Hortonworks Data Platform

Apache Spark Component Guide

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Hortonworks Data Platform: Apache Spark Component Guide

The Hortonworks Data Platform, powered by Apache Hadoop, is a massively scalable and 100% open source platform for storing, processing and analyzing large volumes of data. It is designed to deal with data from many sources and formats in a very quick, easy and cost-effective manner. The Hortonworks Data Platform consists of the essential set of Apache Hadoop projects including MapReduce, Hadoop Distributed File System (HDFS), HCatalog, Pig, Hive, HBase, ZooKeeper and Ambari. Hortonworks is the major contributor of code and patches to many of these projects. These projects have been integrated and tested as part of the Hortonworks Data Platform release process and installation and configuration tools have also been included.

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Table of Contents

List of Tables

1. Analyzing Data with Apache Spark

Hortonworks Data Platform (HDP) supports Apache Spark, a fast, large-scale data processing engine.

Deep integration of Spark with YARN allows Spark to operate as a cluster tenant alongside Apache engines such as Hive, Storm, and HBase, all running simultaneously on a single data platform. Instead of creating and managing a set of dedicated clusters for Spark applications, you can store data in a single location, access and analyze it with multiple processing engines, and leverage your resources.

Spark on YARN leverages YARN services for resource allocation, runs Spark executors in YARN containers, and supports workload management and Kerberos security features. It has two modes:

- YARN-cluster mode, optimized for long-running production jobs
- YARN-client mode, best for interactive use such as prototyping, testing, and debugging

Spark shell and the Spark Thrift server run in YARN-client mode only.

Spark Feature Support

HDP 2.6 supports Spark 1.6 and Spark 2.0, with the following features:

- Spark on YARN
- Spark Core
- Spark SQL and the Spark SQL Thrift server (JDBC and ODBC)
- Spark Streaming
- Spark history server
- DataFrame API
- Optimized Row Columnar (ORC) files
- SparkR, PySpark, MLlib, and the ML Pipeline API
- Hive 1.2.1
- Dynamic resource allocation
- HBase connector

HDP 2.6 also supports Livy, for local and remote access to Spark through REST API.

Table 1.1. Spark and Livy Support by HDP Version

HDP Version(s)	**2.6.0**	**2.5.0** **2.5.3**	**2.4.3**	**2.4.2**	**2.4.0**	**2.3.4** **2.3.4.7** **2.3.6**	**2.3.2**	**2.2.8** **2.2.9** **2.3.0**
Spark Version	**1.6.3** **2.1.0**	**1.6.2**	**1.6.2**	**1.6.1**	**1.6.0**	**1.5.2**	**1.4.1**	**1.3.1**
Livy Version(s)	**0.3**							
Feature:								
Spark Core	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spark on YARN	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spark on YARN, Kerberos-enabled clusters	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spark history server	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spark MLlib	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hive 13 (or later) support, including `collect_list` UDF	1.2.1	1.2.1	1.2.1	1.2.1	1.2.1	1.2.1	0.13.1	0.13.1
ML Pipeline API	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
DataFrames API	Yes	Yes	Yes	Yes	Yes	Yes	Yes	TP
ORC Files	Yes	Yes	Yes	Yes	Yes	Yes	Yes	TP
PySpark	Yes	Yes	Yes	Yes	Yes	Yes	Yes	TP
Spark SQL	Yes	Yes	Yes	Yes	Yes	Yes	TP	TP
Spark Thrift server (JDBC, ODBC)	Yes	Yes	Yes	Yes	Yes	Yes	TP	TP
Spark Streaming	Yes	Yes	Yes	Yes	Yes	Yes	TP	TP
Dynamic resource allocation	Yes*	Yes*	Yes*	Yes*	Yes*	Yes*	TP	TP
SparkR	Yes	Yes	TP	TP	TP	TP	TP	
HBase connector	Yes	Yes	TP	TP				
GraphX	TP	TP	TP	TP	TP	TP		

TP: Tech Preview

* Note: Dynamic Resource Allocation does not work with Spark Streaming.

The following features are available as technical previews, and are considered under development. Do not use these features in your production systems. If you have questions regarding these features, contact Support by logging a case on the Hortonworks Support Portal at https://support.hortonworks.com.

- GraphX
- DataSet API

The following features and associated tools are not officially supported by Hortonworks:

- Spark Standalone

- Spark on Mesos
- Jupyter (formerly IPython) Notebook

2. Installing Spark

Before installing Spark, ensure that your cluster meets the following prerequisites:

- HDP cluster stack version 2.6.0 or later
- (Optional) Ambari version 2.5.0 or later
- HDFS and YARN deployed on the cluster

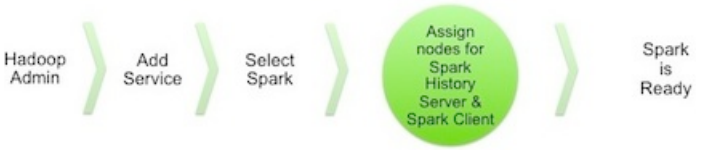
You can choose to install Spark version 1, Spark version 2, or both. (To specify which version of Spark runs a job, see Specifying Which Version of Spark to Run.)

Additionally, note the following requirements and recommendations for optional Spark services and features:

- Spark Thrift server requires Hive deployed on the cluster.
- SparkR requires R binaries installed on all nodes, and SparkR is not currently supported on SLES. remove when
- Spark access through Livy requires the Livy server installed on the cluster.
  - For clusters managed by Ambari, see Installing Spark Using Ambari.
  - For clusters not managed by Ambari, see "Installing and Configuring Livy" in the Spark or Spark 2 chapter of the *Command Line Installation Guide*, depending on the version of Spark installed on your cluster.
- PySpark requires Python installed on all nodes.
- Spark Pyenv requires Python version 2.7, Python version 3.4, or later; Pyenv does not support Python 2.6.
- For optimal performance with MLlib, consider installing the `netlib-java` library.

2.1. Installing Spark Using Ambari

The following diagram shows the Spark installation process using Ambari. Before you install Spark using Ambari, refer to Adding a Service in the *Ambari Operations Guide* for background information about how to install Hortonworks Data Platform (HDP) components using Ambari.



Caution

During the installation process, Ambari creates and edits several configuration files. If you configure and manage your cluster using Ambari, do not edit these

files during or after installation. Instead, use the Ambari web UI to revise configuration settings.

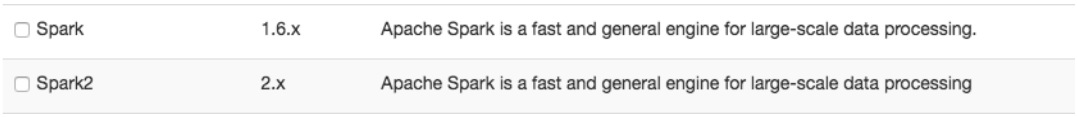
To install Spark using Ambari, complete the following steps.

1. Click the Ambari "Services" tab.

2. In the Ambari "Actions" menu, select "Add Service."

   This starts the Add Service wizard, displaying the Choose Services page. Some of the services are enabled by default.

3. Scroll through the alphabetic list of components on the Choose Services page, and select "Spark", "Spark2", or both:



4. Click "Next" to continue.

5. On the Assign Masters page, review the node assignment for the Spark History Server or Spark2 History Server, depending on which Spark versions you are installing. Modify the node assignment if desired, and click "Next":

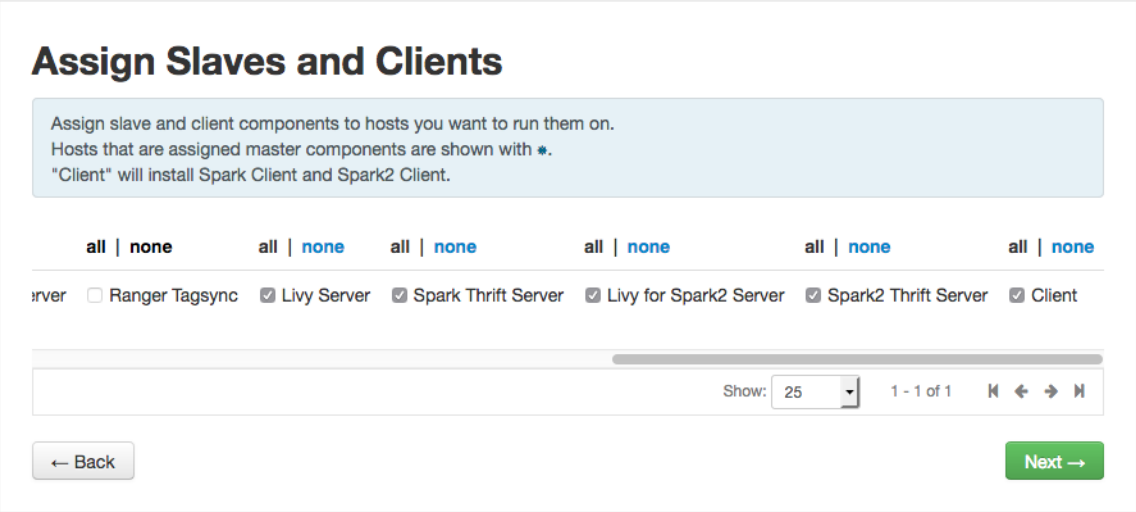
6. On the Assign Slaves and Clients page:

   a. Scroll to the right and choose the "Client" nodes that you want to run Spark clients. These are the nodes from which Spark jobs can be submitted to YARN.

   b. To install the optional Livy server, for security and user impersonation features, check the "Livy Server" box for the desired node assignment on the Assign Slaves and Clients page, for the version(s) of Spark you are deploying.

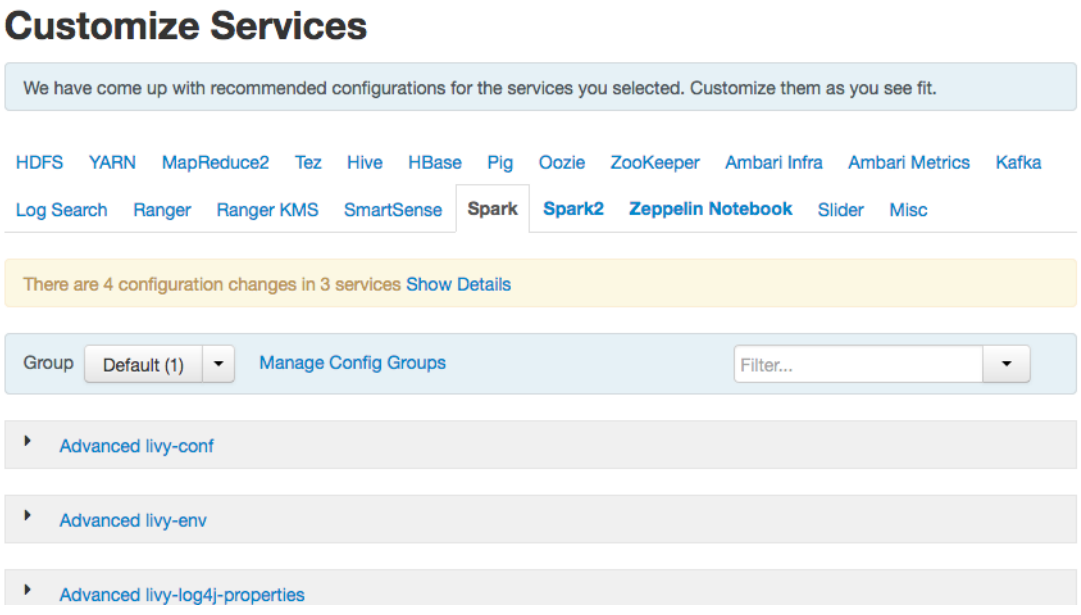
   c. To install the optional Spark Thrift server at this time, for ODBC or JDBC access, review Spark Thrift Server node assignments on the Assign Slaves and Clients page and assign one or two nodes to it, as needed for the version(s) of Spark you are deploying. (To install the Thrift server later, see Installing the Spark Thrift Server after Deploying Spark.)

      Deploying the Thrift server on multiple nodes increases scalability of the Thrift server. When specifying the number of nodes, take into consideration the cluster capacity allocated to Spark.



7. Click "Next" to continue.

8. Unless you are installing the Spark Thrift server now, use the default values displayed on the Customize Services page. Note that there are two tabs, one for Spark settings, and one for Spark2 settings.



9. If you are installing the Spark Thrift server at this time, complete the following steps:

   a. Click the "Spark" or "Spark2" tab on the Customize Services page, depending on which version of Spark you are installing.

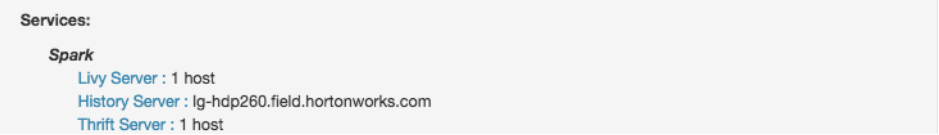
   b. Navigate to the "Advanced spark-thrift-sparkconf" group.

   c. Set the `spark.yarn.queue` value to the name of the YARN queue that you want to use.

10. Click "Next" to continue.

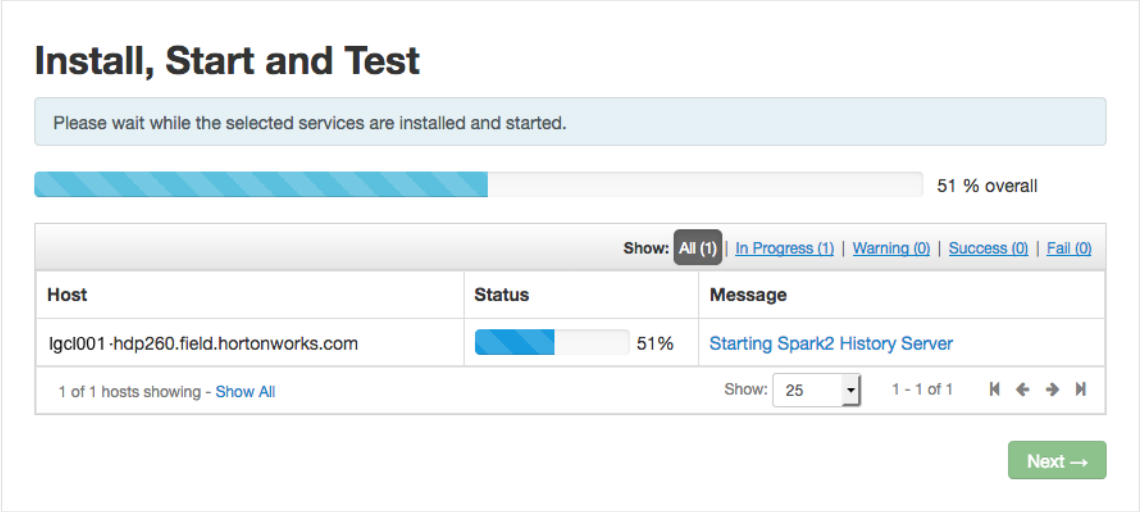
11. If Kerberos is enabled on the cluster, review principal and keytab settings on the Configure Identities page, modify settings if desired, and then click Next.

12. When the wizard displays the Review page, ensure that all HDP components correspond to HDP 2.6.0 or later. Scroll down and check the node assignments for selected services; for example:



13. Click "Deploy" to begin installation.

14. When Ambari displays the Install, Start and Test page, monitor the status bar and messages for progress updates:



15. When the wizard presents a summary of results, click "Complete" to finish installing Spark.

2.2. Installing Spark Manually

If you want to install Spark or Spark 2 on a cluster that is not managed by Ambari, see Installing and Configuring Apache Spark or Installing and Configuring Apache Spark 2, in the *Command Line Installation Guide*.

If you previously installed Spark on a cluster not managed by Ambari, and you want to move to Spark 2:

1. Install Spark 2 according to the Spark 2 instructions in the *Command Line Installation Guide*.
2. Ensure that each version of Spark uses a different port.
3. Test your Spark jobs on Spark 2. To direct a job to Spark 2 when Spark 1 is the default version, see Specifying Which Version of Spark to Run.

