Red Hat Streams for Apache Kafka 2.7

Using Streams for Apache Kafka on RHEL in KRaft mode

Configure and manage a deployment of Streams for Apache Kafka 2.7 on Red Hat Enterprise Linux

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Legal Notice

Abstract

Configure the operators and Kafka components deployed with Streams for Apache Kafka to build a large-scale messaging network.

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PREFACE

PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

We appreciate your feedback on our documentation.

To propose improvements, open a Jira issue and describe your suggested changes. Provide as much detail as possible to enable us to address your request quickly.

Prerequisite

- You have a Red Hat Customer Portal account. This account enables you to log in to the Red Hat Jira Software instance.
  If you do not have an account, you will be prompted to create one.

Procedure

1. Click the following: Create issue.
2. In the **Summary** text box, enter a brief description of the issue.
3. In the **Description** text box, provide the following information:
   - The URL of the page where you found the issue.
   - A detailed description of the issue.
     You can leave the information in any other fields at their default values.
4. Add a reporter name.
5. Click **Create** to submit the Jira issue to the documentation team.

Thank you for taking the time to provide feedback.

CHAPTER 1. OVERVIEW OF STREAMS FOR APACHE KAFKA

AMQ streams supports highly scalable, distributed, and high-performance data streaming based on the Apache Kafka project.

The main components comprise:

Kafka Broker

Messaging broker responsible for delivering records from producing clients to consuming clients.

Kafka Streams API

API for writing *stream processor* applications.

Producer and Consumer APIs

Java-based APIs for producing and consuming messages to and from Kafka brokers.

Kafka Bridge

Streams for Apache Kafka Bridge provides a RESTful interface that allows HTTP-based clients to interact with a Kafka cluster.

Kafka Connect

A toolkit for streaming data between Kafka brokers and other systems using *Connector* plugins.

Kafka MirrorMaker

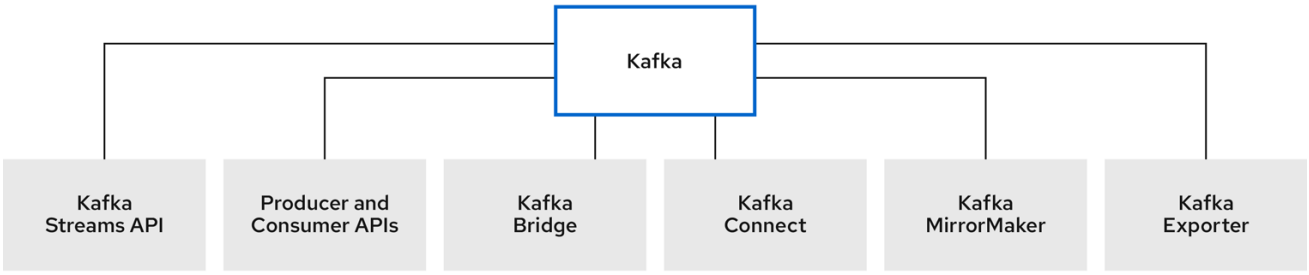
Replicates data between two Kafka clusters, within or across data centers.

Kafka Exporter

An exporter used in the extraction of Kafka metrics data for monitoring.

A cluster of Kafka brokers is the hub connecting all these components.

Figure 1.1. Streams for Apache Kafka architecture



1.1. USING THE KAFKA BRIDGE TO CONNECT WITH A KAFKA CLUSTER

You can use the Streams for Apache Kafka Bridge API to create and manage consumers and send and receive records over HTTP rather than the native Kafka protocol.

When you set up the Kafka Bridge you configure HTTP access to the Kafka cluster. You can then use the Kafka Bridge to produce and consume messages from the cluster, as well as performing other operations through its REST interface.

Additional resources

- For information on installing and using the Kafka Bridge, see Using the Streams for Apache Kafka Bridge.

1.2. DOCUMENT CONVENTIONS

User-replaced values

User-replaced values, also known as *replaceables*, are shown in with angle brackets (< >). Underscores (_) are used for multi-word values. If the value refers to code or commands, **monospace** is also used.

For example, the following code shows that **<bootstrap_address>** and **<topic_name>** must be replaced with your own address and topic name:

```
bin/kafka-console-consumer.sh --bootstrap-server <broker_host>:<port> --topic <topic_name> --from-beginning
```

CHAPTER 2. FIPS SUPPORT

Federal Information Processing Standards (FIPS) are standards for computer security and interoperability. To use FIPS with Streams for Apache Kafka, you must have a FIPS-compliant OpenJDK (Open Java Development Kit) installed on your system. If your RHEL system is FIPS-enabled, OpenJDK automatically switches to FIPS mode when running Streams for Apache Kafka. This ensures that Streams for Apache Kafka uses the FIPS-compliant security libraries provided by OpenJDK.

Minimum password length

When running in the FIPS mode, SCRAM-SHA-512 passwords need to be at least 32 characters long. If you have a Kafka cluster with custom configuration that uses a password length that is less than 32 characters, you need to update your configuration. If you have any users with passwords shorter than 32 characters, you need to regenerate a password with the required length.

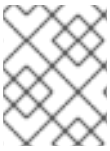
Additional resources

- What are Federal Information Processing Standards (FIPS)

2.1. INSTALLING STREAMS FOR APACHE KAFKA WITH FIPS MODE ENABLED

Enable FIPS mode before you install Streams for Apache Kafka on RHEL. Red Hat recommends installing RHEL with FIPS mode enabled, as opposed to enabling FIPS mode later. Enabling FIPS mode during the installation ensures that the system generates all keys with FIPS-approved algorithms and continuous monitoring tests in place.

With RHEL running in FIPS mode, you must ensure that the Streams for Apache Kafka configuration is FIPS-compliant. Additionally, your Java implementation must also be FIPS-compliant.

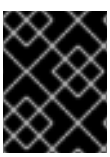


NOTE

Running Streams for Apache Kafka on RHEL in FIPS mode requires a FIPS-compliant JDK.

Procedure

1. Install RHEL in FIPS mode.
   For further information, see the information on security hardening in the RHEL documentation.
2. Proceed with the installation of Streams for Apache Kafka.
3. Configure Streams for Apache Kafka to use FIPS-compliant algorithms and protocols.
   If used, ensure that the following configuration is compliant:
   - SSL cipher suites and TLS versions must be supported by the JDK framework.
   - SCRAM-SHA-512 passwords must be at least 32 characters long.



IMPORTANT

Make sure that your installation environment and Streams for Apache Kafka configuration remains compliant as FIPS requirements change.

CHAPTER 3. GETTING STARTED

Streams for Apache Kafka is distributed in a ZIP file that contains installation artifacts for the Kafka components.

NOTE

The Kafka Bridge has separate installation files. For information on installing and using the Kafka Bridge, see Using the Streams for Apache Kafka Bridge .

3.1. INSTALLATION ENVIRONMENT

Streams for Apache Kafka runs on Red Hat Enterprise Linux. The host (node) can be a physical or virtual machine (VM). Use the installation files provided with Streams for Apache Kafka to install Kafka components. You can install Kafka in a single-node or multi-node environment.

Single-node environment

A single-node Kafka cluster runs instances of Kafka components on a single host. This configuration is not suitable for a production environment.

Multi-node environment

A multi-node Kafka cluster runs instances of Kafka components on multiple hosts.

We recommended that you run Kafka and other Kafka components, such as Kafka Connect, on separate hosts. By running the components in this way, it's easier to maintain and upgrade each component.

Kafka clients establish a connection to the Kafka cluster using the **bootstrap.servers** configuration property. If you are using Kafka Connect, for example, the Kafka Connect configuration properties must include a **bootstrap.servers** value that specifies the hostname and port of the hosts where the Kafka brokers are running. If the Kafka cluster is running on more than one host with multiple Kafka brokers, you specify a hostname and port for each broker. Each Kafka broker is identified by a **node.id**.

3.1.1. Data storage considerations

An efficient data storage infrastructure is essential to the optimal performance of Streams for Apache Kafka.

Block storage is required. File storage, such as NFS, does not work with Kafka.

Choose from one of the following options for your block storage:

- Cloud-based block storage solutions, such as Amazon Elastic Block Store (EBS)
- Local storage
- Storage Area Network (SAN) volumes accessed by a protocol such as *Fibre Channel* or *iSCSI*

3.1.2. File systems

Kafka uses a file system for storing messages. Streams for Apache Kafka is compatible with the XFS and ext4 file systems, which are commonly used with Kafka. Consider the underlying architecture and requirements of your deployment when choosing and setting up your file system.

For more information, refer to Filesystem Selection in the Kafka documentation.

3.2. DOWNLOADING STREAMS FOR APACHE KAFKA

A ZIP file distribution of Streams for Apache Kafka is available for download from the Red Hat website. You can download the latest version of Red Hat Streams for Apache Kafka from the Streams for Apache Kafka software downloads page.

- For Kafka and other Kafka components, download the **amq-streams-<version>-bin.zip** file
- For Kafka Bridge, download the **amq-streams-<version>-bridge-bin.zip** file.
  For installation instructions, see Using the Streams for Apache Kafka Bridge .

3.3. INSTALLING KAFKA

Use the Streams for Apache Kafka ZIP files to install Kafka on Red Hat Enterprise Linux. You can install Kafka in a single-node or multi-node environment. In this procedure, a single Kafka instance is installed on a single host (node).

The Streams for Apache Kafka installation files include the binaries for running other Kafka components, like Kafka Connect, Kafka MirrorMaker 2, and Kafka Bridge. In a single-node environment, you can run these components from the same host where you installed Kafka. However, we recommend that you add the installation files and run other Kafka components on separate hosts.

Prerequisites

- You have downloaded the installation files.
- You have reviewed the supported configurations in the Streams for Apache Kafka 2.7 on Red Hat Enterprise Linux Release Notes.
- You are logged in to Red Hat Enterprise Linux as admin (**root**) user.

Procedure

Install Kafka on your host.

1. Add a new **kafka** user and group:

```
groupadd kafka
useradd -g kafka kafka
passwd kafka
```

2. Extract and move the contents of the **amq-streams-<version>-bin.zip** file into the **/opt/kafka** directory:

```
unzip amq-streams-<version>-bin.zip -d /opt
mv /opt/kafka*redhat* /opt/kafka
```

3. Change the ownership of the **/opt/kafka** directory to the **kafka** user:

```
chown -R kafka:kafka /opt/kafka
```

4. Create directory **/var/lib/kafka** for storing Kafka data and set its ownership to the **kafka** user:

```
mkdir /var/lib/kafka
chown -R kafka:kafka /var/lib/kafka
```

You can now run a default configuration of Kafka as a single-node cluster .

You can also use the installation to run other Kafka components, like Kafka Connect, on the same host.

To run other components, specify the hostname and port to connect to the Kafka broker using the **bootstrap.servers** property in the component configuration.

Example bootstrap servers configuration pointing to a single Kafka broker on the same host

```
bootstrap.servers=localhost:9092
```

However, we recommend installing and running Kafka components on separate hosts.

5. (Optional) Install Kafka components on separate hosts.
   a. Extract the installation files to the **/opt/kafka** directory on each host.
   b. Change the ownership of the **/opt/kafka** directory to the **kafka** user.
   c. Add **bootstrap.servers** configuration that connects the component to the host (or hosts in a multi-node environment) running the Kafka brokers.

      Example bootstrap servers configuration pointing to Kafka brokers on different hosts

      ```
      bootstrap.servers=kafka0.<host_ip_address>:9092,kafka1.
      <host_ip_address>:9092,kafka2.<host_ip_address>:9092
      ```

      You can use this configuration for Kafka Connect, MirrorMaker 2, and the Kafka Bridge.

3.4. RUNNING A KAFKA CLUSTER IN KRAFT MODE

Configure and run Kafka in KRaft mode. You can run Kafka as a single-node or multi-node Kafka cluster. Run a minimum of three broker and three controller nodes, with topic replication across the brokers, for stability and availability.

Kafka nodes perform the role of broker, controller, or both.

Broker role

A broker, sometimes referred to as a node or server, orchestrates the storage and passing of messages.

Controller role

A controller coordinates the cluster and manages the metadata used to track the status of brokers and partitions.

NOTE

Cluster metadata is stored in the internal **__cluster_metadata** topic.

You can use combined broker and controller nodes, though you might want to separate these functions. Brokers performing combined roles can be more convenient in simpler deployments.

To identify a cluster, you create an ID. The ID is used when creating logs for the nodes you add to the cluster.

Specify the following in the configuration of each node:

- A node ID
- Broker roles
- A list of nodes (or **voters**) that act as controllers

You specify a list of controllers, configured as **voters**, using the node ID and connection details (hostname and port) for each controller.

You apply broker configuration, including the setting of roles, using a configuration properties file. Broker configuration differs according to role. KRaft provides three example broker configuration properties files.

- **/opt/kafka/config/kraft/broker.properties** has example configuration for a broker role
- **/opt/kafka/config/kraft/controller.properties** has example configuration for a controller role
- **/opt/kafka/config/kraft/server.properties** has example configuration for a combined role

You can base your broker configuration on these example properties files. In this procedure, the example **server.properties** configuration is used.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Procedure

1. Generate a unique ID for the Kafka cluster.
   You can use the **kafka-storage** tool to do this:

   ```
   /opt/kafka/bin/kafka-storage.sh random-uuid
   ```

   The command returns an ID. A cluster ID is required in KRaft mode.

2. Create a configuration properties file for each node in the cluster.
   You can base the file on the examples provided with Kafka.

   a. Specify a role as **broker**, **controller**, or **broker, controller**
      For example, specify **process.roles=broker, controller** for a combined role.

   b. Specify a unique **node.id** for each node in the cluster starting from **0**.
      For example, **node.id=1**.

   c. Specify a list of **controller.quorum.voters** in the format **<node_id>@<hostname:port>**.
      For example, **controller.quorum.voters=1@localhost:9093**.

   d. Specify listeners:

- Configure the name, hostname and port for each listener.
  For example, **listeners=PLAINTEXT:localhost:9092,CONTROLLER:localhost:9093**.
- Configure the listener names used for inter-broker communication.
  For example, **inter.broker.listener.name=PLAINTEXT**.
- Configure the listener names used by the controller quorum.
  For example, **controller.listener.names=CONTROLLER**.
- Configure the name, hostname and port for each listener that is advertised to clients for connection to Kafka.
  For example, **advertised.listeners=PLAINTEXT:localhost:9092**.

3. Set up log directories for each node in your Kafka cluster:

```
/opt/kafka/bin/kafka-storage.sh format -t <uuid> -c /opt/kafka/config/kraft/server.properties
```

   Returns:

```
Formatting /tmp/kraft-combined-logs
```

   Replace <uuid> with the cluster ID you generated. Use the same ID for each node in your cluster.

   Apply the broker configuration using the properties file you created for the broker.

   By default, the log directory (**log.dirs**) specified in the **server.properties** configuration file is set to **/tmp/kraft-combined-logs**. The **/tmp** directory is typically cleared on each system reboot, making it suitable for development environments only.

   You can add a comma-separated list to set up multiple log directories.

4. Start each Kafka node.

```
/opt/kafka/bin/kafka-server-start.sh /opt/kafka/config/kraft/server.properties
```

5. Check that Kafka is running:

```
jcmd | grep kafka
```

   Returns:

```
process ID kafka.Kafka /opt/kafka/config/kraft/server.properties
```

   Check the logs of each node to ensure that they have successfully joined the KRaft cluster:

```
tail -f /opt/kafka/logs/server.log
```

You can now create topics, and send and receive messages from the brokers.

For brokers passing messages, you can use topic replication across the brokers in a cluster for data durability. Configure topics to have a replication factor of at least three and a minimum number of in-sync replicas set to 1 less than the replication factor. For more information, see Section 7.7, “Creating a topic”.

3.5. STOPPING THE STREAMS FOR APACHE KAFKA SERVICES

You can stop Kafka services by running a script. After running the script, all connections to the Kafka services are terminated.

Procedure

1. Stop the Kafka node.

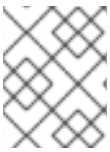
```
su - kafka
/opt/kafka/bin/kafka-server-stop.sh
```

2. Confirm that the Kafka node is stopped.

```
jcmd | grep kafka
```

3.6. PERFORMING A GRACEFUL ROLLING RESTART OF KAFKA BROKERS

This procedure shows how to do a graceful rolling restart of brokers in a multi-node cluster. A rolling restart is usually required following an upgrade or change to the Kafka cluster configuration properties.



NOTE

Some broker configurations do not need a restart of the broker. For more information, see Updating Broker Configs in the Apache Kafka documentation.

After you perform a restart of a broker, check for under-replicated topic partitions to make sure that replica partitions have caught up.

To achieve a graceful restart with no loss of availability, ensure that you are replicating topics and that at least the minimum number of replicas (**min.insync.replicas**) replicas are in sync. The **min.insync.replicas** configuration determines the minimum number of replicas that must acknowledge a write for the write to be considered successful.

For a multi-node cluster, the standard approach is to have a topic replication factor of at least 3 and a minimum number of in-sync replicas set to 1 less than the replication factor. If you are using **acks=all** in your producer configuration for data durability, check that the broker you restarted is in sync with all the partitions it's replicating before restarting the next broker.

Single-node clusters are unavailable during a restart, since all partitions are on the same broker.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- The Kafka cluster is operating as expected.
  Check for under-replicated partitions or any other issues affecting broker operation. The steps in this procedure describe how to check for under-replicated partitions.

Procedure

Perform the following steps on each Kafka broker. Complete the steps on the first broker before moving on to the next. Perform the steps on the brokers that also act as controllers last. Otherwise, the controllers need to change on more than one restart.

1. Stop the Kafka broker:

```
/opt/kafka/bin/kafka-server-stop.sh
```

2. Make any changes to the broker configuration that require a restart after completion. For further information, see the following:

   - Configuring Kafka
   - Upgrading Kafka nodes

3. Restart the Kafka broker:

```
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
```

4. Check that Kafka is running:

```
jcmd | grep kafka
```

   Returns:

```
process ID kafka.Kafka /opt/kafka/config/kraft/server.properties
```

   Check the logs of each node to ensure that they have successfully joined the KRaft cluster:

```
tail -f /opt/kafka/logs/server.log
```

5. Wait until the broker has zero under-replicated partitions. You can check from the command line or use metrics.

   - Use the **kafka-topics.sh** command with the **--under-replicated-partitions** parameter:

```
/opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_host>:<port>  --describe --under-replicated-partitions
```

     For example:

```
/opt/kafka/bin/kafka-topics.sh --bootstrap-server localhost:9092 --describe --under-replicated-partitions
```

     The command provides a list of topics with under-replicated partitions in a cluster.

     Topics with under-replicated partitions

```
Topic: topic3 Partition: 4 Leader: 2 Replicas: 2,3 Isr: 2
Topic: topic3 Partition: 5 Leader: 3 Replicas: 1,2 Isr: 1
Topic: topic1 Partition: 1 Leader: 3 Replicas: 1,3 Isr: 3
# …
```

Under-replicated partitions are listed if the ISR (in-sync replica) count is less than the number of replicas. If a list is not returned, there are no under-replicated partitions.

- Use the **UnderReplicatedPartitions** metric:

```
kafka.server:type=ReplicaManager,name=UnderReplicatedPartitions
```

The metric provides a count of partitions where replicas have not caught up. You wait until the count is zero.

TIP

Use the Kafka Exporter to create an alert when there are one or more under-replicated partitions for a topic.

Checking logs when restarting

If a broker fails to start, check the application logs for information. You can also check the status of a broker shutdown and restart in the **/opt/kafka/logs/server.log** application log.

CHAPTER 4. MIGRATING TO KRAFT MODE

If you are using ZooKeeper for metadata management of your Kafka cluster, you can migrate to using Kafka in KRaft mode. KRaft mode replaces ZooKeeper for distributed coordination, offering enhanced reliability, scalability, and throughput.

During the migration, you install a quorum of controller nodes that replaces ZooKeeper for management of your cluster. You enable KRaft migration in the controller configuration by setting the **zookeeper.metadata.migration.enable** property to **true**. When the controllers are started, you enable KRaft migration on the current cluster brokers using the same configuration property. After the migration is complete, you switch the brokers to using KRaft and the controllers out of migration mode.

Before starting the migration, verify that your environment can support Kafka in KRaft mode, as KRaft does not support JBOD storage with multiple disks.

Prerequisites

- You are logged in to Red Hat Enterprise Linux as the **kafka** user.
- Streams for Apache Kafka is installed on each host, and the configuration files are available.
- You must be using Streams for Apache Kafka 2.7 or newer with Kafka 3.7.0 or newer. If you are using an earlier version of Streams for Apache Kafka, upgrade before migrating to KRaft mode.
- Logging is enabled to check the migration process.
  It is useful to set a **DEBUG** level in **log4j.properties** for the root logger on the controllers and brokers in the cluster. For the controller logger specific to migration, set **TRACE**:

  #### Controller logging configuration

  ```
  log4j.rootLogger=DEBUG
  log4j.logger.org.apache.kafka.metadata.migration=TRACE
  ```

Procedure

1. Retrieve the cluster ID of your Kafka cluster.
   You can use the **zookeeper-shell** tool to do this:

   ```
   /opt/kafka/bin/zookeeper-shell.sh localhost:2181 get /cluster/id
   ```

   The command returns the cluster ID.

2. Install a KRaft controller quorum to the cluster.

   a. Configure a controller node on each host using the **controller.properties** file.
   At a minimum, each controller requires the following configuration:

   - A unique node ID
   - The migration enabled flag set to **true**
   - ZooKeeper connection details
   - Controller listeners

- A quorum of controller voters

  Example controller configuration

  ```
  process.roles=controller
  node.id=1

  zookeeper.metadata.migration.enable=true
  zookeeper.connect=zoo1.my-domain.com:2181,zoo2.my-
  domain.com:2181,zoo3.my-domain.com:2181

  listeners=CONTROLLER://0.0.0.0:9090
  controller.listener.names=CONTROLLER
  listener.security.protocol.map=CONTROLLER:PLAINTEXT
  controller.quorum.voters=1@localhost:9090
  ```

  The format for the controller quorum is **<node_id>@<hostname>:<port>** in a comma-separated list.

b. Set up log directories for each controller node:

```
/opt/kafka/bin/kafka-storage.sh format -t <uuid> -c
/opt/kafka/config/kraft/controller.properties
```

Returns:

```
Formatting /tmp/kraft-controller-logs
```

Replace <uuid> with the cluster ID you retrieved. Use the same cluster ID for each controller node in your cluster.

Apply the controller configuration using the properties file you configured for the controller.

By default, the log directory (**log.dirs**) specified in the **controller.properties** configuration file is set to **/tmp/kraft-controller-logs**. The **/tmp** directory is typically cleared on each system reboot, making it suitable for development environments only.

You can add a comma-separated list to set up multiple log directories.

c. Start each controller.

```
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/controller.properties
```

d. Check that Kafka is running:

```
jcmd | grep kafka
```

Returns:

```
process ID kafka.Kafka /opt/kafka/config/kraft/controller.properties
```

Check the logs of each controller to ensure that they have successfully joined the KRaft cluster:

```
tail -f /opt/kafka/logs/controller.log
```

3. Enable migration on each broker.

   a. If running, stop the Kafka broker running on the host.

   ```
   /opt/kafka/bin/kafka-server-stop.sh
   jcmd | grep kafka
   ```

   If you are running Kafka on a multi-node cluster, see Section 3.6, "Performing a graceful rolling restart of Kafka brokers".

   b. Enable migration using the **server.properties** file.
   At a minimum, each broker requires the following additional configuration:

   - Inter-broker protocol version set to version 3.5.
   - The migration enabled flag
   - Controller listeners
   - A quorum of controller voters

   Example broker configuration

   ```
   broker.id=0
   inter.broker.protocol.version=3.5

   zookeeper.metadata.migration.enable=true
   zookeeper.connect=zoo1.my-domain.com:2181,zoo2.my-domain.com:2181,zoo3.my-domain.com:2181

   listeners=CONTROLLER://0.0.0.0:9090
   controller.listener.names=CONTROLLER
   listener.security.protocol.map=CONTROLLER:PLAINTEXT
   controller.quorum.voters=1@localhost:9090
   ```

   The ZooKeeper connection details should already be present. The controller configuration for the brokers is the same as for the controllers.

   c. Restart the updated broker:

   ```
   /opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
   ```

   The migration starts automatically and can take some time depending on the number of topics and partitions in the cluster.

   d. Check that Kafka is running:

   ```
   jcmd | grep kafka
   ```

   Returns:

   ```
   process ID kafka.Kafka /opt/kafka/config/kraft/server.properties
   ```

4. Check the log on the active controller to ensure that migration is complete:

```
/opt/kafka/bin/zookeeper-shell.sh localhost:2181 get /controller
```

   Look for an **INFO** log entry that says the following: **Completed migration of metadata from ZooKeeper to KRaft.**

5. Switch each broker to run in KRaft mode.

   a. Stop the broker, as before.

   b. Update the broker configuration in the **server.properties** file:

      - Replace the **broker.id** with a **node.id** using the same ID
      - Add a **broker** KRaft role for the broker
      - Remove the inter-broker protocol version (**inter.broker.protocol.version**)
      - Remove the migration enabled flag (**zookeeper.metadata.migration.enable**)
      - Remove ZooKeeper configuration

      Example broker configuration for KRaft

```
node.id=0
process.roles=broker

listeners=CONTROLLER://0.0.0.0:9090
controller.listener.names=CONTROLLER
listener.security.protocol.map=CONTROLLER:PLAINTEXT
controller.quorum.voters=1@localhost:9090
```

   c. If you are using ACLS in your broker configuration, update the authorizer using the **authorizer.class.name** property to the KRaft-based standard authorizer. ZooKeeper-based brokers use **authorizer.class.name=kafka.security.authorizer.AclAuthorizer**.

