

## Running Apache Spark Applications

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## Introduction

You can run Spark applications locally or distributed across a cluster, either by using an interactive shell or by submitting an application. Running Spark applications interactively is commonly performed during the data-exploration phase and for ad hoc analysis.

You can:

- Submit interactive statements through the Scala, Python, or R shell, or through a high-level notebook such as Zeppelin.
- Use APIs to create a Spark application that runs interactively or in batch mode, using Scala, Python, R, or Java.

Because of a limitation in the way Scala compiles code, some applications with nested definitions running in an interactive shell may encounter a Task not serializable exception. Cloudera recommends submitting these applications.

To run applications distributed across a cluster, Spark requires a cluster manager. In CDP, Cloudera supports only the YARN cluster manager. When run on YARN, Spark application processes are managed by the YARN ResourceManager and NodeManager roles. Spark Standalone is not supported.

To launch Spark applications on a cluster, you can use the `spark-submit` script in the `/bin` directory on a gateway host. You can also use the API interactively by launching an interactive shell for Scala (`spark-shell`), Python (`pyspark`), or SparkR. Note that each interactive shell automatically creates `SparkContext` in a variable called `sc`, and `SparkSession` in a variable called `spark`. For more information about `spark-submit`, see the Apache Spark documentation [Submitting Applications](#).

Alternately, you can use Livy to submit and manage Spark applications on a cluster. Livy is a Spark service that allows local and remote applications to interact with Apache Spark over an open source REST interface. Livy offers additional multi-tenancy and security functionality. For more information about using Livy to run Spark Applications, see [Submitting Spark applications using Livy](#) on page 18.

## Running your first Spark application

### About this task



#### Important:

By default, CDH is configured to permit any user to access the Hive Metastore. However, if you have modified the value set for the configuration property `hadoop.proxyuser.hive.groups`, which can be modified in Cloudera Manager by setting the Hive Metastore Access Control and Proxy User Groups Override property, your Spark application might throw exceptions when it is run. To address this issue, make sure you add the groups that contain the Spark users that you want to have access to the metastore when Spark applications are run to this property in Cloudera Manager:

1. In the Cloudera Manager Admin Console Home page, click the Hive service.
2. On the Hive service page, click the Configuration tab.
3. In the Search well, type `hadoop.proxyuser.hive.groups` to locate the Hive Metastore Access Control and Proxy User Groups Override property.
4. Click the plus sign (+), enter the groups you want to have access to the metastore, and then click Save Changes. You must restart the Hive Metastore Server for the changes to take effect by clicking the restart icon at the top of the page.

The simplest way to run a Spark application is by using the Scala or Python shells.

## Procedure

1. To start one of the shell applications, run one of the following commands:

- Scala:

[illegible]

- Python:

[illegible]

`SPARK_HOME` defaults to `/opt/cloudera/parcels/CDH/lib/spark` in parcel installations. In a Cloudera Manager deployment, the shells are also available from `/usr/bin`.

For a complete list of shell options, run `spark-shell` or `pyspark` with the `-h` flag.

2. To run the classic Hadoop word count application, copy an input file to HDFS:

```
hdfs dfs -copyFromLocal INPUT s3a://<BUCKET_NAME>/
```

3. Within a shell, run the word count application using the following code examples, substituting for *NAMENODE* *HOST*, *PATH/TO/INPUT*, and *PATH/TO/OUTPUT*:

Scala:

```
scala> val myfile = sc.textFile("s3a://<BUCKET_NAME>/PATH/TO/INPUT")
scala> val counts = myfile.flatMap(line => line.split(" ")).map(word => (
word, 1)).reduceByKey(_ + _)
scala> counts.saveAsTextFile("s3a://<BUCKET_NAME>/PATH/TO/OUTPUT")
```

Python:

```
>>> myfile = sc.textFile("s3a://BUCKET NAME/PATH/TO/INPUT")
```

```
>>> counts = myfile.flatMap(lambda line: line.split(" ")).map(lambda word:
    (word, 1)).reduceByKey(lambda v1,v2: v1 + v2)
>>> counts.saveAsTextFile("s3a://<BUCKET_NAME>/PATH/TO/OUTPUT")
```

## Running sample Spark applications

### About this task

You can use the following sample Spark Pi and Spark WordCount sample programs to validate your Spark installation and explore how to run Spark jobs from the command line and Spark shell.

### Spark Pi

You can test your Spark installation by running the following compute-intensive example, which calculates pi by “throwing darts” at a circle. The program generates points in the unit square ((0,0) to (1,1)) and counts how many points fall within the unit circle within the square. The result approximates pi.

Follow these steps to run the Spark Pi example:

1. Authenticate using kinit:

```
kinit <USERNAME>
```

2. Run the Apache Spark Pi job in yarn-client mode, using code from org.apache.spark:

```
spark-submit --class org.apache.spark.examples.SparkPi \
  --master yarn-client \
  --num-executors 1 \
  --driver-memory 512m \
  --executor-memory 512m \
  --executor-cores 1 \
```

```
examples/jars/spark-examples*.jar 10
```

Commonly used options include the following:

**--class**

The entry point for your application: for example, `org.apache.spark.examples.SparkPi`.

**--master**

The master URL for the cluster: for example, `spark://23.195.26.187:7077`.

**--deploy-mode**

Whether to deploy your driver on the worker nodes (cluster) or locally as an external client (default is client).

**--conf**

Arbitrary Spark configuration property in key=value format. For values that contain spaces, enclose "key=value" in double quotation marks.

**<application-jar>**

Path to a bundled jar file that contains your application and all dependencies. The URL must be globally visible inside of your cluster: for instance, an `hdfs://` path or a `file://` path that is present on all nodes.

**<application-arguments>**

Arguments passed to the main method of your main class, if any.

Your job should produce output similar to the following. Note the value of pi in the output.

```
17/03/22 23:21:10 INFO DAGScheduler: Job 0 finished: reduce at SparkPi.s
cala:38, took 1.302805 s
Pi is roughly 3.1445191445191445
```

You can also view job status in a browser by navigating to the YARN ResourceManager Web UI and viewing job history server information. (For more information about checking job status and history, see "Tuning Spark" in this guide.)

## Configuring Spark Applications

You can specify Spark application configuration properties as follows:

- Pass properties using the `--conf` command-line switch; for example:

```
spark-submit \
--class com.cloudera.example.YarnExample \
--master yarn \
--deploy-mode cluster \
--conf "spark.eventLog.dir=hdfs:///user/spark/eventlog" \
lib/yarn-example.jar \
10
```

- Specify properties in `spark-defaults.conf`.
- Pass properties directly to the `SparkConf` used to create the `SparkContext` in your Spark application; for example:
  - Scala:

```
val conf = new SparkConf().set("spark.dynamicAllocation.initialExecutors", "5")
```



```
val sc = new SparkContext(conf)
```

- Python:

```
from pyspark import SparkConf, SparkContext
from pyspark.sql import SQLContext
conf = (SparkConf().setAppName('Application name'))
conf.set('spark.hadoop.avro.mapred.ignore.inputs.without.extension',
'false')
sc = SparkContext(conf = conf)
sqlContext = SQLContext(sc)
```

The order of precedence in configuration properties is:

1. Properties passed to SparkConf.
2. Arguments passed to spark-submit, spark-shell, or pyspark.
3. Properties set in spark-defaults.conf.

For more information, see Spark Configuration.

## Configuring Spark application properties in spark-defaults.conf

Specify properties in the spark-defaults.conf file in the form property=value.

To create a comment, add a hash mark ( # ) at the beginning of a line. You cannot add comments to the end or middle of a line.

This example shows an example excerpt of a spark-defaults.conf file:

```
spark.authenticate=false
spark.driver.log.dfsDir=/user/spark/driverLogs
spark.driver.log.persistToDfs.enabled=true
spark.dynamicAllocation.enabled=true
spark.dynamicAllocation.executorIdleTimeout=60
spark.dynamicAllocation.minExecutors=0
spark.dynamicAllocation.schedulerBacklogTimeout=1
spark.eventLog.enabled=true
spark.io.encryption.enabled=false
spark.lineage.enabled=true
spark.network.crypto.enabled=false
spark.serializer=org.apache.spark.serializer.KryoSerializer
spark.shuffle.service.enabled=true
spark.shuffle.service.port=7337
spark.ui.enabled=true
spark.ui.killEnabled=true
spark.yarn.access.hadoopFileSystems=s3a://bucket1,s3a://bucket2
```

Cloudera recommends placing configuration properties that you want to use for every application in spark-defaults.conf. See Application Properties for more information.

## Configuring Spark application logging properties

### Before you begin

Minimum Required Role: Configurator (also provided by Cluster Administrator, Full Administrator)

### About this task

To configure only the logging threshold level, follow the procedure in [Configuring Logging Thresholds](#). To configure any other logging property, do the following:

### Procedure

1. In the Cloudera Data Platform (CDP) Management Console, go to Data Hub Clusters.
2. Find and select the cluster you want to configure.
3. Click the link for the Cloudera Manager URL.
4. Go to the Spark service.
5. Click the Configuration tab.
6. Select Scope Gateway .
7. Select Category Advanced .
8. Locate the Spark Client Advanced Configuration Snippet (Safety Valve) for spark-conf/log4j.properties property.
9. Specify log4j properties. If more than one role group applies to this configuration, edit the value for the appropriate role group. See [Modifying Configuration Properties Using Cloudera Manager](#).
10. Enter a Reason for change, and then click Save Changes to commit the changes.
11. Deploy the client configuration.

## Submitting Spark applications

To submit an application consisting of a Python file or a compiled and packaged Java or Spark JAR, use the `spark-submit` script.

### spark-submit Syntax

```
spark-submit --OPTION VALUE \
  APPLICATION JAR | PYTHON FILE [APPLICATION ARGUMENTS]
```

Example: Running SparkPi on YARN demonstrates how to run one of the sample applications, SparkPi, packaged with Spark. It computes an approximation to the value of pi.