4. When finished testing, optionally remove Spark 1 from the cluster: stop all services and then uninstall Spark. Manually check to make sure all library and configuration directories have been removed.

2.3. Verifying Spark Configuration for Hive Access

When you install Spark using Ambari, the `hive-site.xml` file is automatically populated with the Hive metastore location.

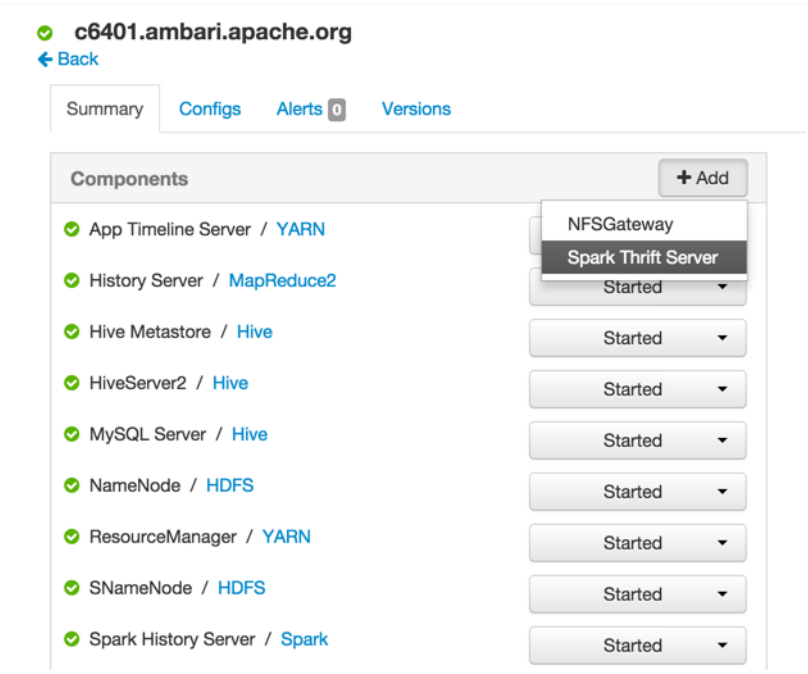
If you move Hive to a different server, edit the SPARK_HOME/`conf/hive-site.xml` file so that it contains only the hive.metastore.uris property. Make sure that the host name points to the URI where the Hive metastore is running, and that the Spark copy of `hive-site.xml` contains only the hive.metastore.uris property.

```
<configuration>
  <property>
  <name>hive.metastore.uris</name>
    <!-- hostname must point to the Hive metastore URI in your cluster -->
    <value>thrift://hostname:9083</value>
    <description>URI for client to contact metastore server</description>
  </property>
</configuration>
```

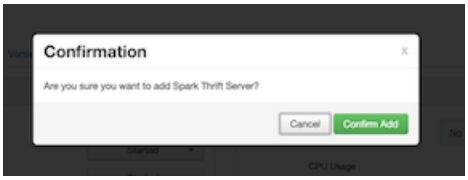
2.4. Installing the Spark Thrift Server After Deploying Spark

To install the Spark Thrift server after deploying Spark over Ambari, add the Thrift service to the specified host or hosts. Deploying the Thrift server on multiple hosts increases scalability of the Thrift server; the number of hosts should take into consideration the cluster capacity allocated to Spark.

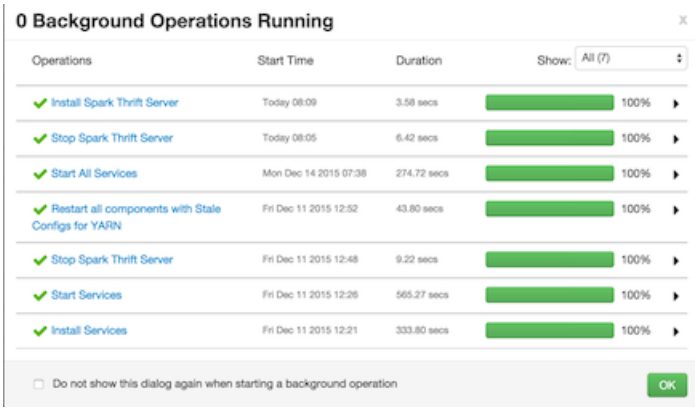
1. On the Summary tab, click "**+ Add**" and choose the Spark Thrift server:



2. When Ambari prompts you to confirm the selection, click **Confirm All**:



The installation process runs in the background until it is complete:



2.5. Validating the Spark Installation

To validate the Spark or Spark2 installation process, run the Spark Pi and WordCount jobs supplied with the Spark package. For more information, see Running Spark Applications.

3. Configuring Spark

This chapter describes how to configure server ports, the Apache Spark history server, the Livy server, and dynamic resource allocation, as well as how to configure Spark for wire encryption, and for a Kerberos-enabled cluster.

3.1. Configuring the Spark Thrift Server

Spark Thrift server is a service that allows JDBC and ODBC clients to run Spark SQL queries. The Spark Thrift server is a variant of HiveServer2.

This subsection describes optional Spark Thrift Server features and configuration steps:

- Enabling user impersonation, so that SQL queries run under the identity of the user who originated the query. (By default, queries run under the account associated with the Spark Thrift server.)
- Customizing the Spark Thrift server port.

For information about configuring the Thrift server on a Kerberos-enabled cluster, see Configuring the Spark Thrift Server in "Configuring Spark for a Kerberos-Enabled Cluster."

3.1.1. Enabling Spark SQL User Impersonation for the Spark Thrift Server

By default, the Spark Thrift server runs queries under the identity of the operating system account running the Spark Thrift server. In a multi-user environment, queries often need to run under the identity of the end user who originated the query; this capability is called "user impersonation."

When user impersonation is enabled, Spark Thrift server runs Spark SQL queries as the submitting user. By running queries under the user account associated with the submitter, the Thrift server can enforce user level permissions and access control lists. Associated data cached in Spark is visible only to queries from the submitting user.

User impersonation enables granular access control for Spark SQL queries at the level of files or tables.

The user impersonation feature is controlled with the doAs property. When doAs is set to true, Spark Thrift server launches an on-demand Spark application to handle user queries. These queries are shared only with connections from the same user. Spark Thrift server forwards incoming queries to the appropriate Spark application for execution, making the Spark Thrift server extremely lightweight: it merely acts as a proxy to forward requests and responses. When all user connections for a Spark application are closed at the Spark Thrift server, the corresponding Spark application also terminates.

Prerequisites

Spark SQL user impersonation is supported for Apache Spark 1 versions 1.6.3 and later.

If storage-based authorization is to be enabled, complete the instructions in Configuring Storage-based Authorization in the *Data Access Guide* before enabling user impersonation.

Enabling User Impersonation on an Ambari-managed Cluster

To enable user impersonation for the Spark Thrift server on an Ambari-managed cluster, complete the following steps:

1. Enable doAs support. Navigate to the "Advanced spark-hive-site-override" section and set `hive.server2.enable.doAs=true`.

2. Add DataNucleus jars to the Spark Thrift server classpath. Navigate to the "Custom spark-thrift-sparkconf" section and set the `spark.jars` property as follows:

```
spark.jars=/usr/hdp/current/spark-thriftserver/lib/datanucleus-api-jdo-3.2.
6.jar,/usr/hdp/current/spark-thriftserver/lib/datanucleus-core-3.2.10.jar,/
usr/hdp/current/spark-thriftserver/lib/datanucleus-rdbms-3.2.9.jar
```

3. (Optional) Disable Spark Yarn application for Spark Thrift server master. Navigate to the "Advanced spark-thrift-sparkconf" section and set `spark.master=local`. This prevents launching a spark-client HiveThriftServer2 application master, which is not needed when `doAs=true` because queries are executed by the Spark AM, launched on behalf of the user. When `spark.master` is set to `local`, SparkContext uses only the local machine for driver and executor tasks.

   (When the Thrift server runs with doAs set to `false`, you should set `spark.master` to `yarn-client`, so that query execution leverages cluster resources.)

4. Restart the Spark Thrift server.

Enabling User Impersonation on an Cluster Not Managed by Ambari

To enable user impersonation for the Spark Thrift server on a cluster not managed by Ambari, complete the following steps:

1. Enable doAs support. Add the following setting to the `/usr/hdp/current/spark-thriftserver/conf/hive-site.xml` file:

```
<property>
    <name>hive.server2.enable.doAs</name>
    <value>true</value>
</property>
```

2. Add DataNucleus jars to the Spark Thrift server classpath. Add the following setting to the `/usr/hdp/current/spark-thriftserver/conf/spark-thrift-sparkconf.conf` file:

```
spark.jars=/usr/hdp/current/spark-thriftserver/lib/datanucleus-api-jdo-3.2.
6.jar,/usr/hdp/current/spark-thriftserver/lib/datanucleus-core-3.2.10.jar,/
usr/hdp/current/spark-thriftserver/lib/datanucleus-rdbms-3.2.9.jar
```

3. (Optional) Disable Spark Yarn application for Spark Thrift server master. Add the following setting to the `/usr/hdp/current/spark-thriftserver/conf/spark-thrift-sparkconf.conf` file:

```
spark.master=local
```

   This prevents launching an unused spark-client HiveThriftServer2 application master, which is not needed when `doAs=true` because queries are executed by the Spark AM,

launched on behalf of the user. When `spark.master` is set to `local`, SparkContext uses only the local machine for driver and executor tasks.

(When the Thrift server runs with `doAs` set to `false`, you should set `spark.master` to `yarn-client`, so that query execution leverages cluster resources.)

4. Restart the Spark Thrift server.

For more information about user impersonation for the Spark Thrift Server, see Using Spark SQL.

3.1.2. Customizing the Spark Thrift Server Port

The default Spark Thrift server port is 10015. To specify a different port, you can navigate to the `hive.server2.thrift.port` setting in the "Advanced spark-hive-site-override" category of the Spark configuration section and update the setting with your preferred port number.

3.2. Configuring the Livy Server

On a cluster managed by Ambari, to configure the optional Livy service, complete the following steps:

1. Navigate to Spark > Configs, Custom livy-conf category.

2. Add `livy.superusers` as a property, and set it to the Zeppelin service account.

For a cluster not managed by Ambari, see "Installing and Configuring Livy" in the Spark or Spark 2 chapter of the *Command Line Installation Guide*, depending on the version of Spark installed on your cluster.

3.2.1. Configuring High Availability for the Livy Server

By default, if the Livy server fails, all connected Spark clusters are terminated. This means that all jobs and data will disappear immediately.

For deployments that require high availability, Livy supports session recovery, which ensures that a Spark cluster remains available if the Livy server fails. After a restart, the Livy server can connect to existing sessions and roll back to the state before failing.

Livy uses several property settings for recovery behavior related to high availability. If your cluster is managed by Ambari, Ambari manages these settings. If your cluster is not managed by Ambari, or for a list of recovery properties, see instructions for enabling Livy recovery in the Spark or Spark2 chapter of the *Command Line Installation Guide*.

3.3. Configuring the Spark History Server

The Spark history server is a monitoring tool that displays information about completed Spark applications. This information is pulled from the data that applications by default write to a directory on Hadoop Distributed File System (HDFS). The information is then presented in a web UI at `<host>:<port>`. (The default port is 18080.)

For information about configuring optional history server properties, see the Apache Monitoring and Instrumentation document.

3.4. Configuring Dynamic Resource Allocation

When the dynamic resource allocation feature is enabled, an application's use of executors is dynamically adjusted based on workload. This means that an application can relinquish resources when the resources are no longer needed, and request them later when there is more demand. This feature is particularly useful if multiple applications share resources in your Spark cluster.

Dynamic resource allocation is available for use by the Spark Thrift server and general Spark jobs.

Note

Dynamic Resource Allocation does not work with Spark Streaming.

You can configure dynamic resource allocation at either the cluster or the job level:

- Cluster level:
  - On an Ambari-managed cluster, the Spark Thrift server uses dynamic resource allocation by default. The Thrift server increases or decreases the number of running executors based on a specified range, depending on load. (In addition, the Thrift server runs in YARN mode by default, so the Thrift server uses resources from the YARN cluster.) The associated shuffle service starts automatically, for use by the Thrift server and general Spark jobs.
  - On a manually installed cluster, dynamic resource allocation is not enabled by default for the Thrift server or for other Spark applications. You can enable and configure dynamic resource allocation and start the shuffle service during the Spark manual installation or upgrade process.
- Job level: You can customize dynamic resource allocation settings on a per-job basis. Job settings override cluster configuration settings.

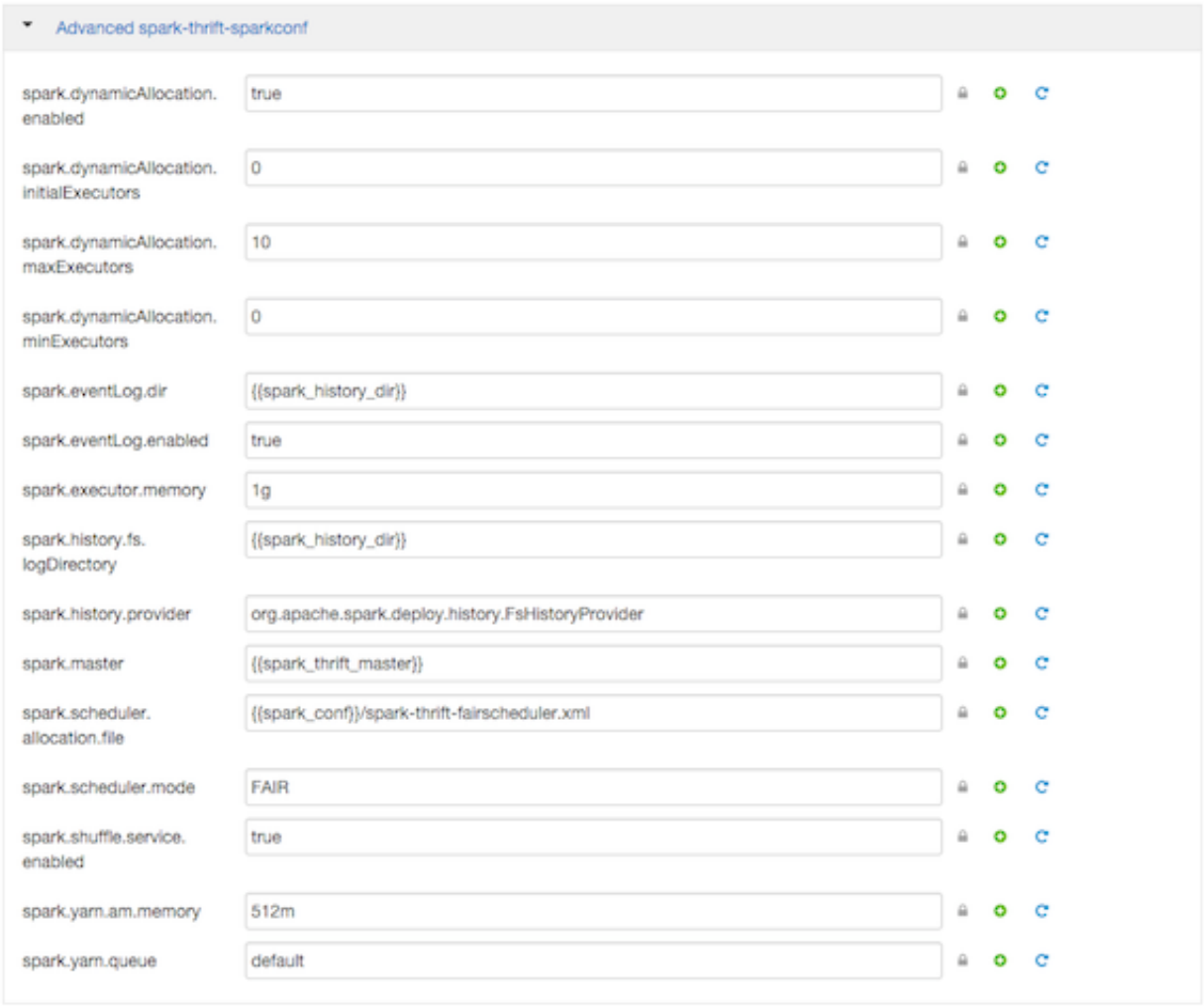
Cluster configuration is the default, unless overridden by job configuration.