      When migrating to KRaft-based brokers, specify **authorizer.class.name=org.apache.kafka.metadata.authorizer.StandardAuthorizer**.

   d. Restart the broker, as before.

6. Switch each controller out of migration mode.

   a. Stop the controller, as before.

   b. Remove the **zookeeper.metadata.migration.enable** property from the **controller.properties** file.

   c. Restart the controller, as before.

      Example controller configuration following migration

```
process.roles=controller
node.id=1
```

```
listeners=CONTROLLER://0.0.0.0:9090
controller.listener.names=CONTROLLER
listener.security.protocol.map=CONTROLLER:PLAINTEXT
controller.quorum.voters=1@localhost:9090
```

CHAPTER 5. CONFIGURING STREAMS FOR APACHE KAFKA

Use the Kafka configuration properties files to configure Streams for Apache Kafka.

The properties file is in Java format, with each property on a separate line in the following format:

```
<option> = <value>
```

Lines starting with **#** or **!** are treated as comments and are ignored by Streams for Apache Kafka components.

```
# This is a comment
```

Values can be split into multiple lines by using \ directly before the newline/carriage return.

```
sasl.jaas.config=org.apache.kafka.common.security.plain.PlainLoginModule required \
    username="bob" \
    password="bobs-password";
```

After saving the changes in the properties file, you need to restart the Kafka node. In a multi-node environment, repeat the process on each node in the cluster.

5.1. USING STANDARD KAFKA CONFIGURATION PROPERTIES

Use standard Kafka configuration properties to configure Kafka components.

The properties provide options to control and tune the configuration of the following Kafka components:

- Brokers
- Topics
- Producer, consumer, and management clients
- Kafka Connect
- Kafka Streams

Broker and client parameters include options to configure authorization, authentication and encryption.

For further information on Kafka configuration properties and how to use the properties to tune your deployment, see the following guides:

- Kafka configuration properties
- Kafka configuration tuning

5.2. LOADING CONFIGURATION VALUES FROM ENVIRONMENT VARIABLES

Use the Environment Variables Configuration Provider plugin to load configuration data from environment variables. You can use the Environment Variables Configuration Provider, for example, to load certificates or JAAS configuration from environment variables.

You can use the provider to load configuration data for all Kafka components, including producers and consumers. Use the provider, for example, to provide the credentials for Kafka Connect connector configuration.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- The Environment Variables Configuration Provider JAR file.
  The JAR file is available from the Streams for Apache Kafka archive.

Procedure

1. Add the Environment Variables Configuration Provider JAR file to the Kafka **libs** directory.
2. Initialize the Environment Variables Configuration Provider in the configuration properties file of the Kafka component. For example, to initialize the provider for Kafka, add the configuration to the **server.properties** file.

   Configuration to enable the Environment Variables Configuration Provider

   ```
   config.providers.env.class=org.apache.kafka.common.config.provider.EnvVarConfigProvider
   ```

3. Add configuration to the properties file to load data from environment variables.

   Configuration to load data from an environment variable

   ```
   option=${env:<MY_ENV_VAR_NAME>}
   ```

   Use capitalized or upper-case environment variable naming conventions, such as **MY_ENV_VAR_NAME**.
4. Save the changes.
5. Restart the Kafka component.
   For information on restarting brokers in a multi-node cluster, see Section 3.6, "Performing a graceful rolling restart of Kafka brokers".

5.3. CONFIGURING KAFKA

Kafka uses properties files to store static configuration. The recommended location for the configuration files is **/opt/kafka/config/kraft/**. The configuration files have to be readable by the **kafka** user.

Streams for Apache Kafka ships example configuration files that highlight various basic and advanced features of the product. They can be found under **config/kraft/** in the Streams for Apache Kafka installation directory as follows:

- (default) **config/kraft/server.properties** for nodes running in combined mode
- **config/kraft/broker.properties** for nodes running as brokers
- **config/kraft/controller.properties** for nodes running as controllers

This chapter explains the most important configuration options.

5.3.1. Listeners

Listeners are used to connect to Kafka brokers. Each Kafka broker can be configured to use multiple listeners. Each listener requires a different configuration so it can listen on a different port or network interface.

To configure listeners, edit the **listeners** property in the Kafka configuration properties file. Add listeners to the **listeners** property as a comma-separated list. Configure each property as follows:

```
<listener_name>://<hostname>:<port>
```

If **<hostname>** is empty, Kafka uses the **java.net.InetAddress.getCanonicalHostName()** class as the hostname.

Example configuration for multiple listeners

```
listeners=internal-1://:9092,internal-2://:9093,replication://:9094
```

When a Kafka client wants to connect to a Kafka cluster, it first connects to the *bootstrap server*, which is one of the cluster nodes. The bootstrap server provides the client with a list of all the brokers in the cluster, and the client connects to each one individually. The list of brokers is based on the configured **listeners**.

Advertised listeners

Optionally, you can use the **advertised.listeners** property to provide the client with a different set of listener addresses than those given in the **listeners** property. This is useful if additional network infrastructure, such as a proxy, is between the client and the broker, or an external DNS name is being used instead of an IP address.

The **advertised.listeners** property is formatted in the same way as the **listeners** property.

Example configuration for advertised listeners

```
listeners=internal-1://:9092,internal-2://:9093
advertised.listeners=internal-1://my-broker-1.my-domain.com:1234,internal-2://my-broker-1.my-domain.com:1235
```

NOTE

The names of the advertised listeners must match those listed in the **listeners** property.

Inter-broker listeners

Inter-broker listeners are used for communication between Kafka brokers. Inter-broker communication is required for:

- Coordinating workloads between different brokers
- Replicating messages between partitions stored on different brokers

The inter-broker listener can be assigned to a port of your choice. When multiple listeners are configured, you can define the name of the inter-broker listener in the **inter.broker.listener.name** property of your broker configuration.

Here, the inter-broker listener is named as **REPLICATION**:

```
listeners=REPLICATION://0.0.0.0:9091
inter.broker.listener.name=REPLICATION
```

Controller listeners

Controller configuration is used to connect and communicate with the controller that coordinates the cluster and manages the metadata used to track the status of brokers and partitions.

By default, communication between the controllers and brokers uses a dedicated controller listener. Controllers are responsible for coordinating administrative tasks, such as partition leadership changes, so one or more of these listeners is required.

Specify listeners to use for controllers using the **controller.listener.names** property. You can specify a quorum of controller voters using the **controller.quorum.voters** property. The quorum enables a leader-follower structure for administrative tasks, with the leader actively managing operations and followers as hot standbys, ensuring metadata consistency in memory and facilitating failover.

```
listeners=CONTROLLER://0.0.0.0:9090
controller.listener.names=CONTROLLER
controller.quorum.voters=1@localhost:9090
```

The format for the controller voters is **<cluster_id>@<hostname>:<port>**.

5.3.2. Commit logs

Apache Kafka stores all records it receives from producers in commit logs. The commit logs contain the actual data, in the form of records, that Kafka needs to deliver. Note that these records differ from application log files, which detail the broker's activities.

Log directories

You can configure log directories using the **log.dirs** property file to store commit logs in one or multiple log directories. It should be set to **/var/lib/kafka** directory created during installation:

```
log.dirs=/var/lib/kafka
```

For performance reasons, you can configure log.dirs to multiple directories and place each of them on a different physical device to improve disk I/O performance. For example:

```
log.dirs=/var/lib/kafka1,/var/lib/kafka2,/var/lib/kafka3
```

5.3.3. Node ID

Node ID is a unique identifier for each node (broker or controller) in the cluster. You can assign an integer greater than or equal to 0 as node ID. The node ID is used to identify the nodes after restarts or crashes and it is therefore important that the ID is stable and does not change over time.

The node ID is configured in the Kafka configuration properties file:

-

```
node.id=1
```

CHAPTER 6. SECURING ACCESS TO KAFKA

Secure your Kafka cluster by managing the access a client has to Kafka brokers. Specify configuration options to secure Kafka brokers and clients

A secure connection between Kafka brokers and clients can encompass the following:

- Encryption for data exchange
- Authentication to prove identity
- Authorization to allow or decline actions executed by users

The authentication and authorization mechanisms specified for a client must match those specified for the Kafka brokers.

6.1. LISTENER CONFIGURATION

Encryption and authentication in Kafka brokers is configured per listener. For more information about Kafka listener configuration, see Section 5.3.1, “Listeners”.

Each listener in the Kafka broker is configured with its own security protocol. The configuration property **listener.security.protocol.map** defines which listener uses which security protocol. It maps each listener name to its security protocol. Supported security protocols are:

PLAINTEXT

Listener without any encryption or authentication.

SSL

Listener using TLS encryption and, optionally, authentication using TLS client certificates.

SASL_PLAINTEXT

Listener without encryption but with SASL-based authentication.

SASL_SSL

Listener with TLS-based encryption and SASL-based authentication.

Given the following **listeners** configuration:

```
listeners=INT1://:9092,INT2://:9093,REPLICATION://:9094
```

the **listener.security.protocol.map** might look like this:

```
listener.security.protocol.map=INT1:SASL_PLAINTEXT,INT2:SASL_SSL,REPLICATION:SSL
```

This would configure the listener **INT1** to use unencrypted connections with SASL authentication, the listener **INT2** to use encrypted connections with SASL authentication and the **REPLICATION** interface to use TLS encryption (possibly with TLS client authentication). The same security protocol can be used multiple times. The following example is also a valid configuration:

```
listener.security.protocol.map=INT1:SSL,INT2:SSL,REPLICATION:SSL
```

Such a configuration would use TLS encryption and TLS authentication (optional) for all interfaces.

6.2. TLS ENCRYPTION

Kafka supports TLS for encrypting communication with Kafka clients.

In order to use TLS encryption and server authentication, a keystore containing private and public keys has to be provided. This is usually done using a file in the Java Keystore (JKS) format. A path to this file is set in the **ssl.keystore.location** property. The **ssl.keystore.password** property should be used to set the password protecting the keystore. For example:

```
ssl.keystore.location=/path/to/keystore/server-1.jks
ssl.keystore.password=123456
```

In some cases, an additional password is used to protect the private key. Any such password can be set using the **ssl.key.password** property.

Kafka is able to use keys signed by certification authorities as well as self-signed keys. Using keys signed by certification authorities should always be the preferred method. In order to allow clients to verify the identity of the Kafka broker they are connecting to, the certificate should always contain the advertised hostname(s) as its Common Name (CN) or in the Subject Alternative Names (SAN).

It is possible to use different SSL configurations for different listeners. All options starting with **ssl.** can be prefixed with **listener.name.<NameOfTheListener>.**, where the name of the listener has to be always in lowercase. This will override the default SSL configuration for that specific listener. The following example shows how to use different SSL configurations for different listeners:

```
listeners=INT1://:9092,INT2://:9093,REPLICATION://:9094
listener.security.protocol.map=INT1:SSL,INT2:SSL,REPLICATION:SSL

# Default configuration - will be used for listeners INT1 and INT2
ssl.keystore.location=/path/to/keystore/server-1.jks
ssl.keystore.password=123456

# Different configuration for listener REPLICATION
listener.name.replication.ssl.keystore.location=/path/to/keystore/replication.jks
listener.name.replication.ssl.keystore.password=123456
```

Additional TLS configuration options

In addition to the main TLS configuration options described above, Kafka supports many options for fine-tuning the TLS configuration. For example, to enable or disable TLS / SSL protocols or cipher suites:

ssl.cipher.suites

List of enabled cipher suites. Each cipher suite is a combination of authentication, encryption, MAC and key exchange algorithms used for the TLS connection. By default, all available cipher suites are enabled.

ssl.enabled.protocols

List of enabled TLS / SSL protocols. Defaults to **TLSv1.2,TLSv1.1,TLSv1**.

6.2.1. Enabling TLS encryption

This procedure describes how to enable encryption in Kafka brokers.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Procedure

1. Generate TLS certificates for all Kafka brokers in your cluster. The certificates should have their advertised and bootstrap addresses in their Common Name or Subject Alternative Name.
2. Edit the Kafka configuration properties file on all cluster nodes for the following:
   - Change the **listener.security.protocol.map** field to specify the **SSL** protocol for the listener where you want to use TLS encryption.
   - Set the **ssl.keystore.location** option to the path to the JKS keystore with the broker certificate.
   - Set the **ssl.keystore.password** option to the password you used to protect the keystore. For example:

```
listeners=UNENCRYPTED://:9092,ENCRYPTED://:9093,REPLICATION://:9094
listener.security.protocol.map=UNENCRYPTED:PLAINTEXT,ENCRYPTED:SSL,REPLICATION:PLAINTEXT
ssl.keystore.location=/path/to/keystore/server-1.jks
ssl.keystore.password=123456
```

3. (Re)start the Kafka brokers

6.3. AUTHENTICATION

To authenticate client connections to your Kafka cluster, the following options are available:

TLS client authentication

TLS (Transport Layer Security) using X.509 certificates on encrypted connections

Kafka SASL

Kafka SASL (Simple Authentication and Security Layer) using supported authentication mechanisms

OAuth 2.0

OAuth 2.0 token-based authentication

SASL authentication supports various mechanisms for both plain unencrypted connections and TLS connections:

- **PLAIN** — Authentication based on usernames and passwords.
- **SCRAM-SHA-256** and **SCRAM-SHA-512** — Authentication using Salted Challenge Response Authentication Mechanism (SCRAM).
- **GSSAPI** — Authentication against a Kerberos server.

WARNING

The **PLAIN** mechanism sends usernames and passwords over the network in an unencrypted format. It should only be used in combination with TLS encryption.

6.3.1. Enabling TLS client authentication

Enable TLS client authentication in Kafka brokers to enhance security for connections to Kafka nodes already using TLS encryption.

Use the **ssl.client.auth** property to set TLS authentication with one of these values:

- **none** — TLS client authentication is off (default)
- **requested** — Optional TLS client authentication
- **required** — Clients must authenticate using a TLS client certificate

When a client authenticates using TLS client authentication, the authenticated principal name is derived from the distinguished name in the client certificate. For instance, a user with a certificate having a distinguished name **CN=someuser** will be authenticated with the principal **CN=someuser,OU=Unknown,O=Unknown,L=Unknown,ST=Unknown,C=Unknown**. This principal name provides a unique identifier for the authenticated user or entity. When TLS client authentication is not used, and SASL is disabled, the principal name defaults to **ANONYMOUS**.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- TLS encryption is enabled.

Procedure

1. Prepare a JKS (Java Keystore) truststore containing the public key of the CA (Certification Authority) used to sign the user certificates.
2. Edit the Kafka configuration properties file on all cluster nodes as follows:
   - Specify the path to the JKS truststore using the **ssl.truststore.location** property.
   - If the truststore is password-protected, set the password using **ssl.truststore.password** property.
   - Set the **ssl.client.auth** property to **required**.

   TLS client authentication configuration

   ```
   ssl.truststore.location=/path/to/truststore.jks
   ssl.truststore.password=123456
   ssl.client.auth=required
   ```

3. (Re)start the Kafka brokers.

6.3.2. Enabling SASL PLAIN client authentication

Enable SASL PLAIN authentication in Kafka to enhance security for connections to Kafka nodes.

SASL authentication is enabled through the Java Authentication and Authorization Service (JAAS) using the **KafkaServer** JAAS context. You can define the JAAS configuration in a dedicated file or directly in the Kafka configuration.

The recommended location for the dedicated file is **/opt/kafka/config/jaas.conf**. Ensure that the file is readable by the **kafka** user. Keep the JAAS configuration file in sync on all Kafka nodes.

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.

Procedure

1. Edit or create the **/opt/kafka/config/jaas.conf** JAAS configuration file to enable the **PlainLoginModule** and specify the allowed usernames and passwords.
   Make sure this file is the same on all Kafka brokers.

   JAAS configuration

   ```
   KafkaServer {
      org.apache.kafka.common.security.plain.PlainLoginModule required
      user_admin="123456"
      user_user1="123456"
      user_user2="123456";
   };
   ```

2. Edit the Kafka configuration properties file on all cluster nodes as follows:

   - Enable SASL PLAIN authentication on specific listeners using the **listener.security.protocol.map** property. Specify **SASL_PLAINTEXT** or **SASL_SSL**.
   - Set the **sasl.enabled.mechanisms** property to **PLAIN**.

     SASL plain configuration

     ```
     listeners=INSECURE://:9092,AUTHENTICATED://:9093,REPLICATION://:9094
     listener.security.protocol.map=INSECURE:PLAINTEXT,AUTHENTICATED:SASL_PLAINT
     EXT,REPLICATION:PLAINTEXT
     sasl.enabled.mechanisms=PLAIN
     ```

3. (Re)start the Kafka brokers using the **KAFKA_OPTS** environment variable to pass the JAAS configuration to Kafka brokers:

   ```
   su - kafka
   export KAFKA_OPTS="-Djava.security.auth.login.config=/opt/kafka/config/jaas.conf";
   /opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
   ```

6.3.3. Enabling SASL SCRAM client authentication

Enable SASL SCRAM authentication in Kafka to enhance security for connections to Kafka nodes.

SASL authentication is enabled through the Java Authentication and Authorization Service (JAAS) using the **KafkaServer** JAAS context. You can define the JAAS configuration in a dedicated file or directly in the Kafka configuration.

The recommended location for the dedicated file is **/opt/kafka/config/jaas.conf**. Ensure that the file is readable by the **kafka** user. Keep the JAAS configuration file in sync on all Kafka nodes.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Procedure

1. Edit or create the **/opt/kafka/config/jaas.conf** JAAS configuration file to enable the **ScramLoginModule**.
   Make sure this file is the same on all Kafka brokers.

   JAAS configuration

   ```
   KafkaServer {
       org.apache.kafka.common.security.scram.ScramLoginModule required;
   };
   ```

2. Edit the Kafka configuration properties file on all cluster nodes as follows:

   - Enable SASL SCRAM authentication on specific listeners using the **listener.security.protocol.map** property. Specify **SASL_PLAINTEXT** or **SASL_SSL**.
   - Set the **sasl.enabled.mechanisms** option to **SCRAM-SHA-256** or **SCRAM-SHA-512**. For example:

     ```
     listeners=INSECURE://:9092,AUTHENTICATED://:9093,REPLICATION://:9094
     listener.security.protocol.map=INSECURE:PLAINTEXT,AUTHENTICATED:SASL_PLAINTEXT,REPLICATION:PLAINTEXT
     sasl.enabled.mechanisms=SCRAM-SHA-512
     ```

3. (Re)start the Kafka brokers using the **KAFKA_OPTS** environment variable to pass the JAAS configuration to Kafka brokers.

   ```
   su - kafka
   export KAFKA_OPTS="-Djava.security.auth.login.config=/opt/kafka/config/jaas.conf";
   /opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
   ```

6.3.4. Enabling multiple SASL mechanisms

When using SASL authentication, you can enable more than one mechanism. Kafka can use more than one SASL mechanism simultaneously. When multiple mechanisms are enabled, you can choose the mechanism specific clients use.

To use more than one mechanism, you set up the configuration required for each mechanism. You can

add different **KafkaServer** JAAS configurations to the same context and enable more than one mechanism in the Kafka configuration as a comma-separated list using the **sasl.mechanism.inter.broker.protocol** property.

JAAS configuration for more than one SASL mechanism

```
KafkaServer {
    org.apache.kafka.common.security.plain.PlainLoginModule required
    user_admin="123456"
    user_user1="123456"
    user_user2="123456";

    com.sun.security.auth.module.Krb5LoginModule required
    useKeyTab=true
    storeKey=true
    keyTab="/etc/security/keytabs/kafka_server.keytab"
    principal="kafka/kafka1.hostname.com@EXAMPLE.COM";

    org.apache.kafka.common.security.scram.ScramLoginModule required;
};
```

SASL mechanisms enabled

```
sasl.enabled.mechanisms=PLAIN,SCRAM-SHA-256,SCRAM-SHA-512
```

6.3.5. Enabling SASL for inter-broker authentication

Enable SASL SCRAM authentication between Kafka nodes to enhance security for inter-broker connections. As well as using SASL authentication for client connections to a Kafka cluster, you can also use SASL for inter-broker authentication. Unlike SASL for client connections, you can only choose one mechanism for inter-broker communication.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- If you are using a SCRAM mechanism, register SCRAM credentials on the Kafka cluster. For all nodes in the Kafka cluster, use the **kafka-storage.sh** tool to add the inter-broker SASL SCRAM user to the **__cluster_metadata** topic. This ensures that the credentials for authentication are updated for bootstrapping before the Kafka cluster is running.

  #### Registering an inter-broker SASL SCRAM user

  ```
  bin/kafka-storage.sh format \
  --config /opt/kafka/config/kraft/server.properties \
  --cluster-id 1 \
  --release-version 3.7 \
  --add-scram 'SCRAM-SHA-512=[name=kafka, password=changeit]' \
  --ignore formatted
  ```

Procedure

1. Specify an inter-broker SASL mechanism in the Kafka configuration using the **sasl.mechanism.inter.broker.protocol** property.

   Inter-broker SASL mechanism

   ```
   sasl.mechanism.inter.broker.protocol=SCRAM-SHA-512
   ```

2. Specify the username and password for inter-broker communication in the **KafkaServer** JAAS context using the **username** and **password** fields.

   Inter-broker JAAS context

   ```
   KafkaServer {
       org.apache.kafka.common.security.plain.ScramLoginModule required
       username="kafka"
       password="changeit"
       # ...
   };
   ```

6.3.6. Adding SASL SCRAM users

This procedure outlines the steps to register new users for authentication using SASL SCRAM in Kafka. SASL SCRAM authentication enhances the security of client connections.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- SASL SCRAM authentication is enabled.

Procedure

- Use the **kafka-configs.sh** tool to add new SASL SCRAM users.

  ```
  /opt/kafka/kafka-configs.sh \
  --bootstrap-server <broker_host>:<port> \
  --alter \
  --add-config 'SCRAM-SHA-512=[password=<password>]' \
  --entity-type users --entity-name <username>
  ```

  For example:

  ```
  /opt/kafka/kafka-configs.sh \
  --bootstrap-server localhost:9092 \
  --alter \
  --add-config 'SCRAM-SHA-512=[password=123456]' \
  --entity-type users \
  --entity-name user1
  ```

6.3.7. Deleting SASL SCRAM users

This procedure outlines the steps to remove users registered for authentication using SASL SCRAM in Kafka.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- SASL SCRAM authentication is enabled.

Procedure

- Use the **kafka-configs.sh** tool to delete SASL SCRAM users.

```
/opt/kafka/bin/kafka-configs.sh \
--bootstrap-server <broker_host>:<port> \
--alter \
--delete-config 'SCRAM-SHA-512' \
--entity-type users \
--entity-name <username>
```

For example:

```
/opt/kafka/bin/kafka-configs.sh \
--bootstrap-server localhost:9092 \
--alter \
--delete-config 'SCRAM-SHA-512' \
--entity-type users \
--entity-name user1
```

6.3.8. Enabling Kerberos (GSSAPI) authentication

Streams for Apache Kafka supports the use of the Kerberos (GSSAPI) authentication protocol for secure single sign-on access to your Kafka cluster. GSSAPI is an API wrapper for Kerberos functionality, insulating applications from underlying implementation changes.

Kerberos is a network authentication system that allows clients and servers to authenticate to each other by using symmetric encryption and a trusted third party, the Kerberos Key Distribution Centre (KDC).

This procedure shows how to configure Streams for Apache Kafka so that Kafka clients can access Kafka using Kerberos (GSSAPI) authentication.

The procedure assumes that a Kerberos *krb5* resource server has been set up on a Red Hat Enterprise Linux host.

The procedure shows, with examples, how to configure:

1. Service principals
2. Kafka brokers to use the Kerberos login
3. Producer and consumer clients to access Kafka using Kerberos authentication

The instructions describe Kerberos set up for a Kafka installation on a single host, with additional configuration for a producer and consumer client.

Prerequisites

To be able to configure Kafka to authenticate and authorize Kerberos credentials, you need the following:

- Access to a Kerberos server
- A Kerberos client on each Kafka broker host

Add service principals for authentication

From your Kerberos server, create service principals (users) for Kafka brokers, and Kafka producer and consumer clients. Service principals must take the form *SERVICE-NAME/FULLY-QUALIFIED-HOST-NAME@DOMAIN-REALM*.

1. Create the service principals, and keytabs that store the principal keys, through the Kerberos KDC.
   Make sure the domain name in the Kerberos principal is in uppercase.

   For example:

   - **kafka/node1.example.redhat.com@EXAMPLE.REDHAT.COM**
   - **producer1/node1.example.redhat.com@EXAMPLE.REDHAT.COM**
   - **consumer1/node1.example.redhat.com@EXAMPLE.REDHAT.COM**

2. Create a directory on the host and add the keytab files:
   For example:

   ```
   /opt/kafka/krb5/kafka-node1.keytab
   /opt/kafka/krb5/kafka-producer1.keytab
   /opt/kafka/krb5/kafka-consumer1.keytab
   ```

3. Ensure the **kafka** user can access the directory:

   ```
   chown kafka:kafka -R /opt/kafka/krb5
   ```

Configure the Kafka broker server to use a Kerberos login

Configure Kafka to use the Kerberos Key Distribution Center (KDC) for authentication using the user principals and keytabs previously created for **kafka**.