**Table 1: spark-submit Arguments**

| Option                       | Description                                                                                                                                                                                                                                                                                         |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>APPLICATION JAR</i>       | Path to a JAR file containing a Spark application. For the client deployment mode, the path must point to a local file. For the cluster deployment mode, the path can be either a local file or a URL globally visible inside your cluster; see <a href="#">Advanced Dependency Management</a> .    |
| <i>PYTHON FILE</i>           | Path to a Python file containing a Spark application. For the client deployment mode, the path must point to a local file. For the cluster deployment mode, the path can be either a local file or a URL globally visible inside your cluster; see <a href="#">Advanced Dependency Management</a> . |
| <i>APPLICATION ARGUMENTS</i> | Arguments to pass to the main method of your application.                                                                                                                                                                                                                                           |

### spark-submit command options

You specify `spark-submit` options using the form `--OPTION VALUE` instead of `--OPTION=VALUE` . (Use a space instead of an equals sign.)

| Option            | Description                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| class             | For Java and Scala applications, the fully qualified classname of the class containing the main method of the application. For example, org.apache.spark.examples.SparkPi.                                                                                                                                                                                                                                                                          |
| conf              | Spark configuration property in <i>KEY=VALUE</i> format. For values that contain spaces, surround " <i>KEY=VALUE</i> " with quotes (as shown).                                                                                                                                                                                                                                                                                                      |
| deploy-mode       | Deployment mode: <i>cluster</i> and <i>client</i> . In cluster mode, the driver runs on worker hosts. In client mode, the driver runs locally as an external client. Use cluster mode with production jobs; client mode is more appropriate for interactive and debugging uses, where you want to see your application output immediately. To see the effect of the deployment mode when running on YARN, see Deployment Modes.<br>Default: client. |
| driver-class-path | Configuration and classpath entries to pass to the driver. JARs added with --jars are automatically included in the classpath.                                                                                                                                                                                                                                                                                                                      |
| driver-cores      | Number of cores used by the driver in cluster mode.<br>Default: 1.                                                                                                                                                                                                                                                                                                                                                                                  |
| driver-memory     | Maximum heap size (represented as a JVM string; for example 1024m, 2g, and so on) to allocate to the driver. Alternatively, you can use the spark.driver.memory property.                                                                                                                                                                                                                                                                           |
| files             | Comma-separated list of files to be placed in the working directory of each executor. For the client deployment mode, the path must point to a local file. For the cluster deployment mode, the path can be either a local file or a URL globally visible inside your cluster; see <a href="#">Advanced Dependency Management</a> .                                                                                                                 |
| jars              | Additional JARs to be loaded in the classpath of drivers and executors in cluster mode or in the executor classpath in client mode. For the client deployment mode, the path must point to a local file. For the cluster deployment mode, the path can be either a local file or a URL globally visible inside your cluster; see <a href="#">Advanced Dependency Management</a> .                                                                   |
| master            | The location to run the application.                                                                                                                                                                                                                                                                                                                                                                                                                |
| packages          | Comma-separated list of Maven coordinates of JARs to include on the driver and executor classpaths. The local Maven, Maven central, and remote repositories specified in repositories are searched in that order. The format for the coordinates is groupId:artifactId:version.                                                                                                                                                                     |
| py-files          | Comma-separated list of .zip, .egg, or .py files to place on PYTHONPATH. For the client deployment mode, the path must point to a local file. For the cluster deployment mode, the path can be either a local file or a URL globally visible inside your cluster; see <a href="#">Advanced Dependency Management</a> .                                                                                                                              |
| repositories      | Comma-separated list of remote repositories to search for the Maven coordinates specified in packages.                                                                                                                                                                                                                                                                                                                                              |

Table 2: Master Values

| Master   | Description                                                                                                                                               |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| local    | Run Spark locally with one worker thread (that is, no parallelism).                                                                                       |
| local[K] | Run Spark locally with <i>K</i> worker threads. (Ideally, set this to the number of cores on your host.)                                                  |
| local[*] | Run Spark locally with as many worker threads as logical cores on your host.                                                                              |
| yarn     | Run using a YARN cluster manager. The cluster location is determined by <i>HADOOP_CONF_DIR</i> or <i>YARN_CONF_DIR</i> . See Configuring the Environment. |

## Spark cluster execution overview

Spark orchestrates its operations through the driver program. When the driver program is run, the Spark framework initializes executor processes on the cluster hosts that process your data. The following occurs when you submit a Spark application to a cluster:

1. The driver is launched and invokes the main method in the Spark application.

2. The driver requests resources from the cluster manager to launch executors.
3. The cluster manager launches executors on behalf of the driver program.
4. The driver runs the application. Based on the transformations and actions in the application, the driver sends tasks to executors.
5. Tasks are run on executors to compute and save results.
6. If dynamic allocation is enabled, after executors are idle for a specified period, they are released.
7. When driver's main method exits or calls `SparkContext.stop`, it terminates any outstanding executors and releases resources from the cluster manager.

## Canary test for pyspark command

The following example shows a simple `pyspark` session that refers to the `SparkContext`, calls the `collect()` function which runs a Spark 2 job, and writes data to HDFS. This sequence of operations helps to check if there are obvious configuration issues that prevent Spark jobs from working at all. For the HDFS path for the output directory, substitute a path that exists on your own system.

```
$ hdfs dfs -mkdir /user/systest/spark
$ pyspark
...
SparkSession available as 'spark'.
>>> strings = ["one","two","three"]
>>> s2 = sc.parallelize(strings)
>>> s3 = s2.map(lambda word: word.upper())
>>> s3.collect()
['ONE', 'TWO', 'THREE']
>>> s3.saveAsTextFile('hdfs:///user/systest/spark/canary_test')
>>> quit()
$ hdfs dfs -ls /user/systest/spark
Found 1 items
drwxr-xr-x  - systest supergroup          0 2016-08-26 14:41 /user/systest/
spark/canary_test
$ hdfs dfs -ls /user/systest/spark/canary_test
Found 3 items
-rw-r--r--  3 systest supergroup          0 2016-08-26 14:41 /user/systest/
spark/canary_test/_SUCCESS
-rw-r--r--  3 systest supergroup          4 2016-08-26 14:41 /user/systest/
spark/canary_test/part-00000
-rw-r--r--  3 systest supergroup        10 2016-08-26 14:41 /user/systest/
spark/canary_test/part-00001
$ hdfs dfs -cat /user/systest/spark/canary_test/part-00000
ONE
$ hdfs dfs -cat /user/systest/spark/canary_test/part-00001
TWO
THREE
```

## Fetching Spark Maven dependencies

The Maven coordinates are a combination of `groupId`, `artifactId` and `version`. The `groupId` and `artifactId` are the same as for the upstream Apache Spark project. For example, for `spark-core`, `groupId` is `org.apache.spark`, and `artifactId` is `spark-core_2.11`, both the same as the upstream project. The `version` is different for the Cloudera packaging; see the release notes for the exact name depending on which release you are using.

## Accessing the Spark History Server

You can access the Spark History Server for your Spark cluster from the Cloudera Data Platform (CDP) Management Console interface.

### Procedure

1. In the Management Console, navigate to your Spark cluster (Data Hub Clusters<Cluster Name>).
2. Select the Gateway tab.
3. Click the URL for Spark History Server.

## Running Spark applications on YARN

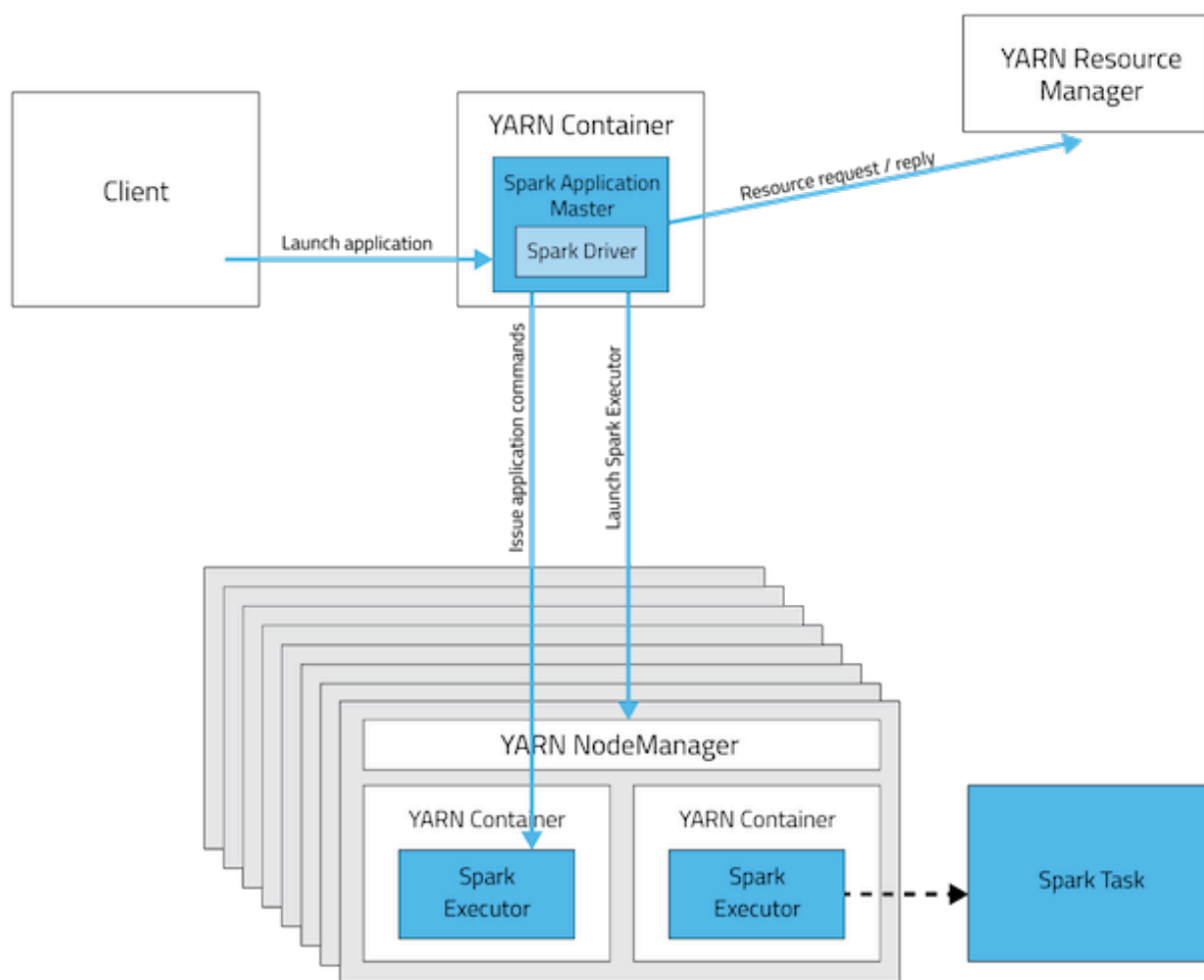
When Spark applications run on a YARN cluster manager, resource management, scheduling, and security are controlled by YARN.