The following subsections describe each configuration approach, followed by a list of dynamic resource allocation properties and a set of instructions for customizing the Spark Thrift server port.

3.4.1. Customizing Dynamic Resource Allocation Settings on an Ambari-Managed Cluster

On an Ambari-managed cluster, dynamic resource allocation is enabled and configured for the Spark Thrift server as part of the Spark installation process. Dynamic resource allocation is not enabled by default for general Spark jobs.

You can review dynamic resource allocation for the Spark Thrift server, and enable and configure settings for general Spark jobs, by choosing **Services** > **Spark** and then navigating to the "Advanced spark-thrift-sparkconf" group:



The "Advanced spark-thrift-sparkconf" group lists required settings. You can specify optional properties in the custom section. For a complete list of DRA properties, see Dynamic Resource Allocation Properties.

Dynamic resource allocation requires an external shuffle service that runs on each worker node as an auxiliary service of NodeManager. If you installed your cluster using Ambari, the service is started automatically for use by the Thrift server and general Spark jobs; no further steps are needed.

3.4.2. Configuring Cluster Dynamic Resource Allocation Manually

To configure a cluster to run Spark jobs with dynamic resource allocation, complete the following steps:

1. Add the following properties to the `spark-defaults.conf` file associated with your Spark installation (typically in the `$SPARK_HOME/conf` directory):

   - Set `spark.dynamicAllocation.enabled` to `true`.

- Set `spark.shuffle.service.enabled` to `true`.

2. (Optional) To specify a starting point and range for the number of executors, use the following properties:

   - `spark.dynamicAllocation.initialExecutors`
   - `spark.dynamicAllocation.minExecutors`
   - `spark.dynamicAllocation.maxExecutors`

   Note that `initialExecutors` must be greater than or equal to `minExecutors`, and less than or equal to `maxExecutors`.

   For a description of each property, see Dynamic Resource Allocation Properties.

3. Start the shuffle service on each worker node in the cluster:

   a. In the `yarn-site.xml` file on each node, add `spark_shuffle` to `yarn.nodemanager.aux-services`, and then set `yarn.nodemanager.aux-services.spark_shuffle.class` to `org.apache.spark.network.yarn.YarnShuffleService`.

   b. Review and, if necessary, edit `spark.shuffle.service.*` configuration settings.

      For more information, see the Apache Spark Shuffle Behavior documentation.

   c. Restart all NodeManagers in your cluster.

3.4.3. Configuring a Job for Dynamic Resource Allocation

There are two ways to customize dynamic resource allocation properties for a specific job:

- Include property values in the `spark-submit` command, using the `-conf` option.

  This approach loads the default `spark-defaults.conf` file first, and then applies property values specified in your `spark-submit` command. Here is an example:

  ```
  spark-submit –conf “property_name=property_value”
  ```

- Create a job-specific `spark-defaults.conf` file and pass it to the `spark-submit` command.

  This approach uses the specified properties file, without reading the default property file. Here is an example:

  ```
  spark-submit –properties-file <property_file>
  ```

3.4.4. Dynamic Resource Allocation Properties

See the following tables for more information about basic and optional dynamic resource allocation properties. For more information, see the Apache Dynamic Resource Allocation documentation.

Table 3.1. Dynamic Resource Allocation Properties

Property Name	Value	Meaning
`spark.dynamicAllocation.enabled`	Default is `true` for the Spark Thrift server, and `false` for Spark jobs.	Specifies whether to use dynamic resource allocation, which scales the number of executors registered for an application up and down based on workload. Note that this feature is currently only available in YARN mode.
`spark.shuffle.service.enabled`	`true`	Enables the external shuffle service, which preserves shuffle files written by executors so that the executors can be safely removed. This property must be set to `true` if `spark.dynamicAllocation.enabled` is `true`.
`spark.dynamicAllocation.initialExecutors`	Default is `spark.dynamicAllocation.minExecutors`	The initial number of executors to run if dynamic resource allocation is enabled. This value must be greater than or equal to the `minExecutors` value, and less than or equal to the `maxExecutors` value.
`spark.dynamicAllocation.maxExecutors`	Default is infinity	Specifies the upper bound for the number of executors if dynamic resource allocation is enabled.
`spark.dynamicAllocation.minExecutors`	Default is 0	Specifies the lower bound for the number of executors if dynamic resource allocation is enabled.

Table 3.2. Optional Dynamic Resource Allocation Properties

Property Name	Value	Meaning
`spark.dynamicAllocation.executorIdleTimeout`	Default is 60 seconds (`60s`)	If dynamic resource allocation is enabled and an executor has been idle for more than this time, the executor is removed.
`spark.dynamicAllocation.cachedExecutorIdleTimeout`	Default is infinity	If dynamic resource allocation is enabled and an executor with cached data blocks has been idle for more than this time, the executor is removed.
`spark.dynamicAllocation.schedulerBacklogTimeout`	1 second (`1s`)	If dynamic resource allocation is enabled and there have been pending tasks backlogged for more than this time, new executors are requested.
`spark.dynamicAllocation.sustainedSchedulerBacklogTimeout`	Default is `schedulerBacklogTimeout`	Same as `spark.dynamicAllocation.schedulerBacklogTimeout`, but used only for subsequent executor requests.

3.5. Configuring Spark for Wire Encryption

You can configure Spark to protect sensitive data in transit, by enabling wire encryption.

In general, encryption protects data by making it unreadable without a phrase or digital key to access the data. Data can be encrypted while it is in transit and when it is at rest:

- "In transit" encryption refers to data that is encrypted when it traverses a network. The data is encrypted between the sender and receiver process across the network. Wire encryption is a form of "in transit" encryption.
- "At rest" or "transparent" encryption refers to data stored in a database, on disk, or on other types of persistent media.

Apache Spark supports "in transit" wire encryption of data for Apache Spark jobs. When encryption is enabled, Spark encrypts all data that is moved across nodes in a cluster on behalf of a job, including the following scenarios:

- Data that is moving between executors and drivers, such as during a `collect()` operation.
- Data that is moving between executors, such as during a shuffle operation.

Spark does not support encryption for connectors accessing external sources; instead, the connectors must handle any encryption requirements. For example, the Spark HDFS connector supports transparent encrypted data access from HDFS: when transparent encryption is enabled in HDFS, Spark jobs can use the HDFS connector to read encrypted data from HDFS.

Spark does not support encrypted data on local disk, such as intermediate data written to a local disk by an executor process when the data does not fit in memory. Additionally, wire encryption is not supported for shuffle files, cached data, and other application files. For these scenarios you should enable local disk encryption through your operating system.

In Spark 2.0, enabling wire encryption also enables HTTPS on the History Server UI, for browsing historical job data.

The following two subsections describe how to configure Spark and Spark2 for wire encryption, respectively.

3.5.1. Configuring Spark for Wire Encryption

Use the following commands to configure Spark (version 1) for wire encryption:

1. On each node, create keystore files, certificates, and truststore files.

   a. Create a keystore file:

```
keytool -genkey \
    -alias <host> \
    -keyalg RSA \
    -keysize 1024 \
    –dname CN=<host>,OU=hw,O=hw,L=paloalto,ST=ca,C=us \
    –keypass <KeyPassword> \
    -keystore <keystore_file> \
    -storepass <storePassword>
```

   b. Create a certificate:

```
keytool -export \
    -alias <host> \
    -keystore <keystore_file> \
    -rfc –file <cert_file> \
    -storepass <StorePassword>
```

c. Create a truststore file:

```
keytool -import \
    -noprompt \
    -alias <host> \
    -file <cert_file> \
    -keystore <truststore_file> \
    -storepass <truststorePassword>
```

2. Create one truststore file that contains the public keys from all certificates.

a. Log on to one host and import the truststore file for that host:

```
keytool -import \
    -noprompt \
    -alias <hostname> \
    -file <cert_file> \
    -keystore <all_jks> \
    -storepass <allTruststorePassword>
```

b. Copy the <all_jks> file to the other nodes in your cluster, and repeat the keytool command on each node.

3. Enable Spark authentication.

a. Set spark.authenticate to true in the yarn-site.xml file:

```
<property>
  <name>spark.authenticate</name>
  <value>true</value>
</property>
```

b. Set the following properties in the spark-defaults.conf file:

```
spark.authenticate true
spark.authenticate.enableSaslEncryption true
```

4. Enable Spark SSL.

Set the following properties in the spark-defaults.conf file:

```
spark.ssl.enabled true
spark.ssl.enabledAlgorithms TLS_RSA_WITH_AES_128_CBC_SHA,
TLS_RSA_WITH_AES_256_CBC_SHA
spark.ssl.keyPassword <KeyPassword>
spark.ssl.keyStore <keystore_file>
spark.ssl.keyStorePassword <storePassword>
spark.ssl.protocol TLS
spark.ssl.trustStore <all_jks>
spark.ssl.trustStorePassword <allTruststorePassword>
```

3.5.2. Configuring Spark2 for Wire Encryption

Use the following commands to configure Spark2 for wire encryption:

1. On each node, create keystore files, certificates, and truststore files.

a. Create a keystore file:

```
keytool -genkey \
    -alias <host> \
    -keyalg RSA \
    -keysize 1024 \
    –dname CN=<host>,OU=hw,O=hw,L=paloalto,ST=ca,C=us \
    –keypass <KeyPassword> \
    -keystore <keystore_file> \
    -storepass <storePassword>
```

b. Create a certificate:

```
keytool -export \
    -alias <host> \
    -keystore <keystore_file> \
    -rfc –file <cert_file> \
    -storepass <StorePassword>
```

c. Create a truststore file:

```
keytool -import \
    -noprompt \
    -alias <host> \
    -file <cert_file> \
    -keystore <truststore_file> \
    -storepass <truststorePassword>
```

2. Create one truststore file that contains the public keys from all certificates.

a. Log on to one host and import the truststore file for that host:

```
keytool -import \
    -noprompt \
    -alias <hostname> \
    -file <cert_file> \
    -keystore <all_jks> \
    -storepass <allTruststorePassword>
```

b. Copy the `<all_jks>` file to the other nodes in your cluster, and repeat the `keytool` command on each node.

3. Enable Spark2 authentication.

a. Set `spark.authenticate` to `true` in the `yarn-site.xml` file:

```
<property>
  <name>spark.authenticate</name>
  <value>true</value>
</property>
```

b. Set the following properties in the `spark-defaults.conf` file:

```
spark.authenticate true
spark.authenticate.enableSaslEncryption true
```

4. Enable Spark2 SSL.

Set the following properties in the `spark-defaults.conf` file:

```
spark.ssl.enabled true
spark.ssl.enabledAlgorithms TLS_RSA_WITH_AES_128_CBC_SHA,
TLS_RSA_WITH_AES_256_CBC_SHA
spark.ssl.keyPassword <KeyPassword>
spark.ssl.keyStore <keystore_file>
spark.ssl.keyStorePassword <storePassword>
spark.ssl.protocol TLS
spark.ssl.trustStore <all_jks>
spark.ssl.trustStorePassword <allTruststorePassword>
```

5. Enable HTTPS for the Spark2 UI.

   Set `spark.ui.https.enabled` to `true` in the `spark-defaults.conf` file:

   ```
   spark.ui.https.enabled true
   ```

   Note: In Spark2, enabling wire encryption also enables HTTPS on the History Server UI, for browsing job history data.

6. (Optional) If you want to enable optional on-disk block encryption, which applies to both shuffle and RDD blocks on disk, complete the following steps:

   a. Add the following properties to the `spark-defaults.conf` file for Spark2:

   ```
   spark.io.encryption.enabled true
   spark.io.encryption.keySizeBits 128
   spark.io.encryption.keygen.algorithm HmacSHA1
   ```

   b. Enable RPC encryption.

   For more information, see the Shuffle Behavior section of Apache Spark Properties documentation, and the Apache Spark Security documentation.

3.6. Configuring Spark for a Kerberos-Enabled Cluster

Before running Spark jobs on a Kerberos-enabled cluster, configure additional settings for the following modules and scenarios:

- Spark history server
- Spark Thrift server
- Individuals who submit jobs
- Processes that submit jobs without human interaction

Each of these scenarios is described in the following subsections.

When Kerberos is enabled on an Ambari-managed cluster, Livy configuration for Kerberos is handled automatically.

3.6.1. Configuring the Spark History Server

The Spark history server daemon must have a Kerberos account and keytab to run on a Kerberos-enabled cluster.

When you enable Kerberos for a Hadoop cluster with Ambari, Ambari configures Kerberos for the history server and automatically creates a Kerberos account and keytab for it. For more information, see Enabling Kerberos Authentication Using Ambari in the *HDP Security Guide*.

If your cluster is not managed by Ambari, or if you plan to enable Kerberos manually for the history server, see Creating Service Principals and Keytab Files for HDP in the *HDP Security Guide*.

3.6.2. Configuring the Spark Thrift Server

If you are installing the Spark Thrift server on a Kerberos-enabled cluster, note the following requirements:

- The Spark Thrift server must run in the same host as `HiveServer2`, so that it can access the `hiveserver2` keytab.
- Permissions in `/var/run/spark` and `/var/log/spark` must specify read/write permissions to the Hive service account.
- You must use the Hive service account to start the `thriftserver` process.

If you access Hive warehouse files through HiveServer2 on a deployment with fine-grained access control, run the Spark Thrift server as user `hive`. This ensures that the Spark Thrift server can access Hive keytabs, the Hive metastore, and HDFS data stored under user `hive`.

Important

If you read files from HDFS directly through an interface such as Hive CLI or Spark CLI (as opposed to HiveServer2 with fine-grained access control), you should use a different service account for the Spark Thrift server. Configure the account so that it can access Hive keytabs and the Hive metastore. Use of an alternate account provides a more secure configuration: when the Spark Thrift server runs queries as user `hive`, all data accessible to user `hive` is accessible to the user submitting the query.

For Spark jobs that are not submitted through the Thrift server, the user submitting the job must have access to the Hive metastore in secure mode, using the `kinit` command.

3.6.3. Setting Up Access for an Account to Submit Jobs

Accounts that submit jobs on behalf of other processes must have a Kerberos account and keytab.

When access is authenticated without human interaction (as happens for processes that submit job requests), the process uses a headless keytab. Security risk is mitigated by ensuring that only the service that should be using the headless keytab has permission to read it.

The following example creates a headless keytab for a `spark` service user account that will submit Spark jobs on node `blue1@example.com`:

1. Create a Kerberos service principal for user `spark`:

   ```
   kadmin.local -q "addprinc -randkey spark/blue1@EXAMPLE.COM"
   ```

2. Create the keytab:

   ```
   kadmin.local -q "xst -k /etc/security/keytabs/spark.keytab
   spark/blue1@EXAMPLE.COM"
   ```

3. For every node of your cluster, create a `spark` user and add it to the `hadoop` group:

   ```
   useradd spark -g hadoop
   ```

4. Make `spark` the owner of the newly created keytab:

   ```
   chown spark:hadoop /etc/security/keytabs/spark.keytab
   ```

5. Limit access by ensuring that user `spark` is the only user with access to the keytab:

   ```
   chmod 400 /etc/security/keytabs/spark.keytab
   ```

In the following example, user `spark` runs the Spark Pi example in a Kerberos-enabled environment:

```
su spark
kinit -kt /etc/security/keytabs/spark.keytab spark/blue1@EXAMPLE.COM
cd /usr/hdp/current/spark-client/
./bin/spark-submit --class org.apache.spark.examples.SparkPi \
    --master yarn-cluster \
    --num-executors 1 \
    --driver-memory 512m \
    --executor-memory 512m \
    --executor-cores 1 \
    lib/spark-examples*.jar 10
```

3.6.4. Setting Up Access for a User to Submit Jobs

Each person who submits jobs must have a Kerberos account and their own keytab; end users should use their own keytabs when submitting a Spark job.

