a list of objects describing the sub-jobs of a job,  
    // and the nodes to which they were dispatched  
    public NodeJobInformation[] getNodeInformation(String jobId) throws Exception;  
}
```

The `getAllJobIds()` method returns the UUIDs of all the jobs currently handled by the server. These UUIDs can be directly used with the other methods of the job management MBean.

The method `getJobInformation()` retrieves information about the state of a job in the server. This method returns an object of type [JobInformation](#), defined as follows:

```
public class JobInformation implements Serializable {  
    // the job's name  
    public String getJobName()  
    // the current number of tasks in the job or sub-job  
    public int getTaskCount()  
    // the priority of this task bundle  
    public int getPriority()  
    // the initial task count of the job (at submission time)  
    public int getInitialTaskCount()  
    // determine whether the job is in suspended state  
    public boolean isSuspended()  
    // set the maximum number of nodes this job can run on  
    public int getMaxNodes()  
    // the pending state of the job  
    // a job is pending if its scheduled execution date/time has not yet been reached  
    public boolean isPending()  
}
```

The method `getNodeInformation()` also allows to obtain information about all the sub-jobs of a job that are dispatched to remote nodes. The return value is an array of objects of type [NodeJobInformation](#), defined as follows:

```
public class NodeJobInformation implements Serializable {
    // The JMX connection information for the node
    public final JPPFManagementInfo nodeInfo;

    // The information about the sub-job
    public final JobInformation jobInfo;
}
```

This class is simply a grouping of two objects of type [JobInformation](#) and [JPPFManagementInfo](#), which we have already seen previously. The `nodeInfo` attribute will allow us to connect to the corresponding node's MBean server and obtain additional job monitoring data.

6.2.2.5 Job notifications

Whenever a job-related event occurs, the job management MBean will emit a notification of type [JobNotification](#), defined as follows:

```
public class JobNotification extends Notification {
    // the information about the job or sub-job
    public JobInformation getJobInformation()

    // the information about the node (for sub-jobs only)
    // null for a job on the server side
    public JPPFManagementInfo getNodeInfo()

    // the creation timestamp for this event
    public long getTimestamp()

    // the type of this job event
    public JobEventType getEventType()
}
```

The value of the job event type (see [JobEventType](#) type safe enumeration) is one of the following:

- `JOB_QUEUED`: a new job was submitted to the JPPF driver queue
- `JOB_ENDED`: a job was completed and sent back to the client
- `JOB_DISPATCHED`: a sub-job was dispatched to a node
- `JOB_RETURNED`: a sub job returned from a node
- `JOB_UPDATED`: one of the job attributes has changed

6.2.3 Accessing and using the server MBeans

As for the nodes, JPPF provides an API that simplifies access to the JMX-based management features of a server, by abstracting most of the complexity of JMX programming. This API is implemented by the class [JMXDriverConnectionWrapper](#), which provides a simplified way of connecting to the server's MBean server, along with a set of convenience methods to easily access the MBeans' exposed methods and attributes. Please note that this class implements the [JPPFDriverAdminMBean](#) interface.

6.2.3.1 Connecting to an MBean server

Connection to a server MBean server is done in two steps:

a. Create an instance of `JMXDriverConnectionWrapper`

To connect to a **local** (same JVM) MBean server, use the no-arg constructor:

```
JMXDriverConnectionWrapper wrapper = new JMXDriverConnectionWrapper();
```

To connect to a **remote** MBean server, use the constructor specifying the management host and port:

```
JMXDriverConnectionWrapper wrapper = new JMXDriverConnectionWrapper(host, port);
```

Here `host` and `port` represent the server's configuration properties “`jppf.management.host`” and “`jppf.management.port`”

b. Initiate the connection to the MBean server and wait until it is established

There are two ways to do this:

Synchronously:

```
// connect and wait for the connection to be established
// choose a reasonable value for the timeout, or 0 for no timeout
wrapper.connectAndWait(timeout);
```

Asynchronously:

```
// initiate the connection; this method returns immediately
wrapper.connect()
// ... do something else ...

// check if we are connected
if (wrapper.isConnected()) ...;
else ...;
```

6.2.3.2 Direct use of the JMX wrapper

JMXDriverConnectionWrapper implements directly the [JPPFDriverAdminMBean](#) interface. This means that all the JPPF server's management and monitoring methods can be used directly from the JMX wrapper. For example:

```
JMXDriverConnectionWrapper wrapper = new JMXDriverConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);
// get the ids of all jobs in the server queue
String jobUids = wrapper.getAllJobIds();
// stop the server in 2 seconds (no restart)
wrapper.restartShutdown(2000L, -1L);
```

6.2.3.3 Use of the JMX wrapper's invoke() method

[JMXConnectionWrapper.invoke\(\)](#) is a generic method that allows invoking any exposed method of an MBean. Here is an example:

```
JMXDriverConnectionWrapper wrapper = new JMXDriverConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);

// equivalent to JPPFStats stats = wrapper.statistics();
JPPFStats stats = (JPPFStats) wrapper.invoke(
    JPPFDriverAdminMBean.MBEAN_NAME, "statistics", (Object[]) null, (String[]) null);
int nbNodes = stats.getNodes().getLatest();
```

6.2.3.4 Use of an MBean proxy

A proxy is a dynamically created object that implements an interface specified at runtime. The standard JMX API provides a way to create a proxy to a remote or local MBean. This is done as follows:

```
JMXDriverConnectionWrapper wrapper = new JMXDriverConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);
// create the proxy instance
DriverJobManagementMBean proxy = wrapper.getProxy(
    DriverJobManagementMBean.MBEAN_NAME, DriverJobManagementMBean.class);
// get the ids of all jobs in the server queue
String jobIds = proxy.getAllJobIds();
```

6.2.3.5 Subscribing to MBean notifications

We have seen that the task monitoring MBean represented by the [JPPFNodeTaskMonitorMBean](#) interface is able to emit notifications of type `TaskExecutionNotification`. There are 2 ways to subscribe to these notifications:

a. Using a proxy to the MBean

```
JMXDriverConnectionWrapper wrapper = new JMXNodeConnectionWrapper(host, port);
wrapper.connectAndWait(timeout);
DriverJobManagementMBean proxy = wrapper.getProxy(
    DriverJobManagementMBean.MBEAN_NAME, DriverJobManagementMBean.class);
// subscribe to all notifications from the MBean
proxy.addNotificationListener(myJobNotificationListener, null, null);
```

b. Using the MBeanServerConnection API

```
JMXDriverConnectionWrapper wrapper = new JMXDriverConnectionWrapper(host, port);
```



```
wrapper.connectAndWait(timeout);
MBeanServerConnection mbsc = wrapper.getMBeanConnection();
ObjectName objectName = new ObjectName(DriverJobManagementMBean.MBEAN_NAME);
// subscribe to all notifications from the MBean
mbsc.addNotificationListener(objectName, myNotificationListener, null, null);
```

Here is an example notification listener implementing the [NotificationListener](#) interface:

```
// this class prints a message each time a job is added to the server's queue
public class MyJobNotificationListener implements NotificationListener {
    // Handle an MBean notification
    public void handleNotification(Notification notification, Object handback) {
        JobNotification jobNotif = (JobNotification) notification;
        JobEventType eventType = jobNotif.getEventType();
        // print a message for new jobs only
        if (eventType.equals(JobEventType.JOB_QUEUED)) {
            String jobId = jobNotif.getJobInformation().getJobId();
            System.out.println("job " + jobId + " was queued at timestamp "
                + jobNotif.getTimestamp());
        }
    }
};

NotificationListener myJobNotificationListener = new MyJobNotificationListener();
```

6.2.4 Remote logging

It is possible to receive logging messages from a driver as JMX notifications. Specific implementations are available for Log4j and JDK logging.

To configure Log4j to send JMX notifications, edit the log4j configuration files of the node and add the following:

```
### direct messages to the JMX Logger ###
log4j.appender.JMX=org.jppf.logging.log4j.JmxAppender
log4j.appender.JMX.layout=org.apache.log4j.PatternLayout
log4j.appender.JMX.layout.ConversionPattern=%d [%-5p] [%c.%M(%L)]: %m\n
### set log levels - for more verbose logging change 'info' to 'debug' ###
log4j.rootLogger=INFO, JPPF, JMX
```

To configure the JDK logging to send JMX notifications, edit the JDK logging configuration file of the driver as follows:

```
# list of handlers
handlers= java.util.logging.FileHandler, org.jppf.logging.jdk.JmxHandler
# Write log messages as JMX notifications.
org.jppf.logging.jdk.JmxHandler.level = FINEST
org.jppf.logging.jdk.JmxHandler.formatter = org.jppf.logging.jdk.JPPFLogFormatter
```

To receive the logging notifications from a remote application, you can use the following code:

```
// get a JMX connection to the node MBean server
JMXDriverConnectionWrapper jmxDriver = new JMXDriverConnectionWrapper(host, port);
jmxDriver.connectAndWait(5000L);
// get a proxy to the MBean
JmxLogger driverProxy =
    jmxDriver.getProxy(JmxLogger.DEFAULT_MBEAN_NAME, JmxLogger.class);
// use a handback object so we know where the log messages come from
String source = "driver " + jmxDriver.getHost() + ":" + jmxDriver.getPort();
// subscribe to all notifications from the MBean
NotificationListener listener = new MyLoggingHandler();
driverProxy.addNotificationListener(listener, null, source);

// Logging notification listener that prints remote log messages to the console
public class MyLoggingHandler implements NotificationListener {
    // handle the logging notifications
    public void handleNotification(Notification notification, Object handback) {
        String message = notification.getMessage();
        String toDisplay = handback.toString() + ": " + message;
        System.out.println(toDisplay);
    }
}
```


7 Extending and Customizing JPPF

Since version 2.0, JPPF provides the ability to extend the framework without having to learn its source code nor its internal workings. This is done using two kinds of extension or customization mechanisms. One, based on the Service Provider Interface (SPI) APIs, enables the developers to simply drop a jar file in the class path of a server or node for the extension to become active. The other mechanism relies on one or more configuration properties to customize specific features in JPPF. We will detail these mechanisms, along with the areas they apply to, in the next sections.

7.1 Pluggable MBeans

Developers can write their own management beans (MBeans) and register them with the JPPF MBean server for a node or a driver. These MBeans can then be accessed, locally or remotely, as any of the built-in JPPF MBeans. Refer to the chapter on management and monitoring, for details on how to connect to an MBean server and use the registered MBeans.

Note: *all JPPF built-in MBeans are implemented via this mechanism.*

Related sample: “Custom MBeans” sample in the JPPF samples pack.

7.1.1 Elements and constraints common to node and server MBeans

The mechanism for pluggable MBeans is based on the [Service Provider Interface](#), which is a light-weight and standard mechanism to provide extensions to Java applications.

The general workflow for adding a pluggable MBean is as follows:

- step 1: implement the MBean: MBean interface + MBean implementation class
- step 2: implement the MBean provider interface provided in JPPF
- step 3: add or update the corresponding service definition file in the `META-INF/services` folder
- step 4: create a jar file containing the above elements and deploy it in the node or server class path

The JPPF MBean handling mechanism relies on standard MBeans that *must* comply with the following constraints:

- the MBean interface name must be of the form `<MyName>MBean` and the MBean implementation class name must be of the form `<MyName>`. For instance, if we want to add a server health monitor, we would create the interface `ServerHealthMonitorMBean` and implement it in a class named `ServerHealthMonitor`.
- the MBean interface and implementation class must be defined in the same package. This is due to the constraints imposed by the JPPF distributed class loading mechanism, which allows nodes to download their custom MBeans from the server. If this constraint is not followed, the default JMX remote connector will be unable to find the MBean implementation class and it will not be possible to use the MBean. The MBean interface and implementation may, however, be in separate jar files or class folders (as long as they are in the same package).
- for custom MBeans that access other MBeans, the order in which the service definition files and their entries are read is important, since it is the order in which the MBeans are instantiated. This means that, if an MBean uses another, the developer must ensure that the dependant MBean is created *after* the one it depends on.
- the MBean provider interface must have a public no-arg constructor

7.1.2 Writing a custom node MBean

In this section we will follow the workflow described in the previous section and create a simple custom node MBean.

Step 1: create the MBean interface and its implementation

In this example, we will create an MBean that exposes a single method to query the number of processors available to the node's JVM. First we create an interface named `AvailableProcessorsMBean`:

```
package org.jppf.example.mbean;

// Exposes one method that queries the node's JVM
// for the number of available processors
public interface AvailableProcessorsMBean {
    // return the available processors as an integer value
    Integer queryAvailableProcessors();
}
```

Now we will create an implementation of this interface, in a class named `AvailableProcessors`, defined in the same Java package `org.jppf.example.mbean`:

```
package org.jppf.example.mbean;

// Implementation of the AvailableProcessorsMBean interface
public class AvailableProcessors implements AvailableProcessorsMBean {
    // return the available processors as an integer value
    public Integer queryAvailableProcessors() {
        // we use the java.lang.Runtime API
        return Runtime.getRuntime().availableProcessors();
    }
}
```

Step 2: implement the node MBean provider interface

To make our MBean pluggable to the nodes, it must be recognized as a corresponding service instance. To this effect, we will create an implementation of the interface [JPPFNodeMBeanProvider](#), which will provide the node with enough information to create the MBean and register it with the MBean server. This interface is defined as follows:

```
// service provider interface for pluggable management beans for JPPF nodes
public interface JPPFNodeMBeanProvider extends JPPFMBeanProvider {
    // return a concrete MBean instance
    // the class of the returned MBean must implement the interface defined by
    // JPPFMBeanProvider.getMBeanInterfaceName()
    public Object createMBean(MonitoredNode node);
}
```

As we can see, this interface declares a single method whose role is to create an instance of our MBean implementation. There is no obligation to use the node parameter, it is provided here because the JPPF built-in node MBean use it. As stated in the method comment, the class of the created object must implement an MBean interface, whose name is given by the method `getMBeanInterfaceName()` in the super-interface [JPPFMBeanProvider](#), defined as follows:

```
// service provider interface for pluggable management beans
public interface JPPFMBeanProvider {
    // return the fully qualified name of the management interface
    // defined by this provider
    public String getMBeanInterfaceName();

    // return the name of the specified MBean
    // this is the name under which the MBean will be registered with the MBean server
    public String getMBeanName();
}
```

Note that the MBean name must follow the specifications for [MBean object names](#).

We will then write our MBean provider implementation. Generally, the convention is to create it in a separate package, whose name is that of the MBean interface with a “.spi” suffix. We will write it as follows:

```
// AvailableProcessors MBean provider implementation
public class AvailableProcessorsMBeanProvider implements JPPFNodeMBeanProvider {
    // return the fully qualified name of the MBean interface defined by this provider
    public String getMBeanInterfaceName() {
        return "org.jppf.example.mbean.AvailableProcessorsMBean";
    }

    // create a concrete MBean instance
    public Object createMBean(MonitoredNode node) {
        return new AvailableProcessors();
    }

    // return the object name of the specified MBean
    public String getMBeanName() {
        return "org.jppf.example.node.mbean:name=AvailableProcessors,type=node";
    }
}
```

Step 3: create the service definition file

If it doesn't already exist, we create, in the source folder, a subfolder named `META-INF/services`. In this folder, we will create a file named `org.jppf.management.spi.JPPFNodeMBeanProvider`, and open it in a text editor. In the editor, we add a single line containing the fully qualified name of our MBean provider class:

```
org.jppf.example.mbean.node.spi.AvailableProcessorsMBeanProvider
```

Step 4: deploy the MBean

First, create a jar that contains all the artifacts we have created: MBean interface, MBean implementation and MBean provider class files, along with the `META-INF/services` folder. We now have two deployment choices: we can either deploy the MBean on a single node, or deploy it on the server side to make it available to all the nodes attached to the server. To do so, we simply add our deployment jar file to the class path of the node or of the server.

Step 5: using the MBean

We can now write a simple class to test our new custom MBean:

```
package org.jppf.example.node.test;

import org.jppf.management.JMXNodeConnectionWrapper;

// simple class to test a custom node MBean
public class AvailableProcessorsMBeanTest {
    public static void main(String...args) throws Exception {
        // we assume the node is running on localhost and uses the management port 12001
        JMXNodeConnectionWrapper wrapper =
            new JMXNodeConnectionWrapper("localhost", 12001);
        wrapper.connectAndWait(5000L);
        // query the node for the available processors
        int n = (Integer) wrapper.invoke(
            "org.jppf.example.mbean:name=AvailableProcessors,type=node",
            "queryAvailableProcessors", (Object[]) null, (String[]) null);
        System.out.println("The node has " + n + " available processors");
    }
}
```

7.1.3 Writing a custom server MBean

The process is almost exactly the same as for adding custom MBeans to a node. In this example, we will reuse the MBean that we wrote in the previous section, as it applies to any JVM, whether node or server.

Step 1: create the MBean interface and its implementation

We will simply reuse the interface `AvailableProcessorsMBean` and its implementation `AvailableProcessors` that we have already created.

Step 2: implement the node MBean provider interface

This time , we will implement the interface [JPPFDriverMBeanProvider](#):

```
package org.jppf.example.mbean.driver.spi;

import org.jppf.example.mbean.AvailableProcessors;
import org.jppf.management.spi.JPPFDriverMBeanProvider;

// AvailableProcessors MBean provider implementation
public class AvailableProcessorsMBeanProvider implements JPPFDriverMBeanProvider {
    // return the fully qualified name of the MBean interface defined by this provider
    public String getMBeanInterfaceName() {
        return "org.jppf.example.mbean.AvailableProcessorsMBean";
    }

    // create a concrete MBean instance
    public Object createMBean() {
        return new AvailableProcessors();
    }
}
```

```
// return the object name of the specified MBean
public String getMBeanName() {
    return "org.jppf.example.mbean:name=AvailableProcessors,type=driver";
}
}
```

This looks almost exactly the same as for the node MBean provider, except for the following differences:

- the implemented interface is `JPPFDriverMBeanProvider`, and its `createMBean()` method takes no parameter
- we gave a different object name to our MBean: “..., **type=driver**”
- we created the MBean provider in a different package named `org.jppf.example.mbean.driver.spi`.

Step 3: create the service definition file

If it doesn't already exist, we create, in the source folder, a subfolder named `META-INF/services`. In this folder, we will create a file named `org.jppf.management.spi.JPPFDriverMBeanProvider`, and open it in a text editor. In the editor, we add a single line containing the fully qualified name of our MBean provider class:

```
org.jppf.example.mbean.driver.spi.AvailableProcessorsMBeanProvider
```

Step 4: deploy the MBean

Now we just create a jar that contains all the artifacts we have created: MBean interface, MBean implementation and MBean provider class files, along with the `META-INF/services` folder, and add it to the class path of the server.

Step 5: using the MBean

We can write the following simple class to test our new server custom MBean:

```
package org.jppf.example.driver.test;
import org.jppf.management.JMXDriverConnectionWrapper;

// simple class to test a custom node MBean
public class AvailableProcessorsMBeanTest {
    public static void main(String...args) throws Exception {
        // we assume the server is running on localhost and uses the management port 11198
        JMXDriverConnectionWrapper wrapper =
            new JMXDriverConnectionWrapper("localhost", 11198);
        wrapper.connectAndWait(5000L);
        // query the node for the available processors
        int n = (Integer) wrapper.invoke(
            "org.jppf.example.mbean:name=AvailableProcessors,type=driver",
            "queryAvailableProcessors", (Object[]) null, (String[]) null);
        System.out.println("The server has " + n + " available processors");
    }
}
```

7.2 JPPF startup classes

Startup classes allow a piece of code to be executed at startup time of a node or server. They can be used for many purposes, including initialization of resources such as database connections, JMS queues, cache frameworks, authentication, etc ... They permit the creation of any object within the same JVM as the JPPF component they run in.

Startup classes are defined using the Service Provider Interface. The general workflow to create a custom startup class is as follows:

- step 1: create a class implementing the startup class provider interface
- step 2: add or update the corresponding service definition file in the `META-INF/services` folder
- step 3: create a jar file containing the above elements and deploy it in the node or server class path

This mechanism relies on the following rules:

- the provider interface for a node or server startup class extends the interface [JPPFStartup](#), which itself extends [java.lang Runnable](#). Thus, writing a startup class consists essentially in writing code in the `run()` method.
- the provider interface implementation must have a no-arg constructor
- startup classes are instantiated and run just after the JPPF and custom MBeans have been initialized. This allows a startup class to subscribe to any notifications that an MBean may emit.

Related sample: “Startup Classes” sample in the JPPF samples pack.

7.2.1 Node startup classes

Step 1: implement the node startup class provider interface

To make our startup class pluggable to the nodes, it must be recognized as a corresponding service instance. To this effect, we will create an implementation of the interface [JPPFNodeStartupSPI](#), which will provide the node with enough information to create and run the startup class. This interface is defined as follows:

```
public interface JPPFNodeStartupSPI extends JPPFStartup { }
```

As we can see, this is just a marker interface, used to distinguish between node startup classes and server startup classes. As an example, we will create an implementation that simply prints a message when the node starts:

```
package org.jppf.example.startup.node;

import org.jppf.startup.JPPFNodeStartupSPI;

// This is a test of a node startup class
public class TestNodeStartup implements JPPFNodeStartupSPI {
    public void run() {
        System.out.println("I'm a node startup class");
    }
}
```

Step 2: create the service definition file

If it doesn't already exist, we create, in the source folder, a subfolder named `META-INF/services`. In this folder, we will create a file named `org.jppf.startup.JPPFNodeStartupSPI`, and open it in a text editor. In the editor, we add a single line containing the fully qualified name of our startup class:

```
org.jppf.example.startup.node.TestNodeStartup
```

Step 3: deploy the startup class

Now we just create a jar that contains all the artifacts we have created: JPPF node startup provider class, along with the `META-INF/services` folder, and add it to the class path of either the server, if we want all nodes attached to the server to use the startup class, or of the node, if we only want one node to use it.

Important note: *when a node startup class is deployed on the server, the objects it creates (for instance as singletons) can be reused from within the tasks executed by the node.*

7.2.2 Server startup classes

Step 1: implement the server startup class provider interface

In the same way as for a node startup class, we need to implement the interface [JPPFDriverStartupSPI](#), defined as follows:

```
public interface JPPFDriverStartupSPI extends JPPFStartup { }
```

As an example, we will create an implementation that simply prints a message when the server starts:

```
package org.jppf.example.startup.driver;

import org.jppf.startup.JPPFNodeStartupSPI;

// This is a test of a server startup class
public class TestDriverStartup implements JPPFDriverStartupSPI {
    public void run() {
        System.out.println("I'm a server startup class");
    }
}
```

Step 2: create the service definition file

If it doesn't already exist, we create, in the source folder, a subfolder named `META-INF/services`. In this folder, we will create a file named `org.jppf.startup.JPPFDriverStartupSPI`, and open it in a text editor. In the editor, we add a single line containing the fully qualified name of our startup class:

```
org.jppf.example.startup.driver.TestDriverStartup
```

Step 3: deploy the startup class

Now we just create a jar that contains the JPPF server startup provider class , along with the `META-INF/services` folder, and add it to the class path of the server.

7.3 Transforming and encrypting networked data

In JPPF, most of the network traffic is made of serialized Java objects. By default, these serialized objects are sent over the network without any obfuscation or encryption of any sort. This can be considered risky in highly secured environments. To mitigate this risk, JPPF provides a hook that enables transforming a block of data into another block of data, and transform it back into the original data (reverse transformation).

To better understand how this mechanism works, let's first have a high-level overview of how JPPF components send and receive messages over the network. A message in JPPF is composed of a number of blocks of data, each block representing a serialized object (or object graph) and immediately preceded by its own length. A message would look like this:

L ₁	Block ₁	L _n	Block _n
----------------	--------------------	-------	----------------	--------------------

Where:

- Block₁, ..., Block_n are separate blocks of data constituting the message
- L₁, ..., L_n are the lengths of each block of data

The data transformation hook allows developers to transform each block of data. The block lengths are always computed by JPPF. For example if the data transformation used is a form of encryption (and decryption for the reverse operation), then everything except the block lengths will be encrypted.

Related sample: “Data Encryption” sample in the JPPF samples pack

The general workflow to implement and deploy a data transformation is as follows:

Step 1: implement the [JPPFDataTransform](#) interface

This interface is defined as follows:

```
public interface JPPFDataTransform {
    // Transform a block of data into another, transformed one.
    // This operation must be such that the result of unwrapping the data of the
    // destination must be the equal to the source data
    void wrap(InputStream source, OutputStream destination) throws Exception;

    // Transform a block of data into another, reverse-transformed one
    // This method is the reverse operation with regards to wrap()
    void unwrap(InputStream source, OutputStream destination) throws Exception;
}
```

One very important thing to note is that the sequential application of the `wrap()` and `unwrap()` methods must return exactly the original data.

Also keep in mind that the data transformation is completely stateless. For instance there is no knowledge of where the data comes from or where it is going.

We will now write a data transformation that encrypts data using the DES cryptographic algorithm, based on a 56 bits symmetric secret key. This code is available in the related “Data Encryption” sample of the JPPF samples pack. Note that this example is far from totally secure, since the secret key is actually stored with the source code (and in the resulting jar file). It should normally be in a secure location such as a key store. The packaging in the sample is only for demonstration purposes.

Here is our implementation of `JPPFDataTransform`:

```

// Data transform that uses the DES cryptographic algorithm with a 56 bits secret key
public class SecureKeyCipherTransform implements JPPFDataTransform {
    // Secret (symetric) key used for encryption and decryption
    private static SecretKey secretKey = getSecretKey();

    // Encrypt the data using streams
    public void wrap(InputStream source, OutputStream dest) throws Exception {
        // create a cipher instance
        Cipher cipher = Cipher.getInstance(Helper.getTransformation());
        // initialize the cipher with the key stored in the secured keystore
        cipher.init(Cipher.WRAP_MODE, getSecretKey());
        // generate a new key that we will use to encrypt the data
        SecretKey key = generateKey();
        // encrypt the new key, using the secret key found in the keystore
        byte[] keyBytes = cipher.wrap(key);
        // now we write the encrypted key before the data
        DataOutputStream dos = new DataOutputStream(dest);
        // write the key length
        dos.writeInt(keyBytes.length);
        // write the key content
        dos.write(keyBytes);

        // get a new cipher for the actual encryption
        cipher = Cipher.getInstance(Helper.getTransformation());
        // init the cipher in encryption mode
        cipher.init(Cipher.ENCRYPT_MODE, key);
        // obtain a cipher output stream
        CipherOutputStream cos = new CipherOutputStream(dest, cipher);
        // finally, encrypt the data using the new key
        transform(source, cos);
        cos.close();
    }

    // Decrypt the data
    public void unwrap(InputStream source, OutputStream dest) throws Exception {
        // start by reading the secret key to use to decrypt the data
        DataInputStream dis = new DataInputStream(source);
        // read the length of the key
        int keyLength = dis.readInt();
        // read the encrypted key
        byte[] keyBytes = new byte[keyLength];
        dis.read(keyBytes);
        // decrypt the key using the initial key stored in the keystore
        Cipher cipher = Cipher.getInstance(Helper.getTransformation());
        cipher.init(Cipher.UNWRAP_MODE, getSecretKey());
        SecretKey key = (SecretKey) cipher.unwrap(
            keyBytes, Helper.getAlgorithm(), Cipher.SECRET_KEY);

        // get a new cipher for the actual decryption
        cipher = Cipher.getInstance(Helper.getTransformation());
        // init the cipher in decryption mode
        cipher.init(Cipher.DECRYPT_MODE, key);
        // obtain a cipher input stream
        CipherInputStream cis = new CipherInputStream(source, cipher);
        // finally, decrypt the data using the new key
        transform(cis, dest);
        cis.close();
    }