1. Modify the **opt/kafka/config/jaas.conf** file with the following elements:

   ```
   KafkaServer {
       com.sun.security.auth.module.Krb5LoginModule required
       useKeyTab=true
       storeKey=true
       keyTab="/opt/kafka/krb5/kafka-node1.keytab"
       principal="kafka/node1.example.redhat.com@EXAMPLE.REDHAT.COM";
   };
   KafkaClient {
       com.sun.security.auth.module.Krb5LoginModule required debug=true
       useKeyTab=true
       storeKey=true
       useTicketCache=false
   ```

```
    keyTab="/opt/kafka/krb5/kafka-node1.keytab"
    principal="kafka/node1.example.redhat.com@EXAMPLE.REDHAT.COM";
};
```

2. Configure each broker in the Kafka cluster by modifying the listener configuration in the **config/server.properties** file so the listeners use the SASL/GSSAPI login.
   Add the SASL protocol to the map of security protocols for the listener, and remove any unwanted protocols.

   For example:

```
# ...
broker.id=0
# ...
listeners=SECURE://:9092,REPLICATION://:9094 (1)
inter.broker.listener.name=REPLICATION
# ...
listener.security.protocol.map=SECURE:SASL_PLAINTEXT,REPLICATION:SASL_PLAINTEX
T (2)
# ..
sasl.enabled.mechanisms=GSSAPI (3)
sasl.mechanism.inter.broker.protocol=GSSAPI (4)
sasl.kerberos.service.name=kafka (5)
# ...
```

(1) Two listeners are configured: a secure listener for general-purpose communications with clients (supporting TLS for communications), and a replication listener for inter-broker communications.

(2) For TLS-enabled listeners, the protocol name is SASL_PLAINTEXT. For non-TLS-enabled connectors, the protocol name is SASL_PLAINTEXT. If SSL is not required, you can remove the **ssl.*** properties.

(3) SASL mechanism for Kerberos authentication is **GSSAPI**.

(4) Kerberos authentication for inter-broker communication.

(5) The name of the service used for authentication requests is specified to distinguish it from other services that may also be using the same Kerberos configuration.

3. Start the Kafka broker, with JVM parameters to specify the Kerberos login configuration:

```
su - kafka
export KAFKA_OPTS="-Djava.security.krb5.conf=/etc/krb5.conf -
Djava.security.auth.login.config=/opt/kafka/config/jaas.conf"; /opt/kafka/bin/kafka-server-
start.sh -daemon /opt/kafka/config/kraft/server.properties
```

4. Configure Kafka producer and consumer clients to use Kerberos authentication

Configure Kafka producer and consumer clients to use the Kerberos Key Distribution Center (KDC) for authentication using the user principals and keytabs previously created for **producer1** and **consumer1**.

1. Add the Kerberos configuration to the producer or consumer configuration file.
   For example:

/opt/kafka/config/producer.properties

```
# ...
sasl.mechanism=GSSAPI (1)
security.protocol=SASL_PLAINTEXT (2)
sasl.kerberos.service.name=kafka (3)
sasl.jaas.config=com.sun.security.auth.module.Krb5LoginModule required \ (4)
    useKeyTab=true  \
    useTicketCache=false \
    storeKey=true  \
    keyTab="/opt/kafka/krb5/producer1.keytab" \
    principal="producer1/node1.example.redhat.com@EXAMPLE.REDHAT.COM";
# ...
```

1. Configuration for Kerberos (GSSAPI) authentication.
2. Kerberos uses the SASL plaintext (username/password) security protocol.
3. The service principal (user) for Kafka that was configured in the Kerberos KDC.
4. Configuration for the JAAS using the same properties defined in **jaas.conf**.

/opt/kafka/config/consumer.properties

```
# ...
sasl.mechanism=GSSAPI
security.protocol=SASL_PLAINTEXT
sasl.kerberos.service.name=kafka
sasl.jaas.config=com.sun.security.auth.module.Krb5LoginModule required \
    useKeyTab=true  \
    useTicketCache=false \
    storeKey=true  \
    keyTab="/opt/kafka/krb5/consumer1.keytab" \
    principal="consumer1/node1.example.redhat.com@EXAMPLE.REDHAT.COM";
# ...
```

2. Run the clients to verify that you can send and receive messages from the Kafka brokers.
   Producer client:

```
export KAFKA_HEAP_OPTS="-Djava.security.krb5.conf=/etc/krb5.conf -
Dsun.security.krb5.debug=true"; /opt/kafka/bin/kafka-console-producer.sh --producer.config
/opt/kafka/config/producer.properties  --topic topic1 --bootstrap-server
node1.example.redhat.com:9094
```

   Consumer client:

```
export KAFKA_HEAP_OPTS="-Djava.security.krb5.conf=/etc/krb5.conf -
Dsun.security.krb5.debug=true"; /opt/kafka/bin/kafka-console-consumer.sh --
consumer.config /opt/kafka/config/consumer.properties  --topic topic1 --bootstrap-server
node1.example.redhat.com:9094
```

Additional resources

- Kerberos man pages: **krb5.conf**, **kinit**, **klist**, and **kdestroy**

6.4. AUTHORIZATION

Authorization in Kafka brokers is implemented using authorizer plugins.

In this section we describe how to use the **StandardAuthorizer** plugin provided with Kafka.

Alternatively, you can use your own authorization plugins. For example, if you are using OAuth 2.0 token-based authentication, you can use OAuth 2.0 authorization.

6.4.1. Enabling an ACL authorizer

Edit the Kafka configuration properties file to add an ACL authorizer. Enable the authorizer by specifying its fully-qualified name in the **authorizer.class.name** property:

Enabling the authorizer

```
authorizer.class.name=org.apache.kafka.metadata.authorizer.StandardAuthorizer
```

6.4.1.1. ACL rules

An ACL authorizer uses ACL rules to manage access to Kafka brokers.

ACL rules are defined in the following format:

Principal **P** is allowed / denied <operation> **O** on <kafka_resource> **R** from host **H**

For example, a rule might be set so that user **John** can **view** the topic **comments** from host **127.0.0.1**. Host is the IP address of the machine that John is connecting from.

In most cases, the user is a producer or consumer application:

Consumer01 can **write** to the consumer group **accounts** from host **127.0.0.1**

If ACL rules are not present for a given resource, all actions are denied. This behavior can be changed by setting the property **allow.everyone.if.no.acl.found** to **true** in the Kafka configuration file.

6.4.1.2. Principals

A *principal* represents the identity of a user. The format of the ID depends on the authentication mechanism used by clients to connect to Kafka:

- **User:ANONYMOUS** when connected without authentication.
- **User:<username>** when connected using simple authentication mechanisms, such as PLAIN or SCRAM.
  For example **User:admin** or **User:user1**.
- **User:<DistinguishedName>** when connected using TLS client authentication.
  For example **User:CN=user1,O=MyCompany,L=Prague,C=CZ**.
- **User:<Kerberos username>** when connected using Kerberos.

The *DistinguishedName* is the distinguished name from the client certificate.

The *Kerberos username* is the primary part of the Kerberos principal, which is used by default when connecting using Kerberos. You can use the **sasl.kerberos.principal.to.local.rules** property to configure how the Kafka principal is built from the Kerberos principal.

6.4.1.3. Authentication of users

To use authorization, you need to have authentication enabled and used by your clients. Otherwise, all connections will have the principal **User:ANONYMOUS**.

For more information on methods of authentication, see Section 6.3, “Authentication”.

6.4.1.4. Super users

Super users are allowed to take all actions regardless of the ACL rules.

Super users are defined in the Kafka configuration file using the property **super.users**.

For example:

```
super.users=User:admin,User:operator
```

6.4.1.5. Replica broker authentication

When authorization is enabled, it is applied to all listeners and all connections. This includes the inter-broker connections used for replication of data between brokers. If enabling authorization, therefore, ensure that you use authentication for inter-broker connections and give the users used by the brokers sufficient rights. For example, if authentication between brokers uses the **kafka-broker** user, then super user configuration must include the username **super.users=User:kafka-broker**.

NOTE

For more information on the operations on Kafka resources you can control with ACLs, see the Apache Kafka documentation.

6.4.2. Adding ACL rules

When using an ACL authorizer to control access to Kafka based on Access Control Lists (ACLs), you can add new ACL rules using the **kafka-acls.sh** utility.

Use **kafka-acls.sh** parameter options to add, list and remove ACL rules, and perform other functions. The parameters require a double-hyphen convention, such as **--add**.

Prerequisites

- Users have been created and granted appropriate permissions to access Kafka resources.
- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- Authorization is enabled in Kafka brokers.

Procedure

- Run **kafka-acls.sh** with the **--add** option.
  Examples:

- Allow **user1** and **user2** access to read from **myTopic** using the **MyConsumerGroup** consumer group.

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --add --operation Read --topic myTopic --allow-principal User:user1 --allow-principal User:user2

opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --add --operation Describe --topic myTopic --allow-principal User:user1 --allow-principal User:user2

opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --add --operation Read --operation Describe --group MyConsumerGroup --allow-principal User:user1 --allow-principal User:user2
```

- Deny **user1** access to read **myTopic** from IP address host **127.0.0.1**.

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --add --operation Describe --operation Read --topic myTopic --group MyConsumerGroup --deny-principal User:user1 --deny-host 127.0.0.1
```

- Add **user1** as the consumer of **myTopic** with **MyConsumerGroup**.

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --add --consumer --topic myTopic --group MyConsumerGroup --allow-principal User:user1
```

6.4.3. Listing ACL rules

When using an ACL authorizer to control access to Kafka based on Access Control Lists (ACLs), you can list existing ACL rules using the **kafka-acls.sh** utility.

Prerequisites

- ACLs have been added.

Procedure

- Run **kafka-acls.sh** with the **--list** option.
  For example:

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --list --topic myTopic

Current ACLs for resource `Topic:myTopic`:

User:user1 has Allow permission for operations: Read from hosts: *
User:user2 has Allow permission for operations: Read from hosts: *
User:user2 has Deny permission for operations: Read from hosts: 127.0.0.1
User:user1 has Allow permission for operations: Describe from hosts: *
User:user2 has Allow permission for operations: Describe from hosts: *
User:user2 has Deny permission for operations: Describe from hosts: 127.0.0.1
```

6.4.4. Removing ACL rules

When using an ACL authorizer to control access to Kafka based on Access Control Lists (ACLs), you can remove existing ACL rules using the **kafka-acls.sh** utility.

Prerequisites

- ACLs have been added.

Procedure

- Run **kafka-acls.sh** with the **--remove** option.
  Examples:
- Remove the ACL allowing Allow **user1** and **user2** access to read from **myTopic** using the **MyConsumerGroup** consumer group.

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --remove --operation Read --topic myTopic --allow-principal User:user1 --allow-principal User:user2

opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --remove --operation Describe --topic myTopic --allow-principal User:user1 --allow-principal User:user2

opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --remove --operation Read --operation Describe --group MyConsumerGroup --allow-principal User:user1 --allow-principal User:user2
```

- Remove the ACL adding **user1** as the consumer of **myTopic** with **MyConsumerGroup**.

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --remove --consumer --topic myTopic --group MyConsumerGroup --allow-principal User:user1
```

- Remove the ACL denying **user1** access to read **myTopic** from IP address host **127.0.0.1**.

```
opt/kafka/bin/kafka-acls.sh --bootstrap-server localhost:9092 --remove --operation Describe --operation Read --topic myTopic --group MyConsumerGroup --deny-principal User:user1 --deny-host 127.0.0.1
```

6.5. USING OAUTH 2.0 TOKEN-BASED AUTHENTICATION

Streams for Apache Kafka supports the use of OAuth 2.0 authentication using the *OAUTHBEARER* and *PLAIN* mechanisms.

OAuth 2.0 enables standardized token-based authentication and authorization between applications, using a central authorization server to issue tokens that grant limited access to resources.

You can configure OAuth 2.0 authentication, then OAuth 2.0 authorization.

Kafka brokers and clients both need to be configured to use OAuth 2.0. OAuth 2.0 authentication can also be used in conjunction with **simple** or OPA-based Kafka authorization.

Using OAuth 2.0 authentication, application clients can access resources on application servers (called *resource servers*) without exposing account credentials.

The application client passes an access token as a means of authenticating, which application servers can also use to determine the level of access to grant. The authorization server handles the granting of access and inquiries about access.

In the context of Streams for Apache Kafka:

- Kafka brokers act as OAuth 2.0 resource servers
- Kafka clients act as OAuth 2.0 application clients

Kafka clients authenticate to Kafka brokers. The brokers and clients communicate with the OAuth 2.0 authorization server, as necessary, to obtain or validate access tokens.

For a deployment of Streams for Apache Kafka, OAuth 2.0 integration provides:

- Server-side OAuth 2.0 support for Kafka brokers
- Client-side OAuth 2.0 support for Kafka MirrorMaker, Kafka Connect, and the Kafka Bridge

Streams for Apache Kafka on RHEL includes two OAuth 2.0 libraries:

kafka-oauth-client

Provides a custom login callback handler class named **io.strimzi.kafka.oauth.client.JaasClientOauthLoginCallbackHandler**. To handle the **OAUTHBEARER** authentication mechanism, use the login callback handler with the **OAuthBearerLoginModule** provided by Apache Kafka.

kafka-oauth-common

A helper library that provides some of the functionality needed by the **kafka-oauth-client** library.

The provided client libraries also have dependencies on some additional third-party libraries, such as: **keycloak-core**, **jackson-databind**, and **slf4j-api**.

We recommend using a Maven project to package your client to ensure that all the dependency libraries are included. Dependency libraries might change in future versions.

Additional resources

- OAuth 2.0 site

6.5.1. OAuth 2.0 authentication mechanisms

Streams for Apache Kafka supports the OAUTHBEARER and PLAIN mechanisms for OAuth 2.0 authentication. Both mechanisms allow Kafka clients to establish authenticated sessions with Kafka brokers. The authentication flow between clients, the authorization server, and Kafka brokers is different for each mechanism.

We recommend that you configure clients to use OAUTHBEARER whenever possible. OAUTHBEARER provides a higher level of security than PLAIN because client credentials are *never* shared with Kafka brokers. Consider using PLAIN only with Kafka clients that do not support OAUTHBEARER.

You configure Kafka broker listeners to use OAuth 2.0 authentication for connecting clients. If necessary, you can use the OAUTHBEARER and PLAIN mechanisms on the same **oauth** listener. The properties to support each mechanism must be explicitly specified in the **oauth** listener configuration.

OAUTHBEARER overview

To use OAUTHBEARER, set **sasl.enabled.mechanisms** to **OAUTHBEARER** in the OAuth authentication listener configuration for the Kafka broker. For detailed configuration, see Section 6.5.2, "OAuth 2.0 Kafka broker configuration".

```
listener.name.client.sasl.enabled.mechanisms=OAUTHBEARER
```

Many Kafka client tools use libraries that provide basic support for OAUTHBEARER at the protocol level. To support application development, Streams for Apache Kafka provides an *OAuth callback handler* for the upstream Kafka Client Java libraries (but not for other libraries). Therefore, you do not need to write your own callback handlers. An application client can use the callback handler to provide the access token. Clients written in other languages, such as Go, must use custom code to connect to the authorization server and obtain the access token.

With OAUTHBEARER, the client initiates a session with the Kafka broker for credentials exchange, where credentials take the form of a bearer token provided by the callback handler. Using the callbacks, you can configure token provision in one of three ways:

- Client ID and Secret (by using the *OAuth 2.0 client credentials* mechanism)
- A long-lived access token, obtained manually at configuration time
- A long-lived refresh token, obtained manually at configuration time

NOTE

OAUTHBEARER authentication can only be used by Kafka clients that support the OAUTHBEARER mechanism at the protocol level.

PLAIN overview

To use PLAIN, add **PLAIN** to the value of **sasl.enabled.mechanisms**.

```
listener.name.client.sasl.enabled.mechanisms=OAUTHBEARER,PLAIN
```

PLAIN is a simple authentication mechanism used by all Kafka client tools. To enable PLAIN to be used with OAuth 2.0 authentication, Streams for Apache Kafka provides *OAuth 2.0 over PLAIN* server-side callbacks.

Client credentials are handled centrally behind a compliant authorization server, similar to when OAUTHBEARER authentication is used. When used with the OAuth 2.0 over PLAIN callbacks, Kafka clients authenticate with Kafka brokers using either of the following methods:

- Client ID and secret (by using the *OAuth 2.0 client credentials* mechanism)
- A long-lived access token, obtained manually at configuration time

For both methods, the client must provide the PLAIN **username** and **password** properties to pass credentials to the Kafka broker. The client uses these properties to pass a client ID and secret or username and access token.

Client IDs and secrets are used to obtain access tokens.

Access tokens are passed as **password** property values. You pass the access token with or without an **$accessToken:** prefix.

- If you configure a token endpoint (**oauth.token.endpoint.uri**) in the listener configuration, you need the prefix.
- If you don't configure a token endpoint (**oauth.token.endpoint.uri**) in the listener configuration, you don't need the prefix. The Kafka broker interprets the password as a raw access token.

If the **password** is set as the access token, the **username** must be set to the same principal name that the Kafka broker obtains from the access token. You can specify username extraction options in your listener using the **oauth.username.claim**, **oauth.fallback.username.claim**, **oauth.fallback.username.prefix**, and **oauth.userinfo.endpoint.uri** properties. The username extraction process also depends on your authorization server; in particular, how it maps client IDs to account names.

NOTE

OAuth over PLAIN does not support passing a username and password (password grants) using the (deprecated) OAuth 2.0 password grant mechanism.

6.5.1.1. Configuring OAuth 2.0 with properties or variables

You can configure OAuth 2.0 settings using Java Authentication and Authorization Service (JAAS) properties or environment variables.

- JAAS properties are configured in the **server.properties** configuration file, and passed as key-values pairs of the **listener.name.*LISTENER-NAME*.oauthbearer.sasl.jaas.config** property.
- If using environment variables, you still need to provide the **listener.name.*LISTENER-NAME*.oauthbearer.sasl.jaas.config** property in the **server.properties** file, but you can omit the other JAAS properties.
  You can use capitalized or upper-case environment variable naming conventions.

The Streams for Apache Kafka OAuth 2.0 libraries use properties that start with:

- **oauth.** to configure authentication
- **strimzi.** to configure OAuth 2.0 authorization

Additional resources

- OAuth 2.0 Kafka broker configuration

6.5.2. OAuth 2.0 Kafka broker configuration

Kafka broker configuration for OAuth 2.0 authentication involves:

- Creating the OAuth 2.0 client in the authorization server
- Configuring OAuth 2.0 authentication in the Kafka cluster

NOTE

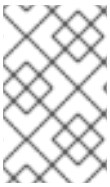
In relation to the authorization server, Kafka brokers and Kafka clients are both regarded as OAuth 2.0 clients.

6.5.2.1. OAuth 2.0 client configuration on an authorization server

To configure a Kafka broker to validate the token received during session initiation, the recommended approach is to create an OAuth 2.0 *client* definition in an authorization server, configured as *confidential*, with the following client credentials enabled:

- Client ID of **kafka-broker** (for example)

- Client ID and secret as the authentication mechanism



NOTE

You only need to use a client ID and secret when using a non-public introspection endpoint of the authorization server. The credentials are not typically required when using public authorization server endpoints, as with fast local JWT token validation.

6.5.2.2. OAuth 2.0 authentication configuration in the Kafka cluster

To use OAuth 2.0 authentication in the Kafka cluster, you enable an OAuth authentication listener configuration for your Kafka cluster, in the Kafka **server.properties** file. A minimum configuration is required. You can also configure a TLS listener, where TLS is used for inter-broker communication.

You can configure the broker for token validation by the authorization server using one of the following methods:

- Fast local token validation: a *JWKS* endpoint in combination with signed JWT-formatted access tokens
- *Introspection* endpoint

You can configure OAUTHBEARER or PLAIN authentication, or both.

The following example shows a minimum configuration that applies a *global* listener configuration, which means that inter-broker communication goes through the same listener as application clients.

The example also shows an OAuth 2.0 configuration for a specific listener, where you specify **listener.name.*LISTENER-NAME*.sasl.enabled.mechanisms** instead of **sasl.enabled.mechanisms**. *LISTENER-NAME* is the case-insensitive name of the listener. Here, we name the listener **CLIENT**, so the property name is **listener.name.client.sasl.enabled.mechanisms**.

The example uses OAUTHBEARER authentication.

Example: Minimum listener configuration for OAuth 2.0 authentication using a JWKS endpoint

```
sasl.enabled.mechanisms=OAUTHBEARER (1)
listeners=CLIENT://0.0.0.0:9092 (2)
listener.security.protocol.map=CLIENT:SASL_PLAINTEXT (3)
listener.name.client.sasl.enabled.mechanisms=OAUTHBEARER (4)
sasl.mechanism.inter.broker.protocol=OAUTHBEARER (5)
inter.broker.listener.name=CLIENT (6)
listener.name.client.oauthbearer.sasl.server.callback.handler.class=io.strimzi.kafka.oauth.server.JaasSe
verOauthValidatorCallbackHandler (7)
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAut
hBearerLoginModule required \ (8)
  oauth.valid.issuer.uri="https://<oauth_server_address>" \ (9)
  oauth.jwks.endpoint.uri="https://<oauth_server_address>/jwks" \ (10)
  oauth.username.claim="preferred_username"  \ (11)
  oauth.client.id="kafka-broker" \ (12)
  oauth.client.secret="kafka-secret" \ (13)
  oauth.token.endpoint.uri="https://<oauth_server_address>/token" ; (14)
```

```
listener.name.client.oauthbearer.sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.JaasClien
OauthLoginCallbackHandler 15
listener.name.client.oauthbearer.connections.max.reauth.ms=3600000 16
```

1. Enables the *OAUTHBEARER* mechanism for credentials exchange over SASL.
2. Configures a listener for client applications to connect to. The system **hostname** is used as an advertised hostname, which clients must resolve in order to reconnect. The listener is named **CLIENT** in this example.
3. Specifies the channel protocol for the listener. **SASL_SSL** is for TLS. **SASL_PLAINTEXT** is used for an unencrypted connection (no TLS), but there is risk of eavesdropping and interception at the TCP connection layer.
4. Specifies the *OAUTHBEARER* mechanism for the *CLIENT* listener. The client name (***CLIENT***) is usually specified in uppercase in the **listeners** property, in lowercase for **listener.name** properties (**listener.name.client**), and in lowercase when part of a **listener.name.*client*.*** property.
5. Specifies the *OAUTHBEARER* mechanism for inter-broker communication.
6. Specifies the listener for inter-broker communication. The specification is required for the configuration to be valid.
7. Configures OAuth 2.0 authentication on the client listener.
8. Configures authentication settings for client and inter-broker communication. The **oauth.client.id**, **oauth.client.secret**, and **auth.token.endpoint.uri** properties relate to inter-broker configuration.
9. A valid issuer URI. Only access tokens issued by this issuer will be accepted. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME*.
10. The JWKS endpoint URL. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/certs*.
11. The token claim (or key) that contains the actual user name in the token. The user name is the *principal* used to identify the user. The value will depend on the authentication flow and the authorization server used. If required, you can use a JsonPath expression like **"['user.info'].['user.id']"** to retrieve the username from nested JSON attributes within a token.
12. Client ID of the Kafka broker, which is the same for all brokers. This is the client registered with the authorization server as **kafka-broker**.
13. Secret for the Kafka broker, which is the same for all brokers.
14. The OAuth 2.0 token endpoint URL to your authorization server. For production, always use **https://** urls. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/token*.
15. Enables (and is only required for) OAuth 2.0 authentication for inter-broker communication.
16. (Optional) Enforces session expiry when a token expires, and also activates the Kafka re-authentication mechanism. If the specified value is less than the time left for the access token to expire, then the client will have to re-authenticate before the actual token expiry. By default, the session does not expire when the access token expires, and the client does not attempt re-authentication.

The following example shows a minimum configuration for a TLS listener, where TLS is used for inter-broker communication.

Example: TLS listener configuration for OAuth 2.0 authentication

```
listeners=REPLICATION://kafka:9091,CLIENT://kafka:9092 (1)
listener.security.protocol.map=REPLICATION:SSL,CLIENT:SASL_PLAINTEXT (2)
listener.name.client.sasl.enabled.mechanisms=OAUTHBEARER
inter.broker.listener.name=REPLICATION
listener.name.replication.ssl.keystore.password=<keystore_password> (3)
listener.name.replication.ssl.truststore.password=<truststore_password>
listener.name.replication.ssl.keystore.type=JKS
listener.name.replication.ssl.truststore.type=JKS
listener.name.replication.ssl.secure.random.implementation=SHA1PRNG (4)
listener.name.replication.ssl.endpoint.identification.algorithm=HTTPS (5)
listener.name.replication.ssl.keystore.location=<path_to_keystore> (6)
listener.name.replication.ssl.truststore.location=<path_to_truststore> (7)
listener.name.replication.ssl.client.auth=required (8)
listener.name.client.oauthbearer.sasl.server.callback.handler.class=io.strimzi.kafka.oauth.server.JaasSe
verOauthValidatorCallbackHandler
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAut
hBearerLoginModule required \ (9)
  oauth.valid.issuer.uri="https://<oauth_server_address>" \
  oauth.jwks.endpoint.uri="https://<oauth_server_address>/jwks" \
  oauth.username.claim="preferred_username" ;
```

1. Separate configurations are required for inter-broker communication and client applications.
2. Configures the *REPLICATION* listener to use TLS, and the *CLIENT* listener to use SASL over an unencrypted channel. The client could use an encrypted channel (**SASL_SSL**) in a production environment.
3. The **ssl.** properties define the TLS configuration.
4. Random number generator implementation. If not set, the Java platform SDK default is used.
5. Hostname verification. If set to an empty string, the hostname verification is turned off. If not set, the default value is **HTTPS**, which enforces hostname verification for server certificates.
6. Path to the keystore for the listener.
7. Path to the truststore for the listener.
8. Specifies that clients of the *REPLICATION* listener have to authenticate with a client certificate when establishing a TLS connection (used for inter-broker connectivity).
9. Configures the *CLIENT* listener for OAuth 2.0. Connectivity with the authorization server should use secure HTTPS connections.