In the following example, end user $USERNAME has their own keytab and runs the Spark Pi job in a Kerberos-enabled environment:

```
su $USERNAME
kinit USERNAME@YOUR-LOCAL-REALM.COM
cd /usr/hdp/current/spark-client/
./bin/spark-submit --class org.apache.spark.examples.SparkPi \
    --master yarn-cluster \
    --num-executors 3 \
    --driver-memory 512m \
    --executor-memory 512m \
    --executor-cores 1 \
    lib/spark-examples*.jar 10
```

4. Developing and Running Spark Applications

Apache Spark enables you to quickly develop applications and process jobs. It is designed for fast application development and fast processing. Spark Core is the underlying execution engine; other services, such as Spark SQL, MLlib, and Spark Streaming, are built on top of the Spark Core.

You can run Spark interactively, or from a client program:

- 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.

To launch Spark applications on a cluster, you can use the `spark-submit` script in the Spark `bin` directory. 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`.

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. Features include the following:

- Jobs can be submitted from anywhere, using the REST API.
- Livy supports Spark1, Spark2, Scala 2.10, and Scala 2.11.
- 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. This is important in a multi-tenant environment, and it avoids unnecessary permission escalation.
- Additional security features, including 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.

This chapter describes how to run sample programs that use Spark to compute results, develop applications that use the Livy REST API to access Spark, and configure and use Oozie Spark action.

Additional Resources

For more information about getting started with Spark, see the Apache Spark Quick Start. For extensive information about application development, see the Apache Spark Programming Guide and Submitting Applications.

For detailed information about developing and running Spark applications, see Apache Spark documentation for Spark 1.6.3 and Spark 2.0.

For information about using Spark extensions such as the Spark DataFrame API, Spark SQL, Hive user-defined functions, and external libraries, see Using Spark Extensions.

For more information about Livy, see Running Spark Applications through Livy.

4.1. Specifying Which Version of Spark to Run

More than one version of Spark can run on a node. If your cluster runs Spark 1, you can install Spark 2 and test jobs on Spark 2 in parallel with a Spark 1 working environment. After verifying that all scripts and jobs run successfully with Spark 2 (including any changes for backward compatibility), you can then step through transitioning jobs from Spark 1 to Spark 2. For more information about installing a second version of Spark, see Installing Spark.

Use the following guidelines for determining which version of Spark runs a job by default, and for specifying an alternate version if desired.

- By default, if only one version of Spark is installed on a node, your job runs with the installed version.
- By default, if more than one version of Spark is installed on a node, your job runs with the default version for your HDP package. In HDP 2.6, the default is Spark version 1.6.
- If you want to run jobs on the non-default version of Spark, use one of the following approaches:
  - If you use full paths in your scripts, change `spark-client` to `spark2-client`; for example:

    change `/usr/hdp/current/spark-client/bin/spark-submit`

    to `/usr/hdp/current/spark2-client/bin/spark-submit`.
  - If you do not use full paths, but instead launch jobs from the path, set the `SPARK_MAJOR_VERSION` environment variable to the desired version of Spark before you launch the job.

    For example, if Spark 1.6.3 and Spark 2.0 are both installed on a node and you want to run your job with Spark 2.0, set

    `SPARK_MAJOR_VERSION=2`.

    You can set `SPARK_MAJOR_VERSION` in automation scripts that use Spark, or in your manual settings after logging on to the shell.

    Note: The `SPARK_MAJOR_VERSION` environment variable can be set by any user who logs on to a client machine to run Spark. The scope of the environment variable is local to the user session.

The following example submits a SparkPi job to Spark 2, using `spark-submit` under `/usr/bin`:

1. Navigate to a host where Spark 2.0 is installed.
2. Change to the `Spark2` client directory:

   ```
   cd /usr/hdp/current/spark2-client/
   ```

3. Set the `SPARK_MAJOR_VERSION` environment variable to 2:

   ```
   export SPARK_MAJOR_VERSION=2
   ```

4. Run the Spark Pi example:

   ```
   ./bin/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
   ```

   Note that the path to `spark-examples-*.jar` is different than the path used for Spark 1.x.

To change the environment variable setting later, either remove the environment variable or change the setting to the newly desired version.

4.2. Running Sample Spark 1.x Applications

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

4.2.1. 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. Log on as a user with Hadoop Distributed File System (HDFS) access: for example, your `spark` user, if you defined one, or `hdfs`.

   When the job runs, the library is uploaded into HDFS, so the user running the job needs permission to write to HDFS.

2. Navigate to a node with a Spark client and access the `spark-client` directory:

   ```
   cd /usr/hdp/current/spark-client
   ```

   ```
   su spark
   ```

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

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

```
17/03/12 14:28:35 INFO scheduler.DAGScheduler: Job 0 finished: reduce at
 SparkPi.scala:36, took 1.721177 s
Pi is roughly 3.141296
17/03/12 14:28:35 INFO spark.ContextCleaner: Cleaned accumulator 1
```

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 and Troubleshooting Spark.)

4.2.2. WordCount

WordCount is a simple program that counts how often a word occurs in a text file. The code builds a dataset of (String, Int) pairs called `counts`, and saves the dataset to a file.

The following example submits WordCount code to the Scala shell:

1. Select an input file for the Spark WordCount example.

You can use any text file as input.

2. Log on as a user with HDFS access: for example, your `spark` user (if you defined one) or `hdfs`.

   The following example uses `log4j.properties` as the input file:

   ```
   cd /usr/hdp/current/spark-client/

   su spark
   ```

3. Upload the input file to HDFS:

   ```
   hadoop fs -copyFromLocal /etc/hadoop/conf/log4j.properties /tmp/data
   ```

4. Run the Spark shell:

   ```
   ./bin/spark-shell --master yarn-client --driver-memory 512m --executor-memory 512m
   ```

   You should see output similar to the following (with additional status messages):

   ```
   Welcome to
         ____              __
        / __/__  ___ _____/ /__
       _\ \/ _ \/ _ `/ __/  '_/
      /___/ .__/\_,_/_/ /_/\_\   version 1.6.3
         /_/

   Using Scala version 2.10.5 (Java HotSpot(TM) 64-Bit Server VM, Java 1.8.
   0_112)
   Type in expressions to have them evaluated.
   Type :help for more information.
   Spark context available as sc.
   SQL context available as sqlContext.

   scala>
   ```

5. At the `scala>` prompt, submit the job by typing the following commands, replacing node names, file name, and file location with your own values:

   ```
   val file = sc.textFile("/tmp/data")
   val counts = file.flatMap(line => line.split(" ")).map(word => (word, 1)).
   reduceByKey(_ + _)
   counts.saveAsTextFile("/tmp/wordcount")
   ```

6. Use one of the following approaches to view job output:

   - View output in the Scala shell:

     ```
     scala> counts.count()
     ```

   - View the full output from within the Scala shell:

     ```
     scala> counts.toArray().foreach(println)
     ```

- View the output using HDFS:

  a. Exit the Scala shell.

  b. View WordCount job status:

  ```
  hadoop fs -ls /tmp/wordcount
  ```

  You should see output similar to the following:

  ```
  /tmp/wordcount/_SUCCESS
  /tmp/wordcount/part-00000
  /tmp/wordcount/part-00001
  ```

  c. Use the HDFS `cat` command to list WordCount output:

  ```
  hadoop fs -cat /tmp/wordcount/part-00000
  ```

4.3. Running Sample Spark 2.x Applications

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

4.3.1. 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. Log on as a user with Hadoop Distributed File System (HDFS) access: for example, your `spark` user, if you defined one, or `hdfs`.

   When the job runs, the library is uploaded into HDFS, so the user running the job needs permission to write to HDFS.

2. Navigate to a node with a Spark client and access the `spark2-client` directory:

   ```
   cd /usr/hdp/current/spark2-client

   su spark
   ```

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

   ```
   ./bin/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.
scala: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 and Troubleshooting Spark.)

4.3.2. WordCount

WordCount is a simple program that counts how often a word occurs in a text file. The code builds a dataset of (String, Int) pairs called `counts`, and saves the dataset to a file.

The following example submits WordCount code to the Scala shell:

1. Select an input file for the Spark WordCount example.

   You can use any text file as input.

2. Log on as a user with HDFS access: for example, your `spark` user (if you defined one) or `hdfs`.

   The following example uses `log4j.properties` as the input file:

   ```
   cd /usr/hdp/current/spark2-client/
   ```

```
su spark
```

3. Upload the input file to HDFS:

```
hadoop fs -copyFromLocal /etc/hadoop/conf/log4j.properties /tmp/
data
```

4. Run the Spark shell:

```
./bin/spark-shell --master yarn-client --driver-memory 512m --
executor-memory 512m
```

You should see output similar to the following (with additional status messages):

```
Spark context Web UI available at http://172.26.236.247:4041
Spark context available as 'sc' (master = yarn, app id =
 application_1490217230866_0002).
Spark session available as 'spark'.
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /___/ .__/\_,_/_/ /_/\_\   version 2.1.0.2.6.0.0-598
      /_/

Using Scala version 2.11.8 (Java HotSpot(TM) 64-Bit Server VM, Java 1.8.
0_112)
Type in expressions to have them evaluated.
Type :help for more information.

scala>
```

5. At the `scala>` prompt, submit the job by typing the following commands, replacing node names, file name, and file location with your own values:

```
val file = sc.textFile("/tmp/data")
val counts = file.flatMap(line => line.split(" ")).map(word => (word, 1)).
reduceByKey(_ + _)
counts.saveAsTextFile("/tmp/wordcount")
```

6. Use one of the following approaches to view job output:

   - View output in the Scala shell:

     ```
     scala> counts.count()
     ```

   - View the full output from within the Scala shell:

     ```
     scala> counts.toArray().foreach(println)
     ```

   - View the output using HDFS:

     a. Exit the Scala shell.

     b. View WordCount job status:

        ```
        hadoop fs -ls /tmp/wordcount
        ```

You should see output similar to the following:

```
/tmp/wordcount/_SUCCESS
/tmp/wordcount/part-00000
/tmp/wordcount/part-00001
```

c. Use the HDFS `cat` command to list WordCount output:

```
hadoop fs -cat /tmp/wordcount/part-00000
```

4.4. Running Spark Applications through Livy

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

- Livy 0.3.0 supports Spark1, Spark2, Scala 2.10, and Scala 2.11.
- From the API level, Livy 0.3.0 supports full Spark2 functionality including SparkSession, and SparkSession with Hive enabled.

Livy extends Spark capabilities, offering additional multi-tenancy and security features. Multiple users can share the same server ("user impersonation" support). Jobs can be submitted from anywhere, using the Livy REST API.

To install Livy on an Ambari-managed cluster, see Installing Spark Using Ambari. To install Livy on a cluster not managed by Ambari, see the Spark sections of the *Command Line Installation Guide*.

For additional configuration steps, see Configuring the Livy Server.

4.4.1. Using Livy with Spark1 and Spark2

In HDP 2.6, Livy supports both Spark1 and Spark2 in one build. To specify which version of Spark to use, set SPARK_HOME to Spark1 or Spark2. Livy automatically differentiates between the two.

Here is a sample `export` statement in the `livy-env.sh` file:

```
export SPARK_HOME=<path-to>/spark-2.1.0-bin-hadoop2.6
```

Livy also supports Scala versions 2.10 and 2.11. For the default Scala builds, Spark 1.6 with Scala 2.10 or 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.

4.4.2. Running Spark Jobs Using Livy

Livy supports programmatic and interactive access to Spark:

- Develop a Scala, Java, or Python client that uses the Livy API.

- Run an interactive session, provided by spark-shell, PySpark, or SparkR REPLs.
- Use an interactive notebook to access Spark through Livy.
- Submit batch applications to Spark.

Both approaches are described in more detail in this subsection.

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

4.4.2.1. Using the Livy API to Run Spark Jobs

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

The following two examples calculate Pi. The first example uses the Spark API; the second example uses the Livy API.

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:

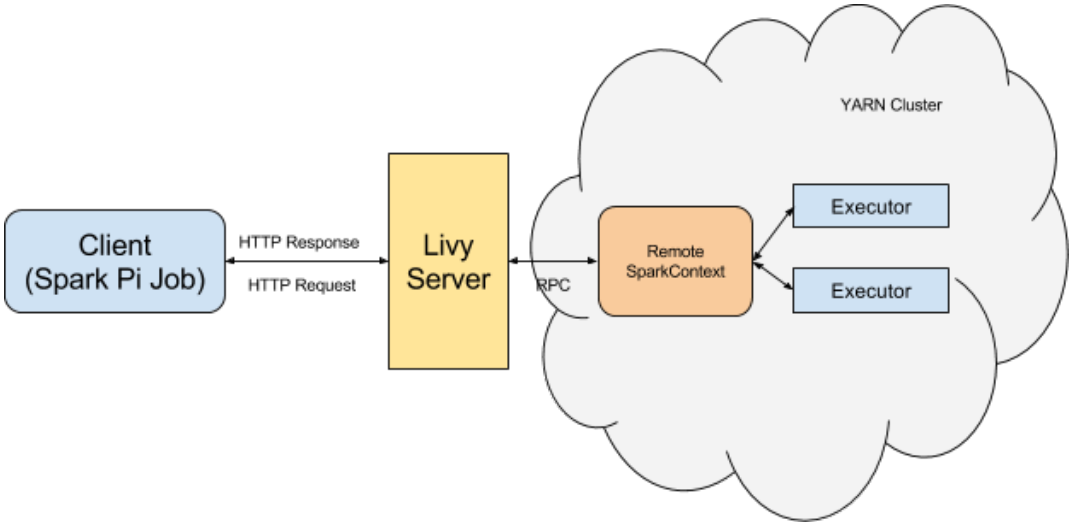
```
def f(_):
    x = random() * 2 - 1
    y = random() * 2 - 1
    return 1 if x ** 2 + y ** 2 <= 1 else 0
    def pi_job(context):
    count = context.sc.parallelize(range(1, samples + 1), slices).map(f).
reduce(add)
    return 4.0 * count / samples
```

Aside from a difference how the entry point is obtained (SparkContext), the logic is the same for both examples.

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, for execution. While the job runs the client waits for the result, using the same path. The following diagram illustrates the process:



4.4.2.2. Running an Interactive Session

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

Livy offers several REST APIs for interactive sessions. The following examples describe how to create an interactive session, submit a statement, and get the result of the statement.

Create an Interactive Session

The following example creates an interactive Spark session. The return ID could be used for further querying. This POST request will bring up a new Spark cluster with a remote Spark interpreter, this remote Spark interpreter is used to receive, execute code snippets and return back 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'}
```