    // Generate a secret key
    private SecretKey generateKey() throws Exception {
        KeyGenerator gen = KeyGenerator.getInstance(Helper.getAlgorithm());
        return gen.generateKey();
    }

    // Transform the specified input source and write it to the specified destination
    private void transform(InputStream source, OutputStream dest) throws Exception {
        byte[] buffer = new byte[8192];
        while (true) {

```

```

        int n = source.read(buffer);
        if (n <= 0) break;
        destination.write(buffer, 0, n);
    }
}

// Get the secret key used for encryption/decryption
private static synchronized SecretKey getSecretKey() {
    if (secretKey == null) {
        try {
            // get the keystore password
            char[] password = Helper.getPassword();
            ClassLoader cl = SecureKeyCipherTransform.class.getClassLoader();
            InputStream is = cl.getResourceAsStream(
                Helper.getKeystoreFolder() + Helper.getKeystoreFilename());
            KeyStore ks = KeyStore.getInstance(Helper.getProvider());
            // load the keystore
            ks.load(is, password);
            // get the secret key from the keystore
            secretKey = (SecretKey) ks.getKey(Helper.getKeyAlias(), password);
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
    return secretKey;
}
}

```

Step 2: deploy the data transform implementation

The implementation code and related resources must be deployed in the class path of **each and every component on the JPPF grid**, including servers, nodes, and client applications. If it is not the case, the results are unpredictable and JPPF will probably stop working altogether. The deployment can be made in the form of a jar file or a class folder, the only constraint being that it must be local to the JVM of each JPPF component.

Step 3: hook the implementation to JPPF

This is done by specifying the property `jppf.data.transform.class` in the JPPF configuration file of each component:

```
jppf.data.transform.class = <fully qualified name of implementation class>
```

In our example it would be:

```
jppf.data.transform.class = org.jppf.example.dataencryption.SecureKeyCipherTransform
```

7.4 Specifying alternate object streams

JPPF performs objects transport and associated serialization by the means of object streams, which are instances of [ObjectInputStream](#) and [ObjectOutputStream](#) or subclasses of these classes.

It is now possible to specify alternate object stream classes for a JPPF grid, enabling the use of non-serializable classes without any extra coding required for the JPPF task developer. JPPF provides 2 ways to achieve this:

7.4.1 Specifying the object stream implementation classes

This is done in the JPPF configuration file, by adding these 2 properties:

```
# configure the object input stream implementation
jppf.object.input.stream.class = my.package.MyObjectInputStream
# configure the object output stream implementation
jppf.object.output.stream.class = my.package.MyObjectOutputStream
```

Please note that the object stream implementations must have a constructor that takes an `InputStream` parameter for the object input stream class, and an `OutputStream` parameter for the object output stream class.

7.4.2 Implementing an object stream builder

An object stream builder is an object that instantiates input and output object streams. It is defined as an implementation of the [JPPFObjectStreamBuilder](#) interface:

```
// Interface for all builders instantiating alternate object input and output streams.
public interface JPPFObjectStreamBuilder {
    // Obtain an input stream used for deserializing objects.
    public ObjectInputStream newObjectInputStream(InputStream in) throws Exception;

    // Obtain an Output stream used for serializing objects.
    public ObjectOutputStream newObjectOutputStream(OutputStream out) throws Exception;
}
```

Then, configure JPPF to use this object stream builder by specifying the following property in the JPPF configuration file:

```
# configure the object stream builder implementation
jppf.object.stream.builder = my.package.MyObjectStreamBuilder
```

Note: when alternate object streams are specified, they must be used by all JPPF clients, servers and nodes, otherwise JPPF will not work. The implementation classes must also be present in the classpath of all JPPF components

7.4.3 Built-in implementations

Out of the box, JPPF provides 3 serialization schemes:

7.4.3.1 Default serialization

This is the default Java serialization mechanism, using the known JDK classes [java.io.ObjectInputStream](#) and [java.io.ObjectOutputStream](#). It is used by default, when no serialization scheme is specified.

7.4.3.2 Generic JPPF serialization

This is a serialization scheme implemented from scratch, which functions pretty much like the standard Java mechanism with one major difference: *it enables the serialization of classes that do not implement [java.io.Serializable](#) nor [java.io.Externalizable](#)*. This allows developers to use classes in their tasks that are not normally serializable and for which they cannot access the source code. We understand that it breaks the contract specified in the JDK for serialization, however it provides an effective workaround for dealing with non-serializable classes in JPPF jobs and tasks.

The JPPF implementation relies on an extension of the standard mechanism by defining 2 new classes: [JPPFObjectInputStream](#) and [JPPFObjectOutputStream](#).

Apart from this, it conforms to the specifications for the standard `ObjectInputStream` and `ObjectOutputStream` classes, in that it processes transient fields in the same manner, and handles the special cases when a class implements the methods `writeObject(ObjectOutputStream)` and `readObject(ObjectInputStream)`, and the `java.io.Externalizable` interface.

This implementation is also slower than the default Java one: serialization and deserialization of an object graph takes generally around 50% more time. This overhead will be significant essentially for very short-lived tasks (i.e. a few milliseconds). It is thus recommended to use the default Java serialization whenever it is possible.

To specify this scheme in your JPPF configuration:

```
# configure the object stream builder implementation
jppf.object.stream.builder = org.jppf.serialization.GenericObjectStreamBuilder

# configure the object input stream implementation
jppf.object.input.stream.class = org.jppf.serialization.JPPFObjectInputStream
# configure the object output stream implementation
jppf.object.output.stream.class = org.jppf.serialization.JPPFObjectOutputStream
```

7.4.3.3 XStream-based serialization

JPPF has a built-in Object Stream Builder that uses XStream to provide XML serialization:

[XstreamObjectStreamBuilder](#). To use it, simply specify:

```
# configure the object stream builder implementation
jppf.object.stream.builder = org.jppf.serialization.XstreamObjectStreamBuilder
```

in the JPPF configuration files.

You will also need the XStream 1.3 (or later) jar file and the xpp3 jar file available in the [XStream](#) distribution

7.5 Creating a custom load-balancer

Related sample: [“CustomLoadBalancer”](#) in the JPPF samples pack.

7.5.1 Overview of JPPF load-balancing

Load-balancing in JPPF relates to the way jobs are split into sub-jobs and how these sub-jobs are dispatched to the nodes for execution in parallel. Each sub-job contains a distinct subset of the tasks in the original job.

The distribution of the tasks to the nodes is performed by the JPPF driver. This work is actually the main factor of the observed performance of the framework. It consists essentially in determining how many tasks will go to each node for execution, out of a set of tasks sent by the client application. Each set of tasks sent to a node is called a "bundle", and the role of the load balancing (or task scheduling) algorithm is to optimize the performance by adjusting the number of task sent to each node. In short: it is about computing the optimal bundle size for each node.

Each load-balancing algorithm is encapsulated within a class implementing the interface [Bundler](#), defined as follows:

```
public interface Bundler {
    // Get the latest computed bundle size
    public int getBundleSize();

    // Feed the bundler with the latest execution result for the corresponding node
    public void feedback(int nbTasks, double totalTime);

    // Make a copy of this bundler
    public Bundler copy();

    // Get the timestamp at which this bundler was created
    public long getTimestamp();

    // Release the resources used by this bundler
    public void dispose();

    // Perform context-independant initializations
    public void setup();

    // Get the parameters profile used by this load-balancer
    public LoadBalancingProfile getProfile();
}
```

In practice, it will be more convenient to extend the abstract class [AbstractBundler](#), which provides a default implementation for each method of the interface.

The load balancing in JPPF is feedback-driven. The server will create a `Bundler` instance for each node that is attached to it. When a set of tasks returns from a node after execution, the server will call the bundler's `feedback()` method so the bundler can recompute the bundle size with up-to-date data. Whether each bundler computes the bundle size independantly from the other bundlers is entirely up to the implementor. Some of the JPPF built-in algorithms do perform independent computations, others don't.

A bundler's life cycle is as follows:

- when the server starts up, it creates a bundler instance based on the load-balancing algorithm specified in the configuration file
- each time a node connects to the server, the server will make a copy of the initial bundler, using the `copy()` method, call the `setup()` method, and assign the new bundler to the node
- when a node is disconnected, the server will call the `dispose()` method on the corresponding bundler, then discard it
- when the load balancing settings are changed using the management APIs or the administration console, the server will create a new initial Bundler instance, based on the new parameters. Then, each time the server needs to provide feedback data from a node, the server will compare the creation timestamps of the initial bundler and of the node's bundler. If the server determines that the node's bundler is older, it will replace it with a copy of the initial bundler, using the `copy()` method and after calling the `setup()` method on the new bundler

Each bundler has an associated load balancing profile, which encapsulates the parameters of the algorithm. These parameters can be read from the JPPF configuration file, or from any other source. Using a profile is not mandatory, in this case you can just have the `getProfile()` method return a `null` value.

In the following sections, we will see in details how to implement a custom load-balancing algorithm, deploy it, and plug it into the JPPF server. We will do this by example, using the built-in “Fixed Size” algorithm, which is simple enough for our purpose.

Note: *all JPPF built-in load balancing algorithms are implemented and plugged-in as custom algorithms*

7.5.2 Implementing the algorithm and its profile

First let's implement our parameters profile. To this effect, we implement the interface [LoadBalancingProfile](#):

```
public interface LoadBalancingProfile extends Serializable {  
    // Make a copy of this profile  
    public LoadBalancingProfile copy();  
}
```

As we can see, this interface has a single method that creates a copy of a profile. Now let's see how it is implemented in the [FixedSizeProfile](#) class:

```
// Profile for the fixed bundle size load-balancing algorithm  
public class FixedSizeProfile implements LoadBalancingProfile {  
    // The bundle size  
    private int size = 1;  
  
    // Default constructor  
    public FixedSizeProfile() {  
    }  
  
    // Initialize this profile with values read from the specified configuration  
    public FixedSizeProfile(TypedProperties config) {  
        size = config.getInt("size", 1);  
    }  
  
    // Make a copy of this profile  
    public LoadBalancingProfile copy() {  
        FixedSizeProfile other = new FixedSizeProfile();  
        other.setSize(size);  
        return other;  
    }  
  
    // Get the bundle size  
    public int getSize() {  
        return size;  
    }  
  
    // Set the bundle size  
    public void setSize(int size) {  
        this.size = size;  
    }  
}
```

This implementation is fairly trivial, the only notable element being the constructor taking a [TypedProperties](#) parameter, which will allow us to read the size parameter from the JPPF configuration file.

Now let's take a look at the algorithm implementation itself:

```
public class FixedSizeBundler extends AbstractBundler {
    // Initialize this bundler
    public FixedSizeBundler(LoadBalancingProfile profile) {
        super(profile);
    }

    // This method always returns a statically assigned bundle size
    public int getBundleSize() {
        return ((FixedSizeProfile) profile).getSize();
    }

    // Make a copy of this bundler
    public Bundler copy() {
        return new FixedSizeBundler(profile.copy());
    }

    // Get the max bundle size that can be used for this bundler
    protected int maxSize() {
        return -1;
    }
}
```

The first thing we can notice is that the `feedback()` method is not even implemented! This is due to the fact that our algorithm is independent from the context and involves no computation. Thus, we use the default implementation in `AbstractBundler`, which does nothing. This is visible in the `getBundleSize()` method, where we simply return the value provided in the parameters `profile`.

We also notice a new method named `maxSize()`. It returns a value representing the maximum bundle size that a bundler can use at a given time. The goal of this is to avoid that a node receives all or most of the tasks, while the other nodes would not receive anything and thus would have nothing to do. This method is declared in the abstract class `AbstractBundler` and doesn't have any default implementation, to avoid any tight coupling between the bundler and the environment in which it runs. This allows the bundler to be used outside of the JPPF server, as is done for instance in the JPPF client when local execution mode is used along with remote execution.

In the context of the server, we have found that an efficient value for `maxSize()` can be computed from the current maximum number of tasks among all the jobs in the server queue. This value is accessible by calling the method [JPPFQueue.getMaxBundleSize\(\)](#). We could then rewrite our `maxSize()` method as follows:

```
protected int maxSize() {
    return JPPFDriver.getQueue().getMaxBundleSize() / 2;
}
```

The algorithm could then determine that a node should not receive more than half of that value (or 75% or any other function of it, whatever is deemed more efficient), so that other nodes will not be idle and the overall throughput will be optimized.

Tip: if your algorithm depends on the number of nodes, you can use a bundler instances count as a static variable in your implementation, and use the `setup()` and `dispose()` methods to increment and decrement the count as needed. For instance:

```
private static AtomicInteger instanceCount = new AtomicInteger(0);

public void setup() {
    instanceCount.incrementAndGet();
}

public void dispose() {
    instanceCount.decrementAndGet();
}
```


7.5.3 Implementing the bundler provider interface

Custom load-balancers are defined and deployed using the Service Provider Interface (SPI) mechanism. For a new load-balancer to be recognized by JPPF, it has to provide an implementation of the [JPPFBundlerProvider](#) interface, which is defined as:

```
public interface JPPFBundlerProvider {
    // Get the name of the algorithm defined by this provider
    // Each algorithm must have a name distinct from that of all other algorithms
    public String getAlgorithmName();

    // Create a bundler instance using the specified parameters profile
    public Bundler createBundler(LoadBalancingProfile profile);

    // Create a bundler profile containing the parameters of the algorithm
    public LoadBalancingProfile createProfile(TypedProperties configuration);
}
```

In the case of our fixed size algorithm, the [FixedSizeBundlerProvider](#) implementation is quite straightforward:

```
public class FixedSizeBundlerProvider implements JPPFBundlerProvider {
    // Get the name of the algorithm defined by this provider
    public String getAlgorithmName() {
        return "manual";
    }

    // Create a bundler instance using the specified parameters profile
    public Bundler createBundler(LoadBalancingProfile profile) {
        return new FixedSizeBundler(profile);
    }

    // Create a bundler profile containing the parameters of the algorithm
    public LoadBalancingProfile createProfile(TypedProperties configuration) {
        return new FixedSizeProfile(configuration);
    }
}
```

7.5.4 Deploying the custom load-balancer

For our custom load-balancer to be recognized and loaded, we need to create the corresponding service definition file. If it doesn't already exist, we create, in the source folder, a subfolder named `META-INF/services`. In this folder, we will create a file named `org.jppf.server.scheduler.bundle.providers.FixedSizeBundlerProvider`, and open it in a text editor. In the editor, we add a single line containing the fully qualified name of our provider implementation:

```
org.jppf.server.scheduler.bundle.providers.FixedSizeBundlerProvider
```

Now, to actually deploy our implementation, we will create a jar file that contains all the artifacts we have created: the `Bundler`, `LoadBalancingProfile` and `JPPFBundlerProvider` implementation classes, along with the `META-INF/services` folder, and add this jar to the class path of the server.

7.5.5 Node-aware load balancers

Load balancers can be made aware of a node's environment and configuration, and make dynamic decisions based on this information.

To this effect, the Bundler implementation will need to also implement the interface [NodeAwareness](#), defined as follows:

```
// Bundler implementations should implement this interface
// if they wish to have access to a node's configuration
public interface NodeAwareness {
    // Get the corresponding node's system information
    JPPFSystemInformation getNodeConfiguration();

    // Set the corresponding node's system information
    void setNodeConfiguration(JPPFSystemInformation nodeConfiguration);
}
```

When implementing this interface, the environment and configuration of the node become accessible via an instance of [JPPFSystemInformation](#).

JPPF guarantees that the node information will never be null once the node is connected to the server. You should not assume, however, that it is true when the Bundler is instantiated (for instance in the constructor).

The method `setConfiguration()` can be called in two occasions:

- when the node connects to the server
- when the node's number of processing threads has been updated dynamically (through the admin console or management APIs)

A sample usage of [NodeAwareness](#) can be found in the CustomLoadBalancer sample, in the JPPF samples pack.

7.5.6 Job-aware load balancers

Load-balancers can gain access to a job's metadata (see the “Job Metadata” section of the Development Guide). This is done by having the Bundler implement the interface [JobAwareness](#), defined as follows:

```
// Bundler implementations should implement this interface
// if they wish to have access to a job's metadata
public interface JobAwareness {
    // Get the current job's metadata
    JobMetadata getJobMetadata();

    // Set the current job's metadata
    void setJobMetadata(JobMetadata metadata);
}
```

When implementing this interface, the job metadata becomes accessible via an instance of [JobMetadata](#).

The method `setJobMetadata()` is always called after the execution policy (if any) has been applied to the node, and before the job is dispatched to the node for execution. This allows the load-balancer to use information about the job when computing the number of tasks to send to the node.

A sample usage of [JobAwareness](#) can be found in the [CustomLoadBalancer](#) sample, in the JPPF samples pack.

7.6 Receiving node connection events in the server

This extension point allows you to register a listener for receiving notifications when a node is connected to, or disconnected from the server. As for other JPPF extensions, it relies on the Service Provider Interface (SPI) mechanism to enable an easy registration.

To implement this extension, you first need to create an implementation of the [NodeConnectionListener](#) interface, defined as follows:

```
public interface NodeConnectionListener extends EventListener {
    // Called when a node is connected to the server
    void nodeConnected(NodeConnectionEvent event);

    // Called when a node is disconnected from the server
    void nodeDisconnected(NodeConnectionEvent event);
}
```

Each notification method receives instances of the [NodeConnectionEvent](#) class, which is defined as:

```
public class NodeConnectionEvent extends EventObject {
    // Get the node information for this event
    public JPPFManagementInfo getNodeInformation()
}
```

As we can see, these event objects are simple wrappers carrying detailed information about the node, via the class [JPPFManagementInfo](#):

```
public class JPPFManagementInfo
    implements Serializable, Comparable<JPPFManagementInfo> {

    // Get the host on which the node is running
    public String getHost()

    // Get the port on which the node's JMX server is listening
    public int getPort()

    // Get the system information associated with the node at the time
    // it established the connection
    public JPPFSystemInformation getSystemInfo()

    // Get the node's unique id (UUID)
    public String getId()

    // Determine whether this information represents another driver,
    // connected as a peer to the current driver
    public boolean isDriver()

    // Determine whether this information represents a real node
    public boolean isNode()
}
```

For details on the available information, we encourage you to read the Javadoc for the class [JPPFSystemInformation](#).

To deploy the extension:

- create a file named **org.jppf.server.event.NodeConnectionListener** in the **META-INF/services** folder
- in this same file, add the fully qualified class name of your `NodeConnectionListener` implementation, for example: `mypackage.MyNodeConnectionListener`. This is the service definition file for the extension.
- create a jar with your code and and service definition file and add it to the driver's classpath, or simply add your classes folder to the driver's classpath.

7.7 Receiving notifications of node life cycle events

This plugin provides the ability to receive notifications of major events occurring within a node, including node startup and termination as well as the start and completion of each job processing.

7.7.1 NodeLifeCycleListener interface

To achieve this, you only need to implement the interface [NodeLifeCycleListener](#), which is defined as follows:

```
public interface NodeLifeCycleListener extends EventListener {
    // Called when the node has finished initializing,
    // and before it starts processing jobs
    void nodeStarting(NodeLifeCycleEvent event);

    // Called when the node is terminating
    void nodeEnding(NodeLifeCycleEvent event);

    // Called before the node starts processing a job
    void jobStarting(NodeLifeCycleEvent event);

    // Called after the node finishes processing a job
    void jobEnding(NodeLifeCycleEvent event);
}
```

Each method in the listener receives an event of type [NodeLifeCycleEvent](#), which provides the following API:

```
public class NodeLifeCycleEvent extends EventObject {
    // Get the job currently being executed
    public JPPFDistributedJob getJob();
    // Get the tasks currently being executed
    public List<Task> getTasks();
    // Get the data provider for the job
    public DataProvider getDataProvider();
    // Get the object representing the current JPPF node
    public Node getNode();
    // Get the class loader used to load the tasks and
    // the classes they need from the client
    public AbstractJPPFClassLoader getTaskClassLoader()
}
```

Please note that the two methods `getJob()`, `getTasks()` and `getTaskClassLoader()` will return `null` for the events of type “`nodeStarting()`” and may return `null` for “`nodeEnding()`” events, as the node may not be processing any job at the time these events occur. On the other hand, `getNode()` will return a non-null value for these events only.

You will also notice that the method `getTasks()` returns a list of [Task<T>](#) instances. `Task<T>` is the interface for all JPPF tasks, and can be safely cast to [JPPFTask](#) for all practical purposes.

[JPPFDistributedJob](#) is an interface common to client side jobs (see [JPPFJob](#)) and server / node side jobs (see [JPPFTaskBundle](#)). It provides the following methods, which can be used in the `NodeLifeCycleListener` implementation:

```
public interface JPPFDistributedJob {
    // Get the user-defined display name for this job
    // This is the name displayed in the administration console
    String getName();

    // Get the universal unique id for this job
    String getUuid();

    // Get the service level agreement between the job and the server
    JobSLA getSLA();

    // Get the user-defined metadata associated with this job
    JobMetadata getMetadata();
}
```

Once the implementation is done, the listener is hooked up to JPPF using the service provider interface:

- create a file in **META-INF/services** named “**org.jppf.node.event.NodeLifeCycleListener**”
- in this file, add the fully qualified class name of your implementation of the interface
- copy the jar file or class folder containing your implementation and service file to either the JPPF driver's class path, if you want it deployed to all nodes connected to that driver, or to the classpath of individual nodes, if you only wish specific nodes to have the add-on.

Here is a simple example illustrating the process.

Our implementation of the [NodeLifeCycleListener](#) interface, which simply prints the events to the node's console:

```
package myPackage;

public class MyNodeListener implements NodeLifeCycleListener {
    public void nodeStarting(NodeLifeCycleEvent event) {
        System.out.println("node ready to process jobs");
    }

    public void nodeEnding(NodeLifeCycleEvent event) {
        System.out.println("node ending");
    }

    public void jobStarting(NodeLifeCycleEvent event) {
        JPPFDistributedJob job = event.getJob();
        System.out.println("node starting job '" + job.getId() + "' with " +
            event.getTasks().size() + " tasks");
    }

    public void jobEnding(NodeLifeCycleEvent event) {
        System.out.println("node finished job '" + event.getJob().getId() + "'");
    }
}
```

Once this is done, we create the file **META-INF/services/org.jppf.node.event.NodeLifeCycleListener** with the following content:

```
myPackage.MyNodeListener
```

Our node listener is now ready to be deployed.

Related JPPF samples:

- [“NodeLifeCycle”](#)
- [“Note Tray”](#)

7.7.2 Extended notifications: the NodeLifeCycleListenerEx interface

JPPF now provides an extension to the [NodeLifeCycleListener](#) interface, by the means of a new interface called [NodeLifeCycleListenerEx](#), which is defined as follows:

```
public interface NodeLifeCycleListenerEx extends NodeLifeCycleListener {
    // Called when the node has loaded a job header and before
    // the DataProvider or any of the tasks has been loaded
    void jobHeaderLoaded(NodeLifeCycleEvent event);
}
```

At the time this method is called, neither the DataProvider (if any) nor the tasks have been deserialized. This means that the tasks can reference classes that are not yet in the classpath, and you can add these classes to the classpath on the fly, for instance by calling `NodeLifeCycleEvent.getTaskClassLoader()`, then invoking the `addURL(URL)` method of the resulting `AbstractJPPFClassLoader`.

To hook this extension up to the JPPF node, you must use the exact same service provider mechanism as for `NodeLifeCycleListener`. The JPPF service loader will automatically determine which services are instances of `NodeLifeCycleListenerEx` and emit the additional notifications accordingly.

Related JPPF sample: [Extended Class Loading](#)

7.8 Node initialization hooks

In the JPPF nodes, the lookup for a server to connect to relies essentially on each node's configuration. Thus, to implement a customized server lookup or failover mechanism, it is necessary to be able to modify the configuration, before the server lookup and connection is attempted. To this effect, JPPF provides a pluggable initialization hook which can be executed by the node before each connection attempt.

An initialization hook is a Java class that implements the interface [InitializationHook](#), which is defined as follows:

```
public interface InitializationHook {  
    // Called each time the node is about to attempt to connect to a driver  
    void initializing(UnmodifiableTypedProperties initialConfiguration);  
}
```

Note that the `initialConfiguration` parameter reflects the exact same set of configuration properties that were loaded by the node at startup time. It is an instance of [UnmodifiableTypedProperties](#), which is an extension of [TypedProperties](#) that does not permit the modification, insertion or removal of any property. To modify the node's configuration, you have to use [JPPFConfiguration.getProperties\(\)](#), which reflects the current configuration and can be modified.

Here is an example implementation:

```
public class MyInitializationHook extends InitializationHook {  
    // an alternate server address read from the configuration  
    private String alternateServer = null;  
    // determines which server address to use  
    private boolean useAlternate = false;  
  
    // This method toggles the JPPF server address between the value set in the  
    // configuration file and an alternate server address  
    public void initializing(UnmodifiableTypedProperties initialConfiguration) {  
        // store the alternate server address  
        if (alternateServer == null) {  
            alternateServer = initialConfiguration.getString("alternate.server.host");  
        }  
        TypedProperties currentConfig = JPPFConfiguration.getProperties();  
        // means the JPPF-configured value is to be used  
        if (!useAlternate) {  
            // reset the server address to its initially configured value  
            String initialServer = initialConfiguration.getString("jppf.server.host");  
            currentConfig.setProperty("jppf.server.host", initialServer);  
            // toggle the server address to use for the next attempt  
            useAlternate = true;  
        } else {  
            // connection to JPPF-configured server failed,  
            // we will now try to connect to the alternate server  
            currentConfig.setProperty("jppf.server.host", alternateServer);  
            // toggle the server address to use for the next attempt  
            useAlternate = false;  
        }  
    }  
}
```

Once the implementation is done, the initialization hook is plugged into JPPF using the service provider interface:

- create a file in **META-INF/services** named **“org.jppf.node.initialization.InitializationHook”**
- in this file, add the fully qualified class name of your implementation of the interface
- copy the jar file or class folder containing your implementation and service file to the classpath of each node.

Related sample: [Initialization Hook sample](#).

7.9 Fork/Join thread pool in the nodes

By default, JPPF nodes use a “standard” thread pool for executing tasks. This add-on allows the use of a [fork/join thread pool](#) instead of the standard one. This enables JPPF tasks to locally (in the node) spawn [ForkJoinTask](#) (or any of its subclasses) instances and have them processed as expected for a `ForkJoinPool`.

To use this add-on, you will need to deploy the jar file "ThreadManagerForkJoin.jar" to either the JPPF server's or node's classpath. If deployed in the server's classpath, it will be available to all nodes.

The next step is to configure each node for use of the fork/join thread pool. This is achieved by adding the following property to the node's configuration:

```
jppf.thread.manager.class = org.jppf.server.node.fj.ThreadManagerForkJoin
```

Here is an example usage, which computes the number of occurrences of each word in a set of documents:

```
public class WordCountTask extends JPPFTask {
    // a list of documents to process
    private final List<String> documents;

    public WordCountTask(final List<String> documents) {
        this.documents = documents;
    }