## Spark on YARN deployment modes

In YARN, each application instance has an ApplicationMaster process, which is the first container started for that application. The application is responsible for requesting resources from the ResourceManager. Once the resources are allocated, the application instructs NodeManagers to start containers on its behalf. ApplicationMasters eliminate the need for an active client: the process starting the application can terminate, and coordination continues from a process managed by YARN running on the cluster.

### Cluster Deployment Mode

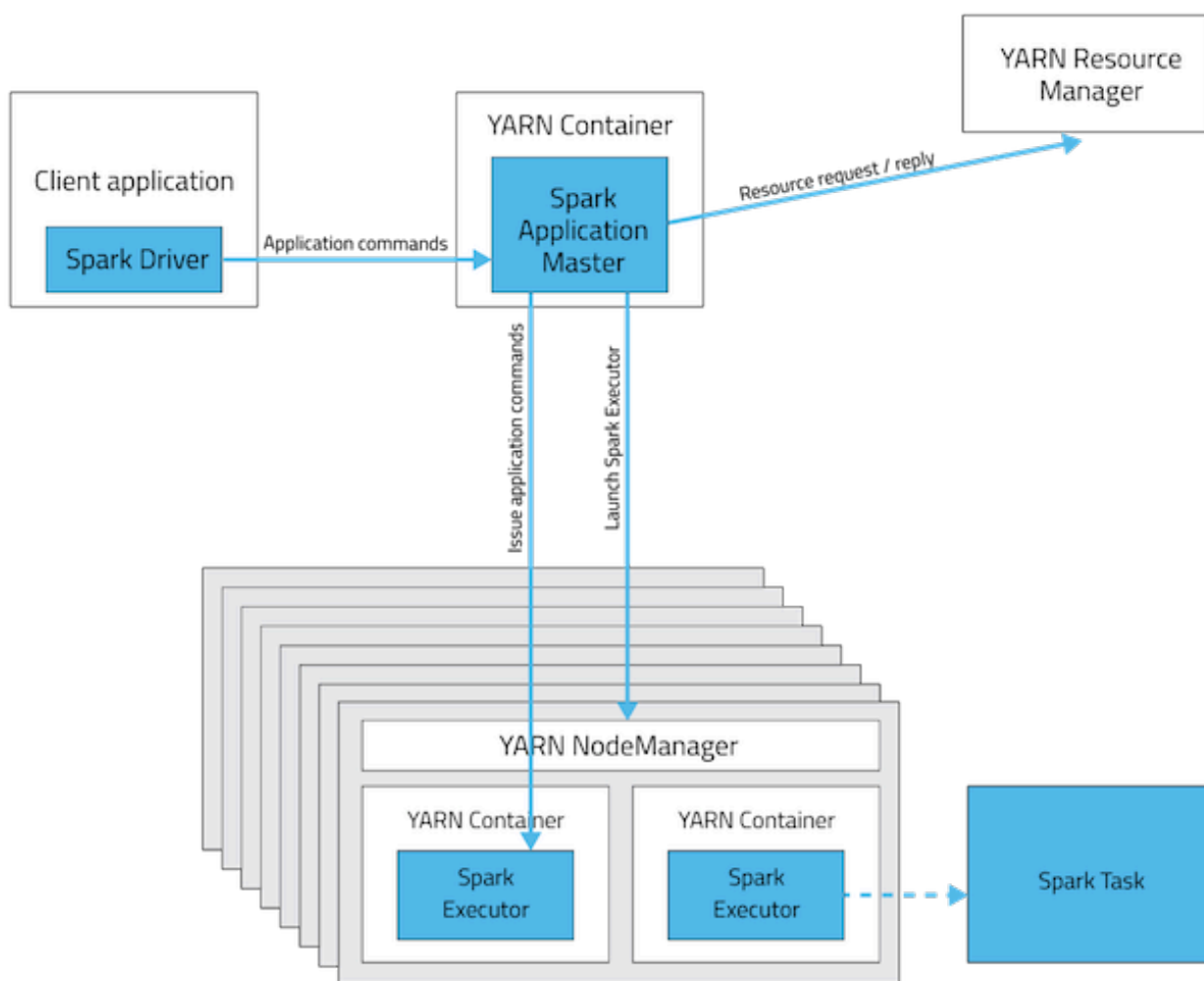
In cluster mode, the Spark driver runs in the ApplicationMaster on a cluster host. A single process in a YARN container is responsible for both driving the application and requesting resources from YARN. The client that launches the application does not need to run for the lifetime of the application.



Cluster mode is not well suited to using Spark interactively. Spark applications that require user input, such as spark-shell and pyspark, require the Spark driver to run inside the client process that initiates the Spark application.

### Client Deployment Mode

In client mode, the Spark driver runs on the host where the job is submitted. The ApplicationMaster is responsible only for requesting executor containers from YARN. After the containers start, the client communicates with the containers to schedule work.



**Table 3: Deployment Mode Summary**

| Mode                      | YARN Client Mode                      | YARN Cluster Mode                     |
|---------------------------|---------------------------------------|---------------------------------------|
| Driver runs in            | Client                                | ApplicationMaster                     |
| Requests resources        | ApplicationMaster                     | ApplicationMaster                     |
| Starts executor processes | YARN NodeManager                      | YARN NodeManager                      |
| Persistent services       | YARN ResourceManager and NodeManagers | YARN ResourceManager and NodeManagers |
| Supports Spark Shell      | Yes                                   | No                                    |

## Submitting Spark Applications to YARN

To submit an application to YARN, use the `spark-submit` script and specify the `--master yarn` flag. For other `spark-submit` options, see [spark-submit command options](#) on page 10.

## Monitoring and Debugging Spark Applications

To obtain information about Spark application behavior you can consult YARN logs and the Spark web application UI. These two methods provide complementary information. For information how to view logs created by Spark applications and the Spark web application UI, see [Monitoring Spark Applications](#).

## Example: Running SparkPi on YARN

These examples demonstrate how to use `spark-submit` to submit the SparkPi Spark example application with various options. In the examples, the argument passed after the JAR controls how close to pi the approximation should be.

In a CDP deployment, `SPARK_HOME` defaults to `/opt/cloudera/parcels/CDH/lib/spark`. The shells are also available from `/bin`.

### Running SparkPi in YARN Cluster Mode

To run SparkPi in cluster mode:

```
spark-submit --class org.apache.spark.examples.SparkPi --master yarn \
--deploy-mode cluster /opt/cloudera/parcels/CDH/jars/spark-examples*.jar 10
```

The command prints status until the job finishes or you press `control-C`. Terminating the `spark-submit` process in cluster mode does not terminate the Spark application as it does in client mode. To monitor the status of the running application, run `yarn application -list`.

### Running SparkPi in YARN Client Mode

To run SparkPi in client mode:

```
spark-submit --class org.apache.spark.examples.SparkPi --master yarn \
--deploy-mode client SPARK_HOME/lib/spark-examples.jar 10
```

### Running Python SparkPi in YARN Cluster Mode

1. Unpack the Python examples archive:

```
sudo su gunzip SPARK_HOME/lib/python.tar.gz
sudo su tar xvf SPARK_HOME/lib/python.tar
```

2. Run the `pi.py` file:

```
spark-submit --master yarn --deploy-mode cluster SPARK_HOME/lib/pi.py 10
```

## Configuring Spark on YARN Applications

In addition to `spark-submit` Options, options for running Spark applications on YARN are listed in `spark-submit` on YARN Options.

**Table 4: `spark-submit` on YARN Options**

| Option                       | Description                                                                                                                                                                                                                                                                                                                                 |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>archives</code>        | Comma-separated list of archives to be extracted into the working directory of each executor. For the client deployment mode, the path must point to a local file. For the cluster deployment mode, the path can be either a local file or a URL globally visible inside your cluster; see <a href="#">Advanced Dependency Management</a> . |
| <code>executor-cores</code>  | Number of processor cores to allocate on each executor. Alternatively, you can use the <code>spark.executor.cores</code> property.                                                                                                                                                                                                          |
| <code>executor-memory</code> | Maximum heap size to allocate to each executor. Alternatively, you can use the <code>spark.executor.memory</code> property.                                                                                                                                                                                                                 |
| <code>num-executors</code>   | Total number of YARN containers to allocate for this application. Alternatively, you can use the <code>spark.executor.instances</code> property. If dynamic allocation is enabled, the initial number of executors is the greater of this value or the <code>spark.dynamicAllocation.initialExecutors</code> value.                         |



| Option | Description                                                                                                                                    |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------|
| queue  | YARN queue to submit to. For more information, see <a href="#">Assigning Applications and Queries to Resource Pools</a> .<br>Default: default. |

During initial installation, Cloudera Manager tunes properties according to your cluster environment.

In addition to the command-line options, the following properties are available:

| Property                           | Description                                                                                                                                                                                                |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| spark.yarn.driver.memoryOverhead   | Amount of extra off-heap memory that can be requested from YARN per driver. Combined with spark.driver.memory, this is the total memory that YARN can use to create a JVM for a driver process.            |
| spark.yarn.executor.memoryOverhead | Amount of extra off-heap memory that can be requested from YARN, per executor process. Combined with spark.executor.memory, this is the total memory YARN can use to create a JVM for an executor process. |

## Dynamic allocation

Dynamic allocation allows Spark to dynamically scale the cluster resources allocated to your application based on the workload. When dynamic allocation is enabled and a Spark application has a backlog of pending tasks, it can request executors. When the application becomes idle, its executors are released and can be acquired by other applications.

In Cloudera Data Platform (CDP), dynamic allocation is enabled by default. The table below describes properties to control dynamic allocation.