Submit a Statement

The following 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}
```

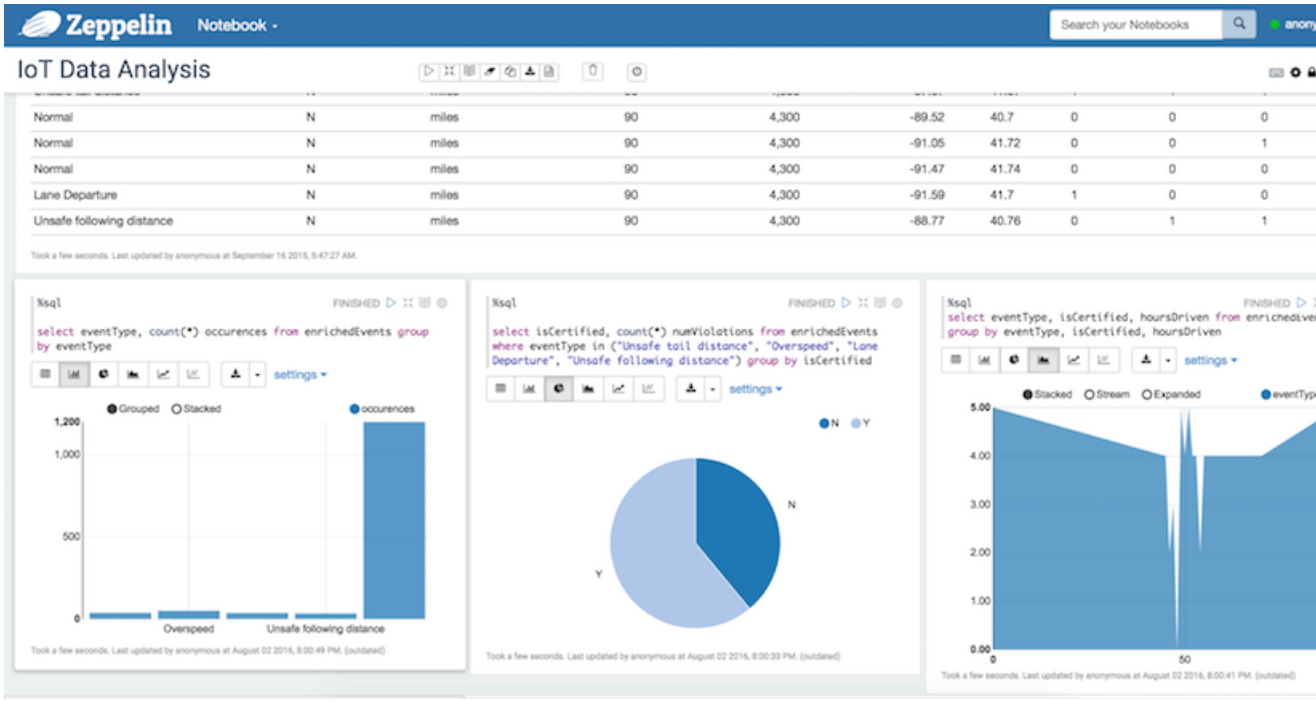
Get the Result of a Statement

The result of a statement is returned in JSON format, which you can parse to extract elements of the result.

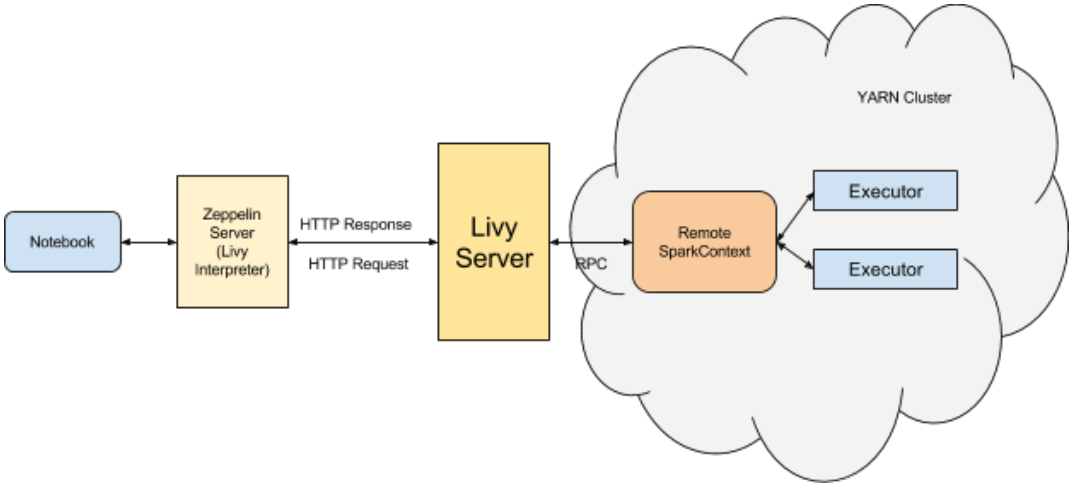
```
GET /sessions/{sessionId}/statements/{statementId}

        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'}
```

4.4.2.3. Using Livy with Interactive Notebooks

Another way to interact with Spark is to use the Apache Zeppelin notebook tool:



After you add code to a Zeppelin notebook, the notebook offloads code execution to Livy and Spark:



4.4.2.4. Submitting Batch Applications to Spark

Spark provides a `spark-submit` command for submitting Spark applications.

Livy provides equivalent functionality through REST APIs. Here is an example that translates `spark-submit` command-line instructions into POST requests.

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 job using Livy:

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.

Note that this POST request does not upload local jars to the cluster. You should add those dependencies to HDFS before running the job. This is the main difference between the Livy API and `spark-submit`.

4.5. Using Apache Oozie Workflows to Automate Apache Spark Jobs

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 the Apache Oozie Spark Action Extension documentation. For general information about Oozie, see Using HDP for Workflow and Scheduling with Oozie. For general information about using Workflow Manager, see the Workflow Management Guide.

Note

In HDP 2.6, Oozie works with either Spark 1 or Spark 2 (not side-by-side deployments). Note, however, that Spark 2 support for Oozie Spark action is available as a technical preview; it is not ready for production deployment. Configuration is through manual steps (not Ambari). For more information, see Configuring Oozie Spark Action for Spark 2.

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.

4.5.1. Configuring Oozie Spark Action

To place a Spark job into an Oozie workflow, you need two configuration files:

- A workflow XML file that defines workflow logic and parameters for running the Spark job. Some of the elements in a Spark action are specific to Spark; others are common to many types of actions.
- A `job.properties` file for configuring the Oozie job.

You can configure a Spark action manually, or on an Ambari-managed cluster you can use the Spark action editor in the Ambari Oozie Workflow Manager (WFM). The Workflow Manager is designed to help build powerful workflows.

For two examples that use Oozie Workflow Manager–one that creates a new Spark action, and another that imports and runs an existing Spark workflow–see the Hortonworks Community Connection article Apache Ambari Workflow Manager View for Apache Oozie: Part 7 (Spark Action & PySpark).

Here is the basic structure of a workflow definition XML file for a Spark action:

```
<workflow-app name="[WF-DEF-NAME]" xmlns="uri:oozie:workflow:0.3">
    ...
```

```
    <action name="[NODE-NAME]">
        <spark xmlns="uri:oozie:spark-action:0.1">
            <job-tracker>[JOB-TRACKER]</job-tracker>
            <name-node>[NAME-NODE]</name-node>
            <prepare>
               <delete path="[PATH]"/>
               ...
               <mkdir path="[PATH]"/>
               ...
            </prepare>
            <job-xml>[SPARK SETTINGS FILE]</job-xml>
            <configuration>
                <property>
                    <name>[PROPERTY-NAME]</name>
                    <value>[PROPERTY-VALUE]</value>
                </property>
                ...
            </configuration>
            <master>[SPARK MASTER URL]</master>
            <mode>[SPARK MODE]</mode>
            <name>[SPARK JOB NAME]</name>
            <class>[SPARK MAIN CLASS]</class>
            <jar>[SPARK DEPENDENCIES JAR / PYTHON FILE]</jar>
            <spark-opts>[SPARK-OPTIONS]</spark-opts>
            <arg>[ARG-VALUE]</arg>
                ...
            <arg>[ARG-VALUE]</arg>
            ...
        </spark>
        <ok to="[NODE-NAME]"/>
        <error to="[NODE-NAME]"/>
    </action>
    ...
</workflow-app>
```

The following examples show a workflow definition XML file and an Oozie job configuration file for running a SparkPi job (Spark version 1.x).

Sample `Workflow.xml` file for `SparkPi` app:

```
<workflow-app xmlns='uri:oozie:workflow:0.5# name='SparkWordCount'>
      <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>
            <prepare>
              <delete path="${nameNode}/user/${wf:user()}/${examplesRoot}/
output-data"/>
            </prepare>
            <master>${master}</master>
            <name>SparkPi</name>
            <class>org.apache.spark.examples.SparkPi</class>
            <jar>lib/spark-examples.jar</jar>
            <spark-opts>--executor-memory 20G --num-executors 50</spark-opts>
            <arg>value=10</arg>
          </spark>
          <ok to="end" />
          <error to="fail" />
        </action>
```

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

Sample `Job.properties` file for `SparkPi` app:

```
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}/apps/
pyspark
master=yarn-cluster
```

4.5.2. Configuring Oozie Spark Action for Spark 2

To use Oozie Spark action with Spark 2 jobs, create a `spark2` ShareLib directory, copy associated files into it, and then point Oozie to `spark2`. (The Oozie ShareLib is a set of libraries that allow jobs to run on any node in a cluster.)

1. Create a `spark2` ShareLib directory under the Oozie ShareLib directory associated with the `oozie` service user:

   ```
   hdfs dfs -mkdir /user/oozie/share/lib/lib_<ts>/spark2
   ```

2. Copy `spark2` jar files from the `spark2` jar directory to the Oozie `spark2` ShareLib:

   ```
   hdfs dfs -put \
       /usr/hdp/<version>/spark2/jars/* \
       /user/oozie/share/lib/lib_<ts>/spark2/
   ```

3. Copy the `oozie-sharelib-spark` jar file from the `spark` ShareLib directory to the `spark2` ShareLib directory:

   ```
   hdfs dfs -cp \
       /user/oozie/share/lib/lib_<ts>/spark/oozie-sharelib-spark-<version>.jar
    \
       /user/oozie/share/lib/lib_<ts>/spark2/
   ```

4. Copy the `hive-site.xml` file from the current `spark` ShareLib to the `spark2` ShareLib:

   ```
   hdfs dfs -cp \
       /user/oozie/share/lib/lib_<ts>/spark/hive-site.xml \
       /user/oozie/share/lib/lib_<ts>/spark2/
   ```

5. Copy Python libraries to the `spark2` ShareLib:

   ```
   hdfs dfs -put \
       /usr/hdp/<version>/spark2/python/lib/py* \
       /user/oozie/share/lib/lib_<ts>/spark2/
   ```

6. Run the Oozie `sharelibupdate` command:

   ```
   oozie admin –sharelibupdate
   ```

To verify the configuration, run the Oozie `shareliblist` command. You should see `spark2` in the results.

```
oozie admin –shareliblist spark2
```

To run a Spark job with the `spark2` ShareLib, add the `action.sharelib.for.spark` property to the `job.properties` file, and set its value to `spark2`:

```
oozie.action.sharelib.for.spark=spark2
```

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

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

5. Using Spark Extensions

Depending on your use case, you can extend your use of Spark into several domains, including:

- Spark DataFrames
- Spark SQL
- Spark Streaming
- Accessing HBase tables, HDFS files, and ORC data (Hive)
- Custom libraries

5.1. Using the Spark DataFrame API

A DataFrame is a distributed collection of data organized into named columns. It is conceptually equivalent to a table in a relational database or a data frame in R or in the Python `pandas` library. You can construct DataFrames from a wide array of sources, including structured data files, Apache Hive tables, and existing Spark resilient distributed datasets (RDD). The Spark DataFrame API is available in Scala, Java, Python, and R.

This subsection contains several examples of DataFrame API use.

To list JSON file contents as a DataFrame:

1. As user `spark`, upload the `people.txt` and `people.json` sample files to the Hadoop Distributed File System (HDFS):

```
cd /usr/hdp/current/spark-client
su spark
hdfs dfs -copyFromLocal examples/src/main/resources/people.txt people.txt
hdfs dfs -copyFromLocal examples/src/main/resources/people.json people.json
```

2. Launch the Spark shell:

```
cd /usr/hdp/current/spark-client
su spark
./bin/spark-shell --num-executors 1 --executor-memory 512m --master yarn-
client
```

3. At the Spark shell, type the following:

```
scala> val df = sqlContext.read.format("json").load("people.json")
```

4. Using `df.show`, display the contents of the DataFrame:

```
scala> df.show
17/03/12 11:24:10 INFO YarnScheduler: Removed TaskSet 2.0, whose tasks have
 all completed, from pool

+----+-------+
| age|   name|
+----+-------+
|null|Michael|
|  30|   Andy|
|  19| Justin|
+----+-------+
```

The following examples use Scala to access DataFrame `df` defined in the previous subsection:

```
// Import the DataFrame functions API
scala> import org.apache.spark.sql.functions._

// Select all rows, but increment age by 1
scala> df.select(df("name"), df("age") + 1).show()

// Select people older than 21
scala> df.filter(df("age") > 21).show()

// Count people by age
scala> df.groupBy("age").count().show()
```

The following example uses the DataFrame API to specify a schema for `people.txt`, and then retrieves names from a temporary table associated with the schema:

```
import org.apache.spark.sql._

val sqlContext = new org.apache.spark.sql.SQLContext(sc)
val people = sc.textFile("people.txt")
val schemaString = "name age"

import org.apache.spark.sql.types.{StructType,StructField,StringType}

val schema = StructType(schemaString.split(" ").map(fieldName =>
 StructField(fieldName, StringType, true)))
val rowRDD = people.map(_.split(",")).map(p => Row(p(0), p(1).trim))
val peopleDataFrame = sqlContext.createDataFrame(rowRDD, schema)

peopleDataFrame.registerTempTable("people")

val results = sqlContext.sql("SELECT name FROM people")

results.map(t => "Name: " + t(0)).collect().foreach(println)
```

This produces output similar to the following:

```
17/03/12 14:36:49 INFO cluster.YarnScheduler: Removed TaskSet 13.0, whose
 tasks have all completed, from pool
17/03/12 14:36:49 INFO scheduler.DAGScheduler: ResultStage 13 (collect at :33)
 finished in 0.129 s
17/03/12 14:36:49 INFO scheduler.DAGScheduler: Job 10 finished: collect
 at :33, took 0.162827 s
Name: Michael
Name: Andy
Name: Justin
```

5.2. Using Spark SQL

Using SQLContext, Apache Spark SQL can read data directly from the file system. This is useful when the data you are trying to analyze does not reside in Apache Hive (for example, JSON files stored in HDFS).

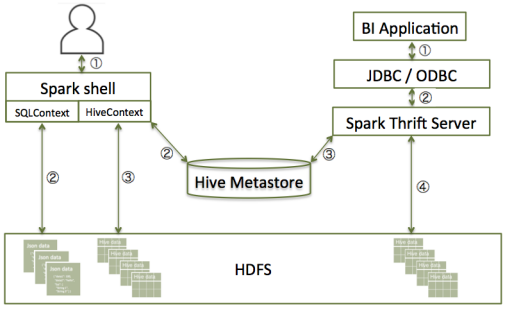
Using HiveContext, Spark SQL can also read data by interacting with the Hive MetaStore. If you already use Hive, you should use HiveContext; it supports all Hive data formats and user-defined functions (UDFs), and it enables you to have full access to the HiveQL parser. HiveContext extends SQLContext, so HiveContext supports all SQLContext functionality.

There are two ways to interact with Spark SQL:

- Interactive access using the Spark shell (see Accessing Spark SQL through the Spark Shell).
- From an application, operating through one of the following two APIs and the Spark Thrift server:
  - JDBC, using your own Java code or the Beeline JDBC client
  - ODBC, through the Simba ODBC driver

  For more information about JDBC and ODBC access, see Accessing Spark SQL through JDBC: Prerequisites and Accessing Spark SQL through JDBC and ODBC.

The following diagram illustrates the access process, depending on whether you are using the Spark shell or business intelligence (BI) application:



This subsection describes how to access Spark SQL through the Spark shell, and through JDBC and ODBC.

5.2.1. Accessing Spark SQL through the Spark Shell

The following sample command launches the Spark shell on a YARN cluster:

```
./bin/spark-shell --num-executors 1 --executor-memory 512m --
master yarn-client
```

To read data directly from the file system, construct a SQLContext. For an example that uses SQLContext and the Spark DataFrame API to access a JSON file, see Using the Spark DataFrame API.

To read data by interacting with the Hive Metastore, construct a HiveContext instance (HiveContext extends SQLContext). For an example of the use of HiveContext (instantiated as `val sqlContext`), see Accessing ORC Files from Spark.

5.2.2. Accessing Spark SQL through JDBC or ODBC: Prerequisites

Using the Spark Thrift server, you can remotely access Spark SQL over JDBC (using the JDBC Beeline client) or ODBC (using the Simba driver).

The following prerequisites must be met before accessing Spark SQL through JDBC or ODBC:

- The Spark Thrift server must be deployed on the cluster.
  - For an Ambari-managed cluster, deploy and launch the Spark Thrift server using the Ambari web UI (see Installing and Configuring Spark Over Ambari).
  - For a cluster that is not managed by Ambari, see Starting the Spark Thrift Server in the *Non-Ambari Cluster Installation Guide*.
- Ensure that SPARK_HOME is defined as your Spark directory:

  ```
  export SPARK_HOME=/usr/hdp/current/spark-client
  ```

If you want to enable user impersonation for the Spark Thrift server, so that the Thrift server runs Spark SQL jobs as the submitting user, see Configuring the Spark Thrift server.

Before accessing Spark SQL through JDBC or ODBC, note the following caveats:

- The Spark Thrift server works in YARN client mode only.
- ODBC and JDBC client configurations must match Spark Thrift server configuration parameters. For example, if the Thrift server is configured to listen in binary mode, the client should send binary requests and use HTTP mode when the Thrift server is configured over HTTP.
- All client requests coming to the Spark Thrift server share a SparkContext.

Additional Spark Thrift Server Commands

To list available Thrift server options, run `./sbin/start-thriftserver.sh --help`.

To manually stop the Spark Thrift server, run the following commands:

```
su spark
./sbin/stop-thriftserver.sh
```

5.2.3. Accessing Spark SQL through JDBC

To access Spark SQL through JDBC, you need a JDBC URL connection string to supply connection information to the JDBC data source. Connection strings for the Spark SQL JDBC driver have the following format:

```
jdbc:hive2://<host>:<port>/<dbName>;<sessionConfs>?
<hiveConfs>#<hiveVars>
```

JDBC Parameter	Description
`host`	The node hosting the Thrift server
`port`	The port number on which the Thrift server listens
`dbName`	The name of the Hive database to run the query against
`sessionConfs`	Optional configuration parameters for the JDBC or ODBC driver in the following format: `<key1>=<value1>;<key2>=<key2>...;`
`hiveConfs`	Optional configuration parameters for Hive on the server in the following format: `<key1>=<value1>;<key2>=<key2>; ...` These settings last for the duration of the user session.
`hiveVars`	Optional configuration parameters for Hive variables in the following format: `<key1>=<value1>;<key2>=<key2>; ...` These settings persist for the duration of the user session.

Note

The Spark Thrift server is a variant of HiveServer2, so you can use many of the same settings. For more information about JDBC connection strings, including transport and security settings, see Hive JDBC and ODBC Drivers in the *HDP Data Access Guide*.

The following connection string accesses Spark SQL through JDBC on a Kerberos-enabled cluster:

```
beeline> !connect jdbc:hive2://localhost:10002/default;httpPath=/;principal=
hive/hdp-team.example.com@EXAMPLE.COM
```

The following connection string accesses Spark SQL through JDBC over HTTP transport on a Kerberos-enabled cluster:

```
beeline> !connect jdbc:hive2://localhost:10002/default;transportMode=
http;httpPath=/;principal=hive/hdp-team.example.com@EXAMPLE.COM
```

To access Spark SQL, complete the following steps:

1. Connect to the Thrift server over the Beeline JDBC client.
   a. From the SPARK_HOME directory, launch Beeline:

```
su spark
./bin/beeline
```

b. At the Beeline prompt, connect to the Spark SQL Thrift server with the JDBC connection string:

```
beeline> !connect jdbc:hive2://localhost:10015
```

The host port must match the host port on which the Spark Thrift server is running.

You should see output similar to the following:

```
beeline> !connect jdbc:hive2://localhost:10015
Connecting to jdbc:hive2://localhost:10015
Enter username for jdbc:hive2://localhost:10015:
Enter password for jdbc:hive2://localhost:10015:
...
Connected to: Spark SQL (version 1.6.3)
Driver: Spark Project Core (version 1.6.3.2.4.0.0-169)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://localhost:10015>
```

2. When connected, issue a Spark SQL statement.

The following example executes a SHOW TABLES query:

```
0: jdbc:hive2://localhost:10015> show tables;
+------------+--------------+--+
| tableName  | isTemporary  |
+------------+--------------+--+
| sample_07  | false        |
| sample_08  | false        |
| testtable  | false        |
+------------+--------------+--+
3 rows selected (2.399 seconds)
0: jdbc:hive2://localhost:10015>
```

5.2.4. Accessing Spark SQL through ODBC

If you want to access Spark SQL through ODBC, first download the ODBC Spark driver for the operating system you want to use for the ODBC client. After downloading the driver, refer to the *Hortonworks ODBC Driver with SQL Connector for Apache Spark User Guide* for installation and configuration instructions.

Drivers and associated documentation are available in the "Hortonworks Data Platform Add-Ons" section of the Hortonworks downloads page (http://hortonworks.com/downloads/) under "Hortonworks ODBC Driver for SparkSQL." If the latest version of HDP is newer than your version, check the Hortonworks Data Platform Archive area of the add-ons section for the version of the driver that corresponds to your version of HDP.

5.2.5. Spark SQL User Impersonation

When user impersonation is enabled for Spark SQL through the Spark Thrift server, the Thrift server runs queries as the submitting user. By running queries under the user account associated with the submitter, the Thrift Server can enforce user level permissions and access control lists. This enables granular access control to Spark SQL at the level of files or tables. Associated data cached in Spark is visible only to queries from the submitting user.

Spark SQL user impersonation is supported for Apache Spark 1 versions 1.6.3 and later. To enable user impersonation, see Enabling User Impersonation for the Spark Thrift Server. The following paragraphs illustrate several features of user impersonation.

5.2.5.1. Permissions and ACL Enforcement

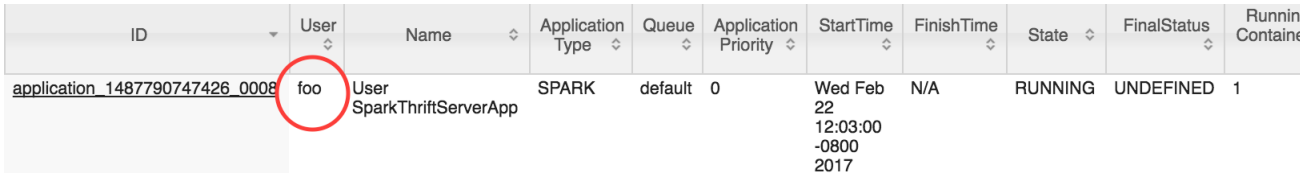
When user impersonation is enabled, permissions and ACL restrictions are applied on behalf of the submitting user. In the following example, “foo_db” database has a table “drivers”, which only user “foo” can access:

```
[root@sandbox spark]# hdfs dfs -ls  /apps/hive/warehouse/foo_db.db
Found 1 items
drwx------   - foo hdfs          0 2017-02-22 14:59 /apps/hive/warehouse/
[root@sandbox spark]#
```

A Beeline session running as user “foo” can access the data, read the drivers table, and create a new table based on the table:

```
[foo@sandbox ~]$ beeline
Beeline version 1.2.1000.2.5.3.0-37 by Apache Hive
beeline> !connect jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM
Connecting to jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM
Enter username for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM:
Enter password for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM:
Connected to: Spark SQL (version 1.6.3)
Driver: Hive JDBC (version 1.2.1000.2.5.3.0-37)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://sandbox.hortonworks.com:10015> show tables;
+------------+--------------+--+
| tableName  | isTemporary  |
+------------+--------------+--+
| drivers    | false        |
+------------+--------------+--+
1 row selected (0.244 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015> select * from drivers limit 2;
+-----------+--------------------+------------+---------------------+------------+-----------+--+
| driverid  |        name        |    ssn     |      location       | certified  | wageplan  |
+-----------+--------------------+------------+---------------------+------------+-----------+--+
| 10        | George Vetticaden  | 621011971  | 244-4532 Nulla Rd.  | N          | miles     |
| 11        | Jamie Engesser     | 262112338  | 366-4125 Ac Street  | N          | miles     |
+-----------+--------------------+------------+---------------------+------------+-----------+--+
2 rows selected (7.505 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015> create table driver_data like drivers;
+---------+--+
| result  |
+---------+--+
+---------+--+
No rows selected (0.658 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015> insert into driver_data select * from drivers;
+---------+--+
| Result  |
+---------+--+
+---------+--+
No rows selected (1.33 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015> select * from driver_data limit 2;
+-----------+--------------------+------------+---------------------+------------+-----------+--+
| driverid  |        name        |    ssn     |      location       | certified  | wageplan  |
+-----------+--------------------+------------+---------------------+------------+-----------+--+
| 10        | George Vetticaden  | 621011971  | 244-4532 Nulla Rd.  | N          | miles     |
| 11        | Jamie Engesser     | 262112338  | 366-4125 Ac Street  | N          | miles     |
+-----------+--------------------+------------+---------------------+------------+-----------+--+
2 rows selected (0.331 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015>
```

Spark queries run in a YARN application as user “foo”:



ID	User	Name	Application Type	Queue	Application Priority	StartTime	FinishTime	State	FinalStatus	Runnin Containe
application_1487790747426_0008	foo	User SparkThriftServerApp	SPARK	default	0	Wed Feb 22 12:03:00 -0800 2017	N/A	RUNNING	UNDEFINED	1

All user permissions and access control lists are enforced while accessing tables, data or other resources. In addition, all output generated is for user “foo”.

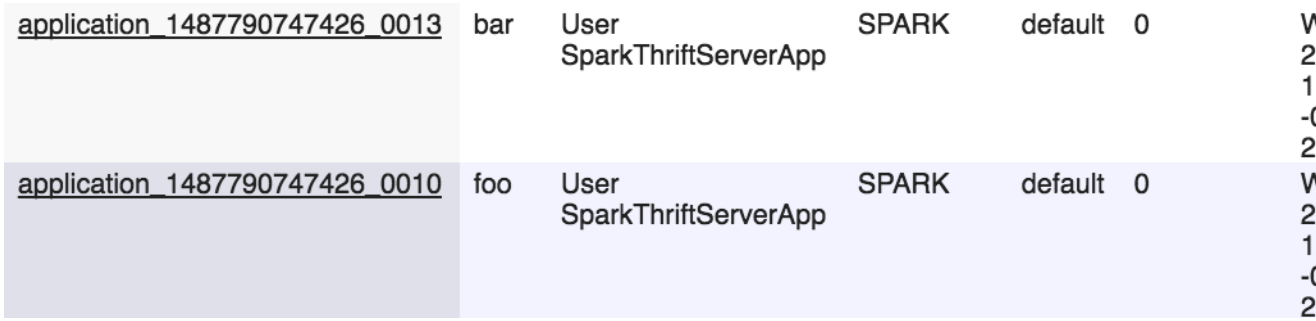
For the table created in the preceding Beeline session, the owner is user “foo”:

```
[root@sandbox spark]# hdfs dfs -ls  /apps/hive/warehouse/foo_db.db
Found 2 items
drwxr-xr-x   - foo hdfs          0 2017-02-22 15:45 /apps/hive/warehouse/foo_db.db/driver_data
drwx------   - foo hdfs          0 2017-02-22 14:59 /apps/hive/warehouse/foo_db.db/drivers
[root@sandbox spark]#
```

The per-user Spark Application Master ("AM") caches data in memory without other users being able to access the data–cached data and state are restricted to the Spark AM running the query. Data and state information are not stored in the Spark Thrift server, so they are not visible to other users. Spark master runs as yarn-cluster, but query execution works as though it is yarn-client (essentially a yarn-cluster user program that accepts queries from STS indefinitely).

5.2.5.2. Spark Thrift Server as Proxy

The Spark Thrift server does not run user queries; it forwards them to the appropriate user-specific Spark AM. This improves the scalability and fault tolerance of the Spark Thrift server.



application_1487790747426_0013	bar	User SparkThriftServerApp	SPARK	default	0	W 2 1 -(2
application_1487790747426_0010	foo	User SparkThriftServerApp	SPARK	default	0	W 2 1 -(2

When user impersonation is enabled for the Spark Thrift server, the Thrift Server is responsible for the following features and capabilities:

- Authorizing incoming user connections (SASL authorization that validates the user Beeline/socket connection).
- Managing Spark applications launched on behalf of users:
  - Launching Spark application if no appropriate application exists for the incoming request.
  - Terminating the Spark AM when all associated user connections are closed at the Spark Thrift server.
- Acting as a proxy and forwarding requests/responses to the appropriate user’s Spark AM.

- Ensuring that long-running Spark SQL sessions persist, by keeping the Kerberos state valid.
  - The Spark Thrift server and Spark AM, when launched on behalf of a user, can be long-running applications in clusters with Kerberos enabled.
  - The submitter's principal and keytab are not required for long-running Spark AM processes, although the Spark Thrift server requires the Hive principal and keytab.

5.2.5.3. Enhancements for Connection URL Support.

The connection URL format for Hive is described in Apache Hive documentation. In user impersonation mode, the Spark Thrift server supports a default database and `hivevar` variables.

Specifying Default Database in the Connection URL

Specifying the connection URL as `jdbc:hive2://$HOST:$PORT/my_db` results in an implicit "use my_db" when a user connects.

For an example, see the preceding Beeline example where the `!connect` command specifies the connection URL for "foo_db".

Support for `hivevar` Variables

Hive variables can be used to parameterize queries. To set a Hive variable, use the `set hivevar` command:

```
set hivevar:key=value
```

You can also set a Hive variable as part of the connection URL. In the following Beeline example, `plan=miles` is appended to the connection URL. The variable is referenced in the query as `${hivevar:plan}`.

```
Beeline version 1.2.1000.2.5.3.0-37 by Apache Hive
beeline> !connect jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;princ
Connecting to jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal
Enter username for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;prin
Enter password for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;prin
Connected to: Spark SQL (version 1.6.3)
Driver: Hive JDBC (version 1.2.1000.2.5.3.0-37)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://sandbox.hortonworks.com:10015>
0: jdbc:hive2://sandbox.hortonworks.com:10015> select * from drivers wher
+-----------+--------------------+------------+---------------------+----
| driverid  |        name        |    ssn     |      location       | cer
+-----------+--------------------+------------+---------------------+----
| 10        | George Vetticaden  | 621011971  | 244-4532 Nulla Rd.  | N
| 11        | Jamie Engesser     | 262112338  | 366-4125 Ac Street  | N
+-----------+--------------------+------------+---------------------+----
2 rows selected (8.897 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015>
```

5.2.5.4. Advanced Connection Management Features

By default, all connections for a user are forwarded to the same Spark AM to execute the query. In some cases, it is necessary to exercise finer-grained control.

Specifying Named Connections

When user impersonation is enabled, Spark supports user-named connections identified by a user-specified `connectionId` (a Hive `conf` parameter in the connection URL). This can be useful when overriding Spark configurations such as queue, memory configuration, or executor configuration settings.

Every Spark AM managed by the Spark Thrift server is associated with a user and `connectionId`. Connection IDs are not globally unique; they are specific to the user.

You can specify `connectionId` to control which Spark AM executes queries. If you not specify `connectionId`, a default connectionId is associated with the Spark AM.

To explicitly name a connection, set the Hive `conf` parameter to `spark.sql.thriftServer.connectionId`, as shown in the following session:

```
[foo@sandbox ~]$ beeline
Beeline version 1.2.1000.2.5.3.0-37 by Apache Hive
beeline> !connect jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftSe
Connecting to jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftServer
Enter username for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftS
Enter password for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftS
Connected to: Spark SQL (version 1.6.3)
Driver: Hive JDBC (version 1.2.1000.2.5.3.0-37)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://sandbox.hortonworks.com:10015>
```

Note: Named connections allow users to specify their own Spark AM connections. They are scoped to individual users, and do not allow a user to access the Spark AM associated with another user.

application_1487790747426_0020	foo	User SparkThriftServerApp connection id = conn1	SPARK	default	0	Wed Feb 22 13:57:15 -0800 2017	N/A	RUNNING	UNDEFINED	1
application_1487790747426_0019	bar	User SparkThriftServerApp connection id = conn1	SPARK	default	0	Wed Feb 22 13:57:01 -0800 2017	N/A	RUNNING	UNDEFINED	1

If the Spark AM is available, the connection is associated with the existing Spark AM.

Data Sharing and Named Connections

Each `connectionId` for a user identifies a different Spark AM.

For a user, cached data is shared and available only within a single AM, not across Spark AM's.

Different user connections on the same Spark AM can leverage previously cached data. Each user connection has its own Hive session (which maintains the current database, Hive variables, and so on), but shares the underlying cached data, executors, and Spark application.

The following example shows a session for the first connection from user "foo" to named connection "conn1":