The following example shows a minimum configuration for OAuth 2.0 authentication using the PLAIN authentication mechanism for credentials exchange over SASL. Fast local token validation is used.

Example: Minimum listener configuration for PLAIN authentication

```
listeners=CLIENT://0.0.0.0:9092 1
listener.security.protocol.map=CLIENT:SASL_PLAINTEXT 2
listener.name.client.sasl.enabled.mechanisms=OAUTHBEARER,PLAIN 3
sasl.mechanism.inter.broker.protocol=OAUTHBEARER 4
inter.broker.listener.name=CLIENT 5
listener.name.client.oauthbearer.sasl.server.callback.handler.class=io.strimzi.kafka.oauth.server.JaasSe
verOauthValidatorCallbackHandler 6
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAut
hBearerLoginModule required \ 7
  oauth.valid.issuer.uri="http://<auth_server>/auth/realms/<realm>" \ 8
  oauth.jwks.endpoint.uri="https://<auth_server>/auth/realms/<realm>/protocol/openid-connect/certs" \
9
  oauth.username.claim="preferred_username"  \ 10
  oauth.client.id="kafka-broker" \ 11
  oauth.client.secret="kafka-secret" \ 12
  oauth.token.endpoint.uri="https://<oauth_server_address>/token" ; 13
listener.name.client.oauthbearer.sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.JaasClien
OauthLoginCallbackHandler 14
listener.name.client.plain.sasl.server.callback.handler.class=io.strimzi.kafka.oauth.server.plain.JaasServ
rOauthOverPlainValidatorCallbackHandler 15
listener.name.client.plain.sasl.jaas.config=org.apache.kafka.common.security.plain.PlainLoginModule
required \ 16
  oauth.valid.issuer.uri="https://<oauth_server_address>" \ 17
  oauth.jwks.endpoint.uri="https://<oauth_server_address>/jwks" \ 18
  oauth.username.claim="preferred_username"  \ 19
  oauth.token.endpoint.uri="http://<auth_server>/auth/realms/<realm>/protocol/openid-connect/token"
; 20
connections.max.reauth.ms=3600000 21
```

1. Configures a listener (named **CLIENT** in this example) for client applications to connect to. The system **hostname** is used as an advertised hostname, which clients must resolve in order to reconnect. Because this is the only configured listener, it is also used for inter-broker communication.

2. Configures the example **CLIENT** listener to use SASL over an unencrypted channel. In a production environment, the client should use an encrypted channel (**SASL_SSL**) in order to guard against eavesdropping and interception at the TCP connection layer.

3. Enables the *PLAIN* authentication mechanism for credentials exchange over SASL as well as *OAUTHBEARER*. OAUTHBEARER is also specified because it is required for inter-broker communication. Kafka clients can choose which mechanism to use to connect.

4. Specifies the *OAUTHBEARER* authentication mechanism for inter-broker communication.

5. Specifies the listener (named **CLIENT** in this example) for inter-broker communication. Required for the configuration to be valid.

6. Configures the server callback handler for the OAUTHBEARER mechanism.

7. Configures authentication settings for client and inter-broker communication using the *OAUTHBEARER* mechanism. The **oauth.client.id**, **oauth.client.secret**, and **oauth.token.endpoint.uri** properties relate to inter-broker configuration.

8 A valid issuer URI. Only access tokens from this issuer are accepted. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME*

9 The JWKS endpoint URL. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/certs*

10 The token claim (or key) that contains the actual user name in the token. The user name is the *principal* used to identify the user. The value will depend on the authentication flow and the authorization server used. If required, you can use a JsonPath expression like **"['user.info'].['user.id']"** to retrieve the username from nested JSON attributes within a token.

11 Client ID of the Kafka broker, which is the same for all brokers. This is the client registered with the authorization server as **kafka-broker**.

12 Secret for the Kafka broker (the same for all brokers).

13 The OAuth 2.0 token endpoint URL to your authorization server. For production, always use **https://** urls. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/token*

14 Enables OAuth 2.0 authentication for inter-broker communication.

15 Configures the server callback handler for *PLAIN* authentication.

16 Configures authentication settings for client communication using *PLAIN* authentication.

oauth.token.endpoint.uri is an optional property that enables OAuth 2.0 over PLAIN using the *OAuth 2.0 client credentials mechanism*.

17 A valid issuer URI. Only access tokens from this issuer are accepted. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME*

18 The JWKS endpoint URL. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/certs*

19 The token claim (or key) that contains the actual user name in the token. The user name is the *principal* used to identify the user. The value will depend on the authentication flow and the authorization server used. If required, you can use a JsonPath expression like **"['user.info'].['user.id']"** to retrieve the username from nested JSON attributes within a token.

20 The OAuth 2.0 token endpoint URL to your authorization server. Additional configuration for the PLAIN mechanism. If specified, clients can authenticate over PLAIN by passing an access token as the **password** using an **$accessToken:** prefix.

For production, always use **https://** urls. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/token*.

21 (Optional) Enforces session expiry when a token expires, and also activates the Kafka re-authentication mechanism. If the specified value is less than the time left for the access token to expire, then the client will have to re-authenticate before the actual token expiry. By default, the session does not expire when the access token expires, and the client does not attempt re-authentication.

6.5.2.3. Fast local JWT token validation configuration

Fast local JWT token validation checks a JWT token signature locally.

The local check ensures that a token:

- Conforms to type by containing a (*typ*) claim value of **Bearer** for an access token
- Is valid (not expired)
- Has an issuer that matches a **validIssuerURI**

You specify a *valid issuer URI* when you configure the listener, so that any tokens not issued by the authorization server are rejected.

The authorization server does not need to be contacted during fast local JWT token validation. You activate fast local JWT token validation by specifying a *JWKs endpoint URI* exposed by the OAuth 2.0 authorization server. The endpoint contains the public keys used to validate signed JWT tokens, which are sent as credentials by Kafka clients.

NOTE

All communication with the authorization server should be performed using HTTPS.

For a TLS listener, you can configure a certificate *truststore* and point to the truststore file.

Example properties for fast local JWT token validation

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule required \
  oauth.valid.issuer.uri="https://<oauth_server_address>" \ 1
  oauth.jwks.endpoint.uri="https://<oauth_server_address>/jwks" \ 2
  oauth.jwks.refresh.seconds="300" \ 3
  oauth.jwks.refresh.min.pause.seconds="1" \ 4
  oauth.jwks.expiry.seconds="360" \ 5
  oauth.username.claim="preferred_username" \ 6
  oauth.ssl.truststore.location="<path_to_truststore_p12_file>" \ 7
  oauth.ssl.truststore.password="<truststore_password>" \ 8
  oauth.ssl.truststore.type="PKCS12" ; 9
```

1. A valid issuer URI. Only access tokens issued by this issuer will be accepted. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME*.
2. The JWKS endpoint URL. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/certs*.
3. The period between endpoint refreshes (default 300).
4. The minimum pause in seconds between consecutive attempts to refresh JWKS public keys. When an unknown signing key is encountered, the JWKS keys refresh is scheduled outside the regular periodic schedule with at least the specified pause since the last refresh attempt. The refreshing of keys follows the rule of exponential backoff, retrying on unsuccessful refreshes with ever increasing pause, until it reaches **oauth.jwks.refresh.seconds**. The default value is 1.
5. The duration the JWKs certificates are considered valid before they expire. Default is **360** seconds. If you specify a longer time, consider the risk of allowing access to revoked certificates.
6. The token claim (or key) that contains the actual user name in the token. The user name is the

7 The location of the truststore used in the TLS configuration.

8 Password to access the truststore.

9 The truststore type in PKCS #12 format.

6.5.2.4. OAuth 2.0 introspection endpoint configuration

Token validation using an OAuth 2.0 introspection endpoint treats a received access token as opaque. The Kafka broker sends an access token to the introspection endpoint, which responds with the token information necessary for validation. Importantly, it returns up-to-date information if the specific access token is valid, and also information about when the token expires.

To configure OAuth 2.0 introspection-based validation, you specify an *introspection endpoint URI* rather than the JWKs endpoint URI specified for fast local JWT token validation. Depending on the authorization server, you typically have to specify a *client ID* and *client secret*, because the introspection endpoint is usually protected.

Example properties for an introspection endpoint

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule required \
  oauth.introspection.endpoint.uri="https://<oauth_server_address>/introspection" \ 1
  oauth.client.id="kafka-broker" \ 2
  oauth.client.secret="kafka-broker-secret" \ 3
  oauth.ssl.truststore.location="<path_to_truststore_p12_file>" \ 4
  oauth.ssl.truststore.password="<truststore_password>" \ 5
  oauth.ssl.truststore.type="PKCS12" \ 6
  oauth.username.claim="preferred_username" ; 7
```

1 The OAuth 2.0 introspection endpoint URI. For example, *https://AUTH-SERVER-ADDRESS/auth/realms/REALM-NAME/protocol/openid-connect/token/introspect*.

2 Client ID of the Kafka broker.

3 Secret for the Kafka broker.

4 The location of the truststore used in the TLS configuration.

5 Password to access the truststore.

6 The truststore type in PKCS #12 format.

7 The token claim (or key) that contains the actual user name in the token. The user name is the *principal* used to identify the user. The value will depend on the authentication flow and the authorization server used. If required, you can use a JsonPath expression like **"['user.info'].['user.id']"** to retrieve the username from nested JSON attributes within a token.

6.5.3. Session re-authentication for Kafka brokers

You can configure OAuth listeners to use Kafka *session re-authentication* for OAuth 2.0 sessions between Kafka clients and Kafka brokers. This mechanism enforces the expiry of an authenticated session between the client and the broker after a defined period of time. When a session expires, the

client immediately starts a new session by reusing the existing connection rather than dropping it.

Session re-authentication is disabled by default. You can enable it in the **server.properties** file. Set the **connections.max.reauth.ms** property for a TLS listener with OAUTHBEARER or PLAIN enabled as the SASL mechanism.

You can specify session re-authentication per listener. For example:

```
listener.name.client.oauthbearer.connections.max.reauth.ms=3600000
```

Session re-authentication must be supported by the Kafka client libraries used by the client.

Session re-authentication can be used with *fast local JWT* or *introspection endpoint* token validation.

Client re-authentication

When the broker's authenticated session expires, the client must re-authenticate to the existing session by sending a new, valid access token to the broker, without dropping the connection.

If token validation is successful, a new client session is started using the existing connection. If the client fails to re-authenticate, the broker will close the connection if further attempts are made to send or receive messages. Java clients that use Kafka client library 2.2 or later automatically re-authenticate if the re-authentication mechanism is enabled on the broker.

Session re-authentication also applies to refresh tokens, if used. When the session expires, the client refreshes the access token by using its refresh token. The client then uses the new access token to re-authenticate over the existing connection.

Session expiry for OAUTHBEARER and PLAIN

When session re-authentication is configured, session expiry works differently for OAUTHBEARER and PLAIN authentication.

For OAUTHBEARER and PLAIN, using the *client ID and secret* method:

- The broker's authenticated session will expire at the configured **connections.max.reauth.ms**.
- The session will expire earlier if the access token expires before the configured time.

For PLAIN using the *long-lived access token* method:

- The broker's authenticated session will expire at the configured **connections.max.reauth.ms**.
- Re-authentication will fail if the access token expires before the configured time. Although session re-authentication is attempted, PLAIN has no mechanism for refreshing tokens.

If **connections.max.reauth.ms** is *not* configured, OAUTHBEARER and PLAIN clients can remain connected to brokers indefinitely, without needing to re-authenticate. Authenticated sessions do not end with access token expiry. However, this can be considered when configuring authorization, for example, by using **keycloak** authorization or installing a custom authorizer.

Additional resources

- OAuth 2.0 Kafka broker configuration
- Configuring OAuth 2.0 support for Kafka brokers

- KIP-368: Allow SASL Connections to Periodically Re-Authenticate

6.5.4. OAuth 2.0 Kafka client configuration

A Kafka client is configured with either:

- The credentials required to obtain a valid access token from an authorization server (client ID and Secret)
- A valid long-lived access token or refresh token, obtained using tools provided by an authorization server

The only information ever sent to the Kafka broker is an access token. The credentials used to authenticate with the authorization server to obtain the access token are never sent to the broker.

When a client obtains an access token, no further communication with the authorization server is needed.

The simplest mechanism is authentication with a client ID and Secret. Using a long-lived access token, or a long-lived refresh token, adds more complexity because there is an additional dependency on authorization server tools.

NOTE

If you are using long-lived access tokens, you may need to configure the client in the authorization server to increase the maximum lifetime of the token.

If the Kafka client is not configured with an access token directly, the client exchanges credentials for an access token during Kafka session initiation by contacting the authorization server. The Kafka client exchanges either:

- Client ID and Secret
- Client ID, refresh token, and (optionally) a secret
- Username and password, with client ID and (optionally) a secret

6.5.5. OAuth 2.0 client authentication flows

OAuth 2.0 authentication flows depend on the underlying Kafka client and Kafka broker configuration. The flows must also be supported by the authorization server used.

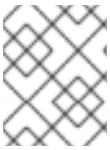
The Kafka broker listener configuration determines how clients authenticate using an access token. The client can pass a client ID and secret to request an access token.

If a listener is configured to use PLAIN authentication, the client can authenticate with a client ID and secret or username and access token. These values are passed as the **username** and **password** properties of the PLAIN mechanism.

Listener configuration supports the following token validation options:

- You can use fast local token validation based on JWT signature checking and local token introspection, without contacting an authorization server. The authorization server provides a JWKS endpoint with public certificates that are used to validate signatures on the tokens.
- You can use a call to a token introspection endpoint provided by an authorization server. Each

time a new Kafka broker connection is established, the broker passes the access token received from the client to the authorization server. The Kafka broker checks the response to confirm whether or not the token is valid.



NOTE

An authorization server might only allow the use of opaque access tokens, which means that local token validation is not possible.

Kafka client credentials can also be configured for the following types of authentication:

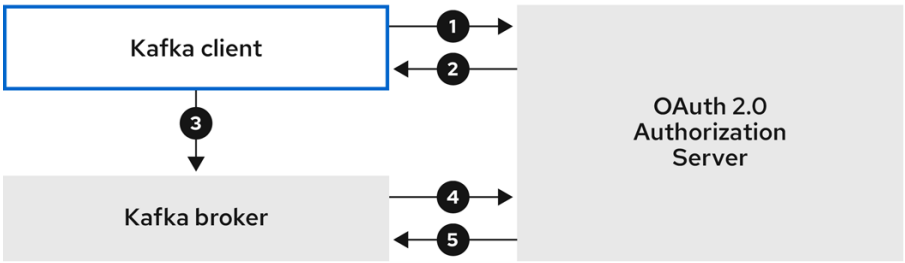
- Direct local access using a previously generated long-lived access token
- Contact with the authorization server for a new access token to be issued (using a client ID and a secret, or a refresh token, or a username and a password)

6.5.5.1. Example client authentication flows using the SASL OAUTHBEARER mechanism

You can use the following communication flows for Kafka authentication using the SASL OAUTHBEARER mechanism.

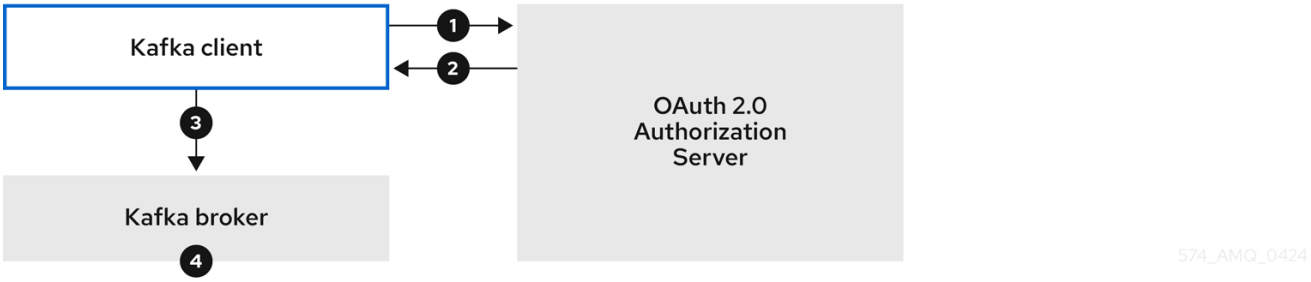
- Client using client ID and secret, with broker delegating validation to authorization server
- Client using client ID and secret, with broker performing fast local token validation
- Client using long-lived access token, with broker delegating validation to authorization server
- Client using long-lived access token, with broker performing fast local validation

Client using client ID and secret, with broker delegating validation to authorization server



1. The Kafka client requests an access token from the authorization server using a client ID and secret, and optionally a refresh token. Alternatively, the client may authenticate using a username and a password.
2. The authorization server generates a new access token.
3. The Kafka client authenticates with the Kafka broker using the SASL OAUTHBEARER mechanism to pass the access token.
4. The Kafka broker validates the access token by calling a token introspection endpoint on the authorization server using its own client ID and secret.
5. A Kafka client session is established if the token is valid.

Client using client ID and secret, with broker performing fast local token validation

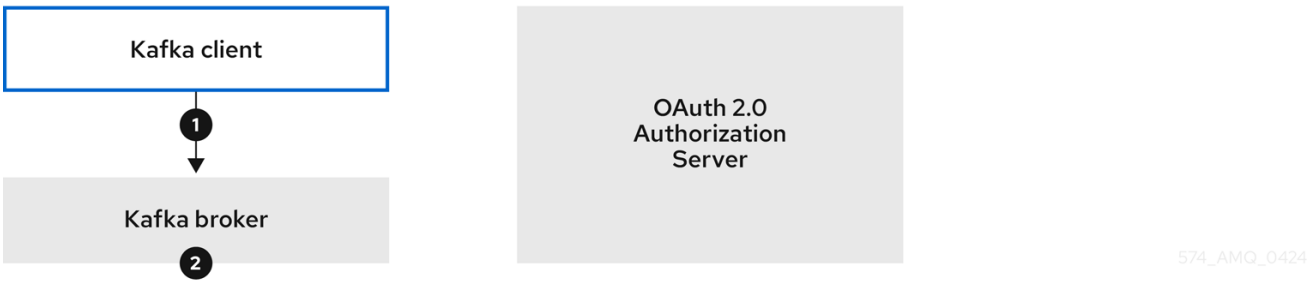


1. The Kafka client authenticates with the authorization server from the token endpoint, using a client ID and secret, and optionally a refresh token. Alternatively, the client may authenticate using a username and a password.
2. The authorization server generates a new access token.
3. The Kafka client authenticates with the Kafka broker using the SASL OAUTHBEARER mechanism to pass the access token.
4. The Kafka broker validates the access token locally using a JWT token signature check, and local token introspection.

Client using long-lived access token, with broker delegating validation to authorization server

1. The Kafka client authenticates with the Kafka broker using the SASL OAUTHBEARER mechanism to pass the long-lived access token.
2. The Kafka broker validates the access token by calling a token introspection endpoint on the authorization server, using its own client ID and secret.
3. A Kafka client session is established if the token is valid.

Client using long-lived access token, with broker performing fast local validation



1. The Kafka client authenticates with the Kafka broker using the SASL OAUTHBEARER mechanism to pass the long-lived access token.

2. The Kafka broker validates the access token locally using a JWT token signature check and local token introspection.

WARNING

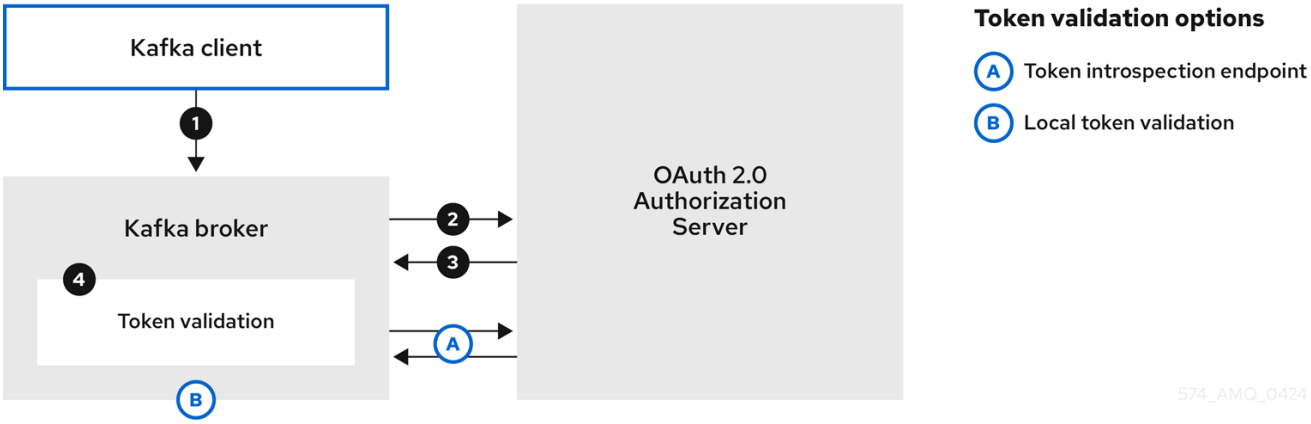
Fast local JWT token signature validation is suitable only for short-lived tokens as there is no check with the authorization server if a token has been revoked. Token expiration is written into the token, but revocation can happen at any time, so cannot be accounted for without contacting the authorization server. Any issued token would be considered valid until it expires.

6.5.5.2. Example client authentication flows using the SASL PLAIN mechanism

You can use the following communication flows for Kafka authentication using the OAuth PLAIN mechanism.

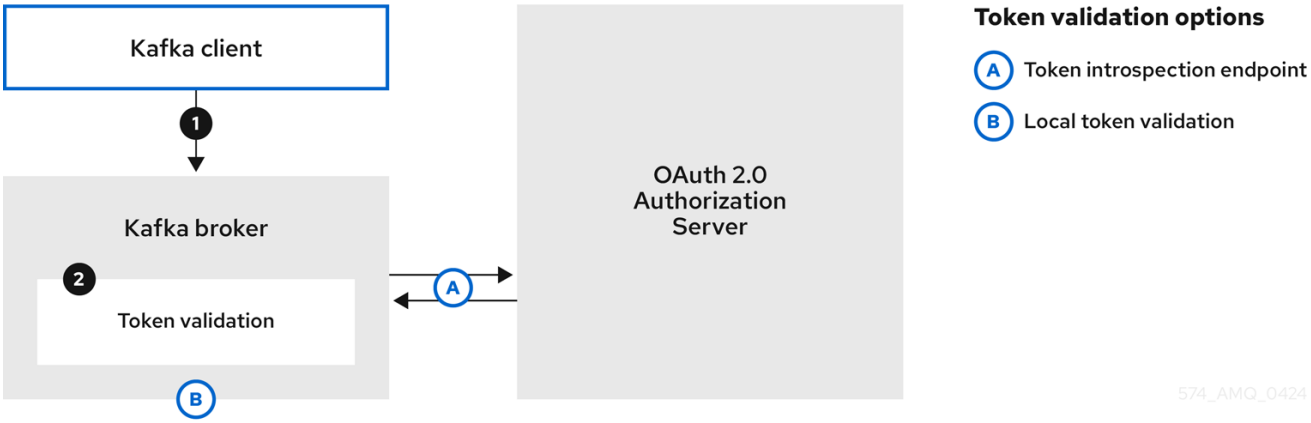
- Client using a client ID and secret, with the broker obtaining the access token for the client
- Client using a long-lived access token without a client ID and secret

Client using a client ID and secret, with the broker obtaining the access token for the client



1. The Kafka client passes a **clientId** as a username and a **secret** as a password.
2. The Kafka broker uses a token endpoint to pass the **clientId** and **secret** to the authorization server.
3. The authorization server returns a fresh access token or an error if the client credentials are not valid.
4. The Kafka broker validates the token in one of the following ways:
    a. If a token introspection endpoint is specified, the Kafka broker validates the access token by calling the endpoint on the authorization server. A session is established if the token validation is successful.
    b. If local token introspection is used, a request is not made to the authorization server. The Kafka broker validates the access token locally using a JWT token signature check.

Client using a long-lived access token without a client ID and secret



1. The Kafka client passes a username and password. The password provides the value of an access token that was obtained manually and configured before running the client.

2. The password is passed with or without an **$accessToken:** string prefix depending on whether or not the Kafka broker listener is configured with a token endpoint for authentication.

    a. If the token endpoint is configured, the password should be prefixed by **$accessToken:** to let the broker know that the password parameter contains an access token rather than a client secret. The Kafka broker interprets the username as the account username.

    b. If the token endpoint is not configured on the Kafka broker listener (enforcing a **no-client-credentials mode**), the password should provide the access token without the prefix. The Kafka broker interprets the username as the account username. In this mode, the client doesn't use a client ID and secret, and the **password** parameter is always interpreted as a raw access token.

3. The Kafka broker validates the token in one of the following ways:

    a. If a token introspection endpoint is specified, the Kafka broker validates the access token by calling the endpoint on the authorization server. A session is established if token validation is successful.

    b. If local token introspection is used, there is no request made to the authorization server. Kafka broker validates the access token locally using a JWT token signature check.

6.5.6. Configuring OAuth 2.0 authentication

OAuth 2.0 is used for interaction between Kafka clients and Streams for Apache Kafka components.