To disable dynamic allocation, set `spark.dynamicAllocation.enabled` to `false`. If you use the `--num-executors` command-line argument or set the `spark.executor.instances` property when running a Spark application, the number of initial executors is the greater of `spark.executor.instances` or `spark.dynamicAllocation.initialExecutors`.

For more information on how dynamic allocation works, see [resource allocation policy](#).

When Spark dynamic resource allocation is enabled, all resources are allocated to the first submitted job available causing subsequent applications to be queued up. To allow applications to acquire resources in parallel, allocate resources to pools and run the applications in those pools and enable applications running in pools to be preempted.

If you are using Spark Streaming, see the recommendation in [Spark Streaming and Dynamic Allocation](#).

**Table 5: Dynamic Allocation Properties**

| Property                                    | Description                                                                                                                                                                                                                                                                          |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| spark.dynamicAllocation.executorIdleTimeout | The length of time executor must be idle before it is removed.<br>Default: 60 s.                                                                                                                                                                                                     |
| spark.dynamicAllocation.enabled             | Whether dynamic allocation is enabled.<br>Default: true.                                                                                                                                                                                                                             |
| spark.dynamicAllocation.initialExecutors    | The initial number of executors for a Spark application when dynamic allocation is enabled. If <code>spark.executor.instances</code> (or its equivalent command-line argument, <code>--num-executors</code> ) is set to a higher number, that number is used instead.<br>Default: 1. |
| spark.dynamicAllocation.minExecutors        | The lower bound for the number of executors.<br>Default: 0.                                                                                                                                                                                                                          |
| spark.dynamicAllocation.maxExecutors        | The upper bound for the number of executors.<br>Default: <code>Integer.MAX_VALUE</code> .                                                                                                                                                                                            |

| Property                                        | Description                                                                                              |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| spark.dynamicAllocation.schedulerBacklogTimeout | The length of time pending tasks must be backlogged before new executors are requested.<br>Default: 1 s. |

## Submitting Spark applications using Livy

Apache Livy is a Spark service that allows local and remote applications to interact with Apache Spark over a REST interface.

You can use Livy to submit and manage Spark jobs on a cluster. Livy extends Spark capabilities, offering additional multi-tenancy and security features. Applications can run code inside Spark without needing to maintain a local Spark context.

Features include the following:

- Jobs can be submitted from anywhere, using the REST API.
- Livy supports user impersonation: the Livy server submits jobs on behalf of the user who submits the requests. Multiple users can share the same server ("user impersonation" support). This is important for multi-tenant environments, and it avoids unnecessary permission escalation.
- Livy supports security features such as Kerberos authentication and wire encryption.
  - REST APIs are backed by SPNEGO authentication, which the requested user should get authenticated by Kerberos at first.
  - RPCs between Livy Server and Remote SparkContext are encrypted with SASL.
  - The Livy server uses keytabs to authenticate itself to Kerberos.

Livy supports programmatic and interactive access to Spark with Scala. For example, you can:

- Use an interactive notebook to access Spark through Livy.
- Develop a Scala, Java, or Python client that uses the Livy API. The Livy REST API supports full Spark functionality including SparkSession, and SparkSession with Hive enabled.
- Run an interactive session, provided by spark-shell, PySpark, or SparkR REPLs.
- Submit batch applications to Spark.

Code runs in a Spark context, either locally or in YARN; YARN cluster mode is recommended.

## Configuring the Livy Thrift Server

The Apache Livy Thrift Server provides a JDBC endpoint for submitting Spark SQL queries. The Livy Thrift Server is disabled by default. The following instructions demonstrate how to enable and configure it using Cloudera Manager.

### Before you begin

The Livy Thrift Server is supported in Cloudera Data Platform 7.1.0 and higher. The Thrift Server is part of the Livy Server. There is no separate process.

The Livy Thrift Server inherits the security configuration of the Livy Server. It uses Kerberos for authentication and TLS for encryption if configured. There is no separate security configuration for the Thrift server.

### Procedure

1. On the Cloudera Manager home page, click the three-dot menu icon next to the Livy service, and then click Configuration.

2. In the Search field, enter `thrift` to filter the configuration options and display the Thrift Server configuration settings.
3. Enable the Livy Thrift Server by checking the box labeled `Enable Livy Thrift Server`.
4. If you want to change the transport mode or port number, modify the `Livy Thrift Server Transport Mode` and `Livy Thrift Server Port` settings.
5. Enter a reason for the change in the provided field at the bottom of the page, and then click `Save Changes`.
6. Return to the Cloudera Manager home page, and then click the stale configuration icon next to the Livy service.
7. Click the `Restart Stale Services` button.
8. Make sure that `Re-deploy client configuration` is checked, and then click `Restart Now`.
9. After the command completes, click `Finish`.

### What to do next

If you want to further configure the Livy Thrift Server, use the Livy Server Advanced Configuration Snippet (Safety Valve) for `livy-conf/livy.conf`:

1. On the Cloudera Manager home page, click the three-dot menu icon next to the Livy service, and then click `Configuration`.
2. In the Search field, enter `livy.conf` to filter the configuration options and display the advanced configuration text box.
3. Enter configuration key pairs, one per line, using the syntax `<PARAMETER> = <VALUE>`. For example:

```
livy.server.thrift.limit.connections.per.user = 10
livy.server.thrift.limit.connections.per.ipaddress = 100
livy.server.thrift.limit.connections.per.user.ipaddress = 10
```

These parameters limit the number of connections to the Thrift server by user, by IP address, and by the combination of both.

4. Enter a reason for the change in the provided field at the bottom of the page, and then click `Save Changes`.
5. Return to the Cloudera Manager home page, and then click the stale configuration icon next to the Livy service.
6. Click the `Restart Stale Services` button.
7. Make sure that `Re-deploy client configuration` is checked, and then click `Restart Now`.
8. After the command completes, click `Finish`.

## Connecting to the Apache Livy Thrift Server

You can connect to the Apache Livy Thrift Server using the Beeline client that is included with Apache Hive.

### Before you begin

The Livy Thrift Server is disabled by default. Make sure that you have enabled it before proceeding. For instructions, see [Configuring the Livy Thrift Server](#).

The information required to form a JDBC URL is included in the Livy client configuration file, `/etc/livy/conf/livy-client.conf`. Make sure that you are on a gateway cluster host managed by Cloudera Manager to ensure that the client configuration is included. You can designate a cluster host as a Livy client by assigning it the Gateway role in the Livy service configuration. For more information about role assignments, see [Managing Roles](#).

## Procedure

1. On a host designated as a Livy Gateway, view the `/etc/livy/conf/livy-client.conf` file and note the values of the following configuration parameters:

### **livy.uri**

This is the URI for the Livy server. The hostname in this URI is the hostname to use for the Thrift server connection.

### **livy.server.thrift.port**

This is the port to use in the JDBC connection URL.

### **livy.server.thrift.transport.mode**

This specifies the transport mode (either binary or http).

2.  **Note:** If you are using a cluster with security enabled, you must authenticate with your user principal using kinit before running beeline. If Kerberos authentication is not used, then the “-u <user> -p <password>” options for beeline should be used to connect as a particular user.

Determine the JDBC connection URL using the following table:

| Connection Mode                     | JDBC Connection URL                                                                                                                                                                                                                                              |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>binary</b>                       | <code>jdbc:hive2://&lt;livy_host&gt;:&lt;port&gt;/&lt;database&gt;</code>                                                                                                                                                                                        |
| <b>binary with Kerberos</b>         | <code>jdbc:hive2://&lt;livy_host&gt;:&lt;port&gt;/&lt;database&gt;;principal=livy/&lt;livy_host&gt;@&lt;REALM&gt;</code>                                                                                                                                         |
| <b>binary with Kerberos and TLS</b> | <code>jdbc:hive2://&lt;livy_host&gt;:&lt;port&gt;/&lt;database&gt;;principal=livy/&lt;livy_host&gt;@&lt;REALM&gt;;ssl=true;sslTrustStore=&lt;path_to_truststore&gt;</code>                                                                                       |
| <b>http</b>                         | <code>jdbc:hive2://&lt;livy_host&gt;:&lt;port&gt;/&lt;database&gt;;transportMode=http;httpPath=cliservice</code>                                                                                                                                                 |
| <b>http with Kerberos</b>           | <code>jdbc:hive2://&lt;livy_host&gt;:&lt;port&gt;/&lt;database&gt;;principal=HTTP/&lt;livy_host&gt;@&lt;REALM&gt;;transportMode=http;httpPath=cliservice</code>                                                                                                  |
| <b>http with Kerberos and TLS</b>   | <code>jdbc:hive2://&lt;livy_host&gt;:&lt;port&gt;/&lt;database&gt;;principal=HTTP/&lt;livy_host&gt;@&lt;REALM&gt;;ssl=true;sslTrustStore=&lt;path_to_truststore&gt;;trustStorePassword=&lt;truststore_password&gt;;transportMode=http;httpPath=cliservice</code> |

3. Run the beeline command.

#### 4. At the Beeline prompt, enter `!connect <jdbc_url>`

You can set configuration options by appending `?<configuration_list>` to the JDBC connection URL. Separate multiple options with a semi-colon (;). Supported options are:

- `livy.session.driverMemory`
- `livy.session.driverCores`
- `livy.session.executorMemory`
- `livy.session.executorCores`
- `livy.session.numExecutors`
- `livy.session.queue`
- `livy.session.name`
- `livy.session.heartbeatTimeoutInSecond`

For example:

```
beeline> !connect jdbc:hive2://cdp01.example.com:10090/db01?livy.session
.driverMemory=4g;livy.session.driverCores=2
```