    @Override
    public void run()
    {
        List<Map<String, Integer>> results = new ArrayList<>();
        // compute word counts in each document
        if (ForkJoinTask.inForkJoinPool()) {
            List<ForkJoinTask<Map<String, Integer>>> tasks = new ArrayList<>();
            // fork one new task per document
            for (String doc: documents) tasks.add(new MyForkJoinTask(doc).fork());
            // wait until all forked tasks have completed (i.e. join)
            for (ForkJoinTask<Map<String, Integer>> task: tasks) results.add(task.join());
        } else {
            // if not in FJ pool, process documents sequentially
            for (String doc: documents) results.add(new MyForkJoinTask(doc).compute());
        }
        // merge the results of all documents
        Map<String, Integer> globalResult = new HashMap<>();
        for (Map<String, Integer> map: results) {
            for (Map.Entry<String, Integer> entry: map.entrySet()) {
                Integer n = globalResult.get(entry.getKey());
                if (n == null) globalResult.put(entry.getKey(), entry.getValue());
                else globalResult.put(entry.getKey(), n + entry.getValue());
            }
        }
        // set the merged word counts as this task's result
        this.setResult(globalResult);
    }
}
```

We can see here that the execution strategy depends on the result of calling `ForkJoinTask.inForkJoinPool()`: if we determine that a fork/join pool is available, then a new task is forked for each document, and thus executed asynchronously. The execution is then synchronized by joining each forked task. Otherwise, the documents are processed sequentially.

In this example, our fork/join task is defined as follows:

```
public class MyForkJoinTask extends RecursiveTask<Map<String, Integer>> {
    // remove spaces and non-word characters
    private static Pattern pattern = Pattern.compile("\\s|\\W");
    private final String document;

    public MyForkJoinTask(final String document) {
        this.document = document;
    }

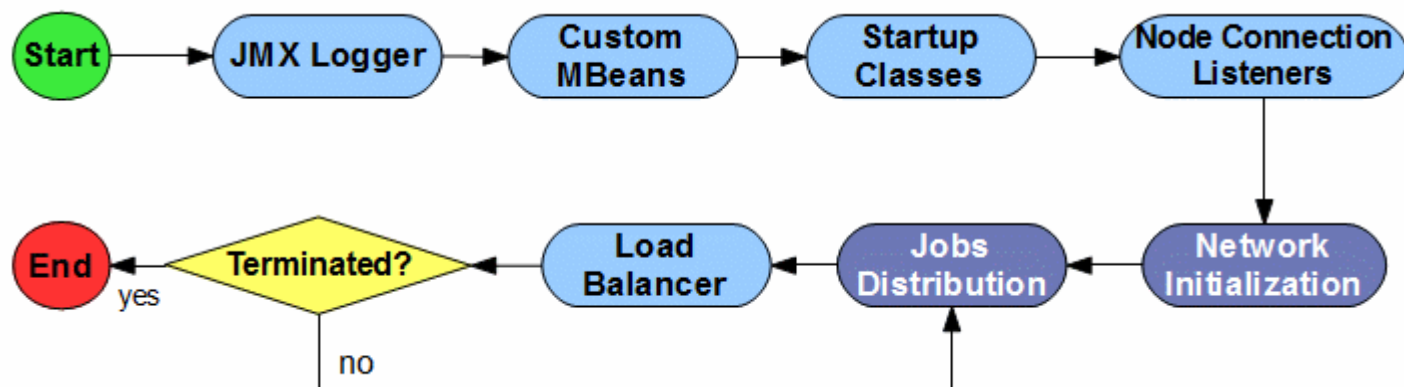
    @Override
    // return a mapping of each word to its number of occurrences
    public Map<String, Integer> compute() {
        Map<String, Integer> result = new HashMap<>();
        // split the document into individual words
        String[] words = pattern.split(document);
        // count the number of occurrences of each word in the document
        for (String word: words) {
            Integer n = result.get(w);
            result.put(word, (n == null) ? 1 : n+1);
        }
        return result;
    }
}
```

Related sample: the fork/join thread pool add-on of the JPPF distribution provides a more sophisticated example, taking full advantage of the fork/join features in Java 7. This example is packaged along with the downloadable “JPPF-x.y.z-jdk7-addons.zip” file.

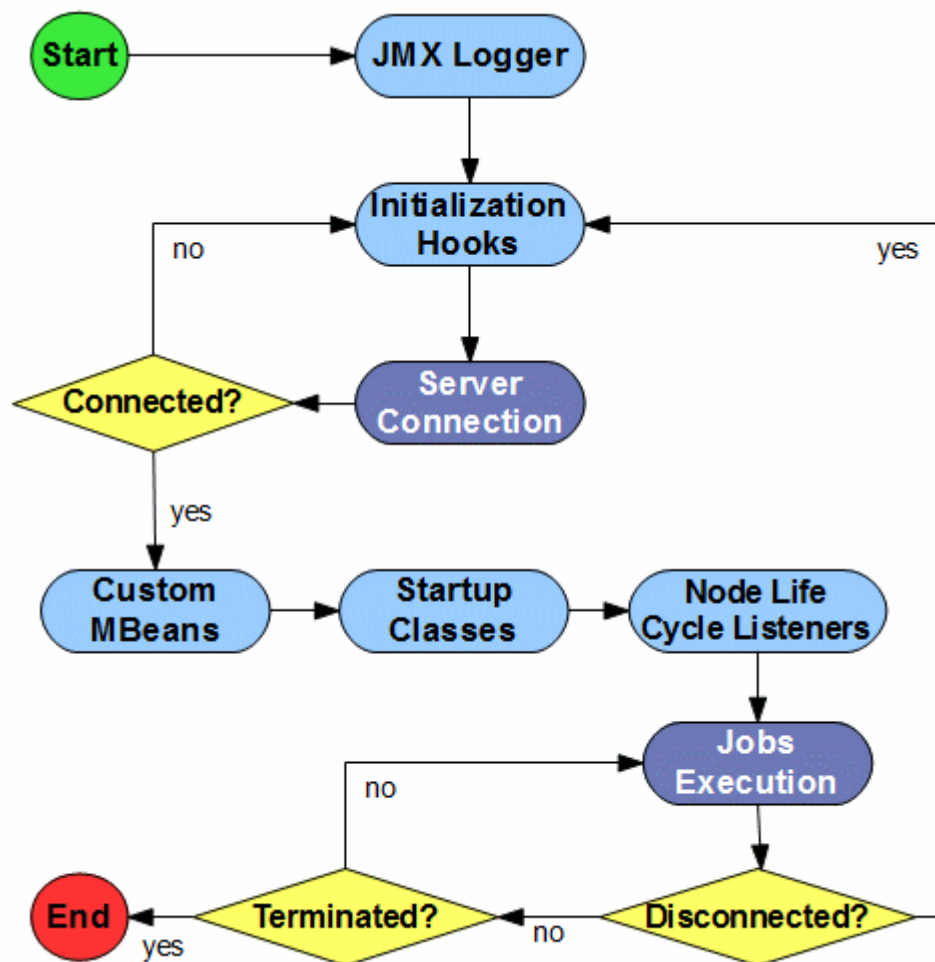
7.10 Flow of customizations in JPPF

The following sections describe the flow of customizations and extensions in JPPF, and especially the order in which they are loaded, both with respect to each other and to the major events in the server and nodes life cycle.

7.10.1 JPPF driver



7.10.2 JPPF node



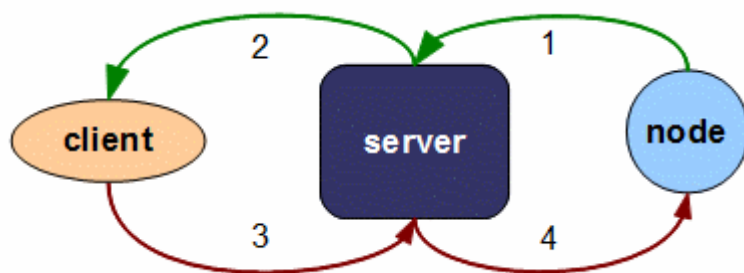
8 Class Loading In JPPF

8.1 How it works

The distributed class loading framework in JPPF is the mechanism that makes it possible to execute code in a node that has not been explicitly deployed to the node's environment. Through this, JPPF tasks whose code (the actual bytecode to execute) is only defined in a JPPF client application, can be executed on remote nodes without the application developer having to worry about how this code will be transported there.

While this mechanism is fully transparent from the client application's perspective, it has a number of implications and particularities that may impact various aspects of JPPF tasks execution, including performance and integration with external libraries.

Let's have a quick view of the path followed by a class loading request at the time a JPPF task is executed within a node:



We can see that this class loading request is executed in four steps:

4. the node sends a network request to the remote server for the class
5. the server forwards the request to the identified remote client
6. the client provides a response (the bytecode of the class) to the server
7. the server forwards the response to the node

Once these steps are performed, the node holds the bytecode of the class and can effectively define and load it as for any standard Java class.

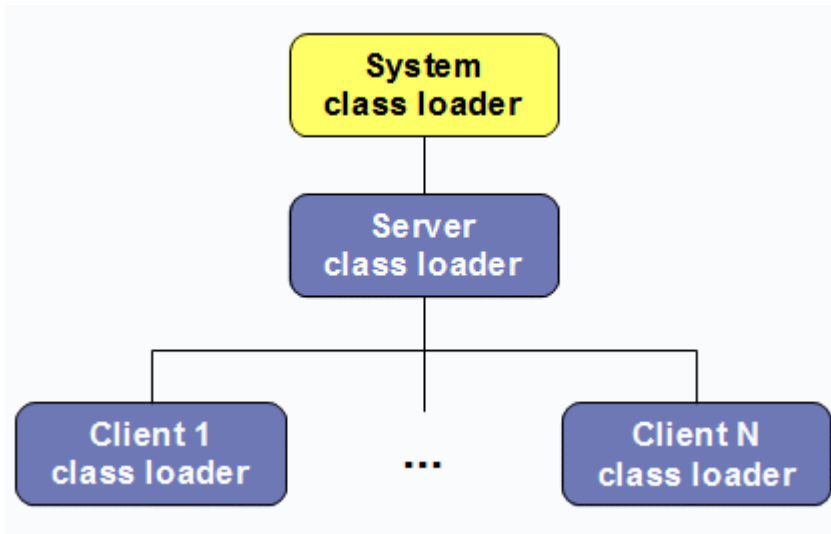
This use case is a simplification of the overall class loading mechanism in JPPF, however it illustrates what actually takes place when a task is executed in a node. This also raises a number of questions that need clarification:

- how does the server know which client to forward a request to?
- how does this fit into the Java class loader delegation model?
- how does it work in complex JPPF topologies with multiple servers?
- how does it apply to JPPF customizations and add-ons or external libraries that are available in the server or node's classpath?
- what is the impact on execution performance?
- what possibilities does this open up for JPPF applications?

We will address these questions in details in the next sections.

8.2 Class loader hierarchy in JPPF nodes

The JPPF class loader mechanism follows a hierarchy based on parent-child relationships between class loader instances, as illustrated in the following picture:



The system class loader is used to start the JPPF node. With most JVMs, it will be an instance of the class [java.net.URLClassLoader](#) and its usage and creation are handled by the JVM.

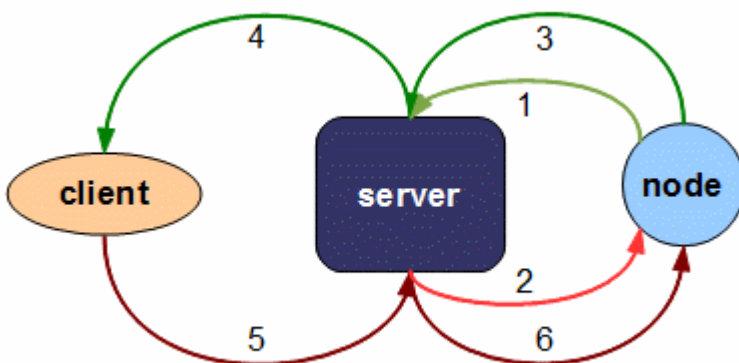
The server class loader is a concrete implementation of the class [AbstractJPPFClassLoader](#) and provides remote access to classes and resources in the server's classpath. It is created at the time the node establishes a connection to the server. It is also discarded when the node disconnects from the server. The parent of the server class loader is the system class loader. Please note that [AbstractJPPFClassLoader](#) is also a subclass of [URLClassLoader](#).

The client class loaders are also concrete implementations of [AbstractJPPFClassLoader](#) and provide remote access to classes and resources in one or more clients' classpaths. Each client class loader is created the first time the node executes a job which was submitted by that client. Thus, the node may hold many client class loaders.

It is important to note that, by design, the JPPF node holds a single network connection to the server, shared by all instances of [AbstractJPPFClassLoader](#), including the server and clients class loaders. This design avoids a lot of potential confusion, inconsistencies and synchronization pitfalls when performing multiple class loading requests in parallel.

By default, a JPPF class loader follows the standard delegation policy to its parent. This means that, when a class is requested from a client class loader, it will first delegate to its parent, the server class loader, who will in turn first delegate to the system class loader. If a class is not found by the parent, then the class loader will look it up in the classpath to which it has access.

Thus, the flow of a request, for a class that is only in a client's class path, becomes a little more complex:

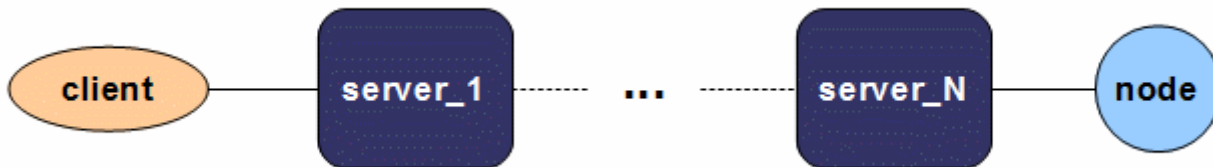


Here, the first two steps are initiated by the server class loader, as a result of the client class loader delegating to its parent. What is missing from this picture are the calls to the system class loader, since they are only meaningful if the requested class is in the node's local classpath.

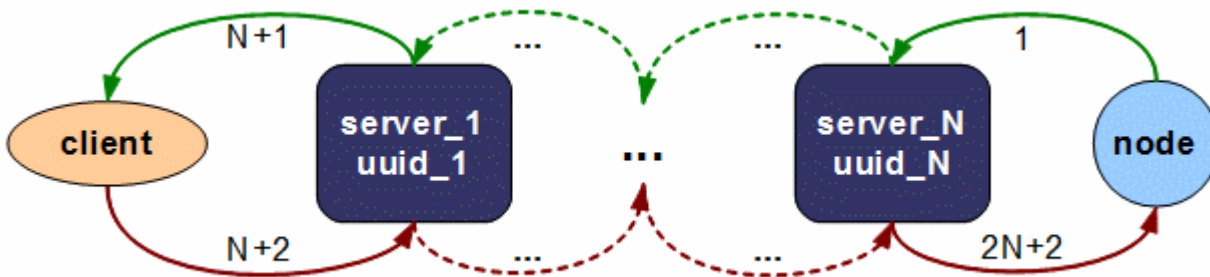
8.3 Relationship between UUIDs and class loaders

We have seen in the *Development Guide* that each JPPF client has its own identifier, unique across the entire JPPF grid. This is also true of servers and nodes. The client UUID is what allows a JPPF node to know which client a class loader is associated with, and use it to route a class loading request from the node down to the client that submitted the job.

If a node only knows the client UUID, then it will only be able to handle the routing of class loading requests in the simplest JPPF grid topology: a topology which only has one server. However, there is a mechanism that allows the class loading to work in much more complex topologies, such as this one:



To this effect, each job executed on a node will transport, in addition to the originating client's UUID, the UUID of each server in the chain of servers that had to be traversed to get to the node. In JPPF terminology, this ordered list of UUIDs is called a *UUID path*. With this information known, it is possible to route a class loading request through any chain of servers, as illustrated in the picture below:



It is also important to note that this does not change anything to the class loader hierarchy within the node. In effect, there is still only one server class loader, which is associated with the server the node is *directly* connected to. This implies that the parent delegation model will not cause a class loading request to traverse the server chain multiple times.

Another implication of using client UUIDs is that it is possible to have multiple versions of the same code running within a node. Let's imagine a situation where two distinct JPPF clients, with separate UUIDs, submit the same tasks. From the node's point of view, the classes will be loaded by two distinct client class loaders, and therefore the classes from the first client will be different from those of the second client, even if they have the exact same bytecode and are downloaded from the same jar file.

The reverse situation may also happen, when two clients with the same UUID submit tasks that use different versions of the same classes. In this case, the tasks will be exposed to errors, especially at deserialization time, if the two versions are incompatible.

8.4 Built-in optimizations

JPPF provides a number of built-in optimizations and capabilities that enable to reduce the class loading overhead and avoid excessive non-heap memory consumption when the number of classes that are loaded becomes large. We will review these features in the next sections.

8.4.1 Deployment to specific grid components

In some situations, there can be a large number of classes to load before a JPPF task can be executed by a node. Even though this class loading overhead is a one-time occurrence, it can take a significant amount of time, especially if the network communication between node and server, or between server and client, is slow. This may happen, for instance, when the tasks rely on many external libraries, causing the loading of the classes within these libraries in addition to the classes in the application.

One way to overcome this issue is to deploy the external libraries to the JPPF server or node's classpath, to significantly reduce the time needed to load the classes in these libraries. The main drawback is that it requires to manage the deployed libraries, to ensure that they are consistently deployed across the grid, especially at such times when some of the libraries must be upgraded or removed, or new ones added. However, it is considered a good practice in production environment where few or no changes are expected during long periods of time.

8.4.2 Using a constant JPPF client UUID

In the *Development Guide*, we have seen that it is possible to set the UUID of a JPPF client to a user-defined value, using the constructor `JPPFClient(String uuid)`. This can be leveraged to force the nodes to reuse the client class loader for the specified UUID, even after the client application is terminated and has been restarted. It also implies that, if multiple clients use the same UUID, the same client class loader will also be used in the nodes. Thus, this feature limits the initial class loading overhead to the first time a job is submitted by the first client to run.

The main drawback is that, if the code of the tasks is changed on the client side, the changes will not be automatically taken into account by the nodes, and some errors may occur, due to an incompatibility between class versions in the node and in the client. If this happens, then you will have to change the client UUID or restart the nodes to force a reload of the classes by the nodes.

8.4.3 Node class loader cache

Each JPPF node maintains a cache of client class loaders. This cache has a bounded size, in order to avoid out of memory conditions caused by too many classes loaded in the JVM. This cache has an eviction policy based on the least recently created class loader. Thus, when the cache size limit is reached and a new class loader needs to be created, the oldest class loader that was created is removed from the cache, which frees up a slot for the new class loader.

As described in the Configuration Guide, the cache size is defined in the node's configuration file as follows:

```
jppf.classloader.cache.size = n
```

where *n* is a strictly positive integer

8.4.4 Local caching of network resources

The class loader also caches, on the node's local file system, all resources found in the classpath via a call to one of its `getResourceAsStream()`, `getResource()` or `getResources()` methods. This avoids a potentially large network overhead the next time the same resources are requested.

By default, the root of this local file cache is located at the default temp directory, such as determined by a call to `System.getProperty("java.io.tmpdir")`. This can be overridden using the following JPPF node configuration property:

```
jppf.resource.cache.dir = some_directory
```

In fact, the full determination of the root for the resources cache is done as follows:

- if the node configuration property "jppf.resource.cache.dir" is defined, then use its value
- otherwise, if the system property "java.io.tmpdir" is defined, then use it
- otherwise, if the system property "user.home" is defined, then use it
- otherwise, if the system property "user.dir" is defined, then use it
- otherwise, use the current directory "."

Additionally, to avoid confusion with any other applications storing temporary files, the JPPF node will store temporary resources in a directory named `".jppf"` under the computed cache root. For instance, if the computed root location is `"/tmp"`, the node will store resources under `"/tmp/.jppf"`.

8.4.5 Classes cache in the JPPF server

Each JPPF server maintains an in-memory cache of classes and resources loaded via the class loading mechanism. This cache speeds up the class loading process by avoiding network lookups on the JPPF clients that hold the requested classes in their classpath. To avoid potential out of memory conditions, this cache uses [soft references](#) to store the bytecode of classes. This means that these classes may be unloaded from the cache by the garbage collector if the memory becomes scarce in the server. However, in most situations the cache still provides a significant speedup.

8.4.6 Node customizations

As seen in the chapter *Extending and Customizing JPPF > Flow of customizations in JPPF*, most node customizations (except for the JMX logger and Initialization hooks) are loaded after the node has established a connection with the server. This enables these customizations to be loaded via the server class loader, which means they can be deployed to the server's classpath and then automatically downloaded from the server by the node.

You may also choose to deploy the customizations to the node's local classpath, in which case you will have to do it for all nodes that require this customization. In this case, the customizations will load faster but they incur the overhead of redeploying new versions to all the nodes.

8.5 Class loader delegation models

As we have seen previously, the JPPF class loaders follow by default the parent-first delegation model. We have also seen that the base class [AbstractJPPFClassLoader](#) is a subclass of [URLClassLoader](#), which maintains a set of URLs for its classpath, each URL pointing to a jar file or class folder. One particularity of [AbstractJPPFClassLoader](#) is that it overrides the `addURL(URL)` method to make it `public` instead of `protected`. The implication is that any node customization or JPPF task will have access to this method, and will be able to dynamically extend the classpath of the JPPF class loaders.

To take advantage of this, the node provides an additional delegation model for its class loaders, which will cause them to first lookup in their URL classpath as specified with call to `addURL(URL)`, and then lookup in the remote server or client.

When this delegation model is activated, the lookup for a class or resource from a client class loader will follow these steps:

- Lookup in the URL classpath
 - client class loader: delegate to the server class loader
 - server class loader: lookup in the URL classpath only
 - if the class is found, then end of lookup
 - otherwise, back to the client class loader, lookup in the URL classpath only
 - if the class is found, end of lookup
- Otherwise lookup in the server or client classpath
 - client class loader: delegate to the server class loader
 - server class loader: send a class loading request to the server
 - if the class is found in the server's classpath or cache, end of lookup
 - otherwise, the client class loader sends a request to the server to lookup in the client's classpath
 - if the class is found, end of lookup
 - otherwise throw a `ClassNotFoundException`

To summarize: when the URL-first delegation model is active, the node will first lookup classes and resources in the local hierarchy of URL classpaths, and then on the network via the JPPF server.

The delegation model is set JVM-wide in a node, it is not possible to specify different models for different class loader instances. There are three ways to specify the class loader delegation model in a node:

Statically in the node configuration:

```
# possible values: parent | url, defaults to parent
jppf.classloader.delegation = parent
```

Dynamically by API:

```
public abstract class AbstractJPPFClassLoader
    extends AbstractJPPFClassLoaderLifeCycle {

    // Determine the class loading delegation model currently in use
    public static synchronized DelegationModel getDelegationModel()

    // Specify the class loading delegation model to use
    public static synchronized void setDelegationModel(final DelegationModel model)
}
```

The delegation model is defined as the type safe enum [DelegationModel](#):

```
public enum DelegationModel {
    // Standard delegation to parent first
    PARENT_FIRST,
    // Delegation to local URL classpath first
    URL_FIRST
}
```

Dynamically via JMX:

The related getter and setter are available in the interface [JPPFNodeAdminMBean](#), which is also implemented by the JMX client [JMXNodeConnectionWrapper](#). These allow you to dynamically and remotely change the node's delegation model:

```
public interface JPPFNodeAdminMBean extends JPPFAdminMBean {
    // Get the current class loader delegation model for the node
    DelegationModel getDelegationModel() throws Exception;

    // Set the current class loader delegation model for the node
    void setDelegationModel(DelegationModel model) throws Exception;
}
```

There is one question we are entitled to ask: *what are the benefits of using the URL-first delegation model?* The short answer is that it essentially provides a significant speedup of the class loading in the node, by providing the ability to download entire jar files and libraries and adding them dynamically to the node's class path. The next section of this chapter will detail how this, among other possibilities, can be achieved.

8.6 JPPF class loading extensions

8.6.1 Dynamically adding to the classpath

As we have seen previously, the class [AbstractJPPFClassLoader](#), or more accurately its direct superclass [AbstractJPPFClassLoaderLifeCycle](#), exposes the `addURL(URL)` method, which is a protected method in the JDK's `URLClassLoader`. This means that it is possible to add jar files or class folders to the class path of a JPPF class loader at run time.

The main benefit of this feature is that it is possible to download entire libraries, then add them to the classpath, and thus dramatically speed up the class loading in the node. In effect, for applications that use a large number of classes, downloading a jar file will take much less time than loading classes one by one from the JPPF server or client.

Furthermore, the downloaded libraries can then be stored on the node's local file system, so they don't have to be downloaded again when the node is restarted. They can also be managed automatically (with custom code) to handle new versions of the libraries and remove old ones.

8.6.2 Downloading multiple resources at once

`AbstractJPPFClassLoader` provides an additional method to download multiple resources in a single request:

```
public URL[] getMultipleResources(final String...names)
```

This is an equivalent to the `getResource(String name)` method, except that it works with multiple resources at once. The returned array of URLs may contain null values, which means the corresponding resources were not found in the class loader's classpath. The main advantage of this method is that it performs all resources lookups in a single request, which implies a single network round-trip when looking up in the server or client's classpath.

For instance this could be used to download a set of jar files and add them dynamically to the classpath, as seen in the previous section.

8.6.3 Resources lookup on the file system

When requesting a resource via one of the `getResourceAsStream()`, `getResource()`, `getResources()` or `getMultipleResources()` methods, the JPPF class loader will lookup the specified resources in the server or client's local file system if they are not found in the class path.

This is provided as a basic convenient way to download files from a JPPF server or client, without having to use or code a specific file download facility (such as having an FTP server on the JPPF server or client).

However, there is a limitation to this facility: the resource path should always be relative to the server or client's current directory (determined via a `System.getProperty("user.dir")` call). In particular, using an absolute path will lead to unpredictable results.

8.7 Related sample

Please look at the [Extended Class Loading](#) sample in the JPPF samples pack.

9 J2EE Connector

9.1 Overview of the JPPF Resource Adapter

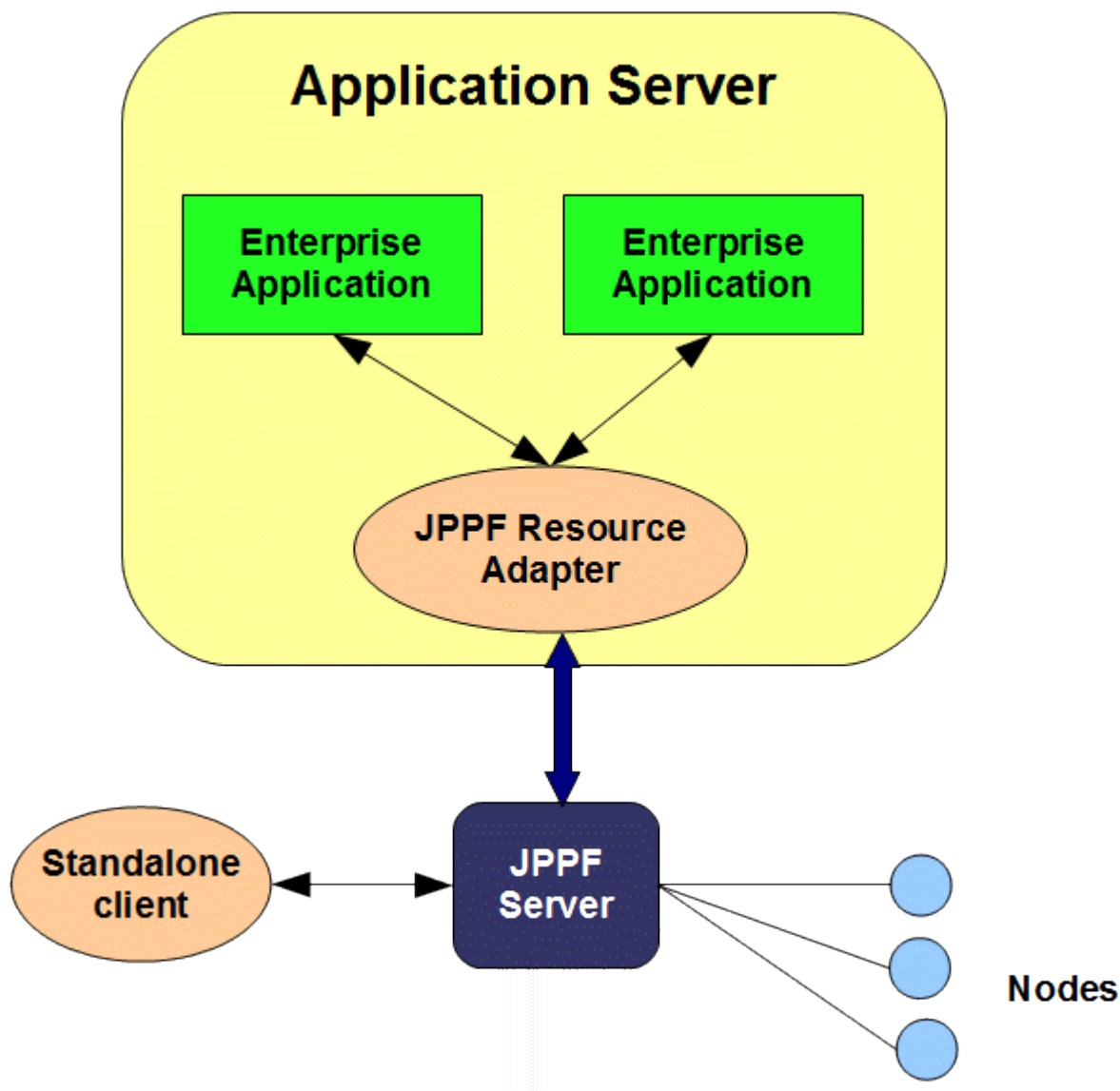
9.1.1 What is it?

The JPPF Resource Adapter is a JCA-compliant resource adapter module that encapsulates a JPPF client. It provides J2EE application servers with an access to JPPF grid services. It is intended for deployment as either a standalone module or embedded within an enterprise application, while preserving the ease of use of JPPF.

9.1.2 Features

- Supports the same configuration properties as a standalone JPPF client, including server discovery, connection to multiple drivers, connection pool per driver
- Supports disconnection from, and reconnection to, any JPPF driver
- Compliant with the [JCA 1.5 specifications](#)
- API similar to that of the standard JPPF client (`submit(job)`)
- No transaction support

9.1.3 Architecture



9.2 Supported Platforms

Note: we have not tested all versions of all platforms, thus it is possible that the integration, with the version of the application server you are using, may not work out-of-the-box. We hope that the existing framework and instructions will allow you to adapt the build scripts and code to do so. If you have issues with a specific port, or if you wish to report one that is not specified in this documentation, we invite you to provide your feedback and comments on the [JPPF Forums](#).

Technology	Tested Platforms
Operating System	All Windows systems supporting JDK 1.5 or later All Linux and Unix systems supporting JDK 1.5 or later
JVM	Sun JDK 1.5 and later IBM JVM 1.5 and later BEA JRockit 1.5 and later
Application Server	JBoss 4.0, 4.2, 5.0, 5.1, 6.0, 7.0 Oracle OC4J 10.1.3.x Sun AS 9.0.x, Glassfish 2.x, 3.x IBM Websphere Application Server 6.1, 7.0 Oracle Weblogic 9.x, 10.x, 11.x Apache Geronimo 2.1.x

9.3 Configuration and build

9.3.1 Requirement

For building, configuring and customizing the JPPF Resource Adapter, you will need the latest version of the JPPF source code distribution. It can be found on the [JPPF download page](#). The name of the file should be "JPPF-2.x-j2ee-connector.zip"

9.3.2 Build structure

The J2EE connector has the following folder structure:

Folder	Description
root folder	The root folder, contains the build.xml Ant build script
appserver	contains common and application server-specific configurations for the JPPF resource adapter and the demo application
build	this folder contains all jars, .ear and .rar files resulting from the build
classes	contains the compiled code of the JPPF resource adapter
config	contains application server-specific resources for the deployment of the resource adapter
docroot	contains resources for the build of the demo application on some application servers
src	contains the source code for the resource adapter and demo application.

9.3.3 Building the JPPF resource adapter

To build the resource adapter:

- Open a command prompt
- Go to the **JPPF-x.y-j2ee-connector** folder
- Enter **"ant build"**
- The resulting .rar and .ear files are generated in the **"build"** subfolder.

9.3.4 Configuring the resource adapter and demo application

The configuration files and deployment descriptors are all contained in the "appserver" folder. The detailed content of this folder is as follows:

Folder	Description
appserver	<p>root folder, contains:</p> <ul style="list-style-type: none">– the resource adapter's deployment descriptor ra.xml. It is in this file that you set the configuration parameters for the connection to the JPPF drivers, by setting the values of the configuration properties as follows: <pre><config-property> <config-property-name>ClientConfiguration</config-property-name> <config-property-type>java.lang.String</config-property-type> <config-property-value> # any server on the network will be automatically detected jppf.local.execution.enabled = true # create a pool of 5 connections for each detected server jppf.pool.size = 5 </config-property-value> </config-property></pre>– the demo application's deployment descriptor application.xml
appserver/common	contains files common to all application servers, for the demo enterprise application
appserver/<server_name>	root of <server_name>-specific configuration and deployment files. Contains a commons-logging.properties file where you can configure which logging framework will be used (i.e. Log4j, JDK logger, etc...)
appserver/<server_name>/application	contains <server_name>-specific deployment descriptor for the demo application, for example: weblogic-application.xml.
appserver/<server_name>/docroot	contains a <server_name>-specific JSP for the demo application. The specificity is the JNDI name used to look up the JPPF connection factory. It relates to the corresponding resource-ref defined in the web.xml descriptor.
appserver/<server_name>/ra	contains a <server_name>-specific deployment descriptor for the resource adapter. It generally contains the definition of the corresponding JCA connection factory. Not all application servers require one. Example: weblogic-ra.xml.
appserver/<server_name>/WEB-INF	contains the <server_name>-specific deployment descriptors for the demo web application. The specificity is mostly in the resource-ref definition of the JNDI name for the JPPF connection factory. For example: web.xml and jboss-web.xml.

9.4 How to use the connector API

To use the JPPF Resource Adapter from your code, follow these steps:

9.4.1 Obtaining and closing a resource adapter connection

The J2EE connector is accessed via the [JPPFConnection](#) interface. This implies that any operation performed should follow these steps:

1. obtain a connection from the resource adapter connection pool
2. perform one or more JPPF-related operation(s)
3. close the connection

The following helper code illustrates how to obtain and release connections from the resource adapter:

```
import javax.naming.*;
import javax.resource.ResourceException;
import javax.resource.cci.ConnectionFactory;

public class JPPFHelper {
    // JNDI name of the JPPFConnectionFactory.
    public static final String JNDI_NAME = "eis/JPPFConnectionFactory";

    // Obtain a JPPF connection from the resource adapter's connection pool
    public static JPPFConnection getConnection()
        throws NamingException, ResourceException {

        // Perform a JNDI lookup of the JPPF connection factory
        InitialContext ctx = new InitialContext();
        JPPFConnectionFactory factory;
        Object objref = ctx.lookup(JNDI_NAME);
        if (objref instanceof JPPFConnectionFactory) {
            factory = (JPPFConnectionFactory) objref;
        } else {
            factory = (JPPFConnectionFactory) javax.rmi.PortableRemoteObject.narrow(
                objref, ConnectionFactory.class);
        }
        // get a JPPFConnection from the connection factory
        return (JPPFConnection) factory.getConnection();
    }

    // Release a connection
    public static void closeConnection(JPPFConnection connection)
        throws ResourceException {
        connection.close();
    }
}
```

Please note that the actual JNDI name for the JPPF connection factory will vary depending on which application server is used:

- on Apache Geronimo: "jca:/JPPF/jca-client/JCAManagedConnectionFactory/eis/JPPFConnectionFactory"
- on JBoss: "java:eis/JPPFConnectionFactory"
- on Websphere: "java:comp/env/eis/JPPFConnectionFactory"
- on all other supported servers: "eis/JPPFConnectionFactory"

9.4.2 Submitting jobs

[JPPFConnection](#) provides two methods for submitting jobs:

```
public interface JPPFConnection extends Connection, JPPFAccessor {
    // Submit a job to the JPPF client
    // This method exits immediately after adding the job to the queue
    String submit(JPPFJob job) throws Exception;

    // Submit a job to the JPPF client and register the specified status listener
    // This method exits immediately after adding the job to the queue
    String submit(JPPFJob job, SubmissionStatusListener listener) throws Exception;
}
```

You will note that both methods actually perform an asynchronous job submission. They return a unique id for the the submission, which is in fact the job UUID. This id is then used to retrieve the job results and its status.

In the following example, a JPPF job is submitted asynchronously. The submission returns an ID that can be used later on to check on the job status and retrieve its results.

```
public String submitJob() throws Exception {
    JPPFConnection connection = null;
    try {
        // get a JPPF Connection
        connection = JPPFHelper.getConnection();
        // create a JPPF job
        JPPFJob job = new JPPFJob();
        job.addTask(new DemoTask());
        // Use the connection to submit the JPPF job and obtain a submission ID
        return connection.submit(job);
    } finally {
        // close the connection
        JPPFHelper.closeConnection(connection);
    }
}
```

9.4.3 Getting the status and results of a job

Here, we check on the status of a job and process the execution results or the resulting error:

```
public void checkStatus(String submitId) throws Exception {
    JPPFConnection connection = null;
    try {
        connection = JPPFHelper.getConnection();
        // Use the connection to check the status from the submission ID
        SubmissionStatus status = connection.getSubmissionStatus(submitID);
        if (status.equals(SubmissionStatus.COMPLETE)) {
            // if successful process the results
            List<JPPFTask> results = connection.getSubmissionResults(submitID);
        } else if (status.equals(SubmissionStatus.FAILED)) {
            // if failed process the errors
        }
    } finally {
        JPPFHelper.closeConnection(connection);
    }
}
```

9.4.4 Cancelling a job

The J2EE allows cancelling a job by calling the method `JPPFConnection.cancelJob(String submitId)`:

```
public void cancelJob(String submitId) throws Exception {
    JPPFConnection connection = null;
    try {
        connection = JPPFHelper.getConnection();
        // cancel the job
        connection.cancelJob(submitID);
    } finally {
        JPPFHelper.closeConnection(connection);
    }
}
```

9.4.5 Synchronous execution

It is also possible to execute a job synchronously, without having to code the job submission and status checking in two different methods. The `JPPFConnection` API provides the method `waitForResults(String submitID)`, which waits until the job has completed and returns the execution results. Here is an example use:

```
// Submit a job and return the execution results
public List<JPPFTask> submitBlockingJob() throws Exception {
    List<JPPFTask> results = null;
    JPPFConnection connection = null;
    try {
        connection = JPPFHelper.getConnection();
        // create a new job
        JPPFJob job = new JPPFJob();
        job.setName("test job");
        // add the tasks to the job
        for (int i=0; i<5; i++) job.addTask(new MyTask(i));
        // submit the job and get the submission id
        String submitID = connection.submit(job);
        // wait until the job has completed
        results = connection.waitForResults(submitID);
    } finally {
        JPPFHelper.closeConnection(connection);
    }
    // now return the results
    return results;
}
```

Please note that, when using the synchronous submission mode from within a transaction, you must be careful as to how long the job will take to execute. If the job execution is too long, this may cause the transaction to time out and roll back, if the execution time is longer than the transaction timeout.

9.4.6 Using submission status events

With the J2EE connector, It is possible to subscribe to events occurring during the life cycle of a job. This can be done via the following two methods:

```
public interface JPPFConnection extends Connection, JPPFAccessor {
    // Add a status listener to the submission with the specified id
    void addSubmissionStatusListener(
        String submissionId, SubmissionStatusListener listener);

    // Submit a job to the JPPF client and register a status listener
    String submit(JPPFJob job, SubmissionStatusListener listener) throws Exception;
}
```

Note that `submit(JPPFJob, SubmissionStatusListener)` submits the job *and* registers the listener in a single atomic operation. As the job submission is asynchronous, this ensures that no event is missed between the submission of the job and the registration of the listener.

The interface [SubmissionStatusListener](#) is defined as follows:

```
public interface SubmissionStatusListener extends EventListener {
    // Called when the status of a job has changed
    void submissionStatusChanged(SubmissionStatusEvent event);
}
```

Each listener receives events of type [SubmissionStatusEvent](#), defined as follows:

```
public class SubmissionStatusEvent extends EventObject {
    // get the status of the job
    public SubmissionStatus getStatus()

    // get the id of the job
    public String getSubmissionId()
}
```

The possible statuses are defined in the enumerated type [SubmissionStatus](#):

```
public enum SubmissionStatus {
    SUBMITTED, // the job was just submitted.
    PENDING,   // the job is currently in the submission queue (on the client side)
    EXECUTING, // the job is being executed
    COMPLETE,  // the job execution is complete
    FAILED     // the job execution has failed
}
```

Here is an exemple usage of the status listeners:

```
public void submitWithListener() throws Exception {
    JPPFConnection connection = null;
    try {
        connection = JPPFHelper.getConnection();
        JPPFJob job = new JPPFJob();
        JPPFTask task = new DemoTask(duration);
        job.addTask(task);

        // a status listener can be added at submission time
        String id = connection.submit(job, new SubmissionStatusListener() {
            public void submissionStatusChanged(SubmissionStatusEvent event) {
                String id = event.getSubmissionId();
                SubmissionStatus status = event.getStatus();
                System.out.println("submission [" + id + "] changed to '" + status + "'");
            }
        });

        // or after the job has been submitted
        connection.addSubmissionStatusListener(id, new SubmissionStatusListener() {
            public void submissionStatusChanged(SubmissionStatusEvent event) {
                String id = event.getSubmissionId();
                SubmissionStatus status = event.getStatus();
                switch(status) {
                    case COMPLETE:// process successful completion
                        break;
                    case FAILED:// process failure
                        break;
                    default:
                        System.out.println("job [" + id + "] changed to '" + status + "'");
                        break;
                }
            }
        });
        List<JPPFask> results = connection.waitForResults(id);
        // ... process the results ...
    } finally {
        JPPFHelper.closeConnection(connection);
    }
}
```

9.5 Deployment on a J2EE application server

9.5.1 Deployment on JBoss 4.x - 6.x

9.5.1.1 Deploying the JPPF resource adapter

copy the file ""jppf_ra_JBoss.rar"" in this folder: <JBOSS_HOME>/server/<your_server>/deploy, where <JBOSS_HOME> is the root installation folder for JBoss, and <your_server> is the server configuration that you use (JBoss comes with 3 configurations: "default", "minimal" and "all")

9.5.1.2 Creating a connection factory

Create, in the <JBOSS_HOME>/server/<your_server>/deploy folder, a file named jppf-ra-JBoss-ds.xml. Edit this file with a text editor and add this content:

```
<?xml version="1.0" encoding="UTF-8"?>
<connection-factories>
  <no-tx-connection-factory>
    <jndi-name>eis/JPPFConnectionFactory</jndi-name>
    <application-managed-security/>
    <rar-name>jppf_ra_JBoss-rar</rar-name>
    <connection-definition>javax.resource.cci.ConnectionFactory</connection-definition>
    <adapter-display-name>JPPF</adapter-display-name>
    <min-pool-size>0</min-pool-size>
    <max-pool-size>10</max-pool-size>
    <blocking-timeout-millis>50000</blocking-timeout-millis>
    <idle-timeout-minutes>15</idle-timeout-minutes>
  </no-tx-connection-factory>
</connection-factories>
```

You can also [download this file](#).

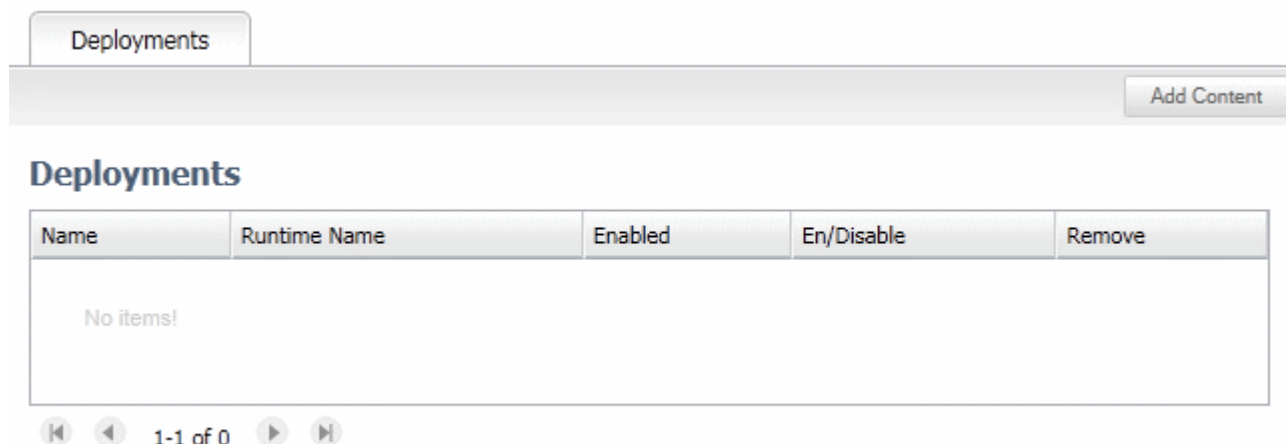
9.5.1.3 Deploying the demo application

Copy the file "JPPF_J2EE_Demo_JBoss-4.0.ear" in the <JBOSS_HOME>/server/<your_server>/deploy folder

9.5.2 Deployment on JBoss 7+

9.5.2.1 Deploying the resource adapter

- in the JBoss administration console, go to the "Deployments" view
- remove any existing JPPF deployments (.rar and .ear)



- click on "Add Content"
- browse to the file "jppf_ra_JBoss-7.rar"

Upload

Step1/2: Deployment Selection

Please choose a file that you want to deploy.

ild\jppf_ra_JBoss-7.rar

Browse...

Next >>

Cancel

- click "next"

Upload

Step 2/2: Verify Deployment Names

Key: Cn0TGRcXbxOgUMHCA09CusCBzVw=

Name: jppf_ra_JBoss-7.rar

Runtime Name: jppf_ra_JBoss-7.rar

Finish

Cancel


- accept the default names and click "Finish"

- back to the "Deployments" view, you should see the deployed resource adapter:

Deployments

Add Content

Deployments

Name	Runtime Name	Enabled	En/Disable	Remove
jppf_ra_JBoss-7.rar	jppf_ra_JBoss-7.rar		Enable	Remove


1-1 of 1

- click on the "Enable" button to start it:

Deployments

Add Content

Deployments

Name	Runtime Name	Enabled	En/Disable	Remove
jppf_ra_JBoss-7.rar	jppf_ra_JBoss-7.rar		Disable	Remove

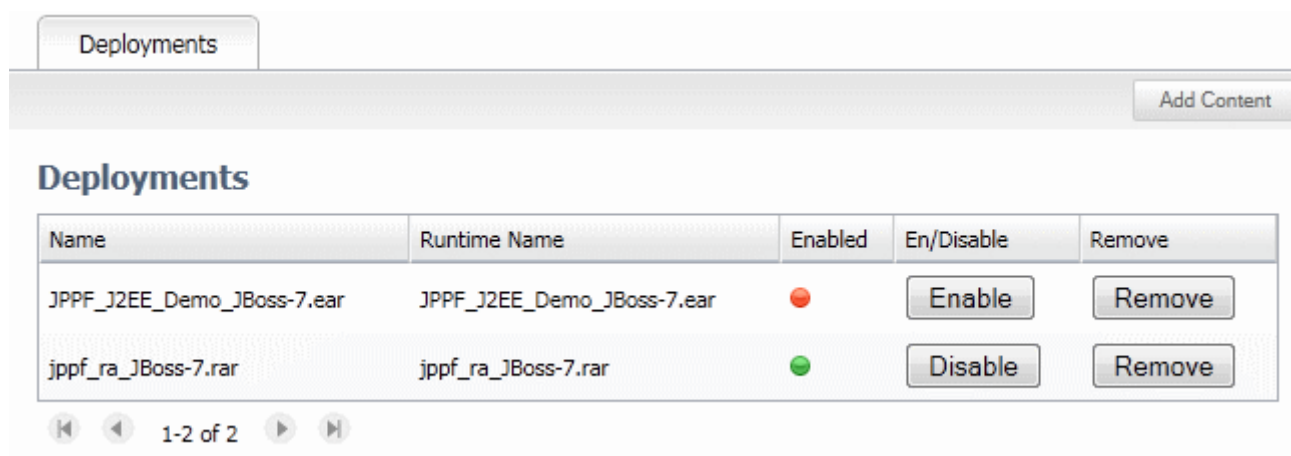
1-1 of 1

9.5.2.2 Deploying the demo application

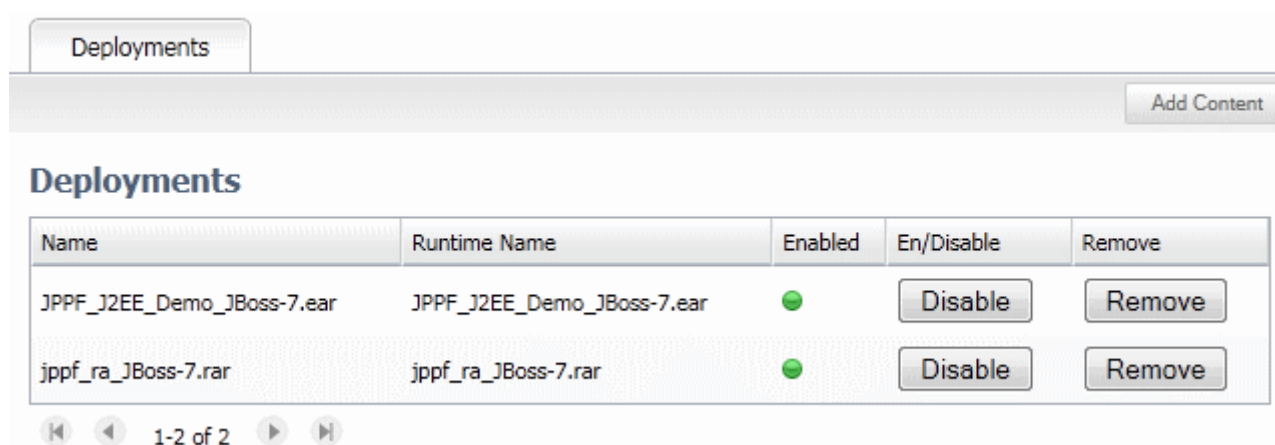
- In the "Deployment" view, click on "Add Content" and browse to "JPPF_J2EE_Demo_JBoss-7.ear"



- click on "Next"
- Accept the default names and click on "Finish"
- You should now see the demo web app in the list of deployments:



- click on the "Enable" button to start it:



9.5.3 Deployment on Oracle OC4J 10.3.1.x

9.5.3.1 Deploying the resource adapter

- in the OC4J administration console, go to "Applications"
- select "Standalone Resource Adapters" view

ORACLE Enterprise Manager 10g
Application Server Control

Setup Logs Help Logout

OC4J: home

Page Refreshed Jul 24, 2007 7:32:12 AM CDT

Home Applications Web Services Performance Administration

This page shows the J2EE applications and application components (EJB Modules, WAR Modules, Resource Adapter Modules) deployed to this OC4J instance.

View Standalone Resource Adapters

Start Stop Undeploy Redeploy Deploy

Select	Resource Adapter	Resource Adapter Module	Status	EIS Type
	OracleASjms	OracleASjms		OracleAS JMS

Home Applications Web Services Performance Administration

Setup | Logs | Help | Logout

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[About Oracle Enterprise Manager 10g Application Server Control](#)

- click on "deploy"
- step 1: browse to the file "jppf_ra_Oracle.rar"



Deploy: Select Archive

[Cancel](#) [Step 1 of 3](#) [Next](#)

Archive

The following types of archives can be deployed: J2EE application (EAR files), Web Modules (WAR files), EJB Modules (EJB JAR files) and Resource Adapter Modules (RAR files).

- ☒ Archive is present on local host. Upload the archive to the server where Application Server Control is running.

Archive Location [Browse...](#)

- ☐ Archive is already present on the server where Application Server Control is running.

Location on Server

The location on server must be the absolute path or the relative path from j2ee/home

Deployment Plan

The deployment plan is an XML file that contains the deployment settings for an application. If you do not have a deployment plan, one will be created automatically during the deployment process. Later in the deployment process, you can optionally edit the deployment plan and save it for a future deployment of this application.

- ☒ Automatically create a new deployment plan.

The deployment plan settings will be based on OC4J defaults and information contained in the archive

- ☐ Deployment plan is present on local host. Upload the deployment plan to the server where Application Server Control is running.

Plan Location [Browse...](#)

- ☐ Deployment plan is already present on server where Application Server Control is running.

Location on Server

The location on server must be the absolute path or the relative path from j2ee/home

[Cancel](#) [Step 1 of 3](#) [Next](#)

[Setup](#) | [Logs](#) | [Help](#) | [Logout](#)

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[About Oracle Enterprise Manager 10g Application Server Control](#)

- click "next"
- step 2: enter "JPPF" as the Resource Adapter Name



Deploy: Application Attributes

[Cancel](#) [Back](#) [Step 2 of 3](#) [Next](#)

Archive Type **Resource Adapter Module (RAR file)**
Archive Location **jppf_ra_Oracle-10.rar**
Deployment Plan **Creating a new plan**

* Resource Adapter Name

[Cancel](#) [Back](#) [Step 2 of 3](#) [Next](#)

[Help](#) | [Logout](#)

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[About Oracle Enterprise Manager 10g Application Server Control](#)

- click "next"
- step 3: click on "deploy"
- after deployment is complete, click on "return"
- restart the application server

9.5.3.2 Deploying the demo application

- in OC4J console, go to "Applications"
- select "Applications" view

ORACLE Enterprise Manager 10g
Application Server Control

Setup Logs Help Logout

OC4J: home

Page Refreshed Jul 24, 2007 7:45:10 AM CDT

Home Applications Web Services Performance Administration

This page shows the J2EE applications and application components (EJB Modules, WAR Modules, Resource Adapter Modules) deployed to this OC4J instance.

View Applications

Start Stop Restart Undeploy Redeploy Deploy

Select All Select None Expand All Collapse All

Select	Name	Status	Start Time	Active Requests	Request Processing Time (seconds)	Active EJB Methods	Application Defined MBeans
<input type="checkbox"/>	▼ All Applications						
<input type="checkbox"/>	ascontrol	↑	Jul 24, 2007 7:30:50 AM CDT	1	0.08	0	
<input type="checkbox"/>	▼ default	↑	Jul 24, 2007 7:30:49 AM CDT	0	0.00	0	
<input type="checkbox"/>	► Middleware Services						

TIP If you stop a parent application (such as the default application), then Enterprise Manager automatically stops any child applications that depend upon the parent application. Similarly, if you start a child application, Enterprise Manager automatically starts the required parent application.

Home Applications Web Services Performance Administration

Setup Logs Help Logout

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- click on "deploy"
- step 1: browse to the file "JPPF_J2EE_Demo_Oracle.ear"

Select Archive Application Attributes Deployment Settings

Deploy: Select Archive

[Cancel](#) [Step 1 of 3](#) [Next](#)

Archive

The following types of archives can be deployed: J2EE application (EAR files), Web Modules (WAR files), EJB Modules (EJB JAR files) and Resource Adapter Modules (RAR files).

- ☒ Archive is present on local host. Upload the archive to the server where Application Server Control is running.

Archive Location [Browse...](#)

- ☐ Archive is already present on the server where Application Server Control is running.

Location on Server
The location on server must be the absolute path or the relative path from j2ee/home

Deployment Plan

The deployment plan is an XML file that contains the deployment settings for an application. If you do not have a deployment plan, one will be created automatically during the deployment process. Later in the deployment process, you can optionally edit the deployment plan and save it for a future deployment of this application.

- ☒ Automatically create a new deployment plan.

The deployment plan settings will be based on OC4J defaults and information contained in the archive

- ☐ Deployment plan is present on local host. Upload the deployment plan to the server where Application Server Control is running.

Plan Location [Browse...](#)

- ☐ Deployment plan is already present on server where Application Server Control is running.

Location on Server
The location on server must be the absolute path or the relative path from j2ee/home

[Cancel](#) [Step 1 of 3](#) [Next](#)

[Setup](#) | [Logs](#) | [Help](#) | [Logout](#)

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[About Oracle Enterprise Manager 10g Application Server Control](#)

- click "next"
- step 2: enter "jppftest" as the Application Name

Select Archive Application Attributes Deployment Settings

Deploy: Application Attributes

[Cancel](#) [Back](#) [Step 2 of 3](#) [Next](#)

Archive Type **J2EE Application (EAR file)**
Archive Location **JPPF_J2EE_Demo_Oracle-10.ear**
Deployment Plan **Creating a new plan**

Application Name

Parent Application

Bind Web Module to Site

Context Root

Web Module	Context Root
jppftest	<input type="text" value="jppftest"/>

[Cancel](#) [Back](#) [Step 2 of 3](#) [Next](#)

[Help](#) | [Logout](#)

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[About Oracle Enterprise Manager 10g Application Server Control](#)

- click "next"
- step 3: click on "deploy"

- after deployment is complete, click on "return"
- restart the application server

9.5.4 Deployment on SunAS / Glassfish

9.5.4.1 Deploying the Resource Adapter

- in Sun AS console, go to "Applications > Connector modules"

The screenshot shows the Sun Java System Application Server Admin Console. The top navigation bar includes links for HOME, VERSION, UPGRADE, REGISTRATION, LOGOUT, and HELP. The user is logged in as 'admin' on 'localhost' in 'domain1'. The main title is 'Sun Java™ System Application Server Admin Console'. The left sidebar shows a tree view with 'Common Tasks' and 'Applications' expanded, with 'Connector Modules' selected. The main content area shows the 'Connector Modules' page with a breadcrumb 'Application Server > Applications > Connector Modules'. It includes a description of connector modules and a table for 'Deployed Connector Modules (0)'. The table has columns for 'Application Name', 'Enabled', 'Location', and 'Actions'. A message states: 'No applications found. Click "Deploy..." above to deploy a new application.'

- click on "Deploy"
- step 1: browse to the "jppf_ra_Glassfish.rar" file

The screenshot shows the 'Deploy Connector Module (Step 1 of 2)' dialog in the Sun Java System Application Server Admin Console. The dialog has a 'Next' button and a 'Cancel' button. It asks the user to 'Specify the location of an application to deploy. Applications can be in packaged files, such as .rar, or in the standard Connector Module directory format.' There are two radio button options: 'Package file to be uploaded to the Application Server.' and 'Package file or a directory path that is accessible from the server.' The first option is selected. Below it, there is a 'File To Upload:' field with the text 'aces\SourceForge\jca-client\build\jppf_ra_SunAS-9.0.rar' and a 'Browse...' button. The second option is unselected, and below it is a 'File Or Directory:' field.

- click "next"
- step 2: leave all default settings and click "Finish"



Common Tasks

Application Server

Applications

Enterprise Applications

Web Applications

EJB Modules

Connector Modules

Lifecycle Modules

App Client Modules

Web Services

Custom MBeans

Resources

Configuration

Application Server > Applications > Connector Modules

Deploy Connector Module (Step 2 of 2)

Finish

Cancel

Specify settings for the connector module you want to deploy. If the module has already been deployed, choose a different application name and deploy it under a new name.

* Indicates required field

General

File Name: jppf_ra_SunAS-9.0.rar

* Application Name: jppf_ra_SunAS-9

Name must contain only alphanumeric, underscore, dash, or dot characters

Thread Pool ID:

Thread pool ID for connector module (resource adapter)

Status:

☒ Enabled

Run:

☐ Verifier

Perform detailed verification before deploying

Registry Type:

None

Description:

Add a description of the component

Resource Adapter Properties

Additional Properties (4)

Name	Value
ServerHost	
ConnectionPoolSize	
ClassServerPort	
AppServerPort	

9.5.4.2 Creating a connector connection pool

- in the console tree on the left, go to "Resources > Connectors > Connector Connection Pools"

HOME VERSION UPGRADE REGISTRATION LOGOUT HELP

User: admin Server: localhost Domain: domain1

Sun Java™ System Application Server Admin Console

Application Server > Resources > Connectors > Connector Connection PoolsConnector Connection Pools

Deploy the connector module before creating the pool.

Pools (0)

New... Delete

Name	Description	Resource Adapter
No connection pools found. Click "New..." above to create a connection pool.		

- click on "New"

- step 1: enter "JPPFConnectionPool" as the connection pool name and select "jppf_ra_Glassfish" for the resource adapter

HOME VERSION UPGRADE REGISTRATION LOGOUT HELP

User: admin Server: localhost Domain: domain1

Sun Java™ System Application Server Admin Console

Application Server > Resources > Connectors > Connector Connection PoolsNew Connector Connection Pool (Step 1 of 2)

Create a Connector Pool, select the associated Resource Adapter, and click Next.

* Indicates required field

General Settings

* Name: JPPFConnectionPool

* Resource Adapter: jppf_ra_SunAS-9

* Connection Definition: javax.resource.cci.ConnectionFactory

Next Cancel

- click "next"

- step 2: set the pool parameters, select "NoTransaction" for transaction support

HOME

VERSION

UPGRADE

REGISTRATION

LOGOUT

HELP

User: admin Server: localhost Domain: domain1

Sun™ Microsystems, Inc.

Common Tasks

Application Server

Applications

Web Services

Custom MBeans

Resources

JDBC

JMS Resources

JavaMail Sessions

JNDI

Connectors

Connector Resource

Connector Connection Pools

Admin Object Resources

Configuration

Application Server > Resources > Connectors > Connector Connection Pools

New Connector Connection Pool (Step 2 of 2)

Previous

Finish

Cancel

Verify the Connection Pool settings, add properties defining the value for each property, and click Finish.

General Settings

Name:

JPPFConnectionPool

Resource Adapter:

jppf_ra_SunAS-9

Connection Definition:

javax.resource.cci.ConnectionFactory

Description:

Pool Settings

Initial and Minimum Pool Size:

1

Connections

Maximum Pool Size:

10

Connections

Pool Resize Quantity:

2

Connections

Idle Timeout:

300

Seconds

Max Wait Time:

60000

Milliseconds

On Any Failure:

☐ Close All Connections

Transaction Support:

NoTransaction

Level of transaction support

Connection Validation:

☐ Enabled

Validate connections before passing to application

Properties

Additional Properties (0)

Add Property

Delete Properties

Name	Value
No properties found. Click "Add Property" above to add a property.	

- click "Finish"

9.5.4.3 Creating a connection factory

- in the console tree on the left, go to "Resources > Connectors > Connector Resources"

HOME VERSION UPGRADE REGISTRATION LOGOUT HELP

User: admin Server: localhost Domain: domain1

Sun Java™ System Application Server Admin Console

Sun™ Microsystems, Inc.

Common Tasks

- Application Server
 - Applications
 - Web Services
 - Custom MBeans
 - Resources
 - JDBC
 - JMS Resources
 - JavaMail Sessions
 - JNDI
 - Connectors**
 - Connector Resources**
 - Connector Connection
 - Admin Object Resource
 - Configuration

Application Server > Resources > Connectors > Connector Resources

Connector Resources

A connector resource is a program object that provides an application with a connection to an Enterprise Information System (EIS).

Resources (0)

New... Delete

JNDI Name	Enabled	Description
No connector resources found. Click "New..." above to create a connector resource.		

- click on "New"
- for the jndi name, enter "eis/JPPFConnectionFactory"
- for the connection pool, select "JPPFConnectionPool"

HOME VERSION UPGRADE REGISTRATION LOGOUT HELP

User: admin Server: localhost Domain: domain1

Sun Java™ System Application Server Admin Console

Sun™ Microsystems, Inc.

Common Tasks

- Application Server
 - Applications
 - Web Services
 - Custom MBeans
 - Resources
 - JDBC
 - JMS Resources
 - JavaMail Sessions
 - JNDI
 - Connectors**
 - Connector Resources**
 - Connector Connection
 - Admin Object Resource
 - Configuration

Application Server > Resources > Connectors > Connector Resources

New Connector Resource

To create a JDBC resource, specify the connection pool with which it is associated. Multiple JDBC resources can use a single connection pool.

* Indicates required field

* JNDI Name: A unique identifier; contain only alphanumeric, underscore, dash, or dot characters

* Pool Name: Use the [Connector Connection Pools](#) page to create new pools

Description:

Status: ☒ Enabled

OK Cancel

- click "OK"
- restart the application server

9.5.4.4 Deploying the demo application

- in SunAS console, go to "Applications > Enterprise Applications"

The screenshot shows the Sun Java System Application Server Admin Console. The top navigation bar includes links for HOME, VERSION, UPGRADE, REGISTRATION, LOGOUT, and HELP. The user is logged in as 'admin' on 'localhost' in 'domain1'. The main title is 'Sun Java™ System Application Server Admin Console'. The left sidebar shows a tree view with 'Common Tasks' and 'Applications' expanded, with 'Enterprise Applications' selected. The main content area shows the 'Enterprise Applications' page with a breadcrumb 'Application Server > Applications > Enterprise Applications'. It includes a description: 'An enterprise application is a J2EE application in an EAR (Enterprise Application Archive) file or directory.' Below this is a section 'Deployed Enterprise Applications (0)' with buttons for 'Deploy...', 'Undeploy', 'Enable', and 'Disable'. A table with columns 'Application Name', 'Enabled', 'Location', and 'Actions' is shown, containing the message 'No applications found. Click "Deploy..." above to deploy a new application.'

- click on "Deploy"
- step 1: browse to the file "JPPF_J2EE_Demo_Glassfish.ear"

The screenshot shows the 'Deploy Enterprise Application (Step 1 of 2)' dialog in the Sun Java System Application Server Admin Console. The dialog has a 'Next' button and a 'Cancel' button. It includes a description: 'Specify the location of an application to deploy. Applications can be in packaged files, such as .ear, or in the standard Enterprise Application directory format.' The 'Location' section has two radio buttons: 'Package file to be uploaded to the Application Server.' (selected) and 'Package file or a directory path that is accessible from the server.' The first option has a 'File To Upload' field with the text 'forge\jca-client\build\JPPF_J2EE_Demo_SunAS-9.0.ear' and a 'Browse...' button. The second option has a 'File Or Directory' field.

- click "next"
- step 2: leave all default values

HOMEVERSION

UPGRADEREGISTRATIONLOGOUTHELP

User: admin Server: localhost Domain: domain1

Sun Java™ System Application Server Admin Console

Sun™ Microsystems, Inc.

Common Tasks

Application Server

Applications

Enterprise Applications

Web Applications

EJB Modules

Connector Modules

Lifecycle Modules

App Client Modules

Web Services

Custom MBeans

Resources

Configuration

Application Server > Applications > Enterprise Applications

Deploy Enterprise Application (Step 2 of 2)

FinishCancel

By default, the module is available as soon as it is deployed. To disable the module so that it is unavailable after deployment, uncheck the Enabled checkbox. If the module has already been deployed, choose a different application name and deploy it under a new name.

* Indicates required field

General

File Name: JPPF_J2EE_Demo_SunAS-9.0.ear

* Application Name: JPPF_J2EE_Demo_SunAS-9

Name must contain only alphanumeric, underscore, dash, or dot characters

Virtual Servers: server

Associates an internet domain name with a physical server

Status: ☒ Enabled

Java Web Start: ☐ Enabled

Run: ☐ Verifier

Perform detailed verification before deploying

Precompile: ☐ JSPs

Precompile JSPs, deploy only resulting class files

Libraries:

Description:

Add a description of the component

Advanced

Generate: ☐ RMISubs

Generate static RMI stubs and put in client.jar

- click "Finish"
- restart the application server

9.5.5 Deployment on Websphere

9.5.5.1 Deploying the Resource Adapter

- in WAS console, go to "Resources > Resource Adapters > Resource adapters"
- select scope = "Node"

Integrated Solutions Console Welcome lolo Help | Logout

Resource adapters Close page

View: All tasks

- Welcome
- Guided Activities
- Servers
- Applications
- Resources
 - Schedulers
 - Object pool managers
 - JMS
 - JDBC
 - Resource Adapters
 - Resource adapters
 - J2C connection factories
 - J2C activation specifications
 - J2C administered objects
 - Asynchronous beans
 - Cache instances
 - Mail
 - URL
 - Resource Environment
- Security
- Environment
- System administration

Resource adapters

Use this page to manage resource adapters, which provide the fundamental interface for connecting applications to an Enterprise Information System (EIS). The WebSphere(R) Relational Resource Adapter is embedded within the product to provide access to relational databases. To access another type of EIS, use this page to install a standalone resource adapter archive (RAR) file. You can configure multiple resource adapters for each installed RAR file.

Scope: Cell=**biglolo2Node01**Cell, Node=**biglolo2Node01**

Scope specifies the level at which the resource definition is visible. For detailed information on what scope is and how it works, [see the scope settings help](#)

Node=biglolo2Node01

Preferences

Install RAR New Delete

Select	Name	Scope
None		
Total 0		

Field help
For field help information, select a field label or list marker when the help cursor appears.

Page help
[More information about this page](#)

Command Assistance
[View administrative scripting command for last action](#)

- click "Install RAR"

- in the "Install RAR file" page, browse to the "jppf_ra_WebSphere.rar" file

Integrated Solutions Console Welcome lololo Help | Logout

View: All tasks

- Welcome
- Guided Activities
- Servers
- Applications
- Resources
 - Schedulers
 - Object pool managers
 - JMS
 - JDBC
 - Resource Adapters
 - Resource adapters
 - J2C connection factories
 - J2C activation specifications
 - J2C administered objects
 - Asynchronous beans
 - Cache instances
 - Mail
 - URL
 - Resource Environment
- Security
- Environment

Resource adapters

Install RAR File

Use this page to install a RAR file in one of two ways. You can either upload a RAR file from the local file system, or specify an existing RAR file on a server. The RAR file must be installed at the node level, and you can select the node below.

Path

☒ Local path:
Specify path
D:\Workspaces\SourceForge\jca-client\build\jppf_ra_WAS-6.1.rar Browse...

☐ Server path:
Specify path

Scope
Node
biglolo2Node01

Next Cancel

- click "Next"
- click "OK"
- click "Save directly to the master configuration"

Integrated Solutions Console Welcome lololo Help | Logout IBM

View: All tasks

- Welcome
- Guided Activities
- Servers
- Applications
- Resources
 - Schedulers
 - Object pool managers
 - JMS
 - JDBC
 - Resource Adapters
 - Resource adapters
 - J2C connection factories
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 - Asynchronous beans
 - Cache instances
 - Mail
 - URL
 - Resource Environment
- Security
- Environment
- System administration

Resource adapters

Resource adapters

Use this page to manage resource adapters, which provide the fundamental interface for connecting applications to an Enterprise Information System (EIS). The WebSphere(R) Relational Resource Adapter is embedded within the product to provide access to relational databases. To access another type of EIS, use this page to install a standalone resource adapter archive (RAR) file. You can configure multiple resource adapters for each installed RAR file.

☐ Scope: Cell=**biglolo2Node01**Cell, Node=**biglolo2Node01**

Scope specifies the level at which the resource definition is visible. For detailed information on what scope is and how it works, [see the scope settings help](#)

Node=biglolo2Node01

Preferences

Install RAR New Delete

☒ ☐ ☐ ☐

Select	Name	Scope
<input type="checkbox"/>	JPPF	Node=biglolo2Node01

Total 1

Field help
For field help information, select a field label or list marker when the help cursor appears.

Page help
[More information about this page](#)

Command Assistance
[View administrative scripting command for last action](#)

Close page

9.5.5.2 Creating a connection factory

- in the list of resource adapters, click on "JPPF"
- in "Additional Properties", click on "J2C connection factories"
- click on "New"
- enter "JPPF Connection Factory" for the name and "eis/JPPFConnectionFactory" for the JNDI name, leave all other parameters as they are

View: All tasks

Welcome

Guided Activities

Servers

Applications

Resources

Schedulers

Object pool managers

JMS

JDBC

Resource Adapters

Resource adapters

J2C connection factories

J2C activation specifications

J2C administered objects

Asynchronous beans

Cache instances

Mail

URL

Resource Environment

Security

Environment

System administration

Users and Groups

Monitoring and Tuning

Troubleshooting

Service integration

UDDI

Resource adapters

Close

Resource adapters

Messages

Additional Properties for this object will not be available to edit until its general properties are applied by clicking on either Apply or OK.

Resource adapters > JPPF > J2C connection factories > New

Use this page to create a connection factory for use with the resource adapter. The connection factory is a collection of configuration values that define a WebSphere(R) Application Server connection to your Enterprise Information System (EIS). The connection pool manager uses these properties as directions for allocating connections during runtime. You can configure multiple connection factories for each resource adapter.

Configuration

General Properties

* Scope

cells:biglolo2Node01Cell:nodes:biglolo2Node01

* Provider

JPPF

* Name

JPPF Connection Factory

JNDI name

eis/JPPFConnectionFactory

Description

* Connection factory interface

javax.resource.cci.ConnectionFactory

Category

Component-managed authentication alias

Component-managed authentication alias

(none)

The additional properties will not be available until the general properties for this item are applied or saved.

Additional Properties

Connection pool properties

Advanced connection factory properties

Custom properties

Related Items

- click "OK"
- click "Save directly to the master configuration"
- Restart the application server

9.5.5.3 Deploying the demo application

- in Websphere console, go to "Applications > Enterprise Applications"

The screenshot shows the IBM Integrated Solutions Console interface. The left sidebar contains a navigation tree with categories like Welcome, Guided Activities, Servers, Applications, Resources, Security, Environment, System administration, Users and Groups, Monitoring and Tuning, Troubleshooting, Service integration, and UDDI. The 'Applications' category is expanded, showing 'Enterprise Applications' and 'Install New Application'. The main content area is titled 'Enterprise Applications' and includes a 'Close page' link. Below the title, there's a description: 'Use this page to manage installed applications. A single application can be deployed onto multiple servers.' A 'Preferences' section contains buttons for Start, Stop, Install, Uninstall, Update, Rollout Update, Remove File, Export, and E. Below these are icons for file operations. A table lists installed applications:

Select	Name	Application Status
<input type="checkbox"/>	DefaultApplication	
<input type="checkbox"/>	ivtApp	
<input type="checkbox"/>	query	

Total 3

- click on "Install"
- browse to the file "JPPF_J2EE_Demo_WebSphere.ear"
- select "Prompt me only when additional information is required".

The screenshot shows the 'Preparing for the application installation' dialog box. It prompts the user to 'Specify the EAR, WAR, JAR, or SAR module to upload and install.' The dialog has two main sections: 'Path to the new application' and 'Context root'. In the 'Path to the new application' section, the 'Local file system' radio button is selected. The 'Full path' field contains 'PF_J2EE_Demo_WAS-6.1.ear' and has a 'Browse...' button next to it. The 'Remote file system' radio button is unselected. The 'Context root' field is empty, with a note: 'Used only for standalone Web modules (.war files) and SIP modules (.sar files)'. Below these fields is a section titled 'How do you want to install the application?' with two radio buttons: 'Prompt me only when additional information is required.' (selected) and 'Show me all installation options and parameters.' At the bottom are 'Next' and 'Cancel' buttons. A 'Help' sidebar on the right contains 'Field help' (Local file system path) and 'Page help' (More information about this page).

- click "Next"
- step 1: click "Next"
- step 2: check module "jppftest"

- View: All tasks
- Welcome
 - Guided Activities
 - Servers
 - Applications
 - Enterprise Applications
 - Install New Application

- Resources
- Security
- Environment
- System administration
- Users and Groups
- Monitoring and Tuning
- Troubleshooting
- Service integration
- UDDI

Enterprise Applications

Close page

Install New Application

Specify options for installing enterprise applications and modules.

Step 1 Select installation options

→ Step 2: Map modules to servers

★ Step 3 Map resource references to resources

★ Step 4 Map virtual hosts for Web modules

Step 5 Summary

Map modules to servers

Specify targets such as application servers or clusters of application servers where you want to install the application modules. Modules can be installed on the same application server or on different application servers. Also, specify the Web servers as targets that serve as routers for requests. A plug-in configuration file (plugin-cfg.xml) for each Web server is generated, based on the targets specified.

Clusters and Servers:

WebSphere:cell=biglolo2Node01Cell,node=biglolo2Node01,server=server1

Apply



Select	Module	URI	Server
<input checked="" type="checkbox"/>	jppftest	jppftest.war,WEB-INF/web.xml	WebSphere:cell=biglolo2Node01Cell,node=biglolo2Node01,server=server1

Previous

Next

Cancel

- click "Next"
- step 3: select "None" for the authentication method
- check the "jppftest" module and enter "eis/JPPFConnectionFactory" as Target Resource JNDI Name

Install New Application

? -

Specify options for installing enterprise applications and modules.

Step 1 Select installation options

Step 2 Map modules to servers

→ Step 3: Map resource references to resources

★ Step 4 Map virtual hosts for Web modules

Step 5 Summary

Map resource references to resources

Each resource reference that is defined in your application must be mapped to a resource.

javax.resource.cci.ConnectionFactory

To modify Resource Authentication method (if Authorization type is 'container'):

- Select one or more checkboxes in the table
- Select either 'none', 'default', or 'custom login configuration'
 - if 'none' is selected:
 - Select one or more checkboxes in the table
 - if 'default' is selected:
 - select an authentication data entry from the dropdown menu
 - Click Apply
 - if 'custom login configuration' is selected:
 - select a custom login configuration from the dropdown menu
 - Click Apply
 - To edit the properties of the custom login configuration, click Mapping Properties in the table

Specify authentication method:

- ☒ None
- ☐ Use default method (many-to-one mapping)

Authentication data entry

Select... ▼

- ☐ Use custom login configuration

Application login configuration

Select... ▼

Apply




Select	Module	EJB	URI	Resource Reference	Target Resource JNDI Name	Login configuration
<input checked="" type="checkbox"/>	jppftest		jppftest.war,WEB-INF/web.xml	eis/JPPFConnectionFactory	eis/JPPFConnectionFactory Browse...	Resource authorization: Per application

Previous

Next

Cancel

- click "Next"
- step 4: check the "jppftest" module and keep "default_host" as the Virtual host

Integrated Solutions Console Welcome lolo Help | Logout 

Enterprise Applications Close page

View: All tasks

- Welcome
- Guided Activities
- Servers
- Applications
 - Enterprise Applications
 - Install New Application
- Resources
- Security
- Environment
- System administration
- Users and Groups
- Monitoring and Tuning
- Troubleshooting
- Service integration
- UDDI

Install New Application ? -

Specify options for installing enterprise applications and modules.

Step 1 Select installation options

Step 2 Map modules to servers

Step 3 Map resource references to resources

→ **Step 4: Map virtual hosts for Web modules**

Step 5 Summary

Map virtual hosts for Web modules

Specify the virtual host where you want to install the Web modules that are contained in your application. You can install Web modules on the same virtual host or disperse them among several hosts.

☒ Apply Multiple Mappings

Select	Web module	Virtual host
<input checked="" type="checkbox"/>	jppftest	default_host


Previous Next Cancel

Help -

Field help
For field help information, select a field label or list marker when the help cursor appears.

Page help
[More information about this page](#)

- click "Next"
- step 5: click "Finish"
- click "Save directly to the master configuration"
- in the list of enterprise applications, check "JPPF Demo"

Integrated Solutions Console Welcome lolo Help | Logout 

Enterprise Applications Close page


View: All tasks

- Welcome
- Guided Activities
- Servers
- Applications
 - Enterprise Applications
 - Install New Application
- Resources
- Security
- Environment
- System administration
- Users and Groups
- Monitoring and Tuning
- Troubleshooting
- Service integration
- UDDI

Enterprise Applications

Use this page to manage installed applications. A single application can be deployed onto multiple servers.





Messages

 Application JPPF Demo on server server1 and node biglolo2Node01 started successfully.

Enterprise Applications

Preferences

Start Stop Install Uninstall Update Rollout Update Remove File Export Export D

Select	Name	Application Status
<input type="checkbox"/>	DefaultApplication	
<input checked="" type="checkbox"/>	JPPF Demo	
<input type="checkbox"/>	ivtApp	
<input type="checkbox"/>	query	

Total 4

- click on "Start"
- restart the application server

9.5.6 Deployment on Weblogic

9.5.6.1 Deploying the resource adapter

- in Weblogic console, go to "Deployments"
- click on "Lock & Edit"

The screenshot displays the Weblogic Server Administration Console interface. The top navigation bar includes the BEA logo, the title "WEBLOGIC SERVER ADMINISTRATION CONSOLE", and user information "Welcome, lcohen" connected to "wls920_domain". Navigation links for Home, Log Out, Preferences, Help, and AskBEA are present. The left sidebar contains a "Change Center" with a message about pending changes and buttons for "Lock & Edit" and "Release Configuration". Below this is the "Domain Structure" tree, where "wls920_domain" is expanded to show "Environment", "Deployments" (highlighted), "Services", "Security Realms", "Interoperability", and "Diagnostics". At the bottom of the sidebar is a "How do I..." section with links to "Install an Enterprise application" and "Configure an Enterprise application". The main content area shows the breadcrumb "Home > Summary of Deployments > jppf_ra_Weblogic-9 > Summary of Environment > Summary of Deployments". The "Summary of Deployments" section has tabs for "Control" and "Monitoring". A text block explains that the page displays a list of J2EE Applications and stand-alone application modules that can be started, stopped, updated, or deleted. Below this, a "Deployments" section contains a table with columns for Name, State, Type, and Deployment Order. The table is currently empty, displaying "There are no items to display". Above and below the table are sets of control buttons: "Install", "Update", "Delete", "Start", and "Stop". The status "Showing 0 - 0 of 0" and navigation links "Previous | Next" are also visible.

- click "Install"
- navigate to the "jppf_ra_Weblogic.rar" file and select it

WEBLOGIC SERVER
 ADMINISTRATION CONSOLE

Change Center
 Welcome, lcohen
 Connected to: wls920_domain
 Home
 Log Out
 Preferences
 Help
 As

View changes and restarts

No pending changes exist. Click the Release Configuration button to allow others to edit the domain.

Lock & Edit

Release Configuration

Domain Structure

- wls920_domain
 - Environment
 - Deployments
 - Services
 - Security Realms
 - Interoperability
 - Diagnostics

How do I...

- Start and stop a deployed Enterprise application
- Configure an Enterprise application
- Create a deployment plan
- Target an Enterprise application to a server
- Test the modules in an Enterprise application

System Status

Health of Running Servers

Failed (0)

Critical (0)

Overloaded (0)

Home > Summary of Deployments > jppf_ra_Weblogic-9 > Summary of Environment > **Summary of Deployments**

Install Application Assistant

Back Next Finish Cancel

Locate deployment to install and prepare for deployment

Select the file path that represents the application root directory, archive file, exploded archive directory, or application module descriptor that you want to install.


Note: Only valid file paths are displayed below. If you cannot find your deployment files, [upload your file\(s\)](#) and/or confirm that your application contains the required deployment descriptors.

Location: 192.168.0.4 \ D: \ Workspaces \ SourceForge \ jca-client \ build

	lib
<input type="radio"/>	JPPF_J2EE_Demo_JBoss-4.0.ear
<input type="radio"/>	JPPF_J2EE_Demo_Oracle-10.ear
<input type="radio"/>	JPPF_J2EE_Demo_SunAS-9.0.ear
<input type="radio"/>	JPPF_J2EE_Demo_WAS-6.1.ear
<input type="radio"/>	JPPF_J2EE_Demo_Weblogic-9.2.ear
<input type="radio"/>	jppf_ra_JBoss-4.0.rar
<input type="radio"/>	jppf_ra_Oracle-10.rar
<input type="radio"/>	jppf_ra_SunAS-9.0.rar
<input type="radio"/>	jppf_ra_WAS-6.1.rar
<input checked="" type="radio"/>	jppf_ra_Weblogic-9.2.rar

Back Next Finish Cancel

- click "Next"
- click "Next"
- click "Finish"


WEBLOGIC SERVER
 ADMINISTRATION CONSOLE

Change Center

Welcome, lcohen
 Connected to: wls920_domain
 Home
 Log Out
 Preferences
 Help
 AskBEA

View changes and restarts

Pending changes exist. They must be activated to take effect.

Activate Changes

Undo All Changes

Domain Structure

- wls920_domain
 - Environment
 - Deployments**
 - Services
 - Security Realms
 - Interoperability
 - Diagnostics

How do I...

- Install an Enterprise application
- Configure an Enterprise application
- Update (redeploy) an Enterprise application
- Start and stop a deployed Enterprise application
- Monitor the modules of an Enterprise application
- Deploy EJB modules
- Install a Web application

System Status

Home > Summary of Deployments > jppf_ra_Weblogic-9 > Summary of Environment > **Summary of Deployments**

Messages

- ☒ The deployment has been installed and added to the list of pending changes successfully.
- ☒ You must also activate the pending changes to commit this, and other updates, to the active system.

Summary of Deployments

Control **Monitoring**

This page displays a list of J2EE Applications and stand-alone application modules that have been installed to this domain. Installed applications and modules can be started, stopped, updated (redeployed), or deleted from the domain by first selecting the application name and using the controls on this page.

To install a new application or module for deployment to targets in this domain, click the Install button.

Deployments

Install
Update
Delete
Start
Stop

Showing 1 - 1 of 1 Previous | Next

<input type="checkbox"/>	Name ^	State	Type	Deployment Order
<input type="checkbox"/>	 jppf_ra_Weblogic-9	distribute Initializing	Resource Adapter	100

Install
Update
Delete
Start
Stop

Showing 1 - 1 of 1 Previous | Next

- click "Activate Changes"
- in the list of deployments, check "jppf_ra_Weblogic"
- select "Start > Servicing all requests"

WEBLOGIC SERVER
 ADMINISTRATION CONSOLE

Change Center

Welcome, lcohen
 Connected to: wls920_domain
 Home
 Log Out
 Preferences
 Help
 AskBE

View changes and restarts

Click the Lock & Edit button to modify, add or delete items in this domain.

Lock & Edit

Release Configuration

Domain Structure

- wls920_domain
 - Environment
 - Deployments**
 - Services
 - Security Realms
 - Interoperability
 - Diagnostics

How do I...

- Install an Enterprise application
- Configure an Enterprise application
- Update (redeploy) an Enterprise application
- Start and stop a deployed Enterprise application
- Monitor the modules of an Enterprise application
- Deploy EJB modules
- Install a Web application

Home > Summary of Deployments > jppf_ra_Weblogic-9 > Summary of Environment > **Summary of Deployments**

Messages

✓ All changes have been activated. No restarts are necessary.

Summary of Deployments

Control **Monitoring**

This page displays a list of J2EE Applications and stand-alone application modules that have been installed to this domain. Installed applications and modules can be started, stopped, updated (redeployed), or deleted from the domain by first selecting the application name and using the controls on this page.

To install a new application or module for deployment to targets in this domain, click the Install button.

Deployments

Install
 Update
 Delete
 Start
 Stop

Showing 1 - 1 of 1 Previous | Next

	Name	Type	Deployment Order
✓	jppf_ra_Weblogic-9	Prepared Resource Adapter	100

Install
 Update
 Delete
 Start
 Stop


Showing 1 - 1 of 1 Previous | Next

- Click "Yes"
- the state of the resource adapter must now show as "Active"
- restart the application server

Note: In the Weblogic output console, you will probably see periodic messages saying that 2 threads are stuck. These warnings are harmless. The related threads are required by the JPPF resource adapter and should not be interrupted. The period of these warnings is determined by a setting of the Weblogic instance called "Stuck Thread Timer Interval", set to 60 seconds by default. Consult with your administrator if you need to change that interval.

9.5.6.2 Deploying the demo application

- in Weblogic console, go to "Deployments"
- click on "Lock & Edit"

**WEBLOGIC SERVER**
ADMINISTRATION CONSOLE

Change Center

View changes and restarts

No pending changes exist.
Click the Release Configuration button to allow others to edit the domain.

Lock & Edit

Release Configuration

Domain Structure

wls920_domain

- Environment
- Deployments**
- Services
- Security Realms
- Interoperability
- Diagnostics

How do I...

System Status

Welcome, lcohen Connected to: wls920_domain [Home](#) [Log Out](#) [Preferences](#) [Help](#) [AskBEA](#)

Home > **Summary of Deployments**

Summary of Deployments

Control **Monitoring**


This page displays a list of J2EE Applications and stand-alone application modules that have been installed to this domain. Installed applications and modules can be started, stopped, updated (redeployed), or deleted from the domain by first selecting the application name and using the controls on this page.

To install a new application or module for deployment to targets in this domain, click the Install button.

Deployments

Install Update Delete Start Stop


Showing 1 - 1 of 1 Previous | Next

<input type="checkbox"/>	Name ^	State	Type	Deployment Order
<input type="checkbox"/>	 jppf_ra_Weblogic-9	Active	Resource Adapter	100

Install Update Delete Start Stop

Showing 1 - 1 of 1 Previous | Next

- click "Install"
- navigate to the "JPPF_J2EE_Demo_Weblogic.ear" file and select it



WEBLOGIC SERVER
ADMINISTRATION CONSOLE

Change Center

[View changes and restarts](#)
No pending changes exist.
Click the Release Configuration button to allow others to edit the domain.

Lock & Edit

Release Configuration

Domain Structure

wls920_domain

- Environment
 - Deployments
- Services
 - Security Realms
- Interoperability
- Diagnostics

How do I...

System Status

Welcome, lcohen Connected to: wls920_domain [Home](#) [Log Out](#) [Preferences](#) [Help](#) [AskBEA](#)

Home > **Summary of Deployments**

Install Application Assistant












Back Next Finish Cancel

Locate deployment to install and prepare for deployment

Select the file path that represents the application root directory, archive file, exploded archive directory, or application module descriptor that you want to install.

Note: Only valid file paths are displayed below. If you cannot find your deployment files, [upload your file\(s\)](#) and/or confirm that your application contains the required deployment descriptors.

Location: 192.168.0.4 \ D: \ Workspaces \ SourceForge \ jca-client \ build

<input type="checkbox"/>	 lib
<input type="radio"/>	 JPPF_J2EE_Demo_IBoss-4.0.ear
<input type="radio"/>	 JPPF_J2EE_Demo_Oracle-10.ear
<input type="radio"/>	 JPPF_J2EE_Demo_SunAS-9.0.ear
<input type="radio"/>	 JPPF_J2EE_Demo_WAS-6.1.ear
<input checked="" type="radio"/>	 JPPF_J2EE_Demo_Weblogic-9.2.ear
<input type="radio"/>	 jppf_ra_IBoss-4.0.rar
<input type="radio"/>	 jppf_ra_Oracle-10.rar
<input type="radio"/>	 jppf_ra_SunAS-9.0.rar
<input type="radio"/>	 jppf_ra_WAS-6.1.rar
<input type="radio"/>	 jppf_ra_Weblogic-9.2.rar

Back Next Finish Cancel

- click "Next"
- click "Finish"



WEBLOGIC SERVER

ADMINISTRATION CONSOLE

Change Center

View changes and restarts

Pending changes exist. They must be activated to take effect.

Activate Changes

Undo All Changes

Domain Structure

wls920_domain

Environment

Deployments

Services

Security Realms

Interoperability

Diagnostics

How do I...

System Status

Welcome, lcohen

Connected to: wls920_domain

Home

Log Out

Preferences

Help

AskBEA

Home > Summary of Deployments

Messages

The deployment has been installed and added to the list of pending changes successfully.

You must also activate the pending changes to commit this, and other updates, to the active system.

Summary of Deployments

Control

Monitoring

This page displays a list of J2EE Applications and stand-alone application modules that have been installed to this domain. Installed applications and modules can be started, stopped, updated (redeployed), or deleted from the domain by first selecting the application name and using the controls on this page.

To install a new application or module for deployment to targets in this domain, click the Install button.

Deployments

Install

Update

Delete

Start

Stop

Showing 1 - 2 of 2 Previous | Next

<input type="checkbox"/>	Name ^	State	Type	Deployment Order
<input type="checkbox"/>	 JPPF_J2EE_Demo_Weblogic-9	distribute Initializing	Enterprise Application	100
<input type="checkbox"/>	 jppf_ra_Weblogic-9	Active	Resource Adapter	100

Install

Update

Delete

Start

Stop

Showing 1 - 2 of 2 Previous | Next

- click "Activate Changes"
- in the list of deployments, check "JPPF_J2EE_Demo_Weblogic"
- select "Start > Servicing All Requests"

WEBLOGIC SERVER
 ADMINISTRATION CONSOLE

Change Center

View changes and restarts

Click the Lock & Edit button to modify, add or delete items in this domain.

Lock & Edit
 Release Configuration

Domain Structure

- wls920_domain
 - Environment
 - Deployments**
 - Services
 - Security Realms
 - Interoperability
 - Diagnostics

How do I...

System Status

Welcome, lcohen
 Connected to: wls920_domain
 Home
 Log Out
 Preferences
 Help
 AskBEA

Home > Summary of Deployments

Messages

All changes have been activated. No restarts are necessary.

Summary of Deployments

Control
 Monitoring

This page displays a list of J2EE Applications and stand-alone application modules that have been installed to this domain. Installed applications and modules can be started, stopped, updated (redeployed), or deleted from the domain by first selecting the application name and using the controls on this page.

To install a new application or module for deployment to targets in this domain, click the Install button.

Deployments

Install
 Update
 Delete
 Start
 Stop
 Showing 1 - 2 of 2
 Previous
 Next

<input type="checkbox"/>	Name ^		Type	Deployment Order
<input checked="" type="checkbox"/>	JPPF_J2EE_Demo_Weblogic-9	Prepared	Enterprise Application	100
<input type="checkbox"/>	jppf_ra_Weblogic-9	Active	Resource Adapter	100

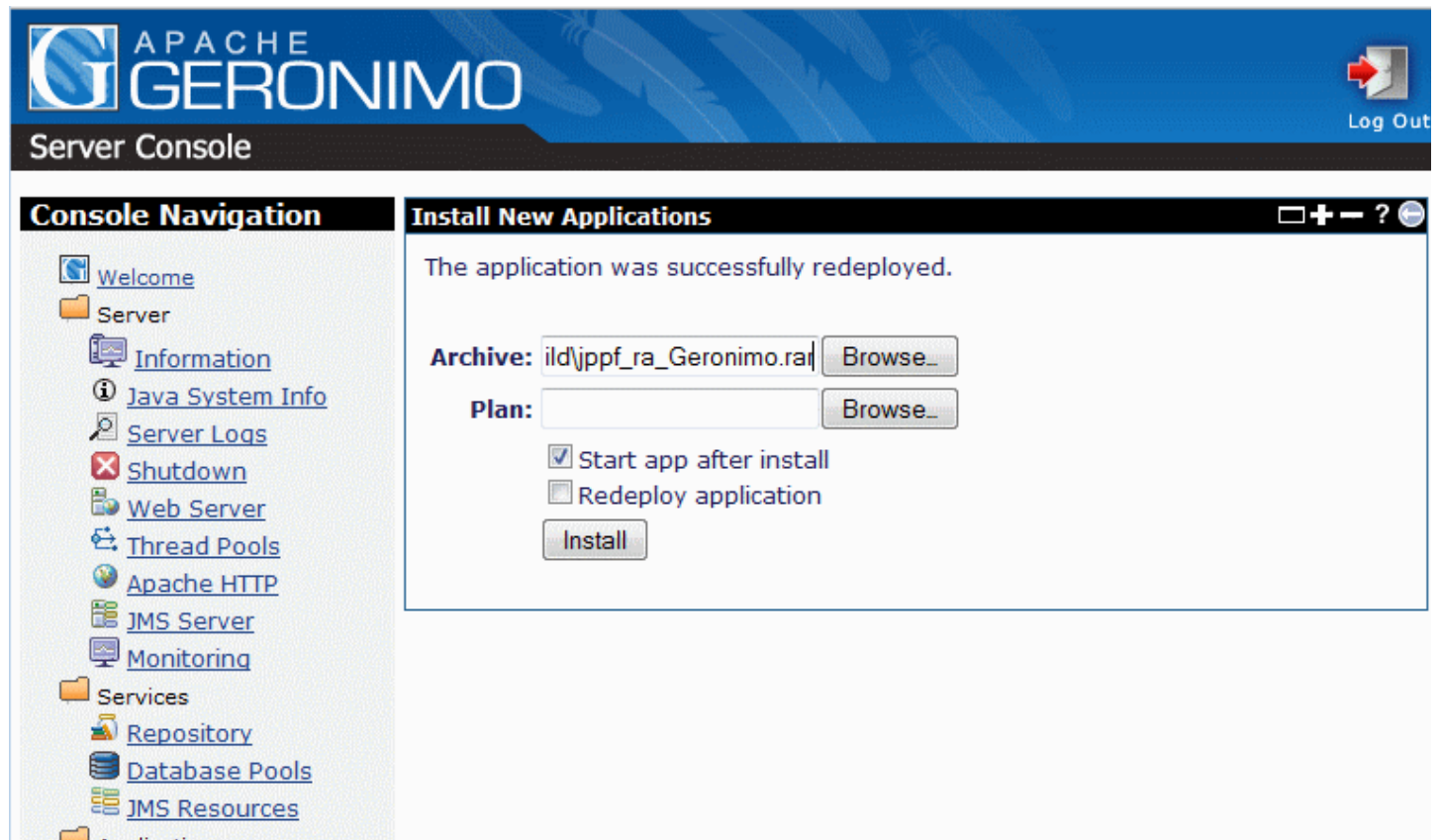
Install
 Update
 Delete
 Start
 Stop
 Showing 1 - 2 of 2
 Previous
 Next

- Click "Yes"
- the state of the demo application must now show as "Active"
- restart the application server

9.5.7 Deployment on Apache Geronimo

9.5.7.1 Deploying the resource adapter

- In the Geronimo administration console, click on “Applications > Deploy new”
- In the “Archive” field, navigate to the file “jppf_ra_Geronimo.rar”

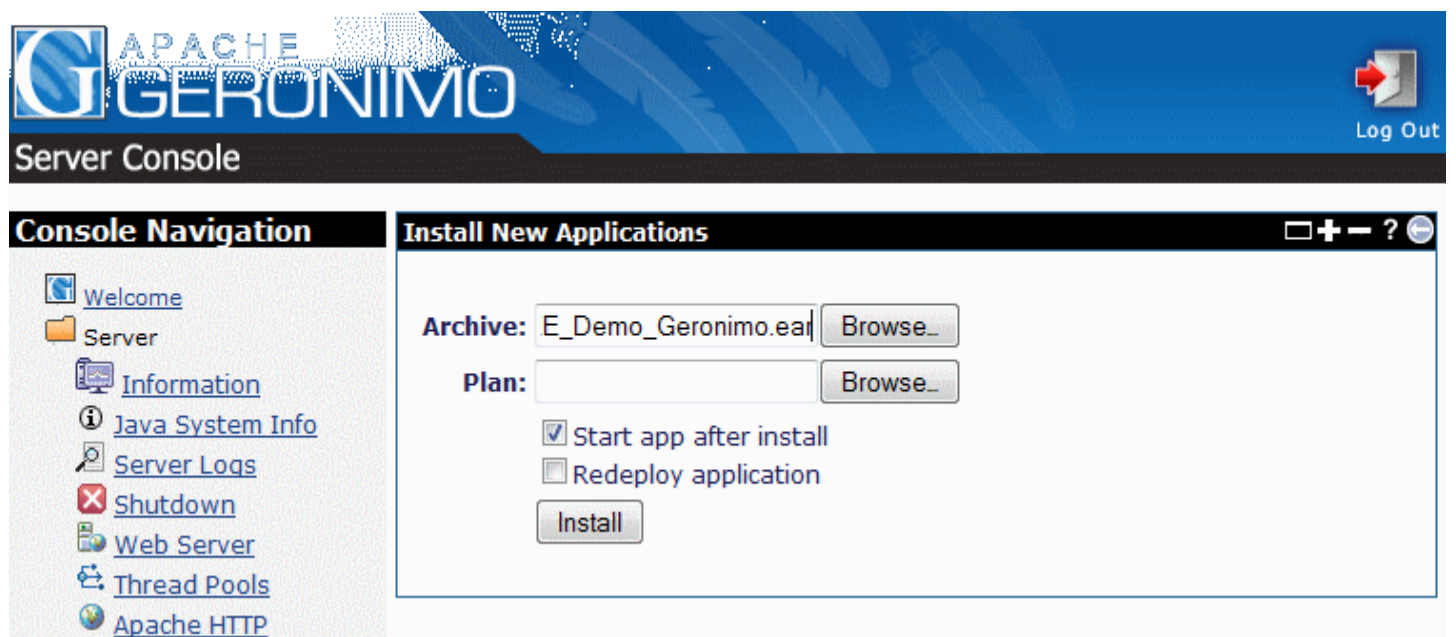


The screenshot shows the Apache Geronimo Server Console. On the left is the 'Console Navigation' menu with links like Welcome, Server, Information, Java System Info, Server Logs, Shutdown, Web Server, Thread Pools, Apache HTTP, JMS Server, Monitoring, Services, Repository, Database Pools, and JMS Resources. The main area is titled 'Install New Applications' and displays a message: 'The application was successfully redeployed.' Below this, there are fields for 'Archive:' (containing 'ild\jppf_ra_Geronimo.rar') and 'Plan:' (empty), each with a 'Browse...' button. There are also checkboxes for 'Start app after install' (checked) and 'Redeploy application' (unchecked), and an 'Install' button.

- click on “Install”

9.5.7.2 Deploying the demo application

- In the Geronimo administration console, click on “Applications > Deploy new”
- In the “Archive” field, navigate to the file “JPPF_J2EE_Demo_Geronimo.ear”



The screenshot shows the Apache Geronimo Server Console. On the left is the 'Console Navigation' menu with links like Welcome, Server, Information, Java System Info, Server Logs, Shutdown, Web Server, Thread Pools, Apache HTTP, JMS Server, Monitoring, Services, Repository, Database Pools, and JMS Resources. The main area is titled 'Install New Applications' and displays a message: 'The application was successfully redeployed.' Below this, there are fields for 'Archive:' (containing 'E_Demo_Geronimo.ear') and 'Plan:' (empty), each with a 'Browse...' button. There are also checkboxes for 'Start app after install' (checked) and 'Redeploy application' (unchecked), and an 'Install' button.

- click on “Install”

9.6 Packaging your enterprise application

For a J2EE enterprise application to work with the JPPF JCA connector, it is necessary to include a JPPF utility library called `jppf-j2ee-client.jar`, which can be found in the `jca-client/build/lib` folder. To ensure that this library can be made visible to all modules in the application, we recommend the following way of packaging it:

- * add `jppf-j2ee-client.jar` in a `lib` folder under the root of the EAR file
- * for each EJB, Web or Resource Adapter module of your application that will use JPPF, add a `Class-Path` entry in the `META-INF/manifest.mf` of the module, which will point to the JPPF library, for instance:
Class-Path: `lib/jppf-j2ee-client.jar`

In a typical J2EE application, it would look like this:

```
MyApplication.ear/
  lib/
    jppf-j2ee-client.jar

  MyEJBModule.jar/
    ...
    META-INF/
      manifest.mf:
        ...
        Class-Path: lib/jppf-j2ee-client.jar
        ...
    ...

  ... other modules ...

  MyWebApp.war/
    ...
    META-INF/
      manifest.mf:
        ...
        Class-Path: lib/jppf-j2ee-client.jar
        ...
    ...
```

Note: If you only need to use JPPF from a web application or module, then you can simply add `jppf-j2ee-client.jar` to the `WEB-INF/lib` folder of the war file.

9.7 Creating an application server port

If the JPPF resource adapter does not include, out-of-the-box, a port for your application server, or your application server version, this section is for you. Here is a sequence of steps to create your own port:

1. copy one of the existing application server-specific folder in `JPPF-2.0-j2ee-connector/appserver` and give it a name that will distinguish it from the others. This name will be used throughout this process, so please make sure it is both unique and meaningful. For the sake of this exercise, we will use a generic name: `"MyServer-1.0"`
2. After creating the `JPPF-2.0-j2ee-connector/appserver/MyServer-1.0` folder, edit the relevant configuration files and deployment descriptors.
3. Open the `build.xml` build script, in the `jca-client` folder, with a text editor.
4. At the start of the file, you will see the following section:

```
<!-- ===== -->
<!-- definition of application server-specific properties -->
<!-- the value is used to generate the names of the corresponding EAR and RAR -->
<!-- ===== -->
<property name="was" value="Websphere"/>
<property name="jboss" value="JBoss"/>
<property name="oracle" value="Oracle"/>
<property name="sunas" value="Glassfish"/>
<property name="weblogic" value="Weblogic"/>
<property name="geronimo" value="Geronimo"/>
```

You can add your own property here, for instance:

```
<property name="myserver10" value="MyServer-1.0"/>
```

The property value must be the name of the folder you just created.

5. (optional) navigate to the Ant target "ear.all" and add your own invocation for generating the demo application EAR:

```
<antcall target="ear">
  <param name="appserver" value="${myserver10}"/>
  <param name="include.client.classes" value="true"/>
</antcall>
```

You may also remove or comment out those you do not need.

6. Navigate to the Ant target "ear.all" and add your own invocation for generating the resource adapter RAR:

```
<antcall target="rar"><param name="appserver" value="${myserver10}"/></antcall>
```

You may also remove or comment out those you do not need.

10 GigaSpaces XAP Connector

10.1 About GigaSpaces and JPPF

GigaSpaces is a full-fledged, non-J2EE application server that can handle, among other features, large distributed datasets. Integrating JPPF within GigaSpaces XAP adds the ability to perform intensive computations on those data, seamlessly and without impacting the performance of the applications running within GigaSpaces. It also provides JPPF applications with capabilities that were so far missing from its design: clustering, replication, transaction management, data access, etc ...

10.2 Installation

10.2.1 Prerequisites

Before installing, please make sure you have the following already installed in your environment:

- Java Runtime Environment (JRE) version 1.5 or later
- Apache Ant version 1.6.2 or later
- GigaSpaces XAP version 6.6 or later

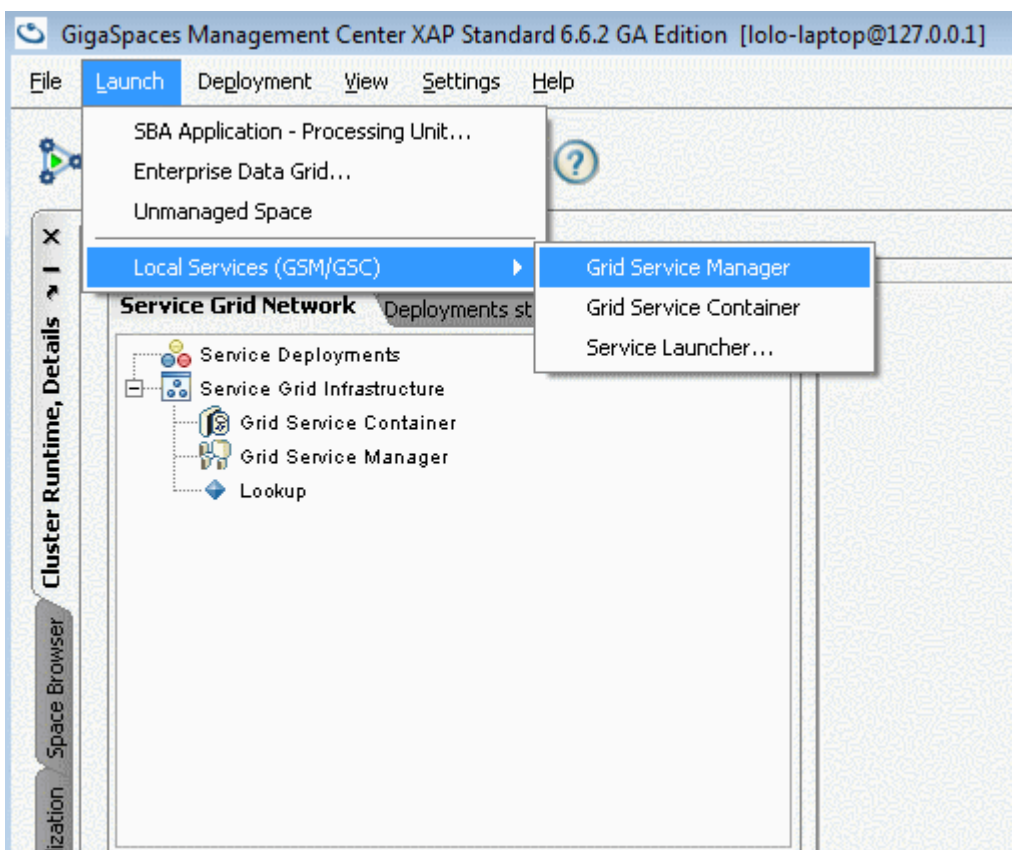
10.2.2 Installing

To install the JPPF / GigaSpaces integration package, perform the following steps:

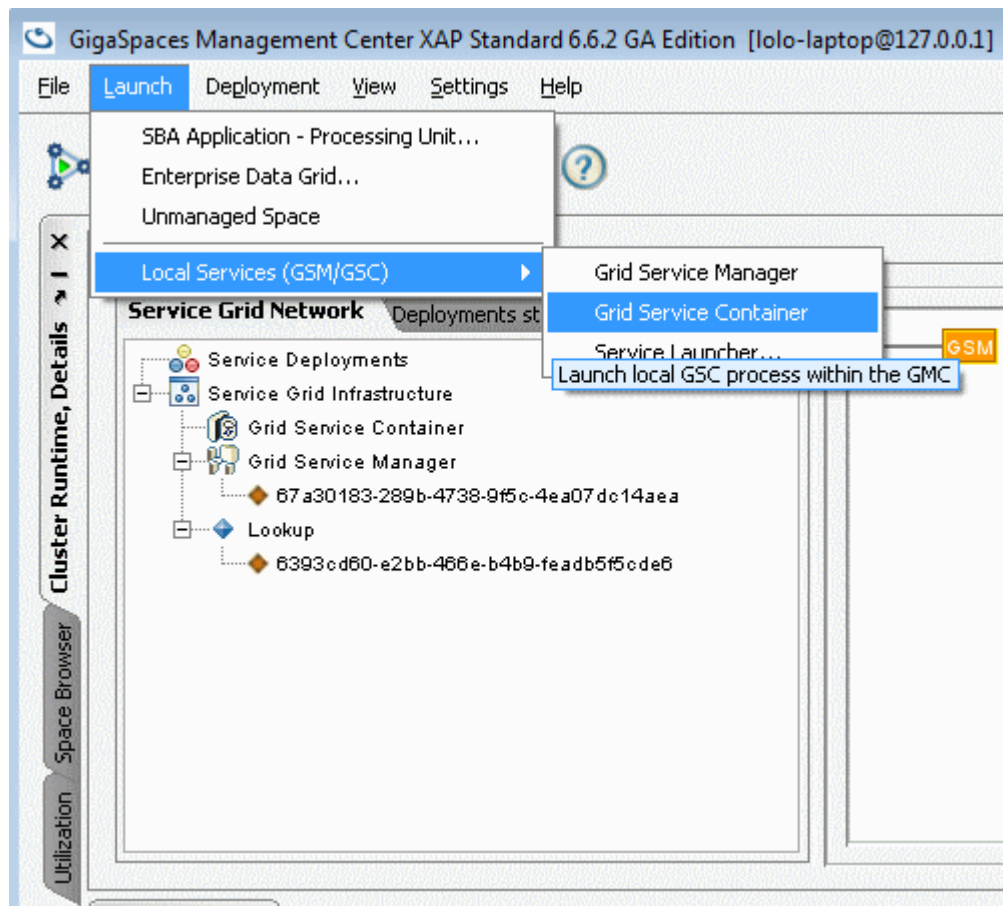
- download the **JPPF-2.x-GigaSpaces-.zip** file from the [JPPF download page](#)
- Unzip this file in a location of your choice, this will create a new folder named "JPPF-GigaSpaces"
- Edit the file "JPPF-GigaSpaces/build.properties" in a text editor and set the appropriate path for the GigaSpaces XAP install root folder
- you are now ready to use the JPPF / GigaSpaces integration

10.3 Deploying the JPPF processing unit

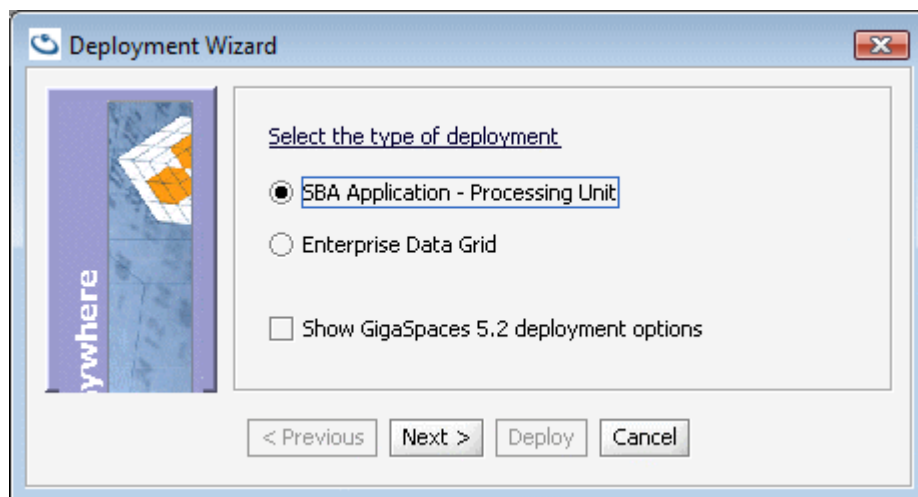
- In the GigaSpaces Management Center, start a Grid Service Manager (GSM):



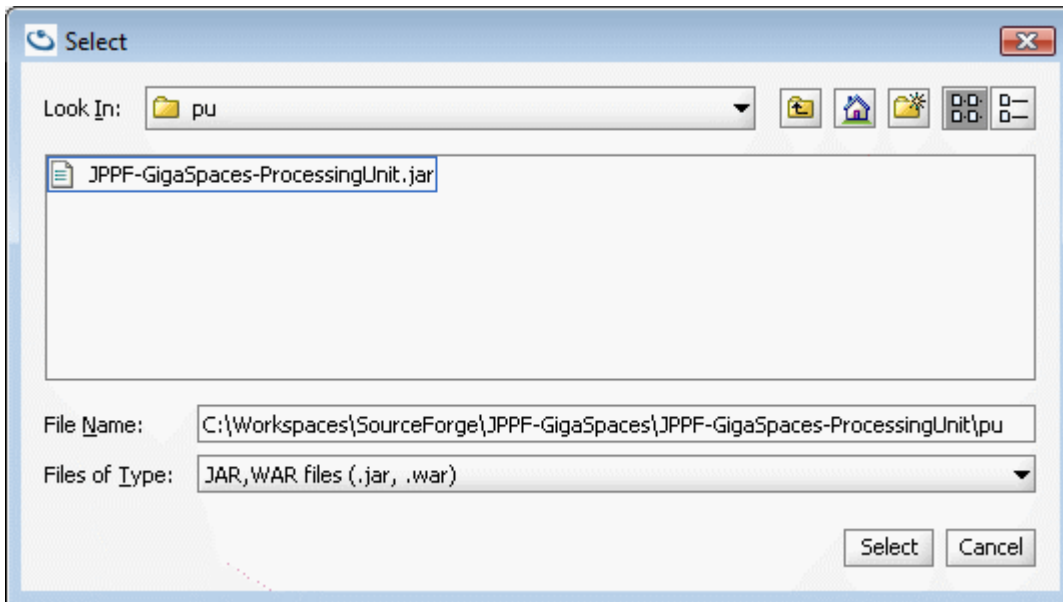
- Next, start a Grid Service Container (GSC):



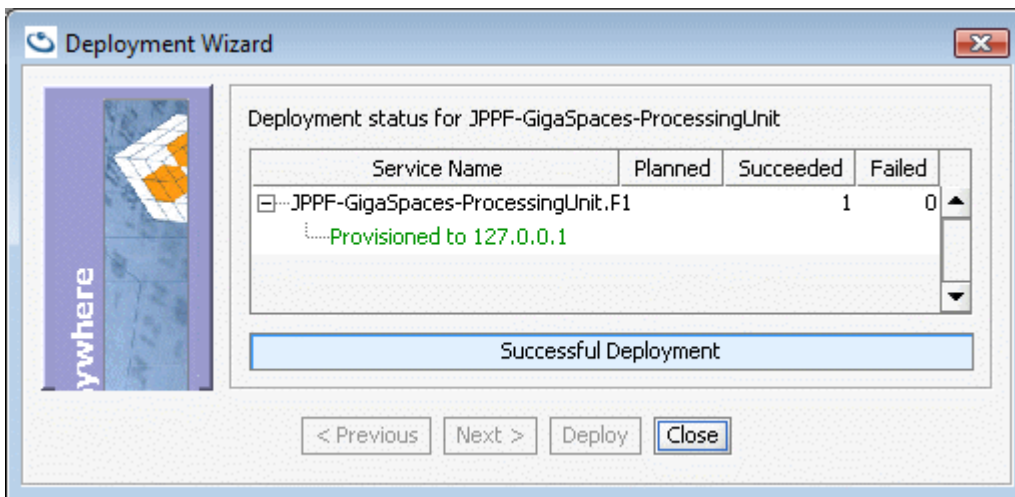
- Next we will deploy a JPPF client as a Processing Unit. To start, open the deployment wizard, as in the screenshot below:



- On the next screen, select the Processing Unit jar file to deploy, located at
<JPPF-GigaSpaces>/JPPF-GigaSpaces-ProcessingUnit/pu/JPPF-GigaSpaces-ProcessingUnit.jar:



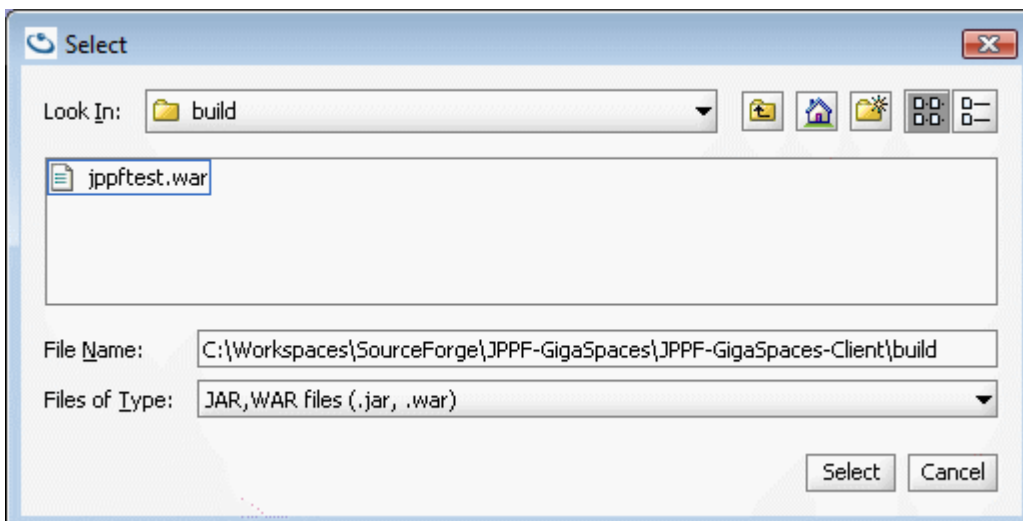
- After selecting the jar file, click "finish" and wait until the processing unit is deployed:



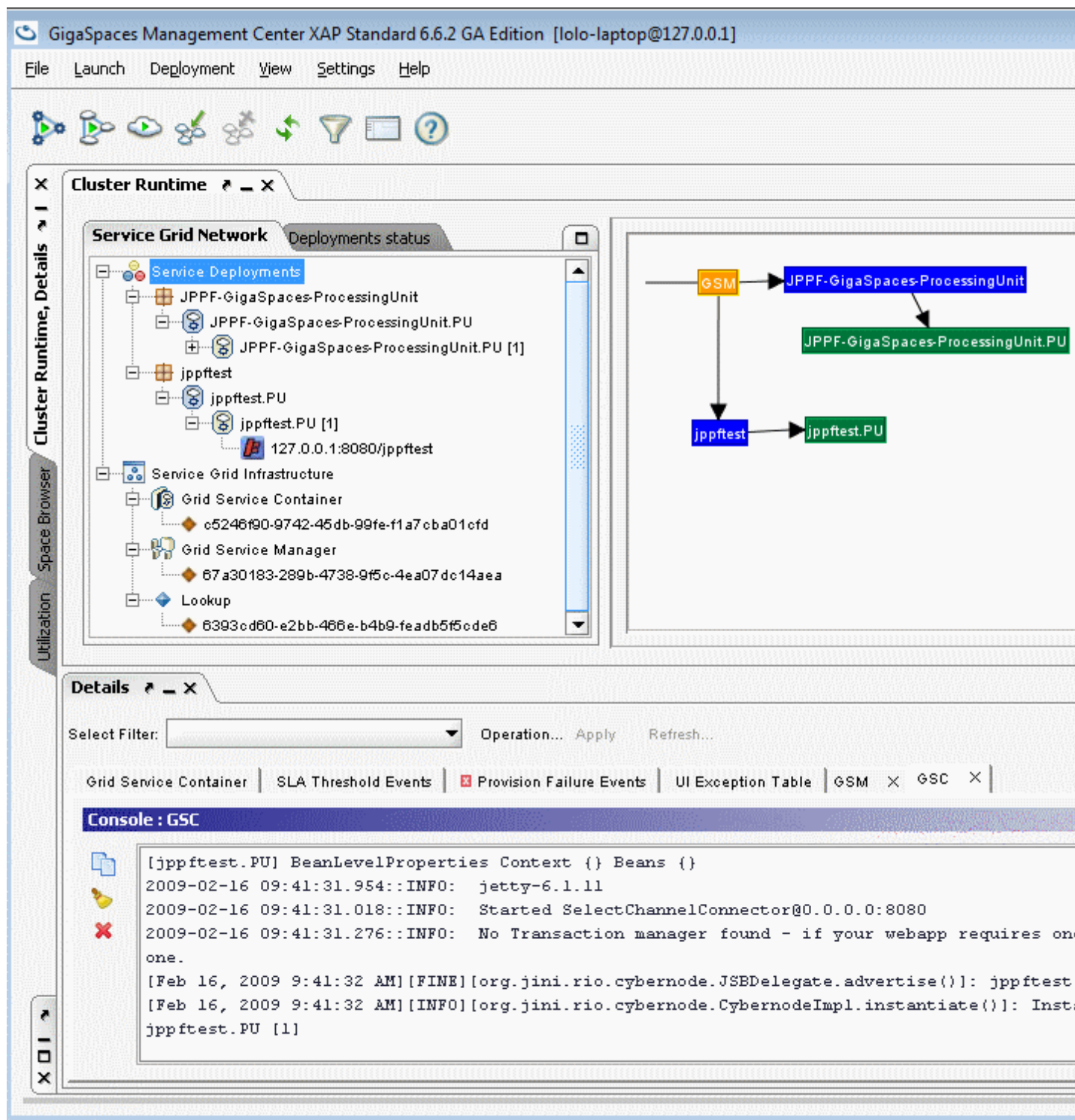
10.4 Deploying the sample web application

We will now deploy a sample web application packaged as a war file

1. First ensure that the JPPF processing unit has been deployed
2. Open the deployment wizard and select the war file to deploy, located at:
`<JPPF-GigaSpaces>/JPPF-GigaSpaces-Client/build/jppftest.war`



3. After selecting the war file, click "finish" and wait until the web application is deployed, the UI should now show both processing unit and web app deployed under the GSM:



4. The web application is now ready to be used at this URL: <http://localhost:8080/jppftest>

10.5 Considerations for deploying JPPF-enabled applications

10.5.1 Available APIs

The JPPF processing unit publishes all its libraries in its "shared-lib" folder, which makes the required JPPF APIs available to other applications deployed within GigaSpaces:

- the job and tasks APIs: JPPFTask, JPPFJob, DataProvider, ExecutionPolicy
- the service API used to submit jobs to the JPPF service: [JPPFService](#)

10.5.2 Spring descriptor

Access to the JPPF service is realized by declaring it as a remotd Spring bean in your application. This is done as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:os-core="http://www.openspaces.org/schema/core"
       xmlns:os-events="http://www.openspaces.org/schema/events"
       xmlns:os-remoting="http://www.openspaces.org/schema/remoting"
       xmlns:os-sla="http://www.openspaces.org/schema/sla"
       xmlns:os-jms="http://www.openspaces.org/schema/jms"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
http://www.springframework.org/schema/beans/spring-beans.xsd
http://www.openspaces.org/schema/core
http://www.openspaces.org/schema/core/openspaces-core.xsd
http://www.openspaces.org/schema/events
http://www.openspaces.org/schema/events/openspaces-events.xsd
http://www.openspaces.org/schema/remoting
http://www.openspaces.org/schema/remoting/openspaces-remoting.xsd
http://www.openspaces.org/schema/jms
http://www.openspaces.org/schema/jms/openspaces-jms.xsd
http://www.openspaces.org/schema/sla
http://www.openspaces.org/schema/sla/openspaces-sla.xsd">

  <!-- Declaration of the JPPF space. -->
  <os-core:space id="space" url="jini://*/*/JPPFSpace" />
  <os-core:giga-space id="gigaSpace" space="space"/>

  <!-- The JPPF service proxy. -->
  <os-remoting:sync-proxy
    id="jppfService" giga-space="gigaSpace"
    interface="org.jppf.gigaspace.JPPFService"/>

  <!--
    The GSClient bean, uses the proxied service
    without any knowledge of the remoting invocation.
  -->
  <bean id="gsclient" class="org.jppf.gigaspace.test.GSClient">
    <property name="jppfService" ref="jppfService"/>
  </bean>
</beans>
```

This descriptor can be found in the distribution as:

<JPPF-GigaSpaces>/JPPF-GigaSpaces-Client/src/client.xml

10.5.3 Usage in application code

Obtaining a reference to the JPPF service is done via the Spring application context:

```
// Parse the application context and instantiate the bean
ClassPathXmlApplicationContext context =
    new ClassPathXmlApplicationContext("classpath:client.xml");
context.start();
// Get a reference to the created bean
GSClient gsc = (GSClient) context.getBean("gsclient");
```

The call to `context.start()` causes the Spring bean's `afterPropertiesSet()` method to be invoked:

```
/**
 * Called after the Spring bean init and submits a JPPF job to the JPPF space.
 * @throws Exception if any error occurs.
 * @see org.springframework.beans.factory.InitializingBean#afterPropertiesSet()
 */
public void afterPropertiesSet() throws Exception {
    // Create a new job and add a task
    JPPFJob newJob = new JPPFJob();
    newJob.addTask(new HelloTask());
    // invoke the JPPF service proxy to submit the job
    this.job = jppfService.submitJob(newJob);
}
```

Putting it all together, here is the code used in our sample web application:

```
package org.jppf.gigaspace.test;

import org.jppf.client.JPPFJob;
import org.jppf.gigaspace.*;
import org.springframework.beans.factory.InitializingBean;
import org.springframework.context.support.ClassPathXmlApplicationContext;

/**
 * Client class used to invoke a JPPF job submission service
 * deployed as a processing unit.
 */
public class GSClient implements InitializingBean {
    private JPPFService jppfService = null;
    private JPPFJob job = null;

    // Entry point for execution of this client as a standalone application.
    public static void main(String[] args) {
        execute();
    }

    /**
     * Initialize the Spring context, invoke the appropriate bean method,
     * and store the results of the JPPF execution.
     * @return the results as a <code>JPPFJob</code> instance.
     */
    public static JPPFJob execute() {
        ClassPathXmlApplicationContext context =
            new ClassPathXmlApplicationContext("classpath:client.xml");
        context.start();
        GSClient gsc = (GSClient) context.getBean("gsclient");
        return gsc.getJob();
    }

    // Called after the Spring bean init and submits a JPPF job to the JPPF space.
    public void afterPropertiesSet() throws Exception {
        JPPFJob newJob = new JPPFJob();
        newJob.addTask(new HelloTask());
        this.job = jppfService.submitJob(newJob);
    }

    // Get a proxy to the service deployed in a GS space.
    public JPPFService getJppfService() {
        return jppfService;
    }

    // Set a proxy to the service deployed in a GS space.
    public void setJppfService(JPPFService service) {
        this.jppfService = service;
    }

    // Get the resulting JPPF job instance.
    public JPPFJob getJob() {
        return job;
    }
}
```

11 Configuration properties reference

11.1 Server properties

Property name	Default Value	Comments
jppf.server.port	11111	JPPF server port
jppf.management.enabled	true	enable server management
jppf.management.host	computed	management server host
jppf.management.port	11198	management remote connector port
jppf.discovery.enabled	true	enable server broadcast and discovery
jppf.discovery.group	230.0.0.1	UDP broadcast group
jppf.discovery.port	11111	UDP broadcast port
jppf.discovery.broadcast.interval	5000	UDP broadcast interval in milliseconds
jppf.peers	null	space separated list of peer server names
jppf.peer.<name>.server.host	localhost	named peer server host name or address
jppf.peer.<name>.server.port	11111	named peer server port
jppf.peer.discovery.enabled	false	enable peer discovery
jppf.load.balancing.algorithm	proportional	load balancing algorithm name
jppf.load.balancing.strategy	jppf	load balancing parameters profile name
strategy.<profile>.<parameter>	null	parameter for the named parameters profile
jppf.jvm.options	null	JVM options for the server process
jppf.object.stream.builder	null	optional object stream builder
jppf.object.input.stream.class	java.io.ObjectInputStream	optional alternate object input stream
jppf.object.output.stream.class	java.io.ObjectOutputStream	optional alternate object input stream
jppf.data.transform.class	null	optional network data transformation
transition.thread.pool.size	number of available CPUs	number of threads performing network I/O
jppf.local.node.enabled	false	enable a node to run in the same JVM
jppf.recovery.enabled	false	enable recovery from hardware failures on the nodes
jppf.recovery.max.retries	3	maximum number of failed pings to the node before the connection is considered broken
jppf.recovery.read.timeout	6000 (6 seconds)	maximum ping response time from the node
jppf.recovery.server.port	22222	port number for the detection of node failure
jppf.recovery.reaper.run.interval	60000 (1 minute)	interval between connection reaper runs
jppf.recovery.reaper.pool.size	number of available CPUs	number of threads allocated to the reaper
jppf.socket.max-idle	-1	number of seconds a socket connection can remain idle before being closed
jppf.nio.connection.check	true	enable/disable network connection checks on write operations

11.2 Node properties

Property name	Default Value	Comments
jppf.server.host	localhost	JPPF server host address
jppf.server.port	11111	JPPF server port
jppf.management.enabled	true	enable server management
jppf.management.host	computed	node's management server host
jppf.management.port	11198	management remote connector port
jppf.discovery.enabled	true	enable server discovery
jppf.discovery.group	230.0.0.1	server discovery: UPD multicast group
jppf.discovery.port	11111	server discovery: UPD multicast port
jppf.discovery.timeout	5000	server discovery timeout in milliseconds
jppf.discovery.ipv4.include	null	IPv4 inclusion patterns for server discovery
jppf.discovery.ipv4.exclude	null	IPv4 exclusion patterns for server discovery
jppf.discovery.ipv6.include	null	IPv6 inclusion patterns for server discovery
jppf.discovery.ipv6.exclude	null	IPv6 exclusion patterns for server discovery
jppf.jvm.options	null	JVM options for the node process
jppf.object.stream.builder	null	optional object stream builder
jppf.object.input.stream.class	java.io.ObjectInputStream	optional alternate object input stream
jppf.object.output.stream.class	java.io.ObjectOutputStream	optional alternate object input stream
jppf.data.transform.class	null	optional network data transformation
reconnect.initial.delay	1	delay in seconds before the first reconnection attempt
reconnect.max.time	60	delay in seconds after which reconnection attempts stop. Negative value = never stop
reconnect.interval	1	frequency in seconds of reconnection attempts
processing.threads	number of available CPUs	number of threads used for tasks execution
jppf.policy.file	null	path to the security policy file, either local to the node or in the server's file system
jppf.idle.mode.enabled	false	enable the idle mode
jppf.idle.timeout	300000 (5 minutes)	the time of keyboard and mouse inactivity before considering the node idle, expressed in milliseconds
jppf.idle.poll.interval	1000 (1 second)	how often the node will check for keyboard and mouse inactivity, in milliseconds
jppf.idle.detector.factory	null	implementation of the idle detector factory
jppf.recovery.enabled	false	enable recovery from hardware failures
jppf.recovery.server.port	22222	port number for the detection of hardware failure
jppf.classloader.cache.size	50	size of the class loader cache for the node
jppf.socket.max-idle	-1	number of seconds a socket connection can remain idle before being closed

11.3 Application client and admin console properties

Property name	Default Value	Comments
jppf.drivers	default-driver	space-separated list of driver names
<driver_name>.jppf.server.host	localhost	named driver's address or host name
<driver_name>.jppf.server.port	11111	named driver's port
<driver_name>.jppf.management.host	localhost	named server's management host
<driver_name>.jppf.management.port	11198	named server's management remote connector port
<driver_name>.jppf.management.enabled	true	enable remote management of named server
<driver_name>.priority	0	named server priority
<driver_name>.jppf.pool.size	1	named server connection pool size
reconnect.initial.delay	1	delay in seconds before the first reconnection attempt
reconnect.max.time	60	delay in seconds after which reconnection attempts stop. Negative value = never stop
reconnect.interval	1	frequency in seconds of reconnection attempts
jppf.local.execution.enabled	true	enable remote execution
jppf.local.execution.enabled	false	enable local execution
jppf.local.execution.threads	number of available CPUs	maximum threads to use for local execution
jppf.pool.size	1	connection pool size when discovery is enabled
jppf.discovery.enabled	true	enable server discovery
jppf.discovery.group	230.0.0.1	server discovery: UDP multicast group
jppf.discovery.port	11111	server discovery: UDP multicast port
jppf.discovery.ipv4.include	null	IPv4 inclusion patterns for server discovery
jppf.discovery.ipv4.exclude	null	IPv4 exclusion patterns for server discovery
jppf.discovery.ipv6.include	null	IPv6 inclusion patterns for server discovery
jppf.discovery.ipv6.exclude	null	IPv6 exclusion patterns for server discovery
jppf.object.stream.builder	null	optional object stream builder
jppf.object.input.stream.class	java.io.ObjectInputStream	optional alternate object input stream
jppf.object.output.stream.class	java.io.ObjectOutputStream	optional alternate object input stream
jppf.data.transform.class	null	optional network data transformation
jppf.ui.splash	true	enable display of splash screen at startup
jppf.socket.max-idle	-1	number of seconds a socket connection can remain idle before being closed
jppf.local.execution.accumulation.size	all tasks	how many completed tasks before notifying
jppf.local.execution.accumulation.time	job completion time	how long before notifying
jppf.local.execution.accumulation.unit	m = milliseconds	time unit to use

12 Execution policy reference

12.1 Execution Policy Elements

12.1.1 NOT

Negates a test

Class name: **org.jppf.node.policy.ExecutionPolicy.Not**

Usage:

```
policy = otherPolicy.not();
```

XML Element: **<NOT>**

Nested element: any other policy element, min = 1, max = 1

Usage:

```
<NOT>
  <Equal ignoreCase="true" valueType="string">
    <Property>some.property</Property>
    <Value>some value here</Value>
  </Equal>
</NOT>
```

12.1.2 AND

Combines multiple tests through a logical AND operator

Class name: **org.jppf.node.policy.ExecutionPolicy.And**

Usage:

```
policy = policy1.and(policy2).and(policy3);
policy = policy1.and(policy2, policy3);
```

XML Element: **<AND>**

Nested element: any other policy element, min = 2, max = unbounded

Usage:

```
<AND>
  <Equal ignoreCase="true" valueType="string">
    <Property>some.property.1</Property>
    <Value>some value here</Value>
  </Equal>
  <LessThan>
    <Property>some.property.2</Property>
    <Value>100</Value>
  </LessThan>
  <Contains ignoreCase="true" valueType="string">
    <Property>some.property.3</Property>
    <Value>substring</Value>
  </Contains>
</AND>
```

12.1.3 OR

Combines multiple tests through a logical OR operator

Class name: **org.jppf.node.policy.ExecutionPolicy.Or**

Usage:

```
policy = policy1.or(policy2).or(policy3);
policy = policy1.or(policy2, policy3);
```

XML Element: **<OR>**

Nested element: any other policy element, min = 2, max = unbounded

Usage:

```
<OR>
  <Equal ignoreCase="true" valueType="string">
    <Property>some.property.1</Property>
```



```

    <Value>some value here</Value>
  </Equal>
  <LessThan>
    <Property>some.property.2</Property>
    <Value>100</Value>
  </LessThan>
  <Contains ignoreCase="true" valueType="string">
    <Property>some.property.3</Property>
    <Value>substring</Value>
  </Contains>
</OR>

```

12.1.4 XOR

Combines multiple tests through a logical XOR operator

Class name: `org.jpff.node.policy.ExecutionPolicy.Xor`

Usage:

```

policy = policy1.xor(policy2).xor(policy3);
policy = policy1.xor(policy2, policy3);

```

XML Element: `<XOR>`

Nested element: any other policy element, min = 2, max = unbounded

Usage:

```

<XOR>
  <Equal ignoreCase="true" valueType="string">
    <Property>some.property.1</Property>
    <Value>some value here</Value>
  </Equal>
  <LessThan>
    <Property>some.property.2</Property>
    <Value>100</Value>
  </LessThan>
  <Contains ignoreCase="true" valueType="string">
    <Property>some.property.3</Property>
    <Value>substring</Value>
  </Contains>
</XOR>

```

12.1.5 Equal

Performs a test of type "property_value = value". The value can be either numeric, boolean or a string.

Class name: `org.jpff.node.policy.Equal`

Constructors:

```

Equal(String propertyName, boolean ignoreCase, String value)
Equal(String propertyName, double value)
Equal(String propertyName, boolean value)

```

Usage:

```

policy = new Equal("some.property", true, "some_value");
policy = new Equal("some.property", 15);
policy = new Equal("some.property", true);

```

XML Element: `<Equal>`

Attributes:

ignoreCase: one of "true" or "false", optional, defaults to "false"

valueType: one of "string", "numeric" or "boolean", optional, defaults to "string"

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : value to compare with, min = 1, max = 1

Usage:

```

<Equal ignoreCase="true" valueType="string">
  <Property>some.property</Property>
  <Value>some value here</Value>
</Equal>

```

12.1.6 LessThan

Performs a test of type "property_value < value"

The value can only be numeric.