In order to use OAuth 2.0 for Streams for Apache Kafka, you must:

1. Configure an OAuth 2.0 authorization server for the Streams for Apache Kafka cluster and Kafka clients

2. Deploy or update the Kafka cluster with Kafka broker listeners configured to use OAuth 2.0

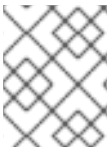
3. Update your Java-based Kafka clients to use OAuth 2.0

6.5.6.1. Configuring Red Hat Single Sign-On as an OAuth 2.0 authorization server

This procedure describes how to deploy Red Hat Single Sign-On as an authorization server and configure it for integration with Streams for Apache Kafka.

The authorization server provides a central point for authentication and authorization, and management of users, clients, and permissions. Red Hat Single Sign-On has a concept of realms where a *realm* represents a separate set of users, clients, permissions, and other configuration. You can use a default *master realm*, or create a new one. Each realm exposes its own OAuth 2.0 endpoints, which means that application clients and application servers all need to use the same realm.

To use OAuth 2.0 with Streams for Apache Kafka, you use a deployment of Red Hat Single Sign-On to create and manage authentication realms.



NOTE

If you already have Red Hat Single Sign-On deployed, you can skip the deployment step and use your current deployment.

Before you begin

You will need to be familiar with using Red Hat Single Sign-On.

For installation and administration instructions, see:

- Server Installation and Configuration Guide
- Server Administration Guide

Prerequisites

- Streams for Apache Kafka and Kafka are running

For the Red Hat Single Sign-On deployment:

- Check the Red Hat Single Sign-On Supported Configurations

Procedure

1. Install Red Hat Single Sign-On.
   You can install from a ZIP file or by using an RPM.
2. Log in to the Red Hat Single Sign-On Admin Console to create the OAuth 2.0 policies for Streams for Apache Kafka.
   Login details are provided when you deploy Red Hat Single Sign-On.
3. Create and enable a realm.
   You can use an existing master realm.
4. Adjust the session and token timeouts for the realm, if required.
5. Create a client called **kafka-broker**.
6. From the **Settings** tab, set:
   - **Access Type** to **Confidential**
   - **Standard Flow Enabled** to **OFF** to disable web login for this client

- **Service Accounts Enabled** to **ON** to allow this client to authenticate in its own name

7. Click **Save** before continuing.
8. From the **Credentials** tab, take a note of the secret for using in your Streams for Apache Kafka cluster configuration.
9. Repeat the client creation steps for any application client that will connect to your Kafka brokers.
   Create a definition for each new client.

   You will use the names as client IDs in your configuration.

What to do next

After deploying and configuring the authorization server, configure the Kafka brokers to use OAuth 2.0 .

6.5.6.2. Configuring OAuth 2.0 support for Kafka brokers

This procedure describes how to configure Kafka brokers so that the broker listeners are enabled to use OAuth 2.0 authentication using an authorization server.

We advise use of OAuth 2.0 over an encrypted interface through configuration of TLS listeners. Plain listeners are not recommended.

Configure the Kafka brokers using properties that support your chosen authorization server, and the type of authorization you are implementing.

Before you start

For more information on the configuration and authentication of Kafka broker listeners, see:

- Listeners
- OAuth 2.0 authentication mechanisms

For a description of the properties used in the listener configuration, see:

- OAuth 2.0 Kafka broker configuration

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- An OAuth 2.0 authorization server is deployed.

Procedure

1. Configure the Kafka broker listener configuration in the **server.properties** file.
   For example, using the OAUTHBEARER mechanism:

```
sasl.enabled.mechanisms=OAUTHBEARER
listeners=CLIENT://0.0.0.0:9092
listener.security.protocol.map=CLIENT:SASL_PLAINTEXT
listener.name.client.sasl.enabled.mechanisms=OAUTHBEARER
sasl.mechanism.inter.broker.protocol=OAUTHBEARER
inter.broker.listener.name=CLIENT
```

```
listener.name.client.oauthbearer.sasl.server.callback.handler.class=io.strimzi.kafka.oauth.server
JaasServerOauthValidatorCallbackHandler
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbear
er.OAuthBearerLoginModule required ;
listener.name.client.oauthbearer.sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.J
asClientOauthLoginCallbackHandler
```

2. Configure broker connection settings as part of the **listener.name.client.oauthbearer.sasl.jaas.config**.
   The examples here show connection configuration options.

   Example 1: Local token validation using a JWKS endpoint configuration

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbear
er.OAuthBearerLoginModule required \
  oauth.valid.issuer.uri="https://<oauth_server_address>/auth/realms/<realm_name>" \

oauth.jwks.endpoint.uri="https://<oauth_server_address>/auth/realms/<realm_name>/protocol/
openid-connect/certs" \
  oauth.jwks.refresh.seconds="300" \
  oauth.jwks.refresh.min.pause.seconds="1" \
  oauth.jwks.expiry.seconds="360" \
  oauth.username.claim="preferred_username" \
  oauth.ssl.truststore.location="<path_to_truststore_p12_file>" \
  oauth.ssl.truststore.password="<truststore_password>" \
  oauth.ssl.truststore.type="PKCS12" ;
listener.name.client.oauthbearer.connections.max.reauth.ms=3600000
```

   Example 2: Delegating token validation to the authorization server through the OAuth 2.0 introspection endpoint

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbear
er.OAuthBearerLoginModule required \

oauth.introspection.endpoint.uri="https://<oauth_server_address>/auth/realms/<realm_name>/
protocol/openid-connect/introspection" \
  # ...
```

3. If required, configure access to the authorization server.
   This step is normally required for a production environment, unless a technology like *service mesh* is used to configure secure channels outside containers.

   a. Provide a custom truststore for connecting to a secured authorization server. SSL is always required for access to the authorization server.
      Set properties to configure the truststore.

      For example:

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauth
bearer.OAuthBearerLoginModule required \
  # ...
  oauth.client.id="kafka-broker" \
  oauth.client.secret="kafka-broker-secret" \
```

```
oauth.ssl.truststore.location="<path_to_truststore_p12_file>" \
oauth.ssl.truststore.password="<truststore_password>" \
oauth.ssl.truststore.type="PKCS12" ;
```

b. If the certificate hostname does not match the access URL hostname, you can turn off certificate hostname validation:

```
oauth.ssl.endpoint.identification.algorithm=""
```

The check ensures that client connection to the authorization server is authentic. You may wish to turn off the validation in a non-production environment.

4. Configure additional properties according to your chosen authentication flow:

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule required \
  # ...

oauth.token.endpoint.uri="https://<oauth_server_address>/auth/realms/<realm_name>/protocol/openid-connect/token" \ 1
  oauth.custom.claim.check="@.custom == 'custom-value'" \ 2
  oauth.scope="<scope>" \ 3
  oauth.check.audience="true" \ 4
  oauth.audience="<audience>" \ 5
  oauth.valid.issuer.uri="https://https://<oauth_server_address>/auth/<realm_name>" \ 6
  oauth.client.id="kafka-broker" \ 7
  oauth.client.secret="kafka-broker-secret" \ 8
  oauth.connect.timeout.seconds=60 \ 9
  oauth.read.timeout.seconds=60 \ 10
  oauth.http.retries=2 \ 11
  oauth.http.retry.pause.millis=300 \ 12
  oauth.groups.claim="$.groups" \ 13
  oauth.groups.claim.delimiter="," \ 14
  oauth.include.accept.header="false" ; 15
```

1 The OAuth 2.0 token endpoint URL to your authorization server. For production, always use **https://** urls. Required when **KeycloakAuthorizer** is used, or an OAuth 2.0 enabled listener is used for inter-broker communication.

2 (Optional) **Custom claim checking**. A JsonPath filter query that applies additional custom rules to the JWT access token during validation. If the access token does not contain the necessary data, it is rejected. When using the *introspection* endpoint method, the custom check is applied to the introspection endpoint response JSON.

3 (Optional) A **scope** parameter passed to the token endpoint. A *scope* is used when obtaining an access token for inter-broker authentication. It is also used in the name of a client for OAuth 2.0 over PLAIN client authentication using a **clientId** and **secret**. This only affects the ability to obtain the token, and the content of the token, depending on the authorization server. It does not affect token validation rules by the listener.

4 (Optional) **Audience checking**. If your authorization server provides an **aud** (audience)

5 (Optional) An **audience** parameter passed to the token endpoint. An *audience* is used when obtaining an access token for inter-broker authentication. It is also used in the name

6 A valid issuer URI. Only access tokens issued by this issuer will be accepted. (Always required.)

7 The configured client ID of the Kafka broker, which is the same for all brokers. This is the client registered with the authorization server as **kafka-broker**. Required when an introspection endpoint is used for token validation, or when **KeycloakAuthorizer** is used.

8 The configured secret for the Kafka broker, which is the same for all brokers. When the broker must authenticate to the authorization server, either a client secret, access token or a refresh token has to be specified.

9 (Optional) The connect timeout in seconds when connecting to the authorization server. The default value is 60.

10 (Optional) The read timeout in seconds when connecting to the authorization server. The default value is 60.

11 The maximum number of times to retry a failed HTTP request to the authorization server. The default value is 0, meaning that no retries are performed. To use this option effectively, consider reducing the timeout times for the **oauth.connect.timeout.seconds** and **oauth.read.timeout.seconds** options. However, note that retries may prevent the current worker thread from being available to other requests, and if too many requests stall, it could make the Kafka broker unresponsive.

12 The time to wait before attempting another retry of a failed HTTP request to the authorization server. By default, this time is set to zero, meaning that no pause is applied. This is because many issues that cause failed requests are per-request network glitches or proxy issues that can be resolved quickly. However, if your authorization server is under stress or experiencing high traffic, you may want to set this option to a value of 100 ms or more to reduce the load on the server and increase the likelihood of successful retries.

13 A JsonPath query used to extract groups information from JWT token or introspection endpoint response. Not set by default. This can be used by a custom authorizer to make authorization decisions based on user groups.

14 A delimiter used to parse groups information when returned as a single delimited string. The default value is ',' (comma).

15 (Optional) Sets **oauth.include.accept.header** to **false** to remove the **Accept** header from requests. You can use this setting if including the header is causing issues when communicating with the authorization server.

5. Depending on how you apply OAuth 2.0 authentication, and the type of authorization server being used, add additional configuration settings:

```
listener.name.client.oauthbearer.sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule required \
  # ...
  oauth.check.issuer=false \ 1
  oauth.fallback.username.claim="<client_id>" \ 2
  oauth.fallback.username.prefix="<client_account>" \ 3
  oauth.valid.token.type="bearer" \ 4
```

```
oauth.userinfo.endpoint.uri="https://<oauth_server_address>/auth/realms/<realm_name>/protocol/openid-connect/userinfo" ; 5
```

1. If your authorization server does not provide an **iss** claim, it is not possible to perform an issuer check. In this situation, set **oauth.check.issuer** to **false** and do not specify a **oauth.valid.issuer.uri**. Default is **true**.

2. An authorization server may not provide a single attribute to identify both regular users and clients. When a client authenticates in its own name, the server might provide a *client ID*. When a user authenticates using a username and password, to obtain a refresh token or an access token, the server might provide a *username* attribute in addition to a client ID. Use this fallback option to specify the username claim (attribute) to use if a primary user ID attribute is not available. If required, you can use a JsonPath expression like **"['client.info'].['client.id']"** to retrieve the fallback username from nested JSON attributes within a token.

3. In situations where **oauth.fallback.username.claim** is applicable, it may also be necessary to prevent name collisions between the values of the username claim, and those of the fallback username claim. Consider a situation where a client called **producer** exists, but also a regular user called **producer** exists. In order to differentiate between the two, you can use this property to add a prefix to the user ID of the client.

4. (Only applicable when using **oauth.introspection.endpoint.uri**) Depending on the authorization server you are using, the introspection endpoint may or may not return the *token type* attribute, or it may contain different values. You can specify a valid token type value that the response from the introspection endpoint has to contain.

5. (Only applicable when using **oauth.introspection.endpoint.uri**) The authorization server may be configured or implemented in such a way to not provide any identifiable information in an introspection endpoint response. In order to obtain the user ID, you can configure the URI of the **userinfo** endpoint as a fallback. The **oauth.fallback.username.claim**, **oauth.fallback.username.claim**, and **oauth.fallback.username.prefix** settings are applied to the response of the **userinfo** endpoint.

What to do next

- Configure your Kafka clients to use OAuth 2.0

6.5.6.3. Configuring Kafka Java clients to use OAuth 2.0

Configure Kafka producer and consumer APIs to use OAuth 2.0 for interaction with Kafka brokers. Add a callback plugin to your client **pom.xml** file, then configure your client for OAuth 2.0.

Specify the following in your client configuration:

- A SASL (Simple Authentication and Security Layer) security protocol:
  - **SASL_SSL** for authentication over TLS encrypted connections
  - **SASL_PLAINTEXT** for authentication over unencrypted connections
    Use **SASL_SSL** for production and **SASL_PLAINTEXT** for local development only. When using **SASL_SSL**, additional **ssl.truststore** configuration is needed. The truststore configuration is required for secure connection (**https://**) to the OAuth 2.0 authorization

server. To verify the OAuth 2.0 authorization server, add the CA certificate for the authorization server to the truststore in your client configuration. You can configure a truststore in PEM or PKCS #12 format.

- A Kafka SASL mechanism:
  - **OAUTHBEARER** for credentials exchange using a bearer token
  - **PLAIN** to pass client credentials (clientId + secret) or an access token
- A JAAS (Java Authentication and Authorization Service) module that implements the SASL mechanism:
  - **org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule** implements the OAuthbearer mechanism
  - **org.apache.kafka.common.security.plain.PlainLoginModule** implements the plain mechanism

  To be able to use the OAuthbearer mechanism, you must also add the custom **io.strimzi.kafka.oauth.client.JaasClientOauthLoginCallbackHandler** class as the callback handler. **JaasClientOauthLoginCallbackHandler** handles OAuth callbacks to the authorization server for access tokens during client login. This enables automatic token renewal, ensuring continuous authentication without user intervention. Additionally, it handles login credentials for clients using the OAuth 2.0 password grant method.
- SASL authentication properties, which support the following authentication methods:
  - OAuth 2.0 client credentials
  - OAuth 2.0 password grant (deprecated)
  - Access token
  - Refresh token

  Add the SASL authentication properties as JAAS configuration (**sasl.jaas.config** and **sasl.login.callback.handler.class**). How you configure the authentication properties depends on the authentication method you are using to access the OAuth 2.0 authorization server. In this procedure, the properties are specified in a properties file, then loaded into the client configuration.

NOTE

You can also specify authentication properties as environment variables, or as Java system properties. For Java system properties, you can set them using **setProperty** and pass them on the command line using the **-D** option.

Prerequisites

- Streams for Apache Kafka and Kafka are running
- An OAuth 2.0 authorization server is deployed and configured for OAuth access to Kafka brokers
- Kafka brokers are configured for OAuth 2.0

Procedure

1. Add the client library with OAuth 2.0 support to the **pom.xml** file for the Kafka client:

```
<dependency>
 <groupId>io.strimzi</groupId>
 <artifactId>kafka-oauth-client</artifactId>
 <version>0.15.0.redhat-00007</version>
</dependency>
```

2. Configure the client properties by specifying the following configuration in a properties file:
   - The security protocol
   - The SASL mechanism
   - The JAAS module and authentication properties according to the method being used
     For example, we can add the following to a **client.properties** file:

     Client credentials mechanism properties

```
security.protocol=SASL_SSL (1)
sasl.mechanism=OAUTHBEARER (2)
ssl.truststore.location=/tmp/truststore.p12 (3)
ssl.truststore.password=$STOREPASS
ssl.truststore.type=PKCS12
sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule
required \
  oauth.token.endpoint.uri="<token_endpoint_url>" \ (4)
  oauth.client.id="<client_id>" \ (5)
  oauth.client.secret="<client_secret>" \ (6)
  oauth.ssl.truststore.location="/tmp/oauth-truststore.p12" \ (7)
  oauth.ssl.truststore.password="$STOREPASS" \ (8)
  oauth.ssl.truststore.type="PKCS12" \ (9)
  oauth.scope="<scope>" \ (10)
  oauth.audience="<audience>" ; (11)
sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.JaasClientOauthLoginCallbackHandler
```

(1) **SASL_SSL** security protocol for TLS-encrypted connections. Use **SASL_PLAINTEXT** over unencrypted connections for local development only.

(2) The SASL mechanism specified as **OAUTHBEARER** or **PLAIN**.

(3) The truststore configuration for secure access to the Kafka cluster.

(4) URI of the authorization server token endpoint.

(5) Client ID, which is the name used when creating the *client* in the authorization server.

(6) Client secret created when creating the *client* in the authorization server.

(7) The location contains the public key certificate (**truststore.p12**) for the authorization server.

8 The password for accessing the truststore.

9 The truststore type.

10 (Optional) The **scope** for requesting the token from the token endpoint. An authorization server may require a client to specify the scope.

11 (Optional) The **audience** for requesting the token from the token endpoint. An authorization server may require a client to specify the audience.

Password grants mechanism properties

```
security.protocol=SASL_SSL
sasl.mechanism=OAUTHBEARER
ssl.truststore.location=/tmp/truststore.p12
ssl.truststore.password=$STOREPASS
ssl.truststore.type=PKCS12
sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule
required \
  oauth.token.endpoint.uri="<token_endpoint_url>" \
  oauth.client.id="<client_id>" \ 1
  oauth.client.secret="<client_secret>" \ 2
  oauth.password.grant.username="<username>" \ 3
  oauth.password.grant.password="<password>" \ 4
  oauth.ssl.truststore.location="/tmp/oauth-truststore.p12" \
  oauth.ssl.truststore.password="$STOREPASS" \
  oauth.ssl.truststore.type="PKCS12" \
  oauth.scope="<scope>" \
  oauth.audience="<audience>" ;
sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.JaasClientOauthLoginCallbackHandler
```

1 Client ID, which is the name used when creating the *client* in the authorization server.

2 (Optional) Client secret created when creating the *client* in the authorization server.

3 Username for password grant authentication. OAuth password grant configuration (username and password) uses the OAuth 2.0 password grant method. To use password grants, create a user account for a client on your authorization server with limited permissions. The account should act like a service account. Use in environments where user accounts are required for authentication, but consider using a refresh token first.

4 Password for password grant authentication.

NOTE

SASL PLAIN does not support passing a username and password (password grants) using the OAuth 2.0 password grant method.

Access token properties

```
security.protocol=SASL_SSL
sasl.mechanism=OAUTHBEARER
ssl.truststore.location=/tmp/truststore.p12
ssl.truststore.password=$STOREPASS
ssl.truststore.type=PKCS12
sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule
required \
  oauth.token.endpoint.uri="<token_endpoint_url>" \
  oauth.access.token="<access_token>" \ 1
  oauth.ssl.truststore.location="/tmp/oauth-truststore.p12" \
  oauth.ssl.truststore.password="$STOREPASS" \
  oauth.ssl.truststore.type="PKCS12" ;
sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.JaasClientOauthLoginCallbacl
Handler
```

1 Long-lived access token for Kafka clients.

Refresh token properties

```
security.protocol=SASL_SSL
sasl.mechanism=OAUTHBEARER
ssl.truststore.location=/tmp/truststore.p12
ssl.truststore.password=$STOREPASS
ssl.truststore.type=PKCS12
sasl.jaas.config=org.apache.kafka.common.security.oauthbearer.OAuthBearerLoginModule
required \
  oauth.token.endpoint.uri="<token_endpoint_url>" \
  oauth.client.id="<client_id>" \ 1
  oauth.client.secret="<client_secret>" \ 2
  oauth.refresh.token="<refresh_token>" \ 3
  oauth.ssl.truststore.location="/tmp/oauth-truststore.p12" \
  oauth.ssl.truststore.password="$STOREPASS" \
  oauth.ssl.truststore.type="PKCS12" ;
sasl.login.callback.handler.class=io.strimzi.kafka.oauth.client.JaasClientOauthLoginCallbacl
Handler
```

1 Client ID, which is the name used when creating the *client* in the authorization server.

2 (Optional) Client secret created when creating the *client* in the authorization server.

3 Long-lived refresh token for Kafka clients.

3. Input the client properties for OAUTH 2.0 authentication into the Java client code.

Example showing input of client properties

```
Properties props = new Properties();
try (FileReader reader = new FileReader("client.properties", StandardCharsets.UTF_8)) {
  props.load(reader);
}
```

4. Verify that the Kafka client can access the Kafka brokers.

6.6. USING OAUTH 2.0 TOKEN-BASED AUTHORIZATION

If you are using OAuth 2.0 with Red Hat Single Sign-On for token-based authentication, you can also use Red Hat Single Sign-On to configure authorization rules to constrain client access to Kafka brokers. Authentication establishes the identity of a user. Authorization decides the level of access for that user.

Streams for Apache Kafka supports the use of OAuth 2.0 token-based authorization through Red Hat Single Sign-On Authorization Services, which allows you to manage security policies and permissions centrally.

Security policies and permissions defined in Red Hat Single Sign-On are used to grant access to resources on Kafka brokers. Users and clients are matched against policies that permit access to perform specific actions on Kafka brokers.

Kafka allows all users full access to brokers by default, and also provides the **AclAuthorizer** and **StandardAuthorizer** plugins to configure authorization based on Access Control Lists (ACLs). The ACL rules managed by these plugins are used to grant or deny access to resources based on the *username*, and these rules are stored within the Kafka cluster itself. However, OAuth 2.0 token-based authorization with Red Hat Single Sign-On offers far greater flexibility on how you wish to implement access control to Kafka brokers. In addition, you can configure your Kafka brokers to use OAuth 2.0 authorization and ACLs.

Additional resources

- Using OAuth 2.0 token-based authentication
- Kafka Authorization
- Red Hat Single Sign-On documentation

6.6.1. OAuth 2.0 authorization mechanism

OAuth 2.0 authorization in Streams for Apache Kafka uses Red Hat Single Sign-On server Authorization Services REST endpoints to extend token-based authentication with Red Hat Single Sign-On by applying defined security policies on a particular user, and providing a list of permissions granted on different resources for that user. Policies use roles and groups to match permissions to users. OAuth 2.0 authorization enforces permissions locally based on the received list of grants for the user from Red Hat Single Sign-On Authorization Services.

6.6.1.1. Kafka broker custom authorizer

A Red Hat Single Sign-On *authorizer* (**KeycloakAuthorizer**) is provided with Streams for Apache Kafka. To be able to use the Red Hat Single Sign-On REST endpoints for Authorization Services provided by Red Hat Single Sign-On, you configure a custom authorizer on the Kafka broker.

The authorizer fetches a list of granted permissions from the authorization server as needed, and enforces authorization locally on the Kafka Broker, making rapid authorization decisions for each client request.

6.6.2. Configuring OAuth 2.0 authorization support

This procedure describes how to configure Kafka brokers to use OAuth 2.0 authorization using Red Hat Single Sign-On Authorization Services.

Before you begin

Consider the access you require or want to limit for certain users. You can use a combination of Red Hat Single Sign-On *groups*, *roles*, *clients*, and *users* to configure access in Red Hat Single Sign-On.

Typically, groups are used to match users based on organizational departments or geographical locations. And roles are used to match users based on their function.

With Red Hat Single Sign-On, you can store users and groups in LDAP, whereas clients and roles cannot be stored this way. Storage and access to user data may be a factor in how you choose to configure authorization policies.

NOTE

Super users always have unconstrained access to a Kafka broker regardless of the authorization implemented on the Kafka broker.

Prerequisites

- Streams for Apache Kafka must be configured to use OAuth 2.0 with Red Hat Single Sign-On for token-based authentication. You use the same Red Hat Single Sign-On server endpoint when you set up authorization.
- You need to understand how to manage policies and permissions for Red Hat Single Sign-On Authorization Services, as described in the Red Hat Single Sign-On documentation .

Procedure

1. Access the Red Hat Single Sign-On Admin Console or use the Red Hat Single Sign-On Admin CLI to enable Authorization Services for the Kafka broker client you created when setting up OAuth 2.0 authentication.
2. Use Authorization Services to define resources, authorization scopes, policies, and permissions for the client.
3. Bind the permissions to users and clients by assigning them roles and groups.
4. Configure the Kafka brokers to use Red Hat Single Sign-On authorization.
   Add the following to the Kafka **server.properties** configuration file to install the authorizer in Kafka:

```
authorizer.class.name=io.strimzi.kafka.oauth.server.authorizer.KeycloakAuthorizer
principal.builder.class=io.strimzi.kafka.oauth.server.OAuthKafkaPrincipalBuilder
```

5. Add configuration for the Kafka brokers to access the authorization server and Authorization Services.
   Here we show example configuration added as additional properties to **server.properties**, but you can also define them as environment variables using capitalized or upper-case naming conventions.

```
strimzi.authorization.token.endpoint.uri="https://<auth_server_address>/auth/realms/REALM-NAME/protocol/openid-connect/token" (1)
strimzi.authorization.client.id="kafka" (2)
```

(1) The OAuth 2.0 token endpoint URL to Red Hat Single Sign-On. For production, always use **https://** urls.

2 The client ID of the OAuth 2.0 client definition in Red Hat Single Sign-On that has Authorization Services enabled. Typically, **kafka** is used as the ID.

6. (Optional) Add configuration for specific Kafka clusters.
For example:

```
strimzi.authorization.kafka.cluster.name="kafka-cluster" 1
```

1 The name of a specific Kafka cluster. Names are used to target permissions, making it possible to manage multiple clusters within the same Red Hat Single Sign-On realm. The default value is **kafka-cluster**.