## Using Livy with Spark

### Scala Support

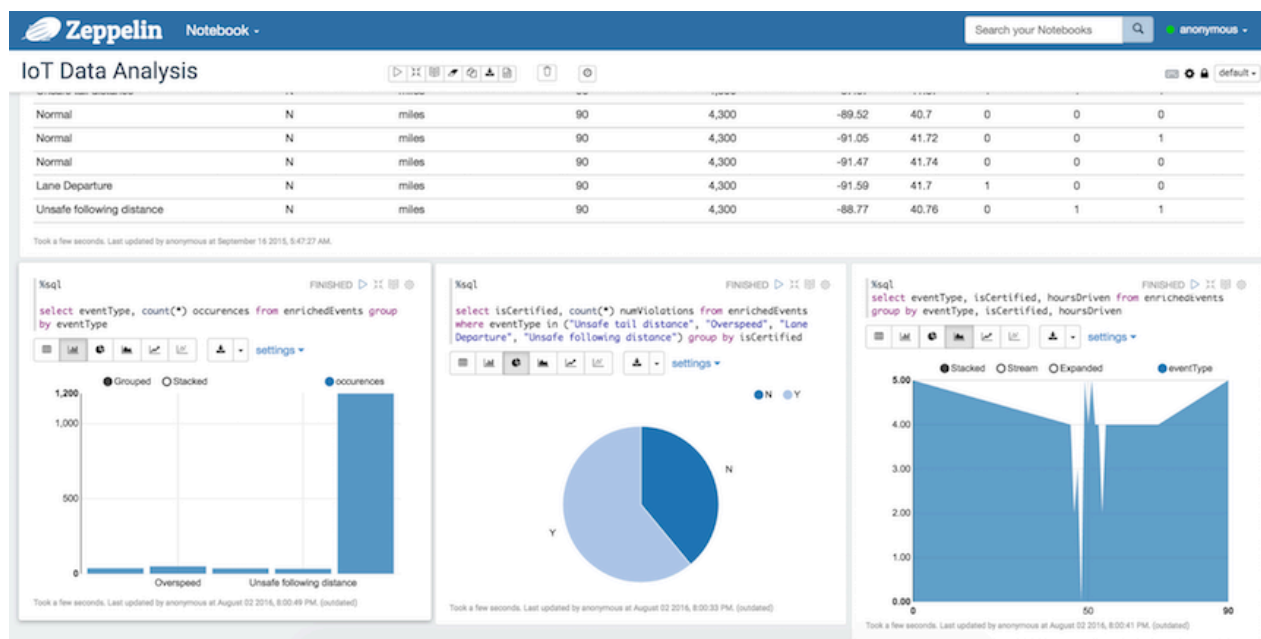
Livy supports Scala versions 2.10 and 2.11.

For default Scala builds, Spark 2.0 with Scala 2.11, Livy automatically detects the correct Scala version and associated jar files.

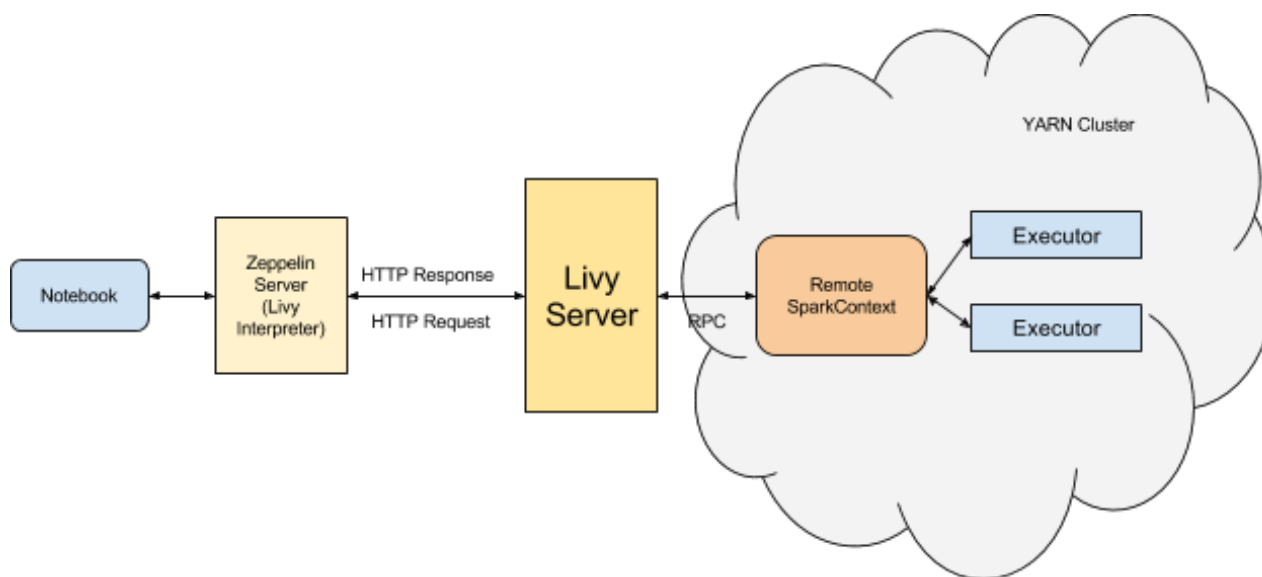
If you require a different Spark-Scala combination, such as Spark 2.0 with Scala 2.10, set `livy.spark.scalaVersion` to the desired version so that Livy uses the right jar files.

## Using Livy with interactive notebooks

You can submit Spark commands through Livy from an interactive Apache Zeppelin notebook:



When you run code in a Zeppelin notebook using the %livy directive, the notebook offloads code execution to Livy and Spark:



For more information about Zeppelin and Livy, see the CDP Apache Zeppelin guide.

## Using the Livy API to run Spark jobs

Using the Livy API to run Spark jobs is similar to using the original Spark API.

The following two examples calculate Pi.

Calculate Pi using the Spark API:

```
def sample(p):
    x, y = random(), random()
    return 1 if x*x + y*y < 1 else 0
count = sc.parallelize(xrange(0, NUM_SAMPLES)).map(sample) \
    .reduce(lambda a, b: a + b)
```

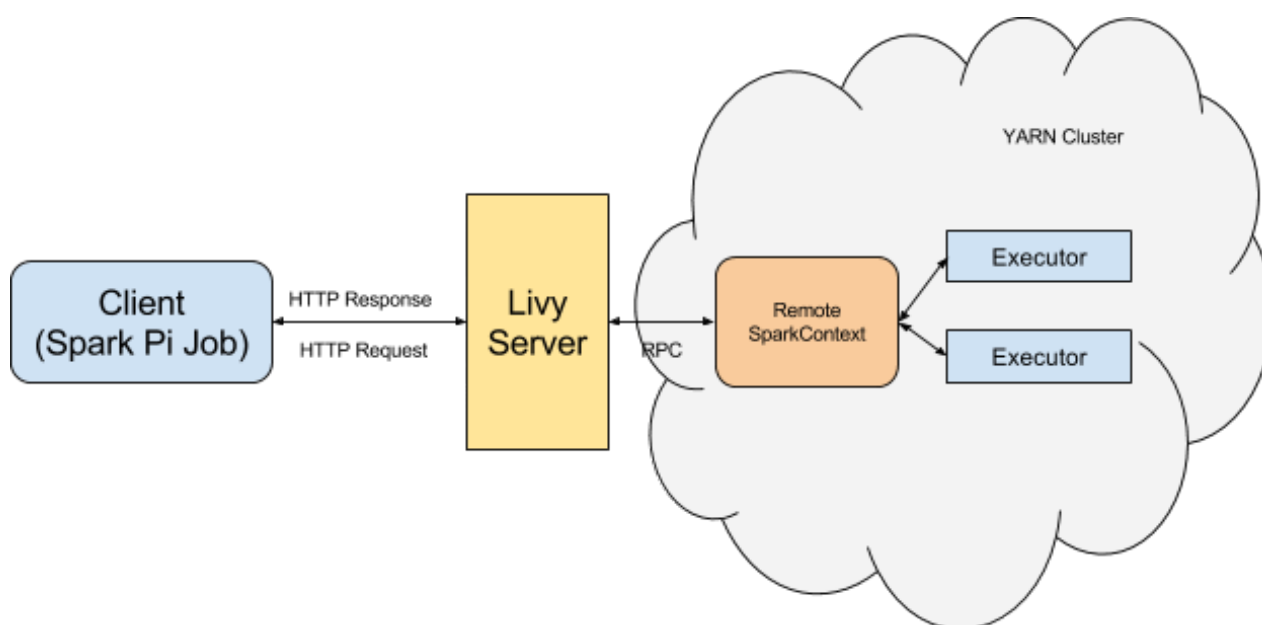
Calculate Pi using the Livy API:

```
def f(_):
    x = random() * 2 - 1
    y = random() * 2 - 1
    return 1 if x ** 2 + y ** 2 <= 1 else 0
def pi_job(context):
    count = context.sc.parallelize(range(1, samples + 1), slices).map(f).re
duce(add)
    return 4.0 * count / samples
```

There are two main differences between the two APIs:

- When using the Spark API, the entry point (SparkContext) is created by user who wrote the code. When using the Livy API, SparkContext is offered by the framework; the user does not need to create it.
- The client submits code to the Livy server through the REST API. The Livy server sends the code to a specific Spark cluster for execution.

Architecturally, the client creates a remote Spark cluster, initializes it, and submits jobs through REST APIs. The Livy server unwraps and rewraps the job, and then sends it to the remote SparkContext through RPC. While the job runs the client waits for the result, using the same path. The following diagram illustrates the process:



## Running an interactive session with the Livy API

### About this task

Running an interactive session with Livy is similar to using Spark shell or PySpark, but the shell does not run locally. Instead, it runs in a remote cluster, transferring data back and forth through a network.

The Livy REST API supports GET, POST, and DELETE calls for interactive sessions.

The following example shows how to create an interactive session, submit a statement, and retrieve the result of the statement; the return ID could be used for further queries.

### Procedure

1. Create an interactive session. The following POST request starts a new Spark cluster with a remote Spark interpreter; the remote Spark interpreter is used to receive and execute code snippets, and return the result.

```

POST /sessions
  host = 'http://localhost:8998'
  data = {'kind': 'spark'}
  headers = {'Content-Type': 'application/json'}
  r = requests.post(host + '/sessions', data=json.dumps(data), headers=headers)
  r.json()

{u'state': u'starting', u'id': 0, u'kind': u'spark'}
  
```

2. Submit a statement. The following POST request submits a code snippet to a remote Spark interpreter, and returns a statement ID for querying the result after execution is finished.

```

POST /sessions/{sessionId}/statements
  data = {'code': 'sc.parallelize(1 to 10).count()'}
  r = requests.post(statements_url, data=json.dumps(data), headers=headers)
  r.json()

{u'output': None, u'state': u'running', u'id': 0}
  
```

- Get the result of a statement. The following GET request returns the result of a statement in JSON format, which you can parse to extract elements of the result.

```
GET /sessions/{sessionId}/statements/{statementId}
    statement_url = host + r.headers['location']
    r = requests.get(statement_url, headers=headers)
    pprint.pprint(r.json())

{u'id': 0,
  u'output': {u'data': {u'text/plain': u'res0: Long = 10'},
              u'execution_count': 0,
              u'status': u'ok'},
  u'state': u'available'}
```

The remainder of this section describes Livy objects and REST API calls for interactive sessions.