```
[foo@sandbox ~]$ beeline
Beeline version 1.2.1000.2.5.3.0-37 by Apache Hive
beeline> !connect jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;princ
Connecting to jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal
Enter username for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;prin
Enter password for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;prin
Connected to: Spark SQL (version 1.6.3)
Driver: Hive JDBC (version 1.2.1000.2.5.3.0-37)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://sandbox.hortonworks.com:10015>
0: jdbc:hive2://sandbox.hortonworks.com:10015> select count(*) from drive
+------+--+
| _c0  |
+------+--+
| 34   |
+------+--+
1 row selected (8.32 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015> cache table drivers;
+---------+--+
| Result  |
+---------+--+
+---------+--+
No rows selected (2.242 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015> select count(*) from drive
+------+--+
| _c0  |
+------+--+
| 34   |
+------+--+
1 row selected (0.323 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015>
```

After caching the 'drivers' table, the query runs an order of magnitude faster.

A second connection to the same `connectionId` from user "foo" leverages the cached table from the other active Beeline session, significantly increasing query execution speed:

```
[foo@sandbox ~]$ beeline
Beeline version 1.2.1000.2.5.3.0-37 by Apache Hive
beeline> !connect jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftSe
Connecting to jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftServer
Enter username for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftS
Enter password for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftS
Connected to: Spark SQL (version 1.6.3)
Driver: Hive JDBC (version 1.2.1000.2.5.3.0-37)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://sandbox.hortonworks.com:10015> select count(*) from drivers;
+------+--+
| _c0  |
+------+--+
| 34   |
+------+--+
1 row selected (0.402 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015>
```

Overriding Spark Configuration Settings

If the Spark Thrift server is unable to find an existing Spark AM for a user connection, by default the Thrift server launches a new Spark AM to service user queries. This is applicable to named connections and unnamed connections. When a new Spark AM is to be launched, you can override current Spark configuration settings by specifying them in the connection URL. Specify Spark configuration settings as `hiveconf` variables prepended by the `sparkconf` prefix:

```
Beeline version 1.2.1000.2.5.3.0-37 by Apache Hive
beeline>
beeline> !connect jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftSe
Connecting to jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftServer
Enter username for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftS
Enter password for jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.COM?spark.sql.thriftS
Connected to: Spark SQL (version 1.6.3)
Driver: Hive JDBC (version 1.2.1000.2.5.3.0-37)
Transaction isolation: TRANSACTION_REPEATABLE_READ
0: jdbc:hive2://sandbox.hortonworks.com:10015> select * from drivers where wageplan="miles";
+-----------+--------------------+------------+---------------------+------------+-----------+--+
| driverid  |        name        |    ssn     |      location       | certified  | wageplan  |
+-----------+--------------------+------------+---------------------+------------+-----------+--+
| 10        | George Vetticaden  | 621011971  | 244-4532 Nulla Rd.  | N          | miles     |
| 11        | Jamie Engesser     | 262112338  | 366-4125 Ac Street  | N          | miles     |
+-----------+--------------------+------------+---------------------+------------+-----------+--+
2 rows selected (10.617 seconds)
0: jdbc:hive2://sandbox.hortonworks.com:10015>
```

The following connection URL includes a `spark.executor.memory` setting of 4 GB:

```
jdbc:hive2://sandbox.hortonworks.com:10015/foo_db;principal=hive/_HOST@REALM.
COM?spark.sql.thriftServer.connectionId=my_conn;sparkconf.spark.executor.
memory=4g
```

The environment tab of the Spark application shows the appropriate value:

5.3. Calling Hive User-Defined Functions

You can call built-in Hive UDFs, UDAFs, and UDTFs and custom UDFs from Spark SQL applications if the functions are available in the standard Hive .jar file. When using Hive UDFs, use HiveContext (not SQLContext).

5.3.1. Using Built-in UDFs

The following interactive example reads and writes to HDFS under Hive directories, using `hiveContext` and the built-in `collect_list(col)` UDF. The `collect_list(col)` UDF returns a list of objects with duplicates. In a production environment, this type of

operation runs under an account with appropriate HDFS permissions; the following example uses `hdfs` user.

1. Launch the Spark Shell on a YARN cluster:

```
su hdfs
cd $SPARK_HOME
./bin/spark-shell --num-executors 2 --executor-memory 512m --master yarn-
client
```

2. At the Scala REPL prompt, construct a HiveContext instance:

```
val hiveContext = new org.apache.spark.sql.hive.HiveContext(sc)
```

3. Invoke the Hive `collect_list` UDF:

```
scala> hiveContext.sql("from TestTable SELECT key, collect_list(value) group
 by key order by key").collect.foreach(println)
```

5.3.2. Using Custom UDFs

You can register custom functions in Python, Java, or Scala, and use them within SQL statements.

When using a custom UDF, ensure that the .jar file for your UDF is included with your application, or use the `--jars` command-line option to specify the file.

The following example uses a custom Hive UDF. This example uses the more limited SQLContext, instead of HiveContext.

1. Launch `spark-shell` with `hive-udf.jar` as its parameter:

```
./bin/spark-shell --jars <path-to-your-hive-udf>.jar
```

2. From `spark-shell`, define a function:

```
scala> sqlContext.sql("""create temporary function balance as 'org.package.
hiveudf.BalanceFromRechargesAndOrders'""");
```

3. From `spark-shell`, invoke your UDF:

```
scala> sqlContext.sql("""
create table recharges_with_balance_array as
select
  reseller_id,
  phone_number,
  phone_credit_id,
  date_recharge,
  phone_credit_value,
  balance(orders,'date_order', 'order_value', reseller_id, date_recharge,
 phone_credit_value) as balance
from orders
""");
```

5.4. Using Spark Streaming

Spark Streaming is an extension of the core `spark` package. Using Spark Streaming, your applications can ingest data from sources such as Apache Kafka and Apache Flume; process

the data using complex algorithms expressed with high-level functions like `map`, `reduce`, `join`, and `window`; and send results to file systems, databases, and live dashboards.

Spark Streaming receives live input data streams and divides the data into batches, which are then processed by the Spark engine to generate the final stream of results in batches:

See the Apache Spark Streaming Programming Guide for conceptual information; programming examples in Scala, Java, and Python; and performance tuning recommendations.

Apache Spark 1.6 has built-in support for the Apache Kafka 08 API. If you want to access a Kafka 0.10 cluster using new Kafka 0.10 APIs (such as wire encryption support) from Spark 1.6 streaming jobs, the spark-kafka-0-10-connector package supports a Kafka 0.10 connector for Spark 1.x streaming. See the package readme file for additional documentation.

The remainder of this subsection describes general steps for developers using Spark Streaming with Kafka on a Kerberos-enabled cluster; it includes a sample `pom.xml` file for Spark Streaming applications with Kafka. For additional examples, see the Apache GitHub example repositories for Scala, Java, and Python.

Important

Dynamic Resource Allocation does not work with Spark Streaming.

5.4.1. Prerequisites

Before running a Spark Streaming application, Spark and Kafka must be deployed on the cluster.

Unless you are running a job that is part of the Spark examples package installed by Hortonworks Data Platform (HDP), you must add or retrieve the HDP spark-streaming-kafka .jar file and associated .jar files before running your Spark job.

5.4.2. Building and Running a Secure Spark Streaming Job

Depending on your compilation and build processes, one or more of the following tasks might be required before running a Spark Streaming job:

- If you are using `maven` as a compile tool:

  1. Add the Hortonworks repository to your `pom.xml` file:

```
<repository>
    <id>hortonworks</id>
    <name>hortonworks repo</name>
    <url>http://repo.hortonworks.com/content/repositories/releases/</url>
</repository>
```

2. Specify the Hortonworks version number for Spark streaming Kafka and streaming dependencies to your `pom.xml` file:

```
<dependency>
    <groupId>org.apache.spark</groupId>
    <artifactId>spark-streaming-kafka_2.10</artifactId>
    <version>1.6.3.2.4.2.0-90</version>
</dependency>

<dependency>
    <groupId>org.apache.spark</groupId>
    <artifactId>spark-streaming_2.10</artifactId>
    <version>1.6.3.2.4.2.0-90</version>
    <scope>provided</scope>
</dependency>
```

   Note that the correct version number includes the Spark version and the HDP version.

3. (Optional) If you prefer to pack an uber .jar rather than use the default ("provided"), add the `maven-shade-plugin` to your `pom.xml` file:

```
<plugin>
    <groupId>org.apache.maven.plugins</groupId>
    <artifactId>maven-shade-plugin</artifactId>
    <version>2.3</version>
    <executions>
        <execution>
            <phase>package</phase>
            <goals>
                <goal>shade</goal>
            </goals>
        </execution>
    </executions>
    <configuration>
        <filters>
            <filter>
                <artifact>*:*</artifact>
                <excludes>
                    <exclude>META-INF/*.SF</exclude>
                    <exclude>META-INF/*.DSA</exclude>
                    <exclude>META-INF/*.RSA</exclude>
                </excludes>
            </filter>
        </filters>
        <finalName>uber-${project.artifactId}-${project.version}</
finalName>
    </configuration>
</plugin>
```

- Instructions for submitting your job depend on whether you used an uber .jar file or not:

- If you kept the default .jar scope and you can access an external network, use `--packages` to download dependencies in the runtime library:

```
spark-submit --master yarn-client \
    --num-executors 1 \
    --packages org.apache.spark:spark-streaming-kafka_2.10:1.6.3.2.4.2.
0-90 \
    --repositories http://repo.hortonworks.com/content/repositories/
releases/ \
    --class <user-main-class> \
    <user-application.jar> \
    <user arg lists>
```

  The artifact and repository locations should be the same as specified in your `pom.xml` file.

- If you packed the .jar file into an uber .jar, submit the .jar file in the same way as you would a regular Spark application:

```
spark-submit --master yarn-client \
    --num-executors 1 \
    --class <user-main-class> \
    <user-uber-application.jar> \
    <user arg lists>
```

For a sample `pom.xml` file, see Sample pom.xml file for Spark Streaming with Kafka.

5.4.3. Running Spark Streaming Jobs on a Kerberos-Enabled Cluster

To run a Spark Streaming job on a Kerberos-enabled cluster, complete the following steps:

1. Select or create a user account to be used as principal.

   This should not be the `kafka` or `spark` service account.

2. Generate a keytab for the user.

3. Create a Java Authentication and Authorization Service (JAAS) login configuration file: for example, `key.conf`.

4. Add configuration settings that specify the user keytab.

   The keytab and configuration files are distributed using YARN local resources. Because they reside in the current directory of the Spark YARN container, you should specify the location as `./v.keytab`.

   The following example specifies keytab location `./v.keytab` for principal `vagrant@example.com`:

```
KafkaClient {
   com.sun.security.auth.module.Krb5LoginModule required
   useKeyTab=true
   keyTab="./v.keytab"
   storeKey=true
   useTicketCache=false
   serviceName="kafka"
   principal="vagrant@EXAMPLE.COM";
};
```

5. In your `spark-submit` command, pass the JAAS configuration file and keytab as local resource files, using the `--files` option, and specify the JAAS configuration file options to the JVM options specified for the driver and executor:

```
spark-submit \
    --files key.conf#key.conf,v.keytab#v.keytab \
    --driver-java-options "-Djava.security.auth.login.config=./key.conf" \
    --conf "spark.executor.extraJavaOptions=-Djava.security.auth.login.
config=./key.conf" \
...
```

6. Pass any relevant Kafka security options to your streaming application.

   For example, the KafkaWordCount example accepts PLAINTEXTSASL as the last option in the command line:

   ```
   KafkaWordCount /vagrant/spark-examples.jar c6402:2181 abc ts 1
   PLAINTEXTSASL
   ```

5.4.4. Sample `pom.xml` File for Spark Streaming with Kafka

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
         xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
             http://maven.apache.org/xsd/maven-4.0.0.xsd">
    <modelVersion>4.0.0</modelVersion>

    <groupId>test</groupId>
    <artifactId>spark-kafka</artifactId>
    <version>1.0-SNAPSHOT</version>

    <repositories>
        <repository>
            <id>hortonworks</id>
            <name>hortonworks repo</name>
            <url>http://repo.hortonworks.com/content/repositories/releases/</
url>
        </repository>
    </repositories>

    <dependencies>
        <dependency>
            <groupId>org.apache.spark</groupId>
            <artifactId>spark-streaming-kafka_2.10</artifactId>
            <version>1.6.3.2.4.2.0-90</version>
        </dependency>
```

```
        <dependency>
            <groupId>org.apache.spark</groupId>
            <artifactId>spark-streaming_2.10</artifactId>
            <version>1.6.3.2.4.2.0-90</version>
            <scope>provided</scope>
        </dependency>
    </dependencies>
    <build>
        <defaultGoal>package</defaultGoal>
        <resources>
            <resource>
                <directory>src/main/resources</directory>
                <filtering>true</filtering>
            </resource>
            <resource>
                <directory>src/test/resources</directory>
                <filtering>true</filtering>
            </resource>
        </resources>
        <plugins>
            <plugin>
                <groupId>org.apache.maven.plugins</groupId>
                <artifactId>maven-resources-plugin</artifactId>
                <configuration>
                    <encoding>UTF-8</encoding>
                </configuration>
                <executions>
                    <execution>
                        <goals>
                            <goal>copy-resources</goal>
                        </goals>
                    </execution>
                </executions>
            </plugin>
            <plugin>
                <groupId>net.alchim31.maven</groupId>
                <artifactId>scala-maven-plugin</artifactId>
                <version>3.2.0</version>
                <configuration>
                    <recompileMode>incremental</recompileMode>
                    <args>
                        <arg>-target:jvm-1.7</arg>
                    </args>
                    <javacArgs>
                        <javacArg>-source</javacArg>
                        <javacArg>1.7</javacArg>
                        <javacArg>-target</javacArg>
                        <javacArg>1.7</javacArg>
                    </javacArgs>
                </configuration>
                <executions>
                    <execution>
                        <id>scala-compile</id>
                        <phase>process-resources</phase>
                        <goals>
                            <goal>compile</goal>
                        </goals>
                    </execution>
                    <execution>
                        <id>scala-test-compile</id>
```

```
                        <phase>process-test-resources</phase>
                        <goals>
                            <goal>testCompile</goal>
                        </goals>
                    </execution>
                </executions>
            </plugin>
            <plugin>
                <groupId>org.apache.maven.plugins</groupId>
                <artifactId>maven-compiler-plugin</artifactId>
                <configuration>
                    <source>1.7</source>
                    <target>1.7</target>
                </configuration>

                <executions>
                    <execution>
                        <phase>compile</phase>
                        <goals>
                            <goal>compile</goal>
                        </goals>
                    </execution>
                </executions>
            </plugin>


            <plugin>
                <groupId>org.apache.maven.plugins</groupId>
                <artifactId>maven-shade-plugin</artifactId>
                <version>2.3</version>
                <executions>
                    <execution>
                        <phase>package</phase>
                        <goals>
                            <goal>shade</goal>
                        </goals>
                    </execution>
                </executions>
                <configuration>
                    <filters>
                        <filter>
                            <artifact>*:*</artifact>
                            <excludes>
                                <exclude>META-INF/*.SF</exclude>
                                <exclude>META-INF/*.DSA</exclude>
                                <exclude>META-INF/*.RSA</exclude>
                            </excludes>
                        </filter>
                    </filters>
                    <finalName>uber-${project.artifactId}-${project.version}</
finalName>
                </configuration>
            </plugin>

        </plugins>

    </build>
</project>
```

5.5. Spark on HBase: Using the HBase Connector

The Spark-HBase connector (`shc`) is a Spark library that supports access to HBase tables as external sources or sinks. Application access is through Spark SQL at the data frame level, with support for optimizations such as partition pruning, predicate pushdown, and scanning.

The connector bridges the gap between the HBase key-value store and complex relational SQL queries. It is useful for Spark applications and interactive tools, as it allows operations such as complex SQL queries on top of an HBase table inside Spark, and table joins against data frames. The connector leverages the standard Spark DataSource API for query optimization.

Note

The Spark HBase connector uses HBase jar files by default. If you want to submit jobs on an HBase cluster with Phoenix enabled, you must include `--jars phoenix-server.jar` in your `spark-submit` command; for example:

```
./bin/spark-submit --class your.application.class \
    --master yarn-client \
    --num-executors 2 \
    --driver-memory 512m \
    --executor-memory 512m --executor-cores 1 \
    --packages com.hortonworks:shc:1.0.0-1.6-s_2.10 \
    --repositories http://repo.hortonworks.com/content/groups/
public/ \
    --jars /usr/hdp/current/phoenix-client/phoenix-server.jar \
    --files /etc/hbase/conf/hbase-site.xml /To/your/application/jar
```

The HBase connector library is available as a Spark package; you can download it from https://github.com/hortonworks-spark/shc. The repository `readme` file contains information about how to use the package with Spark applications.