7. (Optional) Delegate to simple authorization:

```
strimzi.authorization.delegate.to.kafka.acl="true" 1
```

1 Delegate authorization to Kafka **AclAuthorizer** if access is denied by Red Hat Single Sign-On Authorization Services policies. The default is **false**.

8. (Optional) Add configuration for TLS connection to the authorization server.
For example:

```
strimzi.authorization.ssl.truststore.location=<path_to_truststore> 1
strimzi.authorization.ssl.truststore.password=<my_truststore_password> 2
strimzi.authorization.ssl.truststore.type=JKS 3
strimzi.authorization.ssl.secure.random.implementation=SHA1PRNG 4
strimzi.authorization.ssl.endpoint.identification.algorithm=HTTPS 5
```

1 The path to the truststore that contain the certificates.

2 The password for the truststore.

3 The truststore type. If not set, the default Java keystore type is used.

4 Random number generator implementation. If not set, the Java platform SDK default is used.

5 Hostname verification. If set to an empty string, the hostname verification is turned off. If not set, the default value is **HTTPS**, which enforces hostname verification for server certificates.

9. (Optional) Configure the refresh of grants from the authorization server. The grants refresh job works by enumerating the active tokens and requesting the latest grants for each.
For example:

```
strimzi.authorization.grants.refresh.period.seconds="120" 1
strimzi.authorization.grants.refresh.pool.size="10" 2
strimzi.authorization.grants.max.idle.time.seconds="300" 3
strimzi.authorization.grants.gc.period.seconds="300" 4
strimzi.authorization.reuse.grants="false" 5
```

1. Specifies how often the list of grants from the authorization server is refreshed (once per minute by default). To turn grants refresh off for debugging purposes, set to **"0"**.
2. Specifies the size of the thread pool (the degree of parallelism) used by the grants refresh job. The default value is **"5"**.
3. The time, in seconds, after which an idle grant in the cache can be evicted. The default value is 300.
4. The time, in seconds, between consecutive runs of a job that cleans stale grants from the cache. The default value is 300.
5. Controls whether the latest grants are fetched for a new session. When disabled, grants are retrieved from Red Hat Single Sign-On and cached for the user. The default value is **true**.

10. (Optional) Configure network timeouts when communicating with the authorization server. For example:

```
strimzi.authorization.connect.timeout.seconds="60" 1
strimzi.authorization.read.timeout.seconds="60" 2
strimzi.authorization.http.retries="2" 3
```

1. The connect timeout in seconds when connecting to the Red Hat Single Sign-On token endpoint. The default value is **60**.
2. The read timeout in seconds when connecting to the Red Hat Single Sign-On token endpoint. The default value is **60**.
3. The maximum number of times to retry (without pausing) a failed HTTP request to the authorization server. The default value is **0**, meaning that no retries are performed. To use this option effectively, consider reducing the timeout times for the **strimzi.authorization.connect.timeout.seconds** and **strimzi.authorization.read.timeout.seconds** options. However, note that retries may prevent the current worker thread from being available to other requests, and if too many requests stall, it could make the Kafka broker unresponsive.

11. (Optional) Enable OAuth 2.0 metrics for token validation and authorization:

```
oauth.enable.metrics="true" 1
```

1. Controls whether to enable or disable OAuth metrics. The default value is **false**.

12. (Optional) Remove the **Accept** header from requests:

```
oauth.include.accept.header="false" 1
```

1. Set to **false** if including the header is causing issues when communicating with the authorization server. The default value is **true**.

13. Verify the configured permissions by accessing Kafka brokers as clients or users with specific roles, making sure they have the necessary access, or do not have the access they are not supposed to have.

6.7. USING OPA POLICY-BASED AUTHORIZATION

Open Policy Agent (OPA) is an open-source policy engine. You can integrate OPA with Streams for Apache Kafka to act as a policy-based authorization mechanism for permitting client operations on Kafka brokers.

When a request is made from a client, OPA will evaluate the request against policies defined for Kafka access, then allow or deny the request.

NOTE

Red Hat does not support the OPA server.

Additional resources

- Open Policy Agent website

6.7.1. Defining OPA policies

Before integrating OPA with Streams for Apache Kafka, consider how you will define policies to provide fine-grained access controls.

You can define access control for Kafka clusters, consumer groups and topics. For instance, you can define an authorization policy that allows write access from a producer client to a specific broker topic.

For this, the policy might specify the:

- **User principal** and **host address** associated with the producer client
- **Operations** allowed for the client
- **Resource type** (**topic**) and **resource name** the policy applies to

Allow and deny decisions are written into the policy, and a response is provided based on the request and client identification data provided.

In our example the producer client would have to satisfy the policy to be allowed to write to the topic.

6.7.2. Connecting to the OPA

To enable Kafka to access the OPA policy engine to query access control policies, , you configure a custom OPA authorizer plugin (**kafka-authorizer-opa-*VERSION*.jar**) in your Kafka **server.properties** file.

When a request is made by a client, the OPA policy engine is queried by the plugin using a specified URL address and a REST endpoint, which must be the name of the defined policy.

The plugin provides the details of the client request — user principal, operation, and resource — in JSON format to be checked against the policy. The details will include the unique identity of the client; for example, taking the distinguished name from the client certificate if TLS authentication is used.

OPA uses the data to provide a response – either *true* or *false* – to the plugin to allow or deny the request.

6.7.3. Configuring OPA authorization support

This procedure describes how to configure Kafka brokers to use OPA authorization.

Before you begin

Consider the access you require or want to limit for certain users. You can use a combination of *users* and Kafka *resources* to define OPA policies.

It is possible to set up OPA to load user information from an LDAP data source.

NOTE

Super users always have unconstrained access to a Kafka broker regardless of the authorization implemented on the Kafka broker.

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.
- An OPA server must be available for connection.
- The OPA authorizer plugin for Kafka.

Procedure

1. Write the OPA policies required for authorizing client requests to perform operations on the Kafka brokers.
   See Defining OPA policies.

   Now configure the Kafka brokers to use OPA.

2. Install the OPA authorizer plugin for Kafka.
   See Connecting to the OPA.

   Make sure that the plugin files are included in the Kafka classpath.

3. Add the following to the Kafka **server.properties** configuration file to enable the OPA plugin:

   ```
   authorizer.class.name: com.bisnode.kafka.authorization.OpaAuthorizer
   ```

4. Add further configuration to **server.properties** for the Kafka brokers to access the OPA policy engine and policies.
   For example:

   ```
   opa.authorizer.url=https://OPA-ADDRESS/allow (1)
   opa.authorizer.allow.on.error=false (2)
   opa.authorizer.cache.initial.capacity=50000 (3)
   opa.authorizer.cache.maximum.size=50000 (4)
   opa.authorizer.cache.expire.after.seconds=600000 (5)
   super.users=User:alice;User:bob (6)
   ```

1. (Required) The OAuth 2.0 token endpoint URL for the policy the authorizer plugin will query. In this example, the policy is called **allow**.
2. Flag to specify whether a client is allowed or denied access by default if the authorizer plugin fails to connect with the OPA policy engine.
3. Initial capacity in bytes of the local cache. The cache is used so that the plugin does not have to query the OPA policy engine for every request.
4. Maximum capacity in bytes of the local cache.
5. Time in milliseconds that the local cache is refreshed by reloading from the OPA policy engine.
6. A list of user principals treated as super users, so that they are always allowed without querying the Open Policy Agent policy.

   Refer to the Open Policy Agent website for information on authentication and authorization options.

5. Verify the configured permissions by accessing Kafka brokers using clients that have and do not have the correct authorization.

CHAPTER 7. CREATING AND MANAGING TOPICS

Messages in Kafka are always sent to or received from a topic. This chapter describes how to create and manage Kafka topics.

7.1. PARTITIONS AND REPLICAS

A topic is always split into one or more partitions. Partitions act as shards. That means that every message sent by a producer is always written only into a single partition.

Each partition can have one or more replicas, which will be stored on different brokers in the cluster. When creating a topic you can configure the number of replicas using the *replication factor*. *Replication factor* defines the number of copies which will be held within the cluster. One of the replicas for a given partition will be elected as a leader. The leader replica will be used by the producers to send new messages and by the consumers to consume messages. The other replicas will be follower replicas. The followers replicate the leader.

If the leader fails, one of the in-sync followers will automatically become the new leader. Each server acts as a leader for some of its partitions and a follower for others so the load is well balanced within the cluster.

NOTE

The replication factor determines the number of replicas including the leader and the followers. For example, if you set the replication factor to **3**, then there will be one leader and two follower replicas.

7.2. MESSAGE RETENTION

The message retention policy defines how long the messages will be stored on the Kafka brokers. It can be defined based on time, partition size or both.

For example, you can define that the messages should be kept:

- For 7 days
- Until the partition has 1GB of messages. Once the limit is reached, the oldest messages will be removed.
- For 7 days or until the 1GB limit has been reached. Whatever limit comes first will be used.

WARNING

Kafka brokers store messages in log segments. The messages which are past their retention policy will be deleted only when a new log segment is created. New log segments are created when the previous log segment exceeds the configured log segment size. Additionally, users can request new segments to be created periodically.

Kafka brokers support a compacting policy.

For a topic with the compacted policy, the broker will always keep only the last message for each key. The older messages with the same key will be removed from the partition. Because compacting is a periodically executed action, it does not happen immediately when the new message with the same key is sent to the partition. Instead it might take some time until the older messages are removed.

For more information about the message retention configuration options, see Section 7.5, "Topic configuration".

7.3. TOPIC AUTO-CREATION

By default, Kafka automatically creates a topic if a producer or consumer attempts to send or receive messages from a non-existent topic. This behavior is governed by the **auto.create.topics.enable** configuration property, which is set to **true** by default.

For production environments, it is recommended to disable automatic topic creation. To do so, set **auto.create.topics.enable** to **false** in the Kafka configuration properties file:

Disabling automatic topic creation

```
auto.create.topics.enable=false
```

7.4. TOPIC DELETION

Kafka provides the option to prevent topic deletion, controlled by the **delete.topic.enable property**. By default, this property is set to **true**, allowing topics to be deleted.

However, setting it to **false** in the Kafka configuration properties file will disable topic deletion. In this case, attempts to delete a topic will return a success status, but the topic itself will not be deleted.

Disabling topic deletion

```
delete.topic.enable=false
```

7.5. TOPIC CONFIGURATION

Auto-created topics will use the default topic configuration which can be specified in the broker properties file. However, when creating topics manually, their configuration can be specified at creation time. It is also possible to change a topic's configuration after it has been created. The main topic configuration options for manually created topics are:

cleanup.policy

Configures the retention policy to **delete** or **compact**. The **delete** policy will delete old records. The **compact** policy will enable log compaction. The default value is **delete**. For more information about log compaction, see Kafka website.

compression.type

Specifies the compression which is used for stored messages. Valid values are **gzip**, **snappy**, **lz4**, **uncompressed** (no compression) and **producer** (retain the compression codec used by the producer). The default value is **producer**.

max.message.bytes

The maximum size of a batch of messages allowed by the Kafka broker, in bytes. The default value is **1000012**.

min.insync.replicas

The minimum number of replicas which must be in sync for a write to be considered successful. The default value is **1**.

retention.ms

Maximum number of milliseconds for which log segments will be retained. Log segments older than this value will be deleted. The default value is **604800000** (7 days).

retention.bytes

The maximum number of bytes a partition will retain. Once the partition size grows over this limit, the oldest log segments will be deleted. Value of **-1** indicates no limit. The default value is **-1**.

segment.bytes

The maximum file size of a single commit log segment file in bytes. When the segment reaches its size, a new segment will be started. The default value is **1073741824** bytes (1 gibibyte).

The defaults for auto-created topics can be specified in the Kafka broker configuration using similar options:

log.cleanup.policy

See **cleanup.policy** above.

compression.type

See **compression.type** above.

message.max.bytes

See **max.message.bytes** above.

min.insync.replicas

See **min.insync.replicas** above.

log.retention.ms

See **retention.ms** above.

log.retention.bytes

See **retention.bytes** above.

log.segment.bytes

See **segment.bytes** above.

default.replication.factor

Default replication factor for automatically created topics. Default value is **1**.

num.partitions

Default number of partitions for automatically created topics. Default value is **1**.

7.6. INTERNAL TOPICS

Internal topics are created and used internally by the Kafka brokers and clients. Kafka has several internal topics, two of which are used to store consumer offsets (**__consumer_offsets**) and transaction state (**__transaction_state**).

__consumer_offsets and **__transaction_state** topics can be configured using dedicated Kafka broker configuration options starting with prefix **offsets.topic.** and **transaction.state.log.**.

The most important configuration options are:

offsets.topic.replication.factor

Number of replicas for **__consumer_offsets** topic. The default value is **3**.

offsets.topic.num.partitions

Number of partitions for **__consumer_offsets** topic. The default value is **50**.

transaction.state.log.replication.factor

Number of replicas for **__transaction_state** topic. The default value is **3**.

transaction.state.log.num.partitions

Number of partitions for **__transaction_state** topic. The default value is **50**.

transaction.state.log.min.isr

Minimum number of replicas that must acknowledge a write to **__transaction_state** topic to be considered successful. If this minimum cannot be met, then the producer will fail with an exception. The default value is **2**.

7.7. CREATING A TOPIC

Use the **kafka-topics.sh** tool to manage topics. **kafka-topics.sh** is part of the Streams for Apache Kafka distribution and is found in the **bin** directory.

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.

Creating a topic

1. Create a topic using the **kafka-topics.sh** utility and specify the following:
   - Host and port of the Kafka broker in the **--bootstrap-server** option.
   - The new topic to be created in the **--create** option.
   - Topic name in the **--topic** option.
   - The number of partitions in the **--partitions** option.
   - Topic replication factor in the **--replication-factor** option.
     You can also override some of the default topic configuration options using the option **--config**. This option can be used multiple times to override different options.

     ```
     /opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_address> --create --topic <TopicName> --partitions <NumberOfPartitions> --replication-factor <ReplicationFactor> --config <Option1>=<Value1> --config <Option2>=<Value2>
     ```

     Example of the command to create a topic named mytopic

     ```
     /opt/kafka/bin/kafka-topics.sh --bootstrap-server localhost:9092 --create --topic mytopic --partitions 50 --replication-factor 3 --config cleanup.policy=compact --config min.insync.replicas=2
     ```

2. Verify that the topic exists using **kafka-topics.sh**.

```
/opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_address> --describe --topic
<TopicName>
```

Example of the command to describe a topic named mytopic

```
/opt/kafka/bin/kafka-topics.sh --bootstrap-server localhost:9092 --describe --topic mytopic
```

7.8. LISTING AND DESCRIBING TOPICS

The **kafka-topics.sh** tool can be used to list and describe topics. **kafka-topics.sh** is part of the Streams for Apache Kafka distribution and can be found in the **bin** directory.

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.

Describing a topic

1. Describe a topic using the **kafka-topics.sh** utility and specify the following:
   - Host and port of the Kafka broker in the **--bootstrap-server** option.
   - Use the **--describe** option to specify that you want to describe a topic.
   - Topic name must be specified in the **--topic** option.
   - When the **--topic** option is omitted, it describes all available topics.

     ```
     /opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_host>:<port> --describe --topic
     <topic_name>
     ```

     Example of the command to describe a topic named mytopic

     ```
     /opt/kafka/bin/kafka-topics.sh --bootstrap-server localhost:9092 --describe --topic
     mytopic
     ```

     The command lists all partitions and replicas which belong to this topic. It also lists all topic configuration options.

7.9. MODIFYING A TOPIC CONFIGURATION

The **kafka-configs.sh** tool can be used to modify topic configurations. **kafka-configs.sh** is part of the Streams for Apache Kafka distribution and can be found in the **bin** directory.

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.

Modify topic configuration

1. Use the **kafka-configs.sh** tool to get the current configuration.

- Specify the host and port of the Kafka broker in the **--bootstrap-server** option.
- Set the **--entity-type** as **topic** and **--entity-name** to the name of your topic.
- Use **--describe** option to get the current configuration.

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_host>:<port> --entity-type topics --entity-name <topic_name> --describe
```

Example of the command to get configuration of a topic named mytopic

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server localhost:9092 --entity-type topics --entity-name mytopic --describe
```

2. Use the **kafka-configs.sh** tool to change the configuration.
   - Specify the host and port of the Kafka broker in the **--bootstrap-server** option.
   - Set the **--entity-type** as **topic** and **--entity-name** to the name of your topic.
   - Use **--alter** option to modify the current configuration.
   - Specify the options you want to add or change in the option **--add-config**.

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_host>:<port> --entity-type topics --entity-name <topic_name> --alter --add-config <option>=<value>
```

Example of the command to change configuration of a topic named mytopic

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server localhost:9092 --entity-type topics --entity-name mytopic --alter --add-config min.insync.replicas=1
```

3. Use the **kafka-configs.sh** tool to delete an existing configuration option.
   - Specify the host and port of the Kafka broker in the **--bootstrap-server** option.
   - Set the **--entity-type** as **topic** and **--entity-name** to the name of your topic.
   - Use **--delete-config** option to remove existing configuration option.
   - Specify the options you want to remove in the option **--remove-config**.

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_host>:<port> --entity-type topics --entity-name <topic_name> --alter --delete-config <option>
```

Example of the command to change configuration of a topic named mytopic

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server localhost:9092 --entity-type topics --entity-name mytopic --alter --delete-config min.insync.replicas
```

7.10. DELETING A TOPIC

The **kafka-topics.sh** tool can be used to manage topics. **kafka-topics.sh** is part of the Streams for Apache Kafka distribution and can be found in the **bin** directory.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Deleting a topic

1. Delete a topic using the **kafka-topics.sh** utility.
   - Host and port of the Kafka broker in the **--bootstrap-server** option.
   - Use the **--delete** option to specify that an existing topic should be deleted.
   - Topic name must be specified in the **--topic** option.

     ```
     /opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_host>:<port> --delete --topic
     <topic_name>
     ```

     Example of the command to create a topic named mytopic

     ```
     /opt/kafka/bin/kafka-topics.sh --bootstrap-server localhost:9092 --delete --topic mytopic
     ```

2. Verify that the topic was deleted using **kafka-topics.sh**.

   ```
   /opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_host>:<port> --list
   ```

   Example of the command to list all topics

   ```
   /opt/kafka/bin/kafka-topics.sh --bootstrap-server localhost:9092 --list
   ```

CHAPTER 8. USING STREAMS FOR APACHE KAFKA WITH KAFKA CONNECT

Use Kafka Connect to stream data between Kafka and external systems. Kafka Connect provides a framework for moving large amounts of data while maintaining scalability and reliability. Kafka Connect is typically used to integrate Kafka with database, storage, and messaging systems that are external to your Kafka cluster.

Kafka Connect runs in standalone or distributed modes.

Standalone mode

In standalone mode, Kafka Connect runs on a single node. Standalone mode is intended for development and testing.

Distributed mode

In distributed mode, Kafka Connect runs across one or more worker nodes and the workloads are distributed among them. Distributed mode is intended for production.

Kafka Connect uses connector plugins that implement connectivity for different types of external systems. There are two types of connector plugins: sink and source. Sink connectors stream data from Kafka to external systems. Source connectors stream data from external systems into Kafka.

You can also use the Kafka Connect REST API to create, manage, and monitor connector instances.

Connector configuration specifies details such as the source or sink connectors and the Kafka topics to read from or write to. How you manage the configuration depends on whether you are running Kafka Connect in standalone or distributed mode.

- In standalone mode, you can provide the connector configuration as JSON through the Kafka Connect REST API or you can use properties files to define the configuration.
- In distributed mode, you can only provide the connector configuration as JSON through the Kafka Connect REST API.

Handling high volumes of messages

You can tune the configuration to handle high volumes of messages. For more information, see Handling high volumes of messages .

8.1. USING KAFKA CONNECT IN STANDALONE MODE

In Kafka Connect standalone mode, connectors run on the same node as the Kafka Connect worker process, which runs as a single process in a single JVM. This means that the worker process and connectors share the same resources, such as CPU, memory, and disk.

8.1.1. Configuring Kafka Connect in standalone mode

To configure Kafka Connect in standalone mode, edit the **config/connect-standalone.properties** configuration file. The following options are the most important.

bootstrap.servers

A list of Kafka broker addresses used as bootstrap connections to Kafka. For example, **kafka0.my-domain.com:9092,kafka1.my-domain.com:9092,kafka2.my-domain.com:9092**.

key.converter

The class used to convert message keys to and from Kafka format. For example, **org.apache.kafka.connect.json.JsonConverter**.

value.converter

The class used to convert message payloads to and from Kafka format. For example, **org.apache.kafka.connect.json.JsonConverter**.

offset.storage.file.filename

Specifies the file in which the offset data is stored.

Connector plugins open client connections to the Kafka brokers using the bootstrap address. To configure these connections, use the standard Kafka producer and consumer configuration options prefixed by **producer.** or **consumer.**.

8.1.2. Running Kafka Connect in standalone mode

Configure and run Kafka Connect in standalone mode.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- You have specified connector configuration in properties files.
  You can also use the Kafka Connect REST API to manage connectors.

Procedure

1. Edit the **/opt/kafka/config/connect-standalone.properties** Kafka Connect configuration file and set **bootstrap.server** to point to your Kafka brokers. For example:

```
bootstrap.servers=kafka0.my-domain.com:9092,kafka1.my-domain.com:9092,kafka2.my-domain.com:9092
```

2. Start Kafka Connect with the configuration file and specify one or more connector configurations.

```
su - kafka
/opt/kafka/bin/connect-standalone.sh /opt/kafka/config/connect-standalone.properties connector1.properties
[connector2.properties ...]
```

3. Verify that Kafka Connect is running.

```
jcmd | grep ConnectStandalone
```

8.2. USING KAFKA CONNECT IN DISTRIBUTED MODE

In distributed mode, Kafka Connect runs as a cluster of worker processes, with each worker running on a separate node. Connectors can run on any worker in the cluster, allowing for greater scalability and fault tolerance. The connectors are managed by the workers, which coordinate with each other to distribute the work and ensure that each connector is running on a single node at any given time.

8.2.1. Configuring Kafka Connect in distributed mode

To configure Kafka Connect in distributed mode, edit the **config/connect-distributed.properties** configuration file. The following options are the most important.

bootstrap.servers

A list of Kafka broker addresses used as bootstrap connections to Kafka. For example, **kafka0.my-domain.com:9092,kafka1.my-domain.com:9092,kafka2.my-domain.com:9092**.

key.converter

The class used to convert message keys to and from Kafka format. For example, **org.apache.kafka.connect.json.JsonConverter**.

value.converter

The class used to convert message payloads to and from Kafka format. For example, **org.apache.kafka.connect.json.JsonConverter**.

group.id

The name of the distributed Kafka Connect cluster. This must be unique and must not conflict with another consumer group ID. The default value is **connect-cluster**.

config.storage.topic

The Kafka topic used to store connector configurations. The default value is **connect-configs**.

offset.storage.topic

The Kafka topic used to store offsets. The default value is **connect-offset**.

status.storage.topic

The Kafka topic used for worker node statuses. The default value is **connect-status**.

Streams for Apache Kafka includes an example configuration file for Kafka Connect in distributed mode – see **config/connect-distributed.properties** in the Streams for Apache Kafka installation directory.

Connector plugins open client connections to the Kafka brokers using the bootstrap address. To configure these connections, use the standard Kafka producer and consumer configuration options prefixed by **producer.** or **consumer.**.

8.2.2. Running Kafka Connect in distributed mode

Configure and run Kafka Connect in distributed mode.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Running the cluster

1. Edit the **/opt/kafka/config/connect-distributed.properties** Kafka Connect configuration file on all Kafka Connect worker nodes.
    - Set the **bootstrap.server** option to point to your Kafka brokers.
    - Set the **group.id** option.
    - Set the **config.storage.topic** option.
    - Set the **offset.storage.topic** option.
    - Set the **status.storage.topic** option.

For example:

```
bootstrap.servers=kafka0.my-domain.com:9092,kafka1.my-domain.com:9092,kafka2.my-domain.com:9092
group.id=my-group-id
config.storage.topic=my-group-id-configs
offset.storage.topic=my-group-id-offsets
status.storage.topic=my-group-id-status
```

2. Start the Kafka Connect workers with the **/opt/kafka/config/connect-distributed.properties** configuration file on all Kafka Connect nodes.

```
su - kafka
/opt/kafka/bin/connect-distributed.sh /opt/kafka/config/connect-distributed.properties
```

3. Verify that Kafka Connect is running.

```
jcmd | grep ConnectDistributed
```

4. Use the Kafka Connect REST API to manage connectors.

8.3. MANAGING CONNECTORS

The Kafka Connect REST API provides endpoints for creating, updating, and deleting connectors directly. You can also use the API to check the status of connectors or change logging levels. When you create a connector through the API, you provide the configuration details for the connector as part of the API call.

You can also add and manage connectors as plugins. Plugins are packaged as JAR files that contain the classes to implement the connectors through the Kafka Connect API. You just need to specify the plugin in the classpath or add it to a plugin path for Kafka Connect to run the connector plugin on startup.

In addition to using the Kafka Connect REST API or plugins to manage connectors, you can also add connector configuration using properties files when running Kafka Connect in standalone mode. To do this, you simply specify the location of the properties file when starting the Kafka Connect worker process. The properties file should contain the configuration details for the connector, including the connector class, source and destination topics, and any required authentication or serialization settings.

8.3.1. Limiting access to the Kafka Connect API

The Kafka Connect REST API can be accessed by anyone who has authenticated access and knows the endpoint URL, which includes the hostname/IP address and port number. It is crucial to restrict access to the Kafka Connect API only to trusted users to prevent unauthorized actions and potential security issues.