## Livy objects for interactive sessions

See the following tables for Livy objects properties for interactive sessions.

### Session Object

A session object represents an interactive shell:

**Table 6: Session Object**

| Property  | Description                                                           | Type            |
|-----------|-----------------------------------------------------------------------|-----------------|
| id        | A non-negative integer that represents a specific session of interest | int             |
| appId     | Application ID for this session                                       | string          |
| owner     | Remote user who submitted this session                                | string          |
| proxyUser | User ID to impersonate when running                                   | string          |
| kind      | Session kind (see the "kind" table below for values)                  | session kind    |
| log       | Log file data                                                         | list of strings |
| state     | Session state (see the "state" table below for values)                | string          |
| appInfo   | Detailed application information                                      | key=value map   |

The following values are valid for the kind property in a session object:

**Table 7: Session Kind**

| Value    | Description                        |
|----------|------------------------------------|
| spark    | Interactive Scala Spark session    |
| pyspark  | Interactive Python 2 Spark session |
| pyspark3 | Interactive Python 3 Spark session |
| sparkr   | Interactive R Spark session        |

The following values are valid for the state property in a session object:

**Table 8: Session Object State**

| Value       | Description             |
|-------------|-------------------------|
| not_started | Session has not started |



| Value         | Description                        |
|---------------|------------------------------------|
| starting      | Session is starting                |
| idle          | Session is waiting for input       |
| busy          | Session is executing a statement   |
| shutting_down | Session is shutting down           |
| error         | Session terminated due to an error |
| dead          | Session exited                     |
| success       | Session successfully stopped       |

A statement object represents the result of an execution statement.

**Table 9: Statement Object**

| Property | Description                                                             | Type             |
|----------|-------------------------------------------------------------------------|------------------|
| id       | A non-negative integer that represents a specific statement of interest | integer          |
| state    | Execution state (see the following "state" table for values)            | statement state  |
| output   | Execution output (see the following "output" table for values)          | statement output |

The following values are valid for the state property in a statement object:

**Table 10: Statement Object State**

| value      | Description                                    |
|------------|------------------------------------------------|
| waiting    | Statement is queued, execution has not started |
| running    | Statement is running                           |
| available  | Statement has a response ready                 |
| error      | Statement failed                               |
| cancelling | Statement is being cancelled                   |
| cancelled  | Statement is cancelled                         |

The following values are valid for the output property in a statement object:

**Table 11: Statement Object Output**

| Property        | Description                                                   | Type                                                                                                          |
|-----------------|---------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| status          | Execution status, such as "starting", "idle", or "available". | string                                                                                                        |
| execution_count | Execution count                                               | integer (monotonically increasing)                                                                            |
| data            | Statement output                                              | An object mapping a mime type to the result. If the mime type is application/json, the value is a JSON value. |

## Setting Python path variables for Livy

To change the Python executable used by a Livy session, follow the instructions for your version of Python.

pyspark

Livy reads the path from the PYSPARK\_PYTHON environment variable (this is the same as PySpark).

- If Livy is running in local mode, simply set the environment variable (this is the same as PySpark).
- If the Livy session is running in yarn-cluster mode, setspark.yarn.appMasterEnv.PYSPARK\_PYTHON in the SparkConf file, so that the environment variable is passed to the driver.

pyspark3

Livy reads the path from environment variable PYSPARK3\_PYTHON.

- If Livy is running in local mode, simply set the environment variable.
- If the Livy session is running in yarn-cluster mode, setspark.yarn.appMasterEnv.PYSPARK3\_PYTHON in SparkConf file, so that the environment variable is passed to the driver.

## Livy API reference for interactive sessions

GET

GET /sessions returns all active interactive sessions.

| Request Parameter | Description                          | Type |
|-------------------|--------------------------------------|------|
| from              | Starting index for fetching sessions | int  |
| size              | Number of sessions to fetch          | int  |

| Response | Description                        | Type |
|----------|------------------------------------|------|
| from     | Starting index of fetched sessions | int  |
| total    | Number of sessions fetched         | int  |
| sessions | Session list                       | list |

The following response shows zero active sessions:

```
{"from":0,"total":0,"sessions":[]}
```

GET /sessions/{sessionId} returns information about the specified session.

GET /sessions/{sessionId}/state returns the state of the specified session:

| Response | Description                                               | Type   |
|----------|-----------------------------------------------------------|--------|
| id       | A non-negative integer that represents a specific session | int    |
| state    | Current state of the session                              | string |

GET /sessions/{sessionId}/logs retrieves log records for the specified session.

| Request Parameters | Description                               | Type |
|--------------------|-------------------------------------------|------|
| from               | Offset                                    | int  |
| size               | Maximum number of log records to retrieve | int  |

| Response | Description                                               | Type            |
|----------|-----------------------------------------------------------|-----------------|
| id       | A non-negative integer that represents a specific session | int             |
| from     | Offset from the start of the log file                     | int             |
| size     | Number of log records retrieved                           | int             |
| log      | Log records                                               | list of strings |

GET /sessions/{sessionId}/statements returns all the statements in a session.

| Response   | Description                                 | Type |
|------------|---------------------------------------------|------|
| statements | List of statements in the specified session | list |

GET /sessions/{sessionId}/statements/{statementId} returns a specified statement in a session.

| Response                                                                            | Description | Type             |
|-------------------------------------------------------------------------------------|-------------|------------------|
| statement object (for more information see "Livy Objects for Interactive Sessions") | Statement   | statement object |

POST

POST /sessions creates a new interactive Scala, Python, or R shell in the cluster.

| Request Parameter        | Description                                                     | Type             |
|--------------------------|-----------------------------------------------------------------|------------------|
| kind                     | Session kind (required)                                         | session kind     |
| proxyUser                | User ID to impersonate when starting the session                | string           |
| jars                     | Jar files to be used in this session                            | list of strings  |
| pyFiles                  | Python files to be used in this session                         | list of strings  |
| files                    | Other files to be used in this session                          | list of strings  |
| driverMemory             | Amount of memory to use for the driver process                  | string           |
| driverCores              | Number of cores to use for the driver process                   | int              |
| executorMemory           | Amount of memory to use for each executor process               | string           |
| executorCores            | Number of cores to use for each executor process                | int              |
| numExecutors             | Number of executors to launch for this session                  | int              |
| archives                 | Archives to be used in this session                             | list of strings  |
| queue                    | The name of the YARN queue to which the job should be submitted | string           |
| name                     | Name of this session                                            | string           |
| conf                     | Spark configuration properties                                  | Map of key=value |
| heartbeatTimeoutInSecond | Timeout in second to which session be orphaned                  | int              |

| Response                                                                          | Description         | Type           |
|-----------------------------------------------------------------------------------|---------------------|----------------|
| session object (for more information see "Livy Objects for Interactive Sessions") | The created session | session object |

The following response shows a PySpark session in the process of starting:

```
{"id":0,"state":"starting","kind":"pyspark","log":[]}
```

POST /sessions/{sessionId}/statements runs a statement in a session.

| Request Parameter | Description         | Type   |
|-------------------|---------------------|--------|
| code              | The code to execute | string |

| Response                                                                            | Description                      | Type             |
|-------------------------------------------------------------------------------------|----------------------------------|------------------|
| statement object (for more information see "Livy Objects for Interactive Sessions") | Result of an execution statement | statement object |

POST /sessions/{sessionId}/statements/{statementId}/cancel cancels the specified statement in the session.

| Response             | Description         | Type   |
|----------------------|---------------------|--------|
| cancellation message | Reports "cancelled" | string |

DELETE

DELETE /sessions/{sessionId} terminates the session.

## Submitting batch applications using the Livy API

### About this task

Spark provides a `spark-submit` command for submitting batch applications. Livy provides equivalent functionality through REST APIs, using job specifications specified in a JSON document.

The following example shows a `spark-submit` command that submits a SparkPi job, followed by an example that uses Livy POST requests to submit the job. The remainder of this subsection describes Livy objects and REST API syntax. For additional examples and information, see the `readme.rst` file at <https://github.com/hortonworks/livy-release/releases/tag/HDP-2.6.0.3-8-tag>.

The following command uses `spark-submit` to submit a SparkPi job:

```
./bin/spark-submit \
  --class org.apache.spark.examples.SparkPi \
  --master yarn \
  --deploy-mode cluster \
  --executor-memory 20G \
  /path/to/examples.jar 1000
```

To submit the SparkPi job using Livy, complete the following steps. Note: the POST request does not upload local jars to the cluster. You should upload required jar files to HDFS before running the job. This is the main difference between the Livy API and `spark-submit`.

### Procedure

1. Form a JSON structure with the required job parameters:

```
{ "className": "org.apache.spark.examples.SparkPi",
  "executorMemory": "20g",
  "args": [2000],
  "file": "/path/to/examples.jar"
}
```

2. Specify master and deploy mode in the `livy.conf` file.
3. To submit the SparkPi application to the Livy server, use the a POST /batches request.
4. The Livy server helps launch the application in the cluster.

### Livy batch object

Batch session APIs operate on batch objects, defined as follows:

| Property | Description                                                     | Type             |
|----------|-----------------------------------------------------------------|------------------|
| id       | A non-negative integer that represents a specific batch session | int              |
| appId    | The application ID for this session                             | String           |
| appInfo  | Detailed application info                                       | Map of key=value |
| log      | Log records                                                     | list of strings  |
| state    | Batch state                                                     | string           |

## Livy API reference for batch jobs

GET /batches returns all active batch sessions.

| Request Parameters | Description                           | Type |
|--------------------|---------------------------------------|------|
| from               | Starting index used to fetch sessions | int  |
| size               | Number of sessions to fetch           | int  |

| Response | Description                        | Type |
|----------|------------------------------------|------|
| from     | Starting index of fetched sessions | int  |
| total    | Number of sessions fetched         | int  |
| sessions | List of active batch sessions      | list |

GET /batches/{batchId} returns the batch session information as a batch object.