5.6. Accessing HDFS Files from Spark

This subsection contains information for running Spark jobs over HDFS data.

5.6.1. Specifying Compression

To add a compression library to Spark, you can use the `--jars` option. For an example, see Adding Libraries to Spark.

To save a Spark RDD to HDFS in compressed format, use code similar to the following (the example uses the GZip algorithm):

```
rdd.saveAsHadoopFile("/tmp/spark_compressed",
                     "org.apache.hadoop.mapred.TextOutputFormat",
                     compressionCodecClass="org.apache.hadoop.io.compress.
GzipCodec")
```

For more information about supported compression algorithms, see Configuring HDFS Compression in the *HDFS Administration Guide*.

5.6.2. Accessing HDFS from PySpark

When accessing an HDFS file from PySpark, you must set HADOOP_CONF_DIR in an environment variable, as in the following example:

```
export HADOOP_CONF_DIR=/etc/hadoop/conf
[hrt_qa@ip-172-31-42-188 spark]$ pyspark
[hrt_qa@ip-172-31-42-188 spark]$ >>>lines = sc.textFile("hdfs://
ip-172-31-42-188.ec2.internal:8020/tmp/PySparkTest/file-01")
.......
```

If HADOOP_CONF_DIR is not set properly, you might see the following error:

```
Error from secure cluster

2016-08-22 00:27:06,046|t1.machine|INFO|1580|140672245782272|MainThread|
Py4JJavaError: An error occurred while calling z:org.apache.spark.api.python.
PythonRDD.collectAndServe.
2016-08-22 00:27:06,047|t1.machine|INFO|1580|140672245782272|MainThread|: org.
apache.hadoop.security.AccessControlException: SIMPLE authentication is not
 enabled.  Available:[TOKEN, KERBEROS]
2016-08-22 00:27:06,047|t1.machine|INFO|1580|140672245782272|MainThread|at
 sun.reflect.NativeConstructorAccessorImpl.newInstance0(Native Method)
2016-08-22 00:27:06,047|t1.machine|INFO|1580|140672245782272|
MainThread|at sun.reflect.NativeConstructorAccessorImpl.
newInstance(NativeConstructorAccessorImpl.java:57)
2016-08-22 00:27:06,048|t1.machine|INFO|1580|140672245782272|MainThread|at
{code}
```

5.7. Accessing ORC Data in Hive Tables

Apache Spark on HDP supports the Optimized Row Columnar (ORC) file format, a self-describing, type-aware, column-based file format that is one of the primary file formats supported in Apache Hive. ORC reduces I/O overhead by accessing only the columns that are required for the current query. It requires significantly fewer seek operations because all columns within a single group of row data (known as a stripe) are stored together on disk.

Spark ORC data source supports ACID transactions, snapshot isolation, built-in indexes, and complex data types (such as array, map, and struct), and provides read and write access to ORC files. It leverages the Spark SQL Catalyst engine for common optimizations such as column pruning, predicate push-down, and partition pruning.

This subsection has several examples of Spark ORC integration, showing how ORC optimizations are applied to user programs.

5.7.1. Accessing ORC Files from Spark

To start using ORC, you can define a HiveContext instance:

```
import org.apache.spark.sql._
val sqlContext = new org.apache.spark.sql.hive.HiveContext(sc)
```

The following example uses data structures to demonstrate working with complex types. The Person struct data type has a name, an age, and a sequence of contacts, which are themselves defined by names and phone numbers.

1. Define `Contact` and `Person` data structures:

```
case class Contact(name: String, phone: String)
case class Person(name: String, age: Int, contacts: Seq[Contact])
```

2. Create 100 `Person` records:

```
val records = (1 to 100).map { i =>;
  Person(s"name_$i", i, (0 to 1).map { m => Contact(s"contact_$m", s"phone_
$m") })
}
```

   In the physical file, these records are saved in columnar format. When accessing ORC files through the DataFrame API, you see rows.

3. To write person records as ORC files to a directory named “people”, you can use the following command:

```
sc.parallelize(records).toDF().write.format("orc").save("people")
```

4. Read the objects back:

```
val people = sqlContext.read.format("orc").load("people.json")
```

5. For reuse in future operations, register the new "people" directory as temporary table “people”:

```
people.registerTempTable("people")
```

6. After you register the temporary table “people”, you can query columns from the underlying table:

```
sqlContext.sql("SELECT name FROM people WHERE age < 15").count()
```

In this example the physical table scan loads only columns **name** and **age** at runtime, without reading the **contacts** column from the file system. This improves read performance.

You can also use Spark `DataFrameReader` and `DataFrameWriter` methods to access ORC files.

5.7.2. Enabling Predicate Push-Down Optimization

The columnar nature of the ORC format helps avoid reading unnecessary columns, but it is still possible to read unnecessary rows. The example in this subsection reads all rows in which the age value is between 0 and 100, even though the query requested rows in which the age value is less than 15 (`"...WHERE age < 15"`). Such full table scanning is an expensive operation.

ORC avoids this type of overhead by using predicate push-down, with three levels of built-in indexes within each file: *file level*, *stripe level*, and *row level*:

- File-level and stripe-level statistics are in the file footer, making it easy to determine if the rest of the file must be read.
- Row-level indexes include column statistics for each row group and position, for finding the start of the row group.

ORC uses these indexes to move the filter operation to the data loading phase by reading only data that potentially includes required rows.

This combination of predicate push-down with columnar storage reduces disk I/O significantly, especially for larger datasets in which I/O bandwidth becomes the main bottleneck to performance.

By default, ORC predicate push-down is disabled in Spark SQL. To obtain performance benefits from predicate push-down, you must enable it explicitly, as follows:

```
sqlContext.setConf("spark.sql.orc.filterPushdown", "true")
```

5.7.3. Loading ORC Data into DataFrames by Using Predicate Push-Down

DataFrames look similar to Spark RDDs but have higher-level semantics built into their operators. This allows optimization to be pushed down to the underlying query engine.

Here is the Scala API version of the SELECT query used in the previous section, using the DataFrame API:

```
val sqlContext = new org.apache.spark.sql.hive.HiveContext(sc)
sqlContext.setConf("spark.sql.orc.filterPushdown", "true")
val people = sqlContext.read.format("orc").load("peoplePartitioned")
people.filter(people("age") < 15).select("name").show()
```

DataFrames are not limited to Scala. There is a Java API and, for data scientists, a Python API binding:

```
sqlContext = HiveContext(sc)
sqlContext.setConf("spark.sql.orc.filterPushdown", "true")
people = sqlContext.read.format("orc").load("peoplePartitioned")
people.filter(people.age < 15).select("name").show()
```

5.7.4. Optimizing Queries Through Partition Pruning

When predicate push-down optimization is not applicable—for example, if all stripes contain records that match the predicate condition—a query with a *WHERE* clause might need to read the entire data set. This becomes a bottleneck over a large table. Partition pruning is another optimization method; it exploits query semantics to avoid reading large amounts of data unnecessarily.

Partition pruning is possible when data within a table is split across multiple logical partitions. Each partition corresponds to a particular value of a partition column and is stored as a subdirectory within the table root directory on HDFS. Where applicable, only the required partitions (subdirectories) of a table are queried, thereby avoiding unnecessary I/O.

Spark supports saving data in a partitioned layout seamlessly, through the **partitionBy** method available during data source write operations. To partition the "people" table by the “age” column, you can use the following command:

```
people.write.format("orc").partitionBy("age").save("peoplePartitioned")
```

As a result, records are automatically partitioned by the age field and then saved into different directories: for example, `peoplePartitioned/age=1/`, `peoplePartitioned/age=2/`, and so on.

After partitioning the data, subsequent queries can omit large amounts of I/O when the partition column is referenced in predicates. For example, the following query automatically locates and loads the file under `peoplePartitioned/age=20/`and omits all others:

```
val peoplePartitioned = sqlContext.read.format("orc").
load("peoplePartitioned")
peoplePartitioned.registerTempTable("peoplePartitioned")
sqlContext.sql("SELECT * FROM peoplePartitioned WHERE age = 20")
```

5.7.5. Additional Resources

- Apache ORC website: https://orc.apache.org/
- ORC performance: http://hortonworks.com/blog/orcfile-in-hdp-2-better-compression-better-performance/
- Get Started with Spark: http://hortonworks.com/hadoop/spark/get-started/

5.8. Using Custom Libraries with Spark

Spark comes equipped with a selection of libraries, including Spark SQL, Spark Streaming, and MLlib.

If you want to use a custom library, such as a compression library or Magellan, you can use one of the following two `spark-submit` script options:

- The `--jars` option, which transfers associated .jar files to the cluster. Specify a list of comma-separated .jar files.
- The `--packages` option, which pulls files directly from Spark packages. This approach requires an internet connection.

For example, you can use the `--jars` option to add codec files. The following example adds the LZO compression library:

```
spark-submit --driver-memory 1G \
    --executor-memory 1G \
    --master yarn-client \
    --jars /usr/hdp/2.6.0.3-8/hadoop/lib/hadoop-lzo-0.6.0.2.6.0.3-8.jar \
    test_read_write.py
```

For more information about the two options, see Advanced Dependency Management on the Apache Spark "Submitting Applications" web page.

Note

If you launch a Spark job that references a codec library without specifying where the codec resides, Spark returns an error similar to the following:

```
Caused by: java.lang.IllegalArgumentException: Compression codec
 com.hadoop.compression.lzo.LzoCodec not found.
```

To address this issue, specify the codec file with the `--jars` option in your job submit command.

6. Using Spark from R: SparkR

SparkR is an R package that provides a lightweight front end for using Apache Spark from R, supporting large-scale analytics on Hortonworks Data Platform (HDP) from the R language and environment.

SparkR provides a distributed data frame implementation that supports operations like selection, filtering, and aggregation on large datasets. In addition, SparkR supports distributed machine learning through MLlib.

6.1. Prerequisites

Before you run SparkR, ensure that your cluster meets the following prerequisites:

- R must be installed on all nodes.
- JAVA_HOME must be set on all nodes.

Note: SparkR is not currently supported on SLES. Attempts to run SparkR applications fail with "sparkr.zip does not exist for R application in YARN mode.

6.2. SparkR Example

The following example launches SparkR, and then uses R to create a `people` DataFrame in Spark 1.6. The example then lists part of the DataFrame, and reads the DataFrame. (For more information about Spark DataFrames, see "Using the Spark DataFrame API").

1. Launch SparkR:

```
su spark
cd /usr/hdp/2.6.0.0-598/spark/bin
./sparkR
```

Output similar to the following displays:

```
Welcome to
    ____              __
   / __/__  ___ _____/ /__
  _\ \/ _ \/ _ `/ __/  '_/
 /___/ .__/\_,_/_/ /_/\_\   version  1.6.3
    /_/

Spark context is available as sc, SQL context is available as sqlContext
>
```

2. From your R prompt (not the Spark shell), initialize SQLContext, create a DataFrame, and list the first few rows:

```
sqlContext <- sparkRSQL.init(sc)
df <- createDataFrame(sqlContext, faithful)
head(df)
```

You should see results similar to the following:

```
...
 eruptions waiting
1     3.600      79
2     1.800      54
3     3.333      74
4     2.283      62
5     4.533      85
6     2.883      55
```

3. Read the `people` DataFrame:

```
people <- read.df(sqlContext, "people.json", "json")
head(people)
```

You should see results similar to the following:

```
 age    name
1  NA Michael
2  30    Andy
3  19  Justin
```

6.3. Additional Resources

For additional SparkR examples, see the Apache SparkR documentation.

7. Tuning Spark

When tuning Apache Spark applications, it is important to understand how Spark works and what types of resources your application requires. For example, machine learning tasks are usually CPU intensive, whereas extract, transform, load (ETL) operations are I/O intensive.

This chapter provides an overview of approaches for assessing and tuning Spark performance.

7.1. Provisioning Hardware

For general information about Spark memory use, including node distribution, local disk, memory, network, and CPU core recommendations, see the Apache Spark Hardware Provisioning document.

7.2. Checking Job Status

If a job takes longer than expected or does not finish successfully, check the following to understand more about where the job stalled or failed:

- To list running applications by ID from the command line, use `yarn application –list`.
- To see a description of a resilient distributed dataset (RDD) and its recursive dependencies (useful for understanding how jobs are executed) use `toDebugString()` on the RDD.
- To check the query plan when using the DataFrame API, use `DataFrame#explain()`.

7.3. Checking Job History

You can use the following resources to view job history:

- Spark history server UI: view information about Spark jobs that have completed.
  1. On an Ambari-managed cluster, in the Ambari Services tab, select Spark.
  2. Click Quick Links.
  3. Choose the Spark history server UI.

     Ambari displays a list of jobs.
  4. Click "App ID" for job details.
- Spark history server web UI: view information about Spark jobs that have completed.

  In a browser window, navigate to the history server web UI. The default host port is `<host>:18080`.

- YARN web UI: view job history and time spent in various stages of the job:

  `http://<host>:8088/proxy/<job_id>/environment/`

  `http://<host>:8088/proxy/<app_id>/stages/`

- `yarn logs` command: list the contents of all log files from all containers associated with the specified application.

  `yarn logs -applicationId <app_id>`.

- Hadoop Distributed File System (HDFS) shell or API: view container log files.

  For more information, see "Debugging your Application" in the Apache document Running Spark on YARN.

7.4. Improving Software Performance

To improve Spark performance, assess and tune the following operations:

- Minimize shuffle operations where possible.
- Match join strategy (ShuffledHashJoin vs. BroadcastHashJoin) to the table.

  This requires manual configuration.

- Consider switching from the default serializer to the Kryo serializer to improve performance.

  This requires manual configuration and class registration.

- Adjust YARN memory allocation

The following subsection describes YARN memory allocation in more detail.

7.4.1. Configuring YARN Memory Allocation for Spark

This section describes how to manually configure YARN memory allocation settings based on node hardware specifications.

YARN evaluates all available compute resources on each machine in a cluster and negotiates resource requests from applications running in the cluster. YARN then provides processing capacity to each application by allocating containers. A container is the basic unit of processing capacity in YARN; it is an encapsulation of resource elements such as memory (RAM) and CPU.

In a Hadoop cluster, it is important to balance the use of RAM, CPU cores, and disks so that processing is not constrained by any one of these cluster resources.

When determining the appropriate YARN memory configurations for Spark, note the following values on each node:

- RAM (amount of memory)

- CORES (number of CPU cores)

When configuring YARN memory allocation for Spark, consider the following information:

- Driver memory does not need to be large if the job does not aggregate much data (as with a `collect()` action).
- There are tradeoffs between `num-executors` and `executor-memory`.

  Large executor memory does not imply better performance, due to JVM garbage collection. Sometimes it is better to configure a larger number of small JVMs than a small number of large JVMs.
- Executor processes are not released if the job has not finished, even if they are no longer in use.

  Therefore, do not overallocate executors above your estimated requirements.

In `yarn-cluster` mode, the Spark driver runs inside an application master process that is managed by YARN on the cluster. The client can stop after initiating the application. The following example shows starting a YARN client in `yarn-cluster` mode, specifying the number of executors and associated memory and core, and driver memory. The client starts the default Application Master, and SparkPi runs as a child thread of the Application Master. The client periodically polls the Application Master for status updates and displays them on the console.

```
./bin/spark-submit --class org.apache.spark.examples.SparkPi \
    --master yarn-cluster \
    --num-executors 3 \
    --driver-memory 4g \
    --executor-memory 2g \
    --executor-cores 1 \
    lib/spark-examples*.jar 10
```

In `yarn-client` mode, the driver runs in the client process. The application master is used only to request resources for YARN. To launch a Spark application in `yarn-client` mode, replace `yarn-cluster` with `yarn-client`. The following example launches the Spark shell in `yarn-client` mode and specifies the number of executors and associated memory:

```
./bin/spark-shell --num-executors 32 \
    --executor-memory 24g \
    --master yarn-client
```