For improved security, we recommend configuring the following properties for the Kafka Connect API:

- (Kafka 3.4 or later) **org.apache.kafka.disallowed.login.modules** to specifically exclude insecure login modules
- **connector.client.config.override.policy** set to **NONE** to prevent connector configurations from overriding the Kafka Connect configuration and the consumers and producers it uses

8.3.2. Configuring connectors

Use the Kafka Connect REST API or properties files to create, manage, and monitor connector instances. You can use the REST API when using Kafka Connect in standalone or distributed mode. You can use properties files when using Kafka Connect in standalone mode.

8.3.2.1. Using the Kafka Connect REST API to manage connectors

When using the Kafka Connect REST API, you can create connectors dynamically by sending **PUT** or **POST** HTTP requests to the Kafka Connect REST API, specifying the connector configuration details in the request body.

TIP

When you use the **PUT** command, it's the same command for starting and updating connectors.

The REST interface listens on port 8083 by default and supports the following endpoints:

GET /connectors

Return a list of existing connectors.

POST /connectors

Create a connector. The request body has to be a JSON object with the connector configuration.

GET /connectors/<connector_name>

Get information about a specific connector.

GET /connectors/<connector_name>/config

Get configuration of a specific connector.

PUT /connectors/<connector_name>/config

Update the configuration of a specific connector.

GET /connectors/<connector_name>/status

Get the status of a specific connector.

GET /connectors/<connector_name>/tasks

Get a list of tasks for a specific connector

GET /connectors/<connector_name>/tasks/*<task_id>*/status

Get the status of a task for a specific connector

PUT /connectors/<connector_name>/pause

Pause the connector and all its tasks. The connector will stop processing any messages.

PUT /connectors/<connector_name>/stop

Stop the connector and all its tasks. The connector will stop processing any messages. Stopping a connector from running may be more suitable for longer durations than just pausing.

PUT /connectors/<connector_name>/resume

Resume a paused connector.

POST /connectors/<connector_name>/restart

Restart a connector in case it has failed.

POST /connectors/<connector_name>/tasks/*<task_id>*/restart

Restart a specific task.

DELETE /connectors/<connector_name>

Delete a connector.

GET /connectors/<connector_name>/topics

Get the topics for a specific connector.

PUT /connectors/<connector_name>/topics/reset

Empty the set of active topics for a specific connector.

GET /connectors/<connector_name>/offsets

Get the current offsets for a connector.

DELETE /connectors/<connector_name>/offsets

Reset the offsets for a connector, which must be in a stopped state.

PATCH /connectors/<connector_name>/offsets

Adjust the offsets (using an **offset** property in the request) for a connector, which must be in a stopped state.

GET /connector-plugins

Get a list of all supported connector plugins.

GET /connector-plugins/<connector_plugin_type>/config

Get the configuration for a connector plugin.

PUT /connector-plugins/<connector_type>/config/validate

Validate connector configuration.

8.3.2.2. Specifying connector configuration properties

To configure a Kafka Connect connector, you need to specify the configuration details for source or sink connectors. There are two ways to do this: through the Kafka Connect REST API, using JSON to provide the configuration, or by using properties files to define the configuration properties. The specific configuration options available for each type of connector may differ, but both methods provide a flexible way to specify the necessary settings.

The following options apply to all connectors:

name

The name of the connector, which must be unique within the current Kafka Connect instance.

connector.class

The class of the connector plug-in. For example, **org.apache.kafka.connect.file.FileStreamSinkConnector**.

tasks.max

The maximum number of tasks that the specified connector can use. Tasks enable the connector to perform work in parallel. The connector might create fewer tasks than specified.

key.converter

The class used to convert message keys to and from Kafka format. This overrides the default value set by the Kafka Connect configuration. For example, **org.apache.kafka.connect.json.JsonConverter**.

value.converter

The class used to convert message payloads to and from Kafka format. This overrides the default value set by the Kafka Connect configuration. For example, **org.apache.kafka.connect.json.JsonConverter**.

You must set at least one of the following options for sink connectors:

topics

A comma-separated list of topics used as input.

topics.regex

A Java regular expression of topics used as input.

For all other options, see the connector properties in the Apache Kafka documentation.

NOTE

Streams for Apache Kafka includes the example connector configuration files **config/connect-file-sink.properties** and **config/connect-file-source.properties** in the Streams for Apache Kafka installation directory.

Additional resources

- Kafka Connect REST API OpenAPI documentation

8.3.3. Creating connectors using the Kafka Connect API

Use the Kafka Connect REST API to create a connector to use with Kafka Connect.

Prerequisites

- A Kafka Connect installation.

Procedure

1. Prepare a JSON payload with the connector configuration. For example:

```
{
  "name": "my-connector",
  "config": {
  "connector.class": "org.apache.kafka.connect.file.FileStreamSinkConnector",
    "tasks.max": "1",
    "topics": "my-topic-1,my-topic-2",
    "file": "/tmp/output-file.txt"
  }
}
```

2. Send a POST request to ***<KafkaConnectAddress>*:8083/connectors** to create the connector. The following example uses **curl**:

```
curl -X POST -H "Content-Type: application/json" --data @sink-connector.json
http://connect0.my-domain.com:8083/connectors
```

3. Verify that the connector was deployed by sending a GET request to ***<KafkaConnectAddress>*:8083/connectors**. The following example uses **curl**:

```
curl http://connect0.my-domain.com:8083/connectors
```

8.3.4. Deleting connectors using the Kafka Connect API

Use the Kafka Connect REST API to delete a connector from Kafka Connect.

Prerequisites

- A Kafka Connect installation.

Deleting connectors

1. Verify that the connector exists by sending a **GET** request to ***<KafkaConnectAddress>*:8083/connectors/*<ConnectorName>***. The following example uses **curl**:

```
curl http://connect0.my-domain.com:8083/connectors
```

2. To delete the connector, send a **DELETE** request to ***<KafkaConnectAddress>*:8083/connectors**. The following example uses **curl**:

```
curl -X DELETE http://connect0.my-domain.com:8083/connectors/my-connector
```

3. Verify that the connector was deleted by sending a GET request to ***<KafkaConnectAddress>*:8083/connectors**. The following example uses **curl**:

```
curl http://connect0.my-domain.com:8083/connectors
```

8.3.5. Adding connector plugins

Kafka provides example connectors to use as a starting point for developing connectors. The following example connectors are included with Streams for Apache Kafka:

FileStreamSink

Reads data from Kafka topics and writes the data to a file.

FileStreamSource

Reads data from a file and sends the data to Kafka topics.

Both connectors are contained in the **libs/connect-file-<kafka_version>.redhat-<build>.jar** plugin.

To use the connector plugins in Kafka Connect, you can add them to the classpath or specify a plugin path in the Kafka Connect properties file and copy the plugins to the location.

Specifying the example connectors in the classpath

```
CLASSPATH=/opt/kafka/libs/connect-file-<kafka_version>.redhat-<build>.jar opt/kafka/bin/connect-distributed.sh
```

Setting a plugin path

```
plugin.path=/opt/kafka/connector-plugins,/opt/connectors
```

The **plugin.path** configuration option can contain a comma-separated list of paths.

You can add more connector plugins if needed. Kafka Connect searches for and runs connector plugins at startup.

NOTE

When running Kafka Connect in distributed mode, plugins must be made available on all worker nodes.

CHAPTER 9. USING STREAMS FOR APACHE KAFKA WITH MIRRORMAKER 2

Use MirrorMaker 2 to replicate data between two or more active Kafka clusters, within or across data centers.

To configure MirrorMaker 2, edit the **config/connect-mirror-maker.properties** configuration file. If required, you can enable distributed tracing for MirrorMaker 2.

Handling high volumes of messages

You can tune the configuration to handle high volumes of messages. For more information, see Handling high volumes of messages .

NOTE

MirrorMaker 2 has features not supported by the previous version of MirrorMaker. However, you can configure MirrorMaker 2 to be used in legacy mode .

9.1. CONFIGURING ACTIVE/ACTIVE OR ACTIVE/PASSIVE MODES

You can use MirrorMaker 2 in *active/passive* or *active/active* cluster configurations.

active/active cluster configuration

An active/active configuration has two active clusters replicating data bidirectionally. Applications can use either cluster. Each cluster can provide the same data. In this way, you can make the same data available in different geographical locations. As consumer groups are active in both clusters, consumer offsets for replicated topics are not synchronized back to the source cluster.

active/passive cluster configuration

An active/passive configuration has an active cluster replicating data to a passive cluster. The passive cluster remains on standby. You might use the passive cluster for data recovery in the event of system failure.

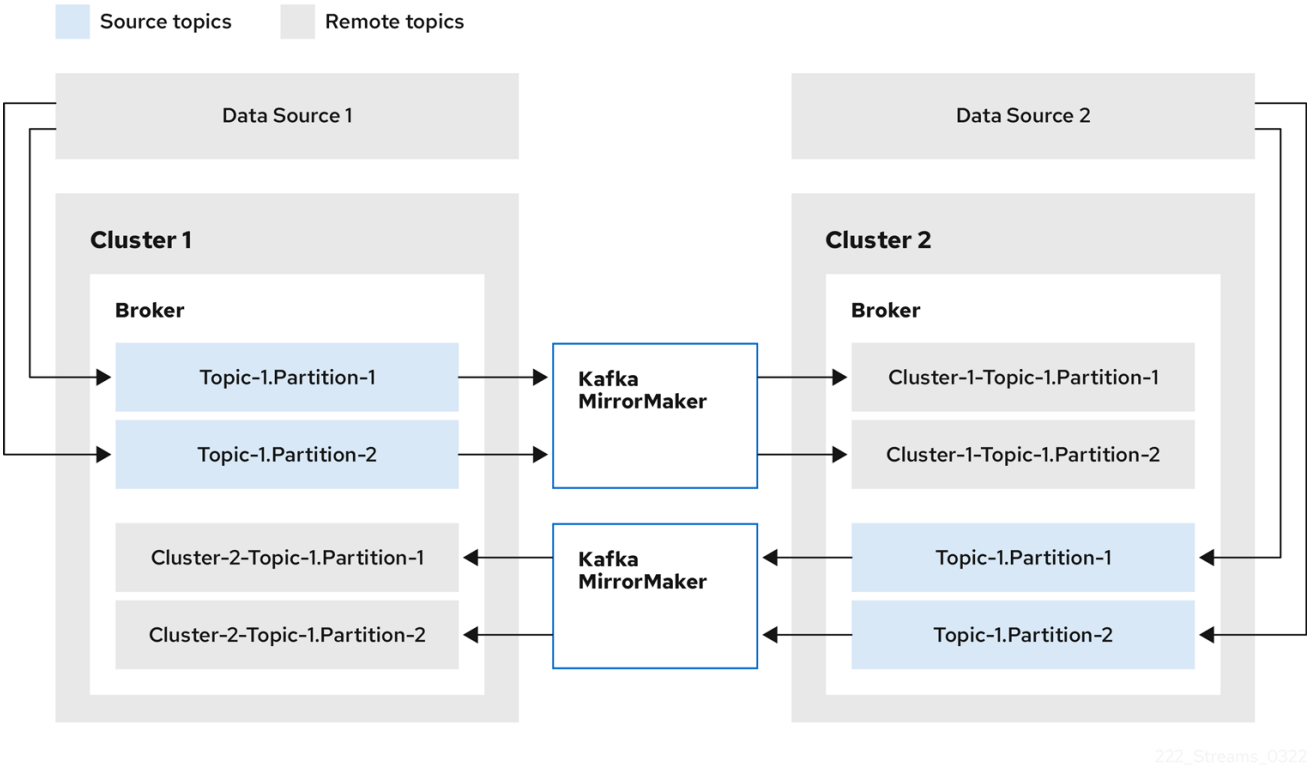
The expectation is that producers and consumers connect to active clusters only. A MirrorMaker 2 cluster is required at each target destination.

9.1.1. Bidirectional replication (active/active)

The MirrorMaker 2 architecture supports bidirectional replication in an *active/active* cluster configuration.

Each cluster replicates the data of the other cluster using the concept of *source* and *remote* topics. As the same topics are stored in each cluster, remote topics are automatically renamed by MirrorMaker 2 to represent the source cluster. The name of the originating cluster is prepended to the name of the topic.

Figure 9.1. Topic renaming



By flagging the originating cluster, topics are not replicated back to that cluster.

The concept of replication through *remote* topics is useful when configuring an architecture that requires data aggregation. Consumers can subscribe to source and remote topics within the same cluster, without the need for a separate aggregation cluster.

9.1.2. Unidirectional replication (active/passive)

The MirrorMaker 2 architecture supports unidirectional replication in an *active/passive* cluster configuration.

You can use an *active/passive* cluster configuration to make backups or migrate data to another cluster. In this situation, you might not want automatic renaming of remote topics.

You can override automatic renaming by adding **IdentityReplicationPolicy** to the source connector configuration. With this configuration applied, topics retain their original names.

9.2. CONFIGURING MIRRORMAKER 2 CONNECTORS

Use MirrorMaker 2 connector configuration for the internal connectors that orchestrate the synchronization of data between Kafka clusters.

MirrorMaker 2 consists of the following connectors:

MirrorSourceConnector

The source connector replicates topics from a source cluster to a target cluster. It also replicates ACLs and is necessary for the **MirrorCheckpointConnector** to run.

MirrorCheckpointConnector

The checkpoint connector periodically tracks offsets. If enabled, it also synchronizes consumer group offsets between the source and target cluster.

MirrorHeartbeatConnector

The heartbeat connector periodically checks connectivity between the source and target cluster.

The following table describes connector properties and the connectors you configure to use them.

Table 9.1. MirrorMaker 2 connector configuration properties

Property	sourceConnector	checkpointConnector	heartbeatConnector
admin.timeout.ms Timeout for admin tasks, such as detecting new topics. Default is **60000** (1 minute).	✓	✓	✓
replication.policy.class Policy to define the remote topic naming convention. Default is **org.apache.kafka.connect.mirror.DefaultReplicationPolicy**.	✓	✓	✓
replication.policy.separator The separator used for topic naming in the target cluster. By default, the separator is set to a dot (.). Separator configuration is only applicable to the **DefaultReplicationPolicy** replication policy class, which defines remote topic names. The **IdentityReplicationPolicy** class does not use the property as topics retain their original names.	✓	✓	✓
consumer.poll.timeout.ms Timeout when polling the source cluster. Default is **1000** (1 second).	✓	✓	
offset-syncs.topic.location The location of the **offset-syncs** topic, which can be the **source** (default) or **target** cluster.	✓	✓	

Property	sourceConnector	checkpointConnector	heartbeatConnector
topic.filter.class Topic filter to select the topics to replicate. Default is **org.apache.kafka.connect.mirror.DefaultTopicFilter**.	✓	✓	
config.property.filter.class Topic filter to select the topic configuration properties to replicate. Default is **org.apache.kafka.connect.mirror.DefaultConfigPropertyFilter**.	✓		
config.properties.exclude Topic configuration properties that should not be replicated. Supports comma-separated property names and regular expressions.	✓		
offset.lag.max Maximum allowable (out-of-sync) offset lag before a remote partition is synchronized. Default is **100**.	✓		
offset-syncs.topic.replication.factor Replication factor for the internal **offset-syncs** topic. Default is **3**.	✓		
refresh.topics.enabled Enables check for new topics and partitions. Default is **true**.	✓		
refresh.topics.interval.seconds Frequency of topic refresh. Default is **600** (10 minutes). By default, a check for new topics in the source cluster is made every 10 minutes. You can change the frequency by adding **refresh.topics.interval.seconds** to the source connector configuration.	✓		

Property	sourceConnector	checkpointConnector	heartbeatConnector
replication.factor The replication factor for new topics. Default is **2**.	✓		
sync.topic.acls.enabled Enables synchronization of ACLs from the source cluster. Default is **true**. For more information, see Section 9.5, "ACL rules synchronization".	✓		
sync.topic.acls.interval.seconds Frequency of ACL synchronization. Default is **600** (10 minutes).	✓		
sync.topic.configs.enabled Enables synchronization of topic configuration from the source cluster. Default is **true**.	✓		
sync.topic.configs.interval.seconds Frequency of topic configuration synchronization. Default **600** (10 minutes).	✓		
checkpoints.topic.replication.factor Replication factor for the internal **checkpoints** topic. Default is **3**.		✓	
emit.checkpoints.enabled Enables synchronization of consumer offsets to the target cluster. Default is **true**.		✓	
emit.checkpoints.interval.seconds Frequency of consumer offset synchronization. Default is **60** (1 minute).		✓	

Property	sourceConnector	checkpointConnector	heartbeatConnector
group.filter.class Group filter to select the consumer groups to replicate. Default is **org.apache.kafka.connect.mirror.DefaultGroupFilter**.		✓	
refresh.groups.enabled Enables check for new consumer groups. Default is **true**.		✓	
refresh.groups.interval.seconds Frequency of consumer group refresh. Default is **600** (10 minutes).		✓	
sync.group.offsets.enabled Enables synchronization of consumer group offsets to the target cluster **__consumer_offsets** topic. Default is **false**.		✓	
sync.group.offsets.interval.seconds Frequency of consumer group offset synchronization. Default is **60** (1 minute).		✓	
emit.heartbeats.enabled Enables connectivity checks on the target cluster. Default is **true**.			✓
emit.heartbeats.interval.seconds Frequency of connectivity checks. Default is **1** (1 second).			✓
heartbeats.topic.replication.factor Replication factor for the internal **heartbeats** topic. Default is **3**.			✓

9.2.1. Changing the location of the consumer group offsets topic

MirrorMaker 2 tracks offsets for consumer groups using internal topics.

offset-syncs topic

The **offset-syncs** topic maps the source and target offsets for replicated topic partitions from record metadata.

checkpoints topic

The **checkpoints** topic maps the last committed offset in the source and target cluster for replicated topic partitions in each consumer group.

As they are used internally by MirrorMaker 2, you do not interact directly with these topics.

MirrorCheckpointConnector emits *checkpoints* for offset tracking. Offsets for the **checkpoints** topic are tracked at predetermined intervals through configuration. Both topics enable replication to be fully restored from the correct offset position on failover.

The location of the **offset-syncs** topic is the **source** cluster by default. You can use the **offset-syncs.topic.location** connector configuration to change this to the **target** cluster. You need read/write access to the cluster that contains the topic. Using the target cluster as the location of the **offset-syncs** topic allows you to use MirrorMaker 2 even if you have only read access to the source cluster.

9.2.2. Synchronizing consumer group offsets

The **__consumer_offsets** topic stores information on committed offsets for each consumer group. Offset synchronization periodically transfers the consumer offsets for the consumer groups of a source cluster into the consumer offsets topic of a target cluster.

Offset synchronization is particularly useful in an *active/passive* configuration. If the active cluster goes down, consumer applications can switch to the passive (standby) cluster and pick up from the last transferred offset position.

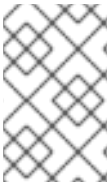
To use topic offset synchronization, enable the synchronization by adding **sync.group.offsets.enabled** to the checkpoint connector configuration, and setting the property to **true**. Synchronization is disabled by default.

When using the **IdentityReplicationPolicy** in the source connector, it also has to be configured in the checkpoint connector configuration. This ensures that the mirrored consumer offsets will be applied for the correct topics.

Consumer offsets are only synchronized for consumer groups that are not active in the target cluster. If the consumer groups are in the target cluster, the synchronization cannot be performed and an **UNKNOWN_MEMBER_ID** error is returned.

If enabled, the synchronization of offsets from the source cluster is made periodically. You can change the frequency by adding **sync.group.offsets.interval.seconds** and **emit.checkpoints.interval.seconds** to the checkpoint connector configuration. The properties specify the frequency in seconds that the consumer group offsets are synchronized, and the frequency of checkpoints emitted for offset tracking. The default for both properties is 60 seconds. You can also change the frequency of checks for new consumer groups using the **refresh.groups.interval.seconds** property, which is performed every 10 minutes by default.

Because the synchronization is time-based, any switchover by consumers to a passive cluster will likely result in some duplication of messages.



NOTE

If you have an application written in Java, you can use the **RemoteClusterUtils.java** utility to synchronize offsets through the application. The utility fetches remote offsets for a consumer group from the **checkpoints** topic.

9.2.3. Deciding when to use the heartbeat connector

The heartbeat connector emits heartbeats to check connectivity between source and target Kafka clusters. An internal **heartbeat** topic is replicated from the source cluster, which means that the heartbeat connector must be connected to the source cluster. The **heartbeat** topic is located on the target cluster, which allows it to do the following:

- Identify all source clusters it is mirroring data from
- Verify the liveness and latency of the mirroring process

This helps to make sure that the process is not stuck or has stopped for any reason. While the heartbeat connector can be a valuable tool for monitoring the mirroring processes between Kafka clusters, it's not always necessary to use it. For example, if your deployment has low network latency or a small number of topics, you might prefer to monitor the mirroring process using log messages or other monitoring tools. If you decide not to use the heartbeat connector, simply omit it from your MirrorMaker 2 configuration.

9.2.4. Aligning the configuration of MirrorMaker 2 connectors

To ensure that MirrorMaker 2 connectors work properly, make sure to align certain configuration settings across connectors. Specifically, ensure that the following properties have the same value across all applicable connectors:

- **replication.policy.class**
- **replication.policy.separator**
- **offset-syncs.topic.location**
- **topic.filter.class**

For example, the value for **replication.policy.class** must be the same for the source, checkpoint, and heartbeat connectors. Mismatched or missing settings cause issues with data replication or offset syncing, so it's essential to keep all relevant connectors configured with the same settings.

9.3. CONNECTOR PRODUCER AND CONSUMER CONFIGURATION

MirrorMaker 2 connectors use internal producers and consumers. If needed, you can configure these producers and consumers to override the default settings.

IMPORTANT

Producer and consumer configuration options depend on the MirrorMaker 2 implementation, and may be subject to change.

Producer and consumer configuration applies to **all** connectors. You specify the configuration in the **config/connect-mirror-maker.properties** file.

Use the properties file to override any default configuration for the producers and consumers in the following format:

- ***<source_cluster_name>*.consumer.*<property>***
- ***<source_cluster_name>*.producer.*<property>***
- ***<target_cluster_name>*.consumer.*<property>***
- ***<target_cluster_name>*.producer.*<property>***

The following example shows how you configure the producers and consumers. Though the properties are set for all connectors, some configuration properties are only relevant to certain connectors.

Example configuration for connector producers and consumers

```
clusters=cluster-1,cluster-2

# ...
cluster-1.consumer.fetch.max.bytes=52428800
cluster-2.producer.batch.size=327680
cluster-2.producer.linger.ms=100
cluster-2.producer.request.timeout.ms=30000
```

9.4. SPECIFYING A MAXIMUM NUMBER OF TASKS

Connectors create the tasks that are responsible for moving data in and out of Kafka. Each connector comprises one or more tasks that are distributed across a group of worker pods that run the tasks. Increasing the number of tasks can help with performance issues when replicating a large number of partitions or synchronizing the offsets of a large number of consumer groups.

Tasks run in parallel. Workers are assigned one or more tasks. A single task is handled by one worker pod, so you don't need more worker pods than tasks. If there are more tasks than workers, workers handle multiple tasks.

You can specify the maximum number of connector tasks in your MirrorMaker configuration using the **tasks.max** property. Without specifying a maximum number of tasks, the default setting is a single task.

The heartbeat connector always uses a single task.

The number of tasks that are started for the source and checkpoint connectors is the lower value between the maximum number of possible tasks and the value for **tasks.max**. For the source connector, the maximum number of tasks possible is one for each partition being replicated from the source cluster. For the checkpoint connector, the maximum number of tasks possible is one for each consumer group being replicated from the source cluster. When setting a maximum number of tasks, consider the number of partitions and the hardware resources that support the process.

If the infrastructure supports the processing overhead, increasing the number of tasks can improve throughput and latency. For example, adding more tasks reduces the time taken to poll the source cluster when there is a high number of partitions or consumer groups.

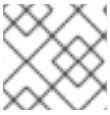
tasks.max configuration for MirrorMaker connectors

```
clusters=cluster-1,cluster-2
# ...
tasks.max = 10
```

By default, MirrorMaker 2 checks for new consumer groups every 10 minutes. You can adjust the **refresh.groups.interval.seconds** configuration to change the frequency. Take care when adjusting lower. More frequent checks can have a negative impact on performance.

9.5. ACL RULES SYNCHRONIZATION

If **AclAuthorizer** is being used, ACL rules that manage access to brokers also apply to remote topics. Users that can read a source topic can read its remote equivalent.



NOTE

OAuth 2.0 authorization does not support access to remote topics in this way.

9.6. RUNNING MIRRORMAKER 2 IN DEDICATED MODE

Use MirrorMaker 2 to synchronize data between Kafka clusters through configuration. This procedure shows how to configure and run a dedicated single-node MirrorMaker 2 cluster. Dedicated clusters use Kafka Connect worker nodes to mirror data between Kafka clusters.

NOTE

It is also possible to run MirrorMaker 2 in distributed mode. MirrorMaker 2 operates as connectors in both dedicated and distributed modes. When running a dedicated MirrorMaker cluster, connectors are configured in the Kafka Connect cluster. As a consequence, this allows direct access to the Kafka Connect cluster, the running of additional connectors, and use of the REST API. For more information, refer to the Apache Kafka documentation.

The configuration must specify:

- Each Kafka cluster
- Connection information for each cluster, including TLS authentication
- The replication flow and direction
  - Cluster to cluster
  - Topic to topic
- Replication rules
- Committed offset tracking intervals

This procedure describes how to implement MirrorMaker 2 by creating the configuration in a properties file, then passing the properties when using the MirrorMaker script file to set up the connections.