GET /batches/{batchId}/state returns the state of batch session:

| Response | Description                                                     | Type   |
|----------|-----------------------------------------------------------------|--------|
| id       | A non-negative integer that represents a specific batch session | int    |
| state    | The current state of batch session                              | string |

GET /batches/{batchId}/log retrieves log records for the specified batch session.

| Request Parameters | Description                       | Type |
|--------------------|-----------------------------------|------|
| from               | Offset into log file              | int  |
| size               | Max number of log lines to return | int  |

| Response | Description                                                     | Type            |
|----------|-----------------------------------------------------------------|-----------------|
| id       | A non-negative integer that represents a specific batch session | int             |
| from     | Offset from start of the log file                               | int             |
| size     | Number of log records returned                                  | int             |
| log      | Log records                                                     | list of strings |

POST /batches creates a new batch environment and runs a specified application:

| Request Body | Description                                       | Type   |
|--------------|---------------------------------------------------|--------|
| file         | File containing the application to run (required) | path   |
| proxyUser    | User ID to impersonate when running the job       | string |
| className    | Application Java or Spark main class              | string |

| Request Body   | Description                                                     | Type            |
|----------------|-----------------------------------------------------------------|-----------------|
| args           | Command line arguments for the application                      | list of strings |
| jars           | Jar files to be used in this session                            | list of strings |
| pyFiles        | Python files to be used in this session                         | list of strings |
| files          | Other files to be used in this session                          | list of strings |
| driverMemory   | Amount of memory to use for the driver process                  | string          |
| driverCores    | Number of cores to use for the driver process                   | int             |
| executorMemory | Amount of memory to use for each executor process               | string          |
| executorCores  | Number of cores to use for each executor                        | int             |
| numExecutors   | Number of executors to launch for this session                  | int             |
| archives       | Archives to be used in this session                             | list of strings |
| queue          | The name of the YARN queue to which the job should be submitted | string          |
| name           | Name of this session                                            | string          |
| conf           | Spark configuration properties                                  | Map of key=val  |

| Response                                                    | Description              | Type         |
|-------------------------------------------------------------|--------------------------|--------------|
| batch object (for more information see "Livy Batch Object") | The created batch object | batch object |

DELETE /batches/{batchId} terminates the Batch job.

## Using PySpark

Apache Spark provides APIs in non-JVM languages such as Python. Many data scientists use Python because it has a rich variety of numerical libraries with a statistical, machine-learning, or optimization focus.

### Running PySpark in a virtual environment

For many PySpark applications, it is sufficient to use `--py-files` to specify dependencies. However, there are times when `--py-files` is inconvenient, such as the following scenarios:

- A large PySpark application has many dependencies, including transitive dependencies.
- A large application needs a Python package that requires C code to be compiled before installation.
- You want to run different versions of Python for different applications.

For these situations, you can create a virtual environment as an isolated Python runtime environment. CDP supports VirtualEnv for PySpark in both local and distributed environments, easing the transition from a local environment to a distributed environment.



**Note:**

This feature is currently only supported in YARN mode.

## Running Spark Python applications

Accessing Spark with Java and Scala offers many advantages: platform independence by running inside the JVM, self-contained packaging of code and its dependencies into JAR files, and higher performance because Spark itself runs in the JVM. You lose these advantages when using the Spark Python API.

Managing dependencies and making them available for Python jobs on a cluster can be difficult. To determine which dependencies are required on the cluster, you must understand that Spark code applications run in Spark executor processes distributed throughout the cluster. If the Python transformations you define use any third-party libraries, such as `NumPy` or `nltk`, Spark executors require access to those libraries when they run on remote executors.

### Setting the Python Path

After the Python packages you want to use are in a consistent location on your cluster, set the appropriate environment variables to the path to your Python executables as follows:

- Specify the Python binary to be used by the Spark driver and executors by setting the `PYSPARK_PYTHON` environment variable in `spark-env.sh`. You can also override the driver Python binary path individually using the `PYSPARK_DRIVER_PYTHON` environment variable. These settings apply regardless of whether you are using `yarn-client` or `yarn-cluster` mode.

Make sure to set the variables using the `export` statement. For example:

```
export PYSPARK_PYTHON=${PYSPARK_PYTHON:-<PATH_TO_PYTHON_EXECUTABLE>}
```

This statement uses [shell parameter expansion](#) to set the `PYSPARK_PYTHON` environment variable to `<PATH_TO_PYTHON_EXECUTABLE>` if it is not set to something else already. If it is already set, it preserves the existing value.

Here are some example Python binary paths:

- Anaconda parcel: `/opt/cloudera/parcels/Anaconda/bin/python`
- Virtual environment: `/PATH/TO/VIRTUALENV/bin/python`
- If you are using `yarn-cluster` mode, in addition to the above, also set `spark.yarn.appMasterEnv.PYSPARK_PYTHON` and `spark.yarn.appMasterEnv.PYSPARK_DRIVER_PYTHON` in `spark-defaults.conf` (using the safety valve) to the same paths.

In Cloudera Manager, set environment variables in `spark-env.sh` and `spark-defaults.conf` as follows:

Minimum Required Role: Configurator (also provided by Cluster Administrator, Full Administrator)

- Go to the Spark service.
- Click the Configuration tab.
- Search for Spark Service Advanced Configuration Snippet (Safety Valve) for `spark-conf/spark-env.sh`.
- Add the `spark-env.sh` variables to the property.
- Search for Spark Client Advanced Configuration Snippet (Safety Valve) for `spark-conf/spark-defaults.conf`.
- Add the `spark-defaults.conf` variables to the property.
- Enter a Reason for change, and then click Save Changes to commit the changes.
- Restart the service.
- Deploy the client configuration.

### Self-Contained Dependencies

In a common situation, a custom Python package contains functionality you want to apply to each element of an RDD. You can use a `map()` function call to make sure that each Spark executor imports the required package, before calling any of the functions inside that package. The following shows a simple example:

```
def import_my_special_package(x):
```

```
import my.special.package
return x

int_rdd = sc.parallelize([1, 2, 3, 4])
int_rdd.map(lambda x: import_my_special_package(x))
int_rdd.collect()
```

You create a simple RDD of four elements and call it `int_rdd`. Then you apply the function `import_my_special_package` to every element of the `int_rdd`. This function imports `my.special.package` and then returns the original argument passed to it. Calling this function as part of a `map()` operation ensures that each Spark executor imports `my.special.package` when needed.

If you only need a single file inside `my.special.package`, you can direct Spark to make this available to all executors by using the `--py-files` option in your `spark-submit` command and specifying the local path to the file. You can also specify this programmatically by using the `sc.addPyFiles()` function. If you use functionality from a package that spans multiple files, you can [make an egg for the package](#), because the `--py-files` flag also accepts a path to an egg file.

If you have a self-contained dependency, you can make the required Python dependency available to your executors in two ways:

- If you depend on only a single file, you can use the `--py-files` command-line option, or programmatically add the file to the SparkContext with `sc.addPyFiles(path)` and specify the local path to that Python file.
- If you have a dependency on a self-contained module (a module with no other dependencies), you can create an egg or zip file of that module and use either the `--py-files` command-line option or programmatically add the module to the SparkContext with `sc.addPyFiles(path)` and specify the local path to that egg or zip file.



**Note:** Libraries that are distributed using the Python “wheel” mechanism cannot be used with the `--py-files` option.

## Complex Dependencies

Some operations rely on complex packages that also have many dependencies. Although such a package is too complex to distribute as a \*.py file, you can create an egg for it and all of its dependencies, and send the egg file to executors using the `--py-files` option.

## Limitations of Distributing Egg Files on Heterogeneous Clusters

If you are running a heterogeneous cluster, with machines of different CPU architectures, sending egg files is impractical because packages that contain native code must be compiled for a single specific CPU architecture. Therefore, distributing an egg for complex, compiled packages like NumPy, SciPy, and pandas often fails. Instead of distributing egg files, install the required Python packages on each host of the cluster and specify the path to the Python binaries for the worker hosts to use.

## Installing and Maintaining Python Environments

Installing and maintaining Python environments can be complex but allows you to use the full Python package ecosystem. Ideally, a sysadmin installs the [Anaconda distribution](#) or sets up a [virtual environment](#) on every host of your cluster with your required dependencies.

If you are using Cloudera Manager, you can deploy the [Anaconda distribution as a parcel](#) as follows:

Minimum Required Role: Cluster Administrator (also provided by Full Administrator)

1. Add the following URL <https://repo.anaconda.com/pkg/misc/parcels/> to the Remote Parcel Repository URLs as described in "Parcel Configuration Settings."
2. Download, distribute, and activate the parcel as described in "Managing Parcels."

Anaconda is installed in `PARCEL DIRECTORY/Anaconda`, where `PARCEL DIRECTORY` is `/opt/cloudera/parcels` by default, but can be changed in parcel configuration settings. The Anaconda parcel is supported by [Continuum Analytics](#).



If you are not using Cloudera Manager, you can set up a virtual environment on your cluster by running commands on each host using [Cluster SSH](#), [Parallel SSH](#), or [Fabric](#). Assuming each host has Python and pip installed, use the following commands to set up the standard data stack (NumPy, SciPy, scikit-learn, and pandas) in a virtual environment on a RHEL 6-compatible system:

```
# Install python-devel:
yum install python-devel

# Install non-Python dependencies required by SciPy that are not installed
  by default:
yum install atlas atlas-devel lapack-devel blas-devel

# install virtualenv:
pip install virtualenv

# create a new virtualenv:
virtualenv MYNEWENV

# activate the virtualenv:
source MYNEWENV/bin/activate

# install packages in MYNEWENV:
pip install numpy
pip install scipy
pip install scikit-learn
pip install pandas
```

## Automating Spark Jobs with Oozie Spark Action

You can use Apache Spark as part of a complex workflow with multiple processing steps, triggers, and interdependencies. You can automate Apache Spark jobs using Oozie Spark action.