Class name: **org.jppf.node.policy.LessThan**

Constructor:

```
LessThan(String propertyName, double value)
```

Usage:

```
policy = new LessThan("some.property", 15.50);
```

XML Element: **<LessThan>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : value to compare with, min = 1, max = 1

Usage:

```
<LessThan>
  <Property>some.property</Property>
  <Value>15.50</Value>
</LessThan>
```

12.1.7 AtMost

Performs a test of type "property_value <= value"

The value can only be numeric.

Class name: **org.jppf.node.policy.AtMost**

Constructor:

```
AtMost(String propertyName, double value)
```

Usage:

```
policy = new AtMost("some.property", 15.49);
```

XML Element: **<AtMost>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : value to compare with, min = 1, max = 1

Usage:

```
<AtMost>
  <Property>some.property</Property>
  <Value>15.49</Value>
</AtMost>
```

12.1.8 MoreThan

Performs a test of type "property_value > value"

The value can only be numeric.

Class name: **org.jppf.node.policy.MoreThan**

Constructor:

```
MoreThan(String propertyName, double value)
```

Usage:

```
policy = new MoreThan("some.property", 15.50);
```

XML Element: **<MoreThan>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : value to compare with, min = 1, max = 1

Usage:

```
<MoreThan>
  <Property>some.property</Property>
  <Value>15.50</Value>
</MoreThan>
```

12.1.9 AtLeast

Performs a test of type "property_value >= value"

The value can only be numeric.

Class name: **org.jppf.node.policy.AtLeast**

Constructor:

```
AtLeast(String propertyName, double value)
```

Usage:

```
policy = new AtLeast("some.property", 15.51);
```

XML Element: **<AtLeast>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : value to compare with, min = 1, max = 1

Usage:

```
<AtLeast>
  <Property>some.property</Property>
  <Value>15.51</Value>
</AtLeast>
```

12.1.10 BetweenII

Performs a test of type "property_value in [a, b]" (range interval with lower and upper bounds included)

The values a and b can only be numeric.

Class name: **org.jppf.node.policy.BetweenII**

Constructor:

```
BetweenII(String propertyName, double a, double b)
```

Usage:

```
policy = new BetweenII("some.property", 1.5, 3.0);
```

XML Element: **<BetweenII>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : the bounds of the interval, min = 2, max = 2

Usage:

```
<BetweenII>
  <Property>some.property</Property>
  <Value>1.5</Value>
  <Value>3.0</Value>
</BetweenII>
```

12.1.11 BetweenIE

Performs a test of type "property_value in [a, b[" (lower bound included, upper bound excluded)

The values a and b can only be numeric.

Class name: **org.jppf.node.policy.BetweenIE**

Constructor:

```
BetweenIE(String propertyName, double a, double b)
```

Usage:

```
policy = new BetweenIE("some.property", 1.5, 3.0);
```

XML Element: **<BetweenIE>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : the bounds of the interval, min = 2, max = 2

Usage:

```
<BetweenIE>
  <Property>some.property</Property>
  <Value>1.5</Value>
  <Value>3.0</Value>
</BetweenIE>
```

12.1.12 BetweenEI

Performs a test of type "property_value in]a, b]" (lower bound excluded, upper bound included)

The values a and b can only be numeric.

Class name: **org.jppf.node.policy.BetweenEI**

Constructor:

```
BetweenEI(String propertyName, double a, double b)
```

Usage:

```
policy = new BetweenEI("some.property", 1.5, 3.0);
```

XML Element: **<BetweenEI>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : the bounds of the interval, min = 2, max = 2

Usage:

```
<BetweenEI>
  <Property>some.property</Property>
  <Value>1.5</Value>
  <Value>3.0</Value>
</BetweenEI>
```

12.1.13 BetweenEE

Performs a test of type “property_value in [a, b[“ (lower and upper bounds excluded)

The values a and b can only be numeric.

Class name: **org.jppf.node.policy.BetweenEE**

Constructor:

```
BetweenEE(String propertyName, double a, double b)
```

Usage:

```
policy = new BetweenEE("some.property", 1.5, 3.0);
```

XML Element: **<BetweenEE>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : the bounds of the interval, min = 2, max = 2

Usage:

```
<BetweenEE>
  <Property>some.property</Property>
  <Value>1.5</Value>
  <Value>3.0</Value>
</BetweenEE>
```

12.1.14 Contains

Performs a test of type “property_value contains substring”

The value can be only a string.

Class name: **org.jppf.node.policy.Contains**

Constructor:

```
Contains(String propertyName, boolean ignoreCase, String value)
```

Usage:

```
policy = new Contains("some.property", true, "some_substring");
```

XML Element: **<Contains>**

Attribute: ignoreCase: one of "true" or "false", optional, defaults to "false"

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : substring to lookup, min = 1, max = 1

Usage:

```
<Contains ignoreCase="true">
  <Property>some.property</Property>
  <Value>some substring</Value>
</Contains>
```

12.1.15 OneOf

Performs a test of type “property_value in { A1, ... , An }” (discrete set).

The values A1 ... An can be either all strings or all numeric.

Class name: **org.jppf.node.policy.OneOf**

Constructor:

```
OneOf(String propertyName, boolean ignoreCase, String...values)
```

```
OneOf(String propertyName, double...values)
```

Usage:

```
policy = new OneOf("user.language", true, "en", "fr", "it");
policy = new OneOf("some.property", 1.2, 5.1, 10.3);
```

XML Element: **<OneOf>**

Attributes:

ignoreCase: one of "true" or "false", optional, defaults to "false"

valueType: one of "string" or "numeric", optional, defaults to "string"

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : substring to lookup, min = 1, max = unbounded

Usage:

```
<OneOf ignoreCase="true">
  <Property>user.language</Property>
  <Value>en</Value>
  <Value>fr</Value>
  <Value>it</Value>
</OneOf>
```

12.1.16 RegExp

Performs a test of type "property_value matches regular_expression"

The regular expression must follow the syntax for the [Java regular expression patterns](#).

Class name: **org.jppf.node.policy.RegExp**

Constructor:

```
RegExp(String propertyName, String pattern)
```

Usage:

```
policy = new RegExp("some.property", "a*z");
```

XML Element: **<RegExp>**

Nested elements:

<Property> : name of a node property, min = 1, max = 1

<Value> : regular expression pattern to match against, min = 1, max = 1

Usage:

```
<RegExp>
  <Property>some.property</Property>
  <Value>a*z</Value>
</RegExp>
```

12.1.17 CustomRule

Performs a user-defined test that can be specified in an XML policy document.

Class name: subclass of **org.jppf.node.policy.CustomPolicy**

Constructor:

```
MySubclassOfCustomPolicy(String...args)
```

Usage:

```
policy = new MySubclassOfCustomPolicy("arg 1", "arg 2", "arg 3");
```

XML Element: **<CustomRule>**

Attribute: class: fully qualified name of a policy class, required

Nested element: <Arg> : custom rule parameters, min = 0, max = unbounded

Usage:

```
<CustomRule class="my.sample.MySubclassOfCustomPolicy">
  <Arg>arg 1</Arg>
  <Arg>arg 2</Arg>
  <Arg>arg 3</Arg>
</CustomRule>
```

12.2 Execution policy properties

12.2.1 Related APIs

All properties can be obtained using the `JPPFSystemInformation` class. This is what is sent to any execution policy object when its [`accepts\(JPPFSystemInformation\)`](#) method is called to evaluate the policy against a specific node or driver connection. As `JPPFSystemInformation` encapsulates several sets of properties, the `ExecutionPolicy` class provides a method [`getProperty\(JPPFSystemInformation, String\)`](#) that will lookup a specified property in the following order:

8. in `JPPFSystemInformation.getJppf()` : JPPF configuration properties
9. in `JPPFSystemInformation.getSystem()` : system properties
10. in `JPPFSystemInformation.getEnv()` : environment variables
11. in `JPPFSystemInformation.getNetwork()` : IPV4 and IPV6 addresses assigned to the node or driver
12. in `JPPFSystemInformation.getRuntime()` : runtime properties
13. in `JPPFSystemInformation.getStorage()` : storage space properties

12.2.2 JPPF configuration properties

The JPPF properties are all the properties defined in the node's or driver's JPPF configuration file, depending on where the execution policy applies.

Additionally, there is one special property “**jppf.channel.local**”, which is set internally by JPPF and which determines whether the job executor is a local node (i.e. node local to the driver's JVM) when used in a server SLA, or a local executor in the client when used in a client SLA. When used in a client SLA, this allows toggling local vs. remote execution on a per-job basis, as in the following example:

```
JPPFJob job = ...;  
// allow job execution only in the client-local executor  
ExecutionPolicy localExecutionPolicy = new Equal("jppf.channel.local", true);  
job.getClientSLA().setExecutionPolicy(localExecutionPolicy);
```

Related APIs:

[`JPPFSystemInformation.getJppf\(\)`](#)
[`JPPFConfiguration.getProperties\(\)`](#)

12.2.3 System properties

The system properties are all the properties accessible through a call to `System.getProperties()` including all the `-Dproperty=value` definitions in the Java command line.

Related APIs:

[`JPPFSystemInformation.getSystem\(\)`](#)
[`SystemUtils.getSystemProperties\(\)`](#)
[`java.lang.System.getProperties\(\)`](#)

12.2.4 Environment variables

These are the operating system environment variables defined at the time the node's JVM was launched.

Related APIs:

[`JPPFSystemInformation.getEnv\(\)`](#)
[`SystemUtils.getEnvironment\(\)`](#)
[`java.lang.System.getenv\(\)`](#)

12.2.5 Runtime properties

These are properties that can be obtained through a call to the JDK Runtime class.

Related APIs:

[`JPPFSystemInformation.getRuntime\(\)`](#)
[`SystemUtils.getRuntimeInformation\(\)`](#)
[`java.lang.Runtime`](#)

List of properties:

`availableProcessors` : number of processors available to the JVM
`freeMemory` : estimated free JVM heap memory, in bytes
`totalMemory` : estimated total JVM heap memory, in bytes
`maxMemory` : maximum JVM heap memory, in bytes, equivalent to the value defined through the `-Xmx` JVM flag

Note: `totalMemory` and `freeMemory` are the values taken when the node first connected to the JPPF server. They may have changed subsequently and should therefore only be used with appropriate precautions.

12.2.6 Network properties

These properties enumerate all IPV4 and IPV6 addresses assigned to the JPPF node's host.

Related APIs:

[`JPPFSystemInformation.getNetwork\(\)`](#)
[`SystemUtils.getNetwork\(\)`](#)
[`java.net.NetworkInterface`](#)

List of properties:

`ipv4.addresses` : space-separated list of IPV4 addresses with associated host in the format `ipv4_address|host_name`
`ipv6.addresses` : space-separated list of IPV6 addresses with associated host in the format `ipv6_address|host_name`

Example:

```
ipv4.addresses = 192.168.121.3|www.myhost.com 127.0.0.1|localhost 254.169.0.12|  
ipv6.addresses = 2001:0db8:85a3:08d3:1319:8a2e:0370:7334|www.myhost.com
```

Note: when a host name cannot be resolved, the right-hand part of the address, on the right of the "|" (pipe character) will be empty

12.2.7 Storage properties

These properties provide storage space information about the node's file system. This is an enumeration of the file system roots with associated information such as root name and storage space information. The storage space information is only available with Java 1.6 or later, as the related APIs did not exist before this version.

Related APIs:

[`JPPFSystemInformation.getStorage\(\)`](#)
[`SystemUtils.getStorageInformation\(\)`](#)
[`File.getFreeSpace\(\)`](#)
[`File.getTotalSpace\(\)`](#)
[`File.getUsableSpace\(\)`](#)

List of properties:

`host.roots.names` = `root_name_0 ... root_name_n-1` : the names of all accessible file system roots
`host.roots.number` = `n` : the number of accessible file system roots

For each root i:

`root.i.name` = `root_name` : for instance "C:\\" on Windows or "/" on Unix
`root.i.space.free` = `space_in_bytes` : current free space for the root (Java 1.6 or later)
`root.i.space.total` = `space_in_bytes` : total space for the root (Java 1.6 or later)
`root.i.space.usable` = `space_in_bytes` : space available to the user the JVM is running under (Java 1.6 or later)

Example:

```
host.roots.names = C:\ D:\
host.roots.number = 2
root.0.name = C:\
root.0.space.free = 921802928128
root.0.space.total = 984302772224
root.0.space.usable = 921802928128
root.1.name = D:\
root.1.space.free = 2241486848
root.1.space.total = 15899463680
root.1.space.usable = 2241486848
```


12.3 Execution policy XML schema

```
<?xml version="1.0" encoding="UTF-8"?>

<!--
  JPPF.
  Copyright (C) 2005-2010 JPPF Team.
  http://www.jppf.org

  Licensed under the Apache License, Version 2.0 (the "License");
  you may not use this file except in compliance with the License.
  You may obtain a copy of the License at

      http://www.apache.org/licenses/LICENSE-2.0

  Unless required by applicable law or agreed to in writing, software
  distributed under the License is distributed on an "AS IS" BASIS,
  WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
  See the License for the specific language governing permissions and
  limitations under the License.
-->

<schema xmlns="http://www.w3.org/2001/XMLSchema"
  xmlns:jppf="http://www.jppf.org/schemas/ExecutionPolicy.xsd"
  targetNamespace="http://www.jppf.org/schemas/ExecutionPolicy.xsd"
  elementFormDefault="unqualified"
  attributeFormDefault="unqualified"
>

  <element name="ExecutionPolicy" type="jppf:OneRuleType"/>

  <group name="Rule">
    <choice>
      <element name="NOT" type="jppf:OneRuleType"/>
      <element name="AND" type="jppf:TwoOrMoreRulesType"/>
      <element name="OR" type="jppf:TwoOrMoreRulesType"/>
      <element name="XOR" type="jppf:TwoOrMoreRulesType"/>
      <element name="LessThan" type="jppf:Numeric2Type"/>
      <element name="AtMost" type="jppf:Numeric2Type"/>
      <element name="MoreThan" type="jppf:Numeric2Type"/>
      <element name="AtLeast" type="jppf:Numeric2Type"/>
      <element name="BetweenII" type="jppf:Numeric3Type"/>
      <element name="BetweenIE" type="jppf:Numeric3Type"/>
      <element name="BetweenEI" type="jppf:Numeric3Type"/>
      <element name="BetweenEE" type="jppf:Numeric3Type"/>
      <element name="Equal" type="jppf:EqualType"/>
      <element name="Contains" type="jppf:ContainsType"/>
      <element name="OneOf" type="jppf:OneOfType"/>
      <element name="RegExp" type="jppf:RegExpType"/>
      <element name="CustomRule" type="jppf:CustomRuleType"/>
    </choice>
  </group>

  <complexType name="OneRuleType">
    <sequence>
      <group ref="jppf:Rule"/>
    </sequence>
  </complexType>

  <complexType name="TwoOrMoreRulesType">
    <sequence minOccurs="2" maxOccurs="unbounded">
      <group ref="jppf:Rule"/>
    </sequence>
  </complexType>
```

```

<!-- test of type "property_value is less than value" -->
<complexType name="Numeric2Type">
  <sequence>
    <element name="Property" type="string"/>
    <element name="Value" type="double"/>
  </sequence>
</complexType>

<!-- test of type "property_value is in range [a, b]" -->
<complexType name="Numeric3Type">
  <sequence>
    <element name="Property" type="string"/>
    <element name="Value" type="double" minOccurs="2" maxOccurs="2"/>
  </sequence>
</complexType>

<!-- test of type "property_value is equal to value" -->
<complexType name="EqualType">
  <sequence>
    <element name="Property" type="string"/>
    <element name="Value" type="string"/>
  </sequence>
  <attribute name="valueType" use="optional" default="string">
    <simpleType>
      <restriction base="string">
        <enumeration value="string"/>
        <enumeration value="numeric"/>
        <enumeration value="boolean"/>
      </restriction>
    </simpleType>
  </attribute>
  <attribute name="ignoreCase" type="jppf:TrueFalse"
    use="optional" default="false"/>
</complexType>

<!-- test of type "property_value contains substring" -->
<complexType name="ContainsType">
  <sequence>
    <element name="Property" type="string"/>
    <element name="Value" type="string"/>
  </sequence>
  <attribute name="ignoreCase" type="jppf:TrueFalse"
    use="optional" default="false"/>
</complexType>

<!-- test of type "property_value is one of { value1, ... , valueN } " -->
<complexType name="OneOfType">
  <sequence>
    <element name="Property" type="string"/>
    <element name="Value" type="string" maxOccurs="unbounded"/>
  </sequence>
  <attribute name="valueType" use="optional" default="string">
    <simpleType>
      <restriction base="string">
        <enumeration value="string"/>
        <enumeration value="numeric"/>
      </restriction>
    </simpleType>
  </attribute>
  <attribute name="ignoreCase" type="jppf:TrueFalse"
    use="optional" default="false"/>
</complexType>

```

```
<!-- test of type "property_value matches regular_expression " -->
<complexType name="RegExpType">
  <sequence>
    <element name="Property" type="string"/>
    <element name="Value" type="string"/>
  </sequence>
</complexType>

<simpleType name="TrueFalse">
  <restriction base="string">
    <enumeration value="true"/>
    <enumeration value="false"/>
  </restriction>
</simpleType>

<complexType name="CustomRuleType">
  <sequence>
    <element name="Arg" type="string" minOccurs="0" maxOccurs="unbounded"/>
  </sequence>
  <attribute name="class" type="string"/>
</complexType>

</schema>
```

13 Deployment and run modes

13.1 JPPF Driver

First you will need to obtain the driver package from the [JPPF download page](#) : **JPPF-x.y.z-driver.zip**.

Unzip the file JPPF-x.y.z-driver.zip in a location where you intend to run the JPPF server from.

This zip file contains all the binaries for running the server only.

To run the driver: go to the JPPF-x.y.z-driver folder and type “**ant run**”.

13.1.1 JPPF Driver as a Windows Service

A JPPF driver can be run as Windows Service using the Java Service Wrapper available at [Tanuki Software](#).

The JPPF-x.y.z-driver.zip distribution and above are prepared for this installation.

To install:

- [download](#) the Java Service Wrapper for your platform and copy the files wrapper.exe, wrapper.dll and wrapper.jar to the JPPF driver install directory
- edit config/wrapper-driver.conf file, check that the setting for wrapper.java.command is valid (either the PATH environment must contain a Java 5 JRE, or the installation directory must be entered here)
- run the **InstallDriverService.bat** file to install the JPPF node service
- run the **UninstallDriverService.bat** file to uninstall the JPPF node service

13.1.2 JPPF Driver as a Linux/Unix daemon

The JPPF driver can be run as a Linux/Unix daemon using the Java Service Wrapper available at [Tanuki Software](#).

The JPPF-x.y.z-driver.zip distribution and above are prepared for this installation.

To install:

- [download](#) the Java Service Wrapper for your platform and copy the files wrapper, libwrapper.so and wrapper.jar to the JPPF node install directory
- don't forget to set the executable bit for the JPPFDriver and wrapper script/executable
- edit config/wrapper-driver.conf file, check that the setting for wrapper.java.command is valid (either the PATH environment must contain a Java 5 JRE, or the installation directory must be entered here)
- open a terminal in the JPPF driver root install directory
- to run the driver as a daemon: **./JPPFDriver start**
- to stop the driver: **./JPPFDriver stop**
- to restart the driver: **./JPPFDriver restart**

13.2 JPPF Node

First you will need to obtain the node package from the [JPPF download page](#) : **JPPF-x.y.z-node.zip**.

Unzip the file JPPF-x.y.z-node.zip in a location where you intend to run a JPPF node on.

This zip file contains all the binaries for running a node only.

To run the node: go to the JPPF-x.y.z-node folder and type “**ant run**”.

13.2.1 JPPF Node as a Windows Service

The JPPF node can be run as Windows Service using the Java Service Wrapper available at

<http://wrapper.tanukisoftware.org/>. The JPPF-x.y.z-node.zip distribution and above are prepared for this installation.

To install:

- [download](#) the Java Service Wrapper for your platform and copy the files wrapper.exe, wrapper.dll and wrapper.jar to the JPPF node install directory
- edit config/wrapper-node.conf file, check that the setting for wrapper.java.command is valid (either the PATH environment must contain a Java 5 JRE, or the installation directory must be entered here)
- run the **InstallNodeService.bat** file to install the JPPF node service
- run the **UninstallNodeService.bat** file to uninstall the JPPF node service

13.2.2 JPPF Node as a Linux/Unix daemon

The JPPF node can be run as a Linux/Unix daemon using the Java Service Wrapper available at [Tanuki Software](#). The JPPF-x.y.z-node.zip distribution and above are prepared for this installation.

To install:

- [download](#) the Java Service Wrapper for your platform and copy the files wrapper, libwrapper.so and wrapper.jar to the JPPF node install directory
- don't forget to set the executable bit for the JPPFNode and wrapper script/executable
- edit the config/wrapper-node.conf file, check that the setting for wrapper.java.command is valid (either the PATH environment must contain a Java 5 JRE, or the installation directory must be entered here)
- open a terminal in the JPPF node root install directory
- to run the node as a daemon: **./JPPFNode start**
- to stop the node: **./JPPFNode stop**
- to restart the node: **./JPPFNode restart**

13.2.3 JPPF Node in “Idle Host” mode

A node can be configured to run only when its host is considered idle, i.e. when no keyboard or mouse activity has occurred for a specified time. This requires additional libraries that must be downloaded separately due to licensing compatibility concerns, and used to compile and build a node add-on. Fortunately, we have automated the download and build process, to make it as easy as possible.

To install and configure a node in idle mode:

- download the [JPPF samples pack](#)
- unzip the **JPPF-x.y.z-samples-pack.zip** anywhere on your file system
- open a command prompt or shell console in **JPPF-x.y.z-samples-pack/IdleSystem**
- run the build script: “**ant jar**”, or simply “**ant**”. This will download 2 jar files “**jna.jar**” and “**platform.jar**” and create a third one “**IdleSystem.jar**”, into the **IdleSystem/lib** directory.
- when this is done, copy the 3 jar files IdleSystem/lib into your node's library directory “**JPPF-x.y.z-node/lib**”
- to configure the node to run in idle mode, open the file “**JPPF-x.y.z-node/config/jppf-node.properties**” in a text editor and create or edit the following properties:
 - **jppf.idle.mode.enabled** = true to enable the idle mode
 - **jppf.idle.timeout** = **6000** to configure the time of keyboard and mouse inactivity before considering the node idle, expressed in milliseconds
 - **jppf.idle.poll.interval** = **1000** to configure how often the node will check for inactivity, in milliseconds
 - **jppf.idle.detector.factory** = **org.jppf.example.idlesystem.IdleTimeDetectorFactoryImpl** please do not change this!
- when this is all done, you can start the node and it will only run when the system has been idle for the configured time, and stop as soon as any keyboard or mouse input occurs

13.3 Running JPPF on Amazon's EC2

13.3.1 Server discovery

EC2 does not allow multicast network communication, so JPPF nodes must know which server to use ahead of time instead of using the auto-discovery feature. So the server property file must set:

```
jppf.discovery.enabled = false
jppf.peer.discovery.enabled = false
```

And the node property file must set:

```
jppf.discovery.enabled = false
jppf.server.host = IP_or_DNS_hostname
```

Similarly the client must set:

```
jppf.discovery.enabled = false
jppf.drivers = driverA
driverA.jppf.server.host = IP_or_DNS_hostname
driverA.jppf.server.port = 11111
```

Amazon charges for network access to a public IP, so you'll want the node to communicate with the internal 10.x.x.x address and not a public IP. More on this detail below...

13.3.2 Firewall configuration

EC2 puts all nodes into “security groups” that define allowed network access. Make sure to start JPPF servers with a special security group that allows access to the standard port 11111 and if you use the management tools remotely, 11198. You may also want to limit these to internal IPs 10.0.0.0/8 if your clients, servers and nodes are all within EC2.

13.3.3 Instance type

EC2 nodes vary the number of available cores, so you may want a different node property file for each instance type you start, with an appropriate number of threads. For instance, on a c1.xlarge instance with 8 cores, you might want to have one additional thread so the CPU would be busy if any one thread was waiting on I/O:

```
processing.threads = 9
```

If your tasks require more I/O, you may need to experiment to find the best completion rate.

13.3.4 IP Addresses

All EC2 instances will have both a public IP address (chosen randomly or your selected elastic IP), and a private internal IP 10.x.x.x. You are charged for traffic between availability zones regardless of address, and even within the same zone if you use the external IP. So you'll want to try to have the systems connect using the 10.x.x.x addresses.

Unfortunately, this complicates things a bit. Ideally you probably want to set up a pre-configured node image (AMI) and launch instances from that image as needed for your JPPF tasks. But you may not know the internal IP of the driver at the time. And you don't want to spend time creating a new AMI each time you launch a new task with a new driver.

One solution is to use a static elastic IP that you will always associate with the JPPF driver and eat the cost of EC2 traffic. It isn't that much really...

Or you can use DNS to publish your 10.x.x.x IP address for the driver before launching nodes, and configure the node AMI to use a fixed DNS hostname.

Or you can do a little programming with the EC2 API to pass the information around. This is the recommended approach. To this effect, JPPF provides a [configuration hook](#), which will allow a node to read its configuration from a source other than a static and local configuration file. The node configuration plugin can read a properties file from S3 instead of a file already on the node. A matching startup task on the driver instance would publish an appropriate properties file to S3. There are lots of other approaches that will give you the same results – just have the server publish its location to some known location and have the node read this and dynamically create its properties instead of having a fixed file.

13.4 Runtime dependencies

13.4.1 Node and Common dependencies

These libraries are those used by the JPPF nodes as well as by all other JPPF components. For greater clarity, they are not shown in the next sections, however they should always be added to the JPPF components' classpath.

Library name	Jar Files	Comments
SLF4J	slf4j-api-1.6.1.jar slf4j-log4j12-1.6.1.jar	Logging wrapper API with Log4j bindings
Log4j	log4j-1.2.15.jar	Logging implementation
JMXMP	jmxremote_optional.jar	JMX remote connector
JPPF node	jppf-common-node.jar	Node bootstrapping API and common JPPF APIs

13.4.2 Driver dependencies

Library name	Jar Files	Comments
JPPF common	jppf-common.jar	Common JPPF APIs not needed to bootstrap a node
JPPF server	jppf-server.jar	Driver-specific code

13.4.3 Client dependencies

Library name	Jar Files	Comments
JPPF common	jppf-common.jar	Common JPPF APIs not needed to bootstrap a node
JPPF client	jppf-client.jar	Client-specific code

13.4.4 Administration console dependencies

Library name	Jar Files	Comments
JPPF common	jppf-common.jar	Common JPPF APIs not needed to bootstrap a node
JPPF client	jppf-client.jar	Client-specific code
JPPF admin	jppf-admin.jar	Administration console-specific code
Rhino	js.jar	Mozilla's JavaScript APIs and engine
Groovy	groovy-all-1.6.5.jar	Groovy scripting engine and APIs
MigLayout	miglayout-3.7-swing.jar	Swing layout library
JFreeChart	jfreechart-1.0.12.jar jcommon-1.0.15.jar	Charting components for Swing GUIs
JGoodies Looks	looks-2.2.2.jar	Swing look and feel
JUNG	jung-algorithms-2.0.1.jar jung-api-2.0.1.jar jung-graph-impl-2.0.1.jar jung-visualization-2.0.1.jar collections-generic-4.01.jar colt-1.2.0.jar concurrent-1.3.4.jar	Graph library