### Before you begin

Spark2 must be installed on the node where the Oozie server is installed.

### About Oozie Spark Action

If you use Apache Spark as part of a complex workflow with multiple processing steps, triggers, and interdependencies, consider using Apache Oozie to automate jobs. Oozie is a workflow engine that executes sequences of actions structured as directed acyclic graphs (DAGs). Each action is an individual unit of work, such as a Spark job or Hive query.

The Oozie "Spark action" runs a Spark job as part of an Oozie workflow. The workflow waits until the Spark job completes before continuing to the next action.

For additional information about Spark action, see [Oozie Spark Action Extension](#) in the Apache Oozie documentation. For general information about Oozie, see [Overview of Oozie](#).



#### Note:

Support for yarn-client execution mode for Oozie Spark action will be removed in a future release. Oozie will continue to support yarn-cluster execution mode for Oozie Spark action.

## Configure Oozie Spark Action for Spark

### 1. Set up .jar file exclusions.

Oozie distributes its own libraries on the ShareLib, which are included on the classpath. These .jar files may conflict with each other if some components require different versions of a library. You can use the `oozie.action.sharelib.for.<action_type>.exclude=<value>` property to address these scenarios.

Spark uses older `jackson-*` .jar versions than Oozie, which creates a runtime conflict in Oozie for Spark and generates a `NoClassDefFoundError` error. This can be resolved by using the `oozie.action.sharelib.for.<action_type>.exclude=<value>` property to exclude the `oozie/jackson.*` .jar files from the classpath. Libraries matching the regex pattern provided as the property value will not be added to the distributed cache.



**Note:** spark2 ShareLib directory will not be created. The named spark directory is used for spark2 libs.

#### Examples

The following examples show how to use a ShareLib exclude on a Java action.

Actual ShareLib content:

```
* /user/oozie/share/lib/lib_20180701/oozie/lib-one-1.5.jar
* /user/oozie/share/lib/lib_20180701/oozie/lib-two-1.5.jar
* /user/oozie/share/lib/lib_20180701/java/lib-one-2.6.jar
* /user/oozie/share/lib/lib_20180701/java/lib-two-2.6.jar
* /user/oozie/share/lib/lib_20180701/java/component-connector.jar
```

Setting the `oozie.action.sharelib.for.java.exclude` property to `oozie/lib-one.*=` results in the following distributed cache content:

```
* /user/oozie/share/lib/lib_20180701/oozie/lib-two-1.5.jar
* /user/oozie/share/lib/lib_20180701/java/lib-one-2.6.jar
* /user/oozie/share/lib/lib_20180701/java/lib-two-2.6.jar
* /user/oozie/share/lib/lib_20180701/java/component-connector.jar
```

Setting the `oozie.action.sharelib.for.java.exclude` property to `oozie/lib-one.*|component-connector.jar=` results in the following distributed cache content:

```
* /user/oozie/share/lib/lib_20180701/oozie/lib-two-1.5.jar
* /user/oozie/share/lib/lib_20180701/java/lib-one-2.6.jar
* /user/oozie/share/lib/lib_20180701/java/lib-two-2.6.jar
```

### 2. Run the Oozie `shareliblist` command to verify the configuration. You should see spark in the results.

```
oozie admin -shareliblist spark
```

The following examples show a workflow definition XML file, an Oozie job configuration file, and a Python script for running a Spark2-Pi job.

Sample Workflow.xml file for spark2-Pi:

```
<workflow-app xmlns='uri:oozie:workflow:0.5' name='SparkPythonPi'>
  <start to='spark-node' />

  <action name='spark-node'>
    <spark xmlns="uri:oozie:spark-action:0.1">
      <job-tracker>${jobTracker}</job-tracker>
      <name-node>${nameNode}</name-node>
      <master>${master}</master>
      <name>Python-Spark-Pi</name>
      <jar>pi.py</jar>
    </spark>
  </action>
</workflow-app>
```

```

        <ok to="end" />
        <error to="fail" />
    </action>

    <kill name="fail">
        <message>Workflow failed, error message [${wf:errorMessage(wf:
lastErrorNode())}]/>
    </kill>
    <end name="end" />
</workflow-app>

```

Sample Job.properties file for spark2-Pi:

```

nameNode=hdfs://host:8020
jobTracker=host:8050
queueName=default
examplesRoot=examples
oozie.use.system.libpath=true
oozie.wf.application.path=${nameNode}/user/${user.name}/${examplesRoot}/app
s/pyspark
master=yarn-cluster
oozie.action.sharelib.for.spark=spark2

```

Sample Python script, lib/pi.py:

```

import sys
from random import random
from operator import add
from pyspark import SparkContext

if __name__ == "__main__":
    """
    Usage: pi [partitions]
    """
    sc = SparkContext(appName="Python-Spark-Pi")
    partitions = int(sys.argv[1]) if len(sys.argv) > 1 else 2
    n = 100000 * partitions

    def f(_):
        x = random() * 2 - 1
        y = random() * 2 - 1
        return 1 if x ** 2 + y ** 2 < 1 else 0

    count = sc.parallelize(range(1, n + 1), partitions).map(f).reduce(add)
    print("Pi is roughly %f" % (4.0 * count / n))

    sc.stop()

```

### Troubleshooting .jar file conflicts with Oozie Spark action

When using Oozie Spark action, Oozie jobs may fail with the following error if there are .jar file conflicts between the "oozie" ShareLib and the "spark" ShareLib.

```

2018-06-04 13:27:32,652 WARN SparkActionExecutor:523 - SERVER[XXXX] USER[XXX
X] GROUP[-] TOKEN[] APP[XXXX] JOB[00000000-<XXXXX>-oozie-oozi-W] ACTION[00000
00-<XXXXXX>-oozie-oozi-W@spark2] Launcher exception: Attempt to add (hdfs://
XXXXX/user/oozie/share/lib/lib_XXXXX/oozie/aws-java-sdk-kms-1.10.6.jar) multi
ple times to the distributed cache.
java.lang.IllegalArgumentException: Attempt to add (hdfs://XXXXX/user/oozie/
share/lib/lib_20170727191559/oozie/aws-java-sdk-kms-1.10.6.jar) multiple ti
mes to the distributed cache.

```

```

at org.apache.spark.deploy.yarn.Client$anonfun$prepareLocalResources$13$a
nonfun$apply$8.apply(Client.scala:632)
at org.apache.spark.deploy.yarn.Client$anonfun$prepareLocalResources$13$a
nonfun$apply$8.apply(Client.scala:623)
at scala.collection.mutable.ArraySeq.foreach(ArraySeq.scala:74)
at org.apache.spark.deploy.yarn.Client$anonfun$prepareLocalResources$13.a
pply(Client.scala:623)
at org.apache.spark.deploy.yarn.Client$anonfun$prepareLocalResources$13.a
pply(Client.scala:622)
at scala.collection.immutable.List.foreach(List.scala:381)
at org.apache.spark.deploy.yarn.Client.prepareLocalResources(Client.scala:62
2)
at org.apache.spark.deploy.yarn.Client.createContainerLaunchContext(Client.s
cala:895)
at org.apache.spark.deploy.yarn.Client.submitApplication(Client.scala:171)
at org.apache.spark.deploy.yarn.Client.run(Client.scala:1231)
at org.apache.spark.deploy.yarn.Client$.main(Client.scala:1290)
at org.apache.spark.deploy.yarn.Client.main(Client.scala)
at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.ja
va:62)
at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccesso
rImpl.java:43)
at java.lang.reflect.Method.invoke(Method.java:498)
at org.apache.spark.deploy.SparkSubmit$.org$apache$spark$deploy$SparkSubmit
$.runMain(SparkSubmit.scala:750)
at org.apache.spark.deploy.SparkSubmit$.doRunMain$1(SparkSubmit.scala:187)
at org.apache.spark.deploy.SparkSubmit$.submit(SparkSubmit.scala:212)
at org.apache.spark.deploy.SparkSubmit$.main(SparkSubmit.scala:126)
at org.apache.spark.deploy.SparkSubmit.main(SparkSubmit.scala)
at org.apache.oozie.action.hadoop.SparkMain.runSpark(SparkMain.java:311)
at org.apache.oozie.action.hadoop.SparkMain.run(SparkMain.java:232)
at org.apache.oozie.action.hadoop.LauncherMain.run(LauncherMain.java:58)
at org.apache.oozie.action.hadoop.SparkMain.main(SparkMain.java:62)
at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.jav
a:62)
at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccess
orImpl.java:43)
at java.lang.reflect.Method.invoke(Method.java:498)
at org.apache.oozie.action.hadoop.LauncherMapper.map(LauncherMapper.java:2
37)
at org.apache.hadoop.mapred.MapRunner.run(MapRunner.java:54)
at org.apache.hadoop.mapred.MapTask.runOldMapper(MapTask.java:453)
at org.apache.hadoop.mapred.MapTask.run(MapTask.java:343)
at org.apache.hadoop.mapred.YarnChild$2.run(YarnChild.java:170)
at java.security.AccessController.doPrivileged(Native Method)
at javax.security.auth.Subject.doAs(Subject.java:422)
at org.apache.hadoop.security.UserGroupInformation.doAs(UserGroupInformatio
n.java:1866)
at org.apache.hadoop.mapred.YarnChild.main(YarnChild.java:164)

```

Run the following commands to resolve this issue.



**Note:**

You may need to perform a backup before running the rm commands.

```

hadoop fs -rm /user/oozie/share/lib/lib_<ts>/spark/aws*
hadoop fs -rm /user/oozie/share/lib/lib_<ts>/spark/azure*
hadoop fs -rm /user/oozie/share/lib/lib_<ts>/spark/hadoop-aws*
hadoop fs -rm /user/oozie/share/lib/lib_<ts>/spark/hadoop-azure*
hadoop fs -rm /user/oozie/share/lib/lib_<ts>/spark/ok*

```

```
hadoop fs -mv /user/oozie/share/lib/lib_<ts>/oozie/jackson* /user/oozie/share/lib/lib_<ts>/oozie.old
```

Next, run the following command to update the Oozie ShareLib:

```
oozie admin -oozie http://<oozie-server-hostname>:11000/oozie -sharelibupdate
```