You can specify the topics and consumer groups you wish to replicate from a source cluster. You specify the names of the source and target clusters, then specify the topics and consumer groups to replicate.

In the following example, topics and consumer groups are specified for replication from cluster 1 to 2.

Example configuration to replicate specific topics and consumer groups

```
clusters=cluster-1,cluster-2
cluster-1->cluster-2.topics = topic-1, topic-2
cluster-1->cluster-2.groups = group-1, group-2
```

You can provide a list of names or use a regular expression. By default, all topics and consumer groups are replicated if you do not set these properties. You can also replicate all topics and consumer groups by using **.*** as a regular expression. However, try to specify only the topics and consumer groups you need to avoid causing any unnecessary extra load on the cluster.

Before you begin

A sample configuration properties file is provided in **./config/connect-mirror-maker.properties**.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Procedure

1. Open the sample properties file in a text editor, or create a new one, and edit the file to include connection information and the replication flows for each Kafka cluster.
   The following example shows a configuration to connect two clusters, *cluster-1* and *cluster-2*, bidirectionally. Cluster names are configurable through the **clusters** property.

   Example MirrorMaker 2 configuration

```
clusters=cluster-1,cluster-2 (1)

cluster-1.bootstrap.servers=<cluster_name>-kafka-bootstrap-<project_name_one>:443 (2)
cluster-1.security.protocol=SSL (3)
cluster-1.ssl.truststore.password=<truststore_name>
cluster-1.ssl.truststore.location=<path_to_truststore>/truststore.cluster-1.jks_
cluster-1.ssl.keystore.password=<keystore_name>
cluster-1.ssl.keystore.location=<path_to_keystore>/user.cluster-1.p12

cluster-2.bootstrap.servers=<cluster_name>-kafka-bootstrap-<project_name_two>:443 (4)
cluster-2.security.protocol=SSL (5)
cluster-2.ssl.truststore.password=<truststore_name>
cluster-2.ssl.truststore.location=<path_to_truststore>/truststore.cluster-2.jks_
cluster-2.ssl.keystore.password=<keystore_name>
cluster-2.ssl.keystore.location=<path_to_keystore>/user.cluster-2.p12

cluster-1->cluster-2.enabled=true (6)
cluster-2->cluster-1.enabled=true (7)
cluster-1->cluster-2.topics=.* (8)
cluster-2->cluster-1.topics=topic-1, topic-2 (9)
cluster-1->cluster-2.groups=.* (10)
cluster-2->cluster-1.groups=group-1, group-2 (11)

replication.policy.separator=- (12)
sync.topic.acls.enabled=false (13)
refresh.topics.interval.seconds=60 (14)
refresh.groups.interval.seconds=60 (15)
```

1. Each Kafka cluster is identified with its alias.
2. Connection information for *cluster-1*, using the *bootstrap address* and port *443*. Both clusters use port *443* to connect to Kafka using OpenShift *Routes*.
3. The **ssl.** properties define TLS configuration for *cluster-1*.
4. Connection information for *cluster-2*.
5. The **ssl.** properties define the TLS configuration for *cluster-2*.
6. Replication flow enabled from *cluster-1* to *cluster-2*.
7. Replication flow enabled from *cluster-2* to *cluster-1*.
8. Replication of all topics from *cluster-1* to *cluster-2*. The source connector replicates the specified topics. The checkpoint connector tracks offsets for the specified topics.
9. Replication of specific topics from *cluster-2* to *cluster-1*.
10. Replication of all consumer groups from *cluster-1* to *cluster-2*. The checkpoint connector replicates the specified consumer groups.
11. Replication of specific consumer groups from *cluster-2* to *cluster-1*.
12. Defines the separator used for the renaming of remote topics.
13. When enabled, ACLs are applied to synchronized topics. The default is **false**.
14. The period between checks for new topics to synchronize.
15. The period between checks for new consumer groups to synchronize.

2. OPTION: If required, add a policy that overrides the automatic renaming of remote topics. Instead of prepending the name with the name of the source cluster, the topic retains its original name.
   This optional setting is used for active/passive backups and data migration.

```
replication.policy.class=org.apache.kafka.connect.mirror.IdentityReplicationPolicy
```

3. OPTION: If you want to synchronize consumer group offsets, add configuration to enable and manage the synchronization:

```
refresh.groups.interval.seconds=60
sync.group.offsets.enabled=true 1
sync.group.offsets.interval.seconds=60 2
emit.checkpoints.interval.seconds=60 3
```

1. Optional setting to synchronize consumer group offsets, which is useful for recovery in an active/passive configuration. Synchronization is not enabled by default.
2. If the synchronization of consumer group offsets is enabled, you can adjust the frequency of the synchronization.
3.

Adjusts the frequency of checks for offset tracking. If you change the frequency of offset synchronization, you might also need to adjust the frequency of these checks.

4. Start Kafka in the target clusters:

```
/opt/kafka/bin/kafka-server-start.sh -daemon \
/opt/kafka/config/kraft/server.properties
```

5. Start MirrorMaker with the cluster connection configuration and replication policies you defined in your properties file:

```
/opt/kafka/bin/connect-mirror-maker.sh \
/opt/kafka/config/connect-mirror-maker.properties
```

MirrorMaker sets up connections between the clusters.

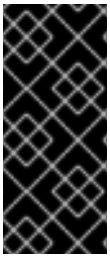
6. For each target cluster, verify that the topics are being replicated:

```
/opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_host>:<port> --list
```

9.7. (DEPRECATED) USING MIRRORMAKER 2 IN LEGACY MODE

This procedure describes how to configure MirrorMaker 2 to use it in legacy mode. Legacy mode supports the previous version of MirrorMaker.

The MirrorMaker script **/opt/kafka/bin/kafka-mirror-maker.sh** can run MirrorMaker 2 in legacy mode.



IMPORTANT

Kafka MirrorMaker 1 (referred to as just *MirrorMaker* in the documentation) has been deprecated in Apache Kafka 3.0.0 and will be removed in Apache Kafka 4.0.0. As a result, Kafka MirrorMaker 1 has been deprecated in Streams for Apache Kafka as well. Kafka MirrorMaker 1 will be removed from Streams for Apache Kafka when we adopt Apache Kafka 4.0.0. As a replacement, use MirrorMaker 2 with the **IdentityReplicationPolicy**.

Prerequisites

You need the properties files you currently use with the legacy version of MirrorMaker.

- **/opt/kafka/config/consumer.properties**
- **/opt/kafka/config/producer.properties**

Procedure

1. Edit the MirrorMaker **consumer.properties** and **producer.properties** files to turn off MirrorMaker 2 features.
For example:

```
replication.policy.class=org.apache.kafka.mirror.LegacyReplicationPolicy (1)

refresh.topics.enabled=false (2)
refresh.groups.enabled=false
```

```
emit.checkpoints.enabled=false
emit.heartbeats.enabled=false
sync.topic.configs.enabled=false
sync.topic.acls.enabled=false
```

1. Emulate the previous version of MirrorMaker.
2. MirrorMaker 2 features disabled, including the internal *checkpoint* and *heartbeat* topics

2. Save the changes and restart MirrorMaker with the properties files you used with the previous version of MirrorMaker:

```
su - kafka /opt/kafka/bin/kafka-mirror-maker.sh \
--consumer.config /opt/kafka/config/consumer.properties \
--producer.config /opt/kafka/config/producer.properties \
--num.streams=2
```

The **consumer** properties provide the configuration for the source cluster and the **producer** properties provide the target cluster configuration.

MirrorMaker sets up connections between the clusters.

3. Start Kafka in the target cluster:

```
su - kafka
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
```

4. For the target cluster, verify that the topics are being replicated:

```
/opt/kafka/bin/kafka-topics.sh --bootstrap-server <broker_host>:<port> --list
```

CHAPTER 10. CONFIGURING LOGGING FOR KAFKA COMPONENTS

Configure the logging levels of Kafka components directly in the configuration properties. You can also change the broker levels dynamically for Kafka brokers, Kafka Connect, and MirrorMaker 2.

Increasing the log level detail, such as from INFO to DEBUG, can aid in troubleshooting a Kafka cluster. However, more verbose logs may also negatively impact performance and make it more difficult to diagnose issues.

10.1. CONFIGURING KAFKA LOGGING PROPERTIES

Kafka components use the Log4j framework for error logging. By default, logging configuration is read from the classpath or **config** directory using the following properties files:

- **log4j.properties** for Kafka
- **connect-log4j.properties** for Kafka Connect and MirrorMaker 2

If they are not set explicitly, loggers inherit the **log4j.rootLogger** logging level configuration in each file. You can change the logging level in these files. You can also add and set logging levels for other loggers.

You can change the location and name of logging properties file using the **KAFKA_LOG4J_OPTS** environment variable, which is used by the start script for the component.

Passing the name and location of the logging properties file used by Kafka nodes

```
su - kafka
export KAFKA_LOG4J_OPTS="-Dlog4j.configuration=file:/my/path/to/log4j.properties"; \
/opt/kafka/bin/kafka-server-start.sh \
/opt/kafka/config/kraft/server.properties
```

Passing the name and location of the logging properties file used by Kafka Connect

```
su - kafka
export KAFKA_LOG4J_OPTS="-Dlog4j.configuration=file:/my/path/to/connect-log4j.properties"; \
/opt/kafka/bin/connect-distributed.sh \
/opt/kafka/config/connect-distributed.properties
```

Passing the name and location of the logging properties file used by MirrorMaker 2

```
su - kafka
export KAFKA_LOG4J_OPTS="-Dlog4j.configuration=file:/my/path/to/connect-log4j.properties"; \
/opt/kafka/bin/connect-mirror-maker.sh \
/opt/kafka/config/connect-mirror-maker.properties
```

10.2. DYNAMICALLY CHANGE LOGGING LEVELS FOR KAFKA BROKER LOGGERS

Kafka broker logging is provided by broker loggers in each broker. Dynamically change the logging level for broker loggers at runtime without having to restart the broker.

You can also reset broker loggers dynamically to their default logging levels.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- Kafka is running.

Procedure

1. Switch to the **kafka** user:

```
su - kafka
```

2. List all the broker loggers for a broker by using the **kafka-configs.sh** tool:

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_address> --describe --entity-type broker-loggers --entity-name BROKER-ID
```

For example, for broker **0**:

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server localhost:9092 --describe --entity-type broker-loggers --entity-name 0
```

This returns the logging level for each logger: **TRACE**, **DEBUG**, **INFO**, **WARN**, **ERROR**, or **FATAL**.

For example:

```
#...
kafka.controller.ControllerChannelManager=INFO sensitive=false synonyms={}
kafka.log.TimeIndex=INFO sensitive=false synonyms={}
```

3. Change the logging level for one or more broker loggers. Use the **--alter** and **--add-config** options and specify each logger and its level as a comma-separated list in double quotes.

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_address> --alter --add-config "LOGGER-ONE=NEW-LEVEL,LOGGER-TWO=NEW-LEVEL" --entity-type broker-loggers --entity-name BROKER-ID
```

For example, for broker **0**:

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server localhost:9092 --alter --add-config "kafka.controller.ControllerChannelManager=WARN,kafka.log.TimeIndex=WARN" --entity-type broker-loggers --entity-name 0
```

If successful this returns:

```
Completed updating config for broker: 0.
```

Resetting a broker logger

You can reset one or more broker loggers to their default logging levels by using the **kafka-configs.sh** tool. Use the **--alter** and **--delete-config** options and specify each broker logger as a comma-separated list in double quotes:

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server localhost:9092 --alter --delete-config "LOGGER-ONE,LOGGER-TWO" --entity-type broker-loggers --entity-name BROKER-ID
```

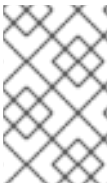
Additional resources

- Updating Broker Configs in the Apache Kafka documentation

10.3. DYNAMICALLY CHANGE LOGGING LEVELS FOR KAFKA CONNECT AND MIRRORMAKER 2

Dynamically change logging levels for Kafka Connect workers or MirrorMaker 2 connectors at runtime without having to restart.

Use the Kafka Connect API to change the log level temporarily for a worker or connector logger. The Kafka Connect API provides an **admin/loggers** endpoint to get or modify logging levels. When you change the log level using the API, the logger configuration in the **connect-log4j.properties** configuration file does not change. If required, you can permanently change the logging levels in the configuration file.



NOTE

You can only change the logging level of MirrorMaker 2 at runtime when in distributed or standalone mode. Dedicated MirrorMaker 2 clusters have no Kafka Connect REST API, so changing the logging level is not possible.

The default listener for the Kafka Connect API is on port 8083, which is used in this procedure. You can change or add more listeners, and also enable TLS authentication, using **admin.listeners** configuration.

Example listener configuration for the admin endpoint

```
admin.listeners=https://localhost:8083
admin.listeners.https.ssl.truststore.location=/path/to/truststore.jks
admin.listeners.https.ssl.truststore.password=123456
admin.listeners.https.ssl.keystore.location=/path/to/keystore.jks
admin.listeners.https.ssl.keystore.password=123456
```

If you do not want the **admin** endpoint to be available, you can disable it in the configuration by specifying an empty string.

Example listener configuration to disable the admin endpoint

```
admin.listeners=
```

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.
- Kafka is running.

- Kafka Connect or MirrorMaker 2 is running.

Procedure

1. Switch to the **kafka** user:

```
su - kafka
```

2. Check the current logging level for the loggers configured in the **connect-log4j.properties** file:

```
$ cat /opt/kafka/config/connect-log4j.properties

# ...
log4j.rootLogger=INFO, stdout, connectAppender
# ...
log4j.logger.org.reflections=ERROR
```

Use a curl command to check the logging levels from the **admin/loggers** endpoint of the Kafka Connect API:

```
curl -s http://localhost:8083/admin/loggers/ | jq

{
  "org.reflections": {
    "level": "ERROR"
  },
  "root": {
    "level": "INFO"
  }
}
```

jq prints the output in JSON format. The list shows standard **org** and **root** level loggers, plus any specific loggers with modified logging levels.

If you configure TLS (Transport Layer Security) authentication for the **admin.listeners** configuration in Kafka Connect, then the address of the loggers endpoint is the value specified for **admin.listeners** with the protocol as https, such as **https://localhost:8083**.

You can also get the log level of a specific logger:

```
curl -s
http://localhost:8083/admin/loggers/org.apache.kafka.connect.mirror.MirrorCheckpointConnecto
r | jq

{
  "level": "INFO"
}
```

3. Use a PUT method to change the log level for a logger:

```
curl -Ss -X PUT -H 'Content-Type: application/json' -d '{"level": "TRACE"}'
http://localhost:8083/admin/loggers/root

{
```

```
  # ...

  "org.reflections": {
    "level": "TRACE"
  },
  "org.reflections.Reflections": {
    "level": "TRACE"
  },
  "root": {
    "level": "TRACE"
  }
}
```

If you change the **root** logger, the logging level for loggers that used the root logging level by default are also changed.

CHAPTER 11. SETTING LIMITS ON BROKERS USING THE KAFKA STATIC QUOTA PLUGIN

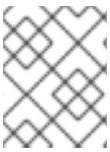
IMPORTANT

The Kafka Static Quota plugin is a Technology Preview only. Technology Preview features are not supported with Red Hat production service-level agreements (SLAs) and might not be functionally complete. Red Hat does not recommend implementing any Technology Preview features in production environments. This Technology Preview feature provides early access to upcoming product innovations, enabling you to test functionality and provide feedback during the development process. For more information about the support scope of Red Hat Technology Preview features, see Technology Preview Features Support Scope .

Use the *Kafka Static Quota* plugin to set throughput and storage limits on brokers in your Kafka cluster. You enable the plugin and set limits by adding properties to the Kafka configuration file. You can set a byte-rate threshold and storage quotas to put limits on the clients interacting with your brokers.

You can set byte-rate thresholds for producer and consumer bandwidth. The total limit is distributed across all clients accessing the broker. For example, you can set a byte-rate threshold of 40 MBps for producers. If two producers are running, they are each limited to a throughput of 20 MBps.

Storage quotas throttle Kafka disk storage limits between a soft limit and hard limit. The limits apply to all available disk space. Producers are slowed gradually between the soft and hard limit. The limits prevent disks filling up too quickly and exceeding their capacity. Full disks can lead to issues that are hard to rectify. The hard limit is the maximum storage limit.



NOTE

For JBOD storage, the limit applies across all disks. If a broker is using two 1 TB disks and the quota is 1.1 TB, one disk might fill and the other disk will be almost empty.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.

Procedure

1. Edit the Kafka configuration properties file.
   The plugin properties are shown in this example configuration.

   Example Kafka Static Quota plugin configuration

```
# ...
client.quota.callback.class=io.strimzi.kafka.quotas.StaticQuotaCallback 1
client.quota.callback.static.produce=1000000 2
client.quota.callback.static.fetch=1000000 3
client.quota.callback.static.storage.soft=400000000000 4
client.quota.callback.static.storage.hard=500000000000 5
client.quota.callback.static.storage.check-interval=5 6
# ...
```

1. Loads the Kafka Static Quota plugin.
2. Sets the producer byte-rate threshold. 1 MBps in this example.
3. Sets the consumer byte-rate threshold. 1 MBps in this example.
4. Sets the lower soft limit for storage. 400 GB in this example.
5. Sets the higher hard limit for storage. 500 GB in this example.
6. Sets the interval in seconds between checks on storage. 5 seconds in this example. You can set this to 0 to disable the check.

2. Start the Kafka broker with the default configuration file.

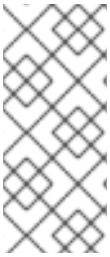
```
su - kafka
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
```

3. Verify that the Kafka broker is running.

```
jcmd | grep Kafka
```

CHAPTER 12. SCALING CLUSTERS BY ADDING OR REMOVING BROKERS

Scaling Kafka clusters by adding brokers can increase the performance and reliability of the cluster. Adding more brokers increases available resources, allowing the cluster to handle larger workloads and process more messages. It can also improve fault tolerance by providing more replicas and backups. Conversely, removing underutilized brokers can reduce resource consumption and improve efficiency. Scaling must be done carefully to avoid disruption or data loss. By redistributing partitions across all brokers in the cluster, the resource utilization of each broker is reduced, which can increase the overall throughput of the cluster.



NOTE

To increase the throughput of a Kafka topic, you can increase the number of partitions for that topic. This allows the load of the topic to be shared between different brokers in the cluster. However, if every broker is constrained by a specific resource (such as I/O), adding more partitions will not increase the throughput. In this case, you need to add more brokers to the cluster.

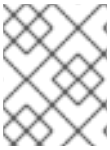
Adding brokers when running a multi-node Kafka cluster affects the number of brokers in the cluster that act as replicas. The actual replication factor for topics is determined by settings for the **default.replication.factor** and **min.insync.replicas**, and the number of available brokers. For example, a replication factor of 3 means that each partition of a topic is replicated across three brokers, ensuring fault tolerance in the event of a broker failure.

Example replica configuration

```
default.replication.factor = 3
min.insync.replicas = 2
```

When you add or remove brokers, Kafka does not automatically reassign partitions. The best way to do this is using Cruise Control. You can use Cruise Control's **add-brokers** and **remove-brokers** modes when scaling a cluster up or down.

- Use the **add-brokers** mode after scaling up a Kafka cluster to move partition replicas from existing brokers to the newly added brokers.
- Use the **remove-brokers** mode before scaling down a Kafka cluster to move partition replicas off the brokers that are going to be removed.



NOTE

When scaling down brokers, you cannot specify which specific pod to remove from the cluster. Instead, the broker removal process starts from the highest numbered pod.

CHAPTER 13. USING CRUISE CONTROL FOR CLUSTER REBALANCING

Cruise Control is an open source system for automating Kafka operations, such as monitoring cluster workload, rebalancing a cluster based on predefined constraints, and detecting and fixing anomalies. It consists of four main components—the Load Monitor, the Analyzer, the Anomaly Detector, and the Executor—and a REST API for client interactions.

You can use Cruise Control to *rebalance* a Kafka cluster. Cruise Control for Streams for Apache Kafka on Red Hat Enterprise Linux is provided as a separate zipped distribution.

Streams for Apache Kafka utilizes the REST API to support the following Cruise Control features:

- Generating optimization proposals from optimization goals.
- Rebalancing a Kafka cluster based on an optimization proposal.

Optimization goals

An optimization goal describes a specific objective to achieve from a rebalance. For example, a goal might be to distribute topic replicas across brokers more evenly. You can change what goals to include through configuration. A goal is defined as a hard goal or soft goal. You can add hard goals through Cruise Control deployment configuration. You also have main, default, and user-provided goals that fit into each of these categories.

- **Hard goals** are preset and must be satisfied for an optimization proposal to be successful.
- **Soft goals** do not need to be satisfied for an optimization proposal to be successful. They can be set aside if it means that all hard goals are met.
- **Main goals** are inherited from Cruise Control. Some are preset as hard goals. Main goals are used in optimization proposals by default.
- **Default goals** are the same as the main goals by default. You can specify your own set of default goals.
- **User-provided** goals are a subset of default goals that are configured for generating a specific optimization proposal.

Optimization proposals

Optimization proposals comprise the goals you want to achieve from a rebalance. You generate an optimization proposal to create a summary of proposed changes and the results that are possible with the rebalance. The goals are assessed in a specific order of priority. You can then choose to approve or reject the proposal. You can reject the proposal to run it again with an adjusted set of goals.
You can generate and approve an optimization proposal by making a request to one of the following API endpoints.

- **/rebalance** endpoint to run a full rebalance.
- **/add_broker** endpoint to rebalance after adding brokers when scaling up a Kafka cluster.
- **/remove_broker** endpoint to rebalance before removing brokers when scaling down a Kafka cluster.

You configure optimization goals through a configuration properties file. Streams for Apache Kafka provides example properties files for Cruise Control.

13.1. CRUISE CONTROL COMPONENTS AND FEATURES

Cruise Control consists of four main components—the Load Monitor, the Analyzer, the Anomaly Detector, and the Executor—and a REST API for client interactions. Streams for Apache Kafka utilizes the REST API to support the following Cruise Control features:

- Generating optimization proposals from optimization goals.
- Rebalancing a Kafka cluster based on an optimization proposal.

Optimization goals

An optimization goal describes a specific objective to achieve from a rebalance. For example, a goal might be to distribute topic replicas across brokers more evenly. You can change what goals to include through configuration. A goal is defined as a hard goal or soft goal. You can add hard goals through Cruise Control deployment configuration. You also have main, default, and user-provided goals that fit into each of these categories.

- **Hard goals** are preset and must be satisfied for an optimization proposal to be successful.
- **Soft goals** do not need to be satisfied for an optimization proposal to be successful. They can be set aside if it means that all hard goals are met.
- **Main goals** are inherited from Cruise Control. Some are preset as hard goals. Main goals are used in optimization proposals by default.
- **Default goals** are the same as the main goals by default. You can specify your own set of default goals.
- **User-provided goals** are a subset of default goals that are configured for generating a specific optimization proposal.

Optimization proposals

Optimization proposals comprise the goals you want to achieve from a rebalance. You generate an optimization proposal to create a summary of proposed changes and the results that are possible with the rebalance. The goals are assessed in a specific order of priority. You can then choose to approve or reject the proposal. You can reject the proposal to run it again with an adjusted set of goals.
You can generate an optimization proposal in one of three modes.

- **full** is the default mode and runs a full rebalance.
- **add-brokers** is the mode you use after adding brokers when scaling up a Kafka cluster.
- **remove-brokers** is the mode you use before removing brokers when scaling down a Kafka cluster.

Other Cruise Control features are not currently supported, including self healing, notifications, write-your-own goals, and changing the topic replication factor.

Additional resources

- Cruise Control documentation

13.2. DOWNLOADING CRUISE CONTROL

A ZIP file distribution of Cruise Control is available for download from the Red Hat website. You can download the latest version of Red Hat Streams for Apache Kafka from the Streams for Apache Kafka software downloads page.

Procedure

1. Download the latest version of the **Red Hat Streams for Apache Kafka Cruise Control** archive from the Red Hat Customer Portal .
2. Create the **/opt/cruise-control** directory:

```
sudo mkdir /opt/cruise-control
```

3. Extract the contents of the Cruise Control ZIP file to the new directory:

```
unzip amq-streams-<version>-cruise-control-bin.zip -d /opt/cruise-control
```

4. Change the ownership of the **/opt/cruise-control** directory to the **kafka** user:

```
sudo chown -R kafka:kafka /opt/cruise-control
```

13.3. DEPLOYING THE CRUISE CONTROL METRICS REPORTER

Before starting Cruise Control, you must configure the Kafka brokers to use the provided Cruise Control Metrics Reporter. The file for the Metrics Reporter is supplied with the Streams for Apache Kafka installation artifacts.

When loaded at runtime, the Metrics Reporter sends metrics to the **__CruiseControlMetrics** topic, one of three auto-created topics. Cruise Control uses these metrics to create and update the workload model and to calculate optimization proposals.

Prerequisites

- Streams for Apache Kafka is installed on each host , and the configuration files are available.
- You are logged in to Red Hat Enterprise Linux as the **kafka** user.

Procedure

For each broker in the Kafka cluster and one at a time:

1. Stop the Kafka broker:

```
/opt/kafka/bin/kafka-server-stop.sh
```

2. Edit the Kafka configuration properties file to configure the Cruise Control Metrics Reporter.
   a. Add the **CruiseControlMetricsReporter** class to the **metric.reporters** configuration option. Do not remove any existing Metrics Reporters.

```
metric.reporters=com.linkedin.kafka.cruisecontrol.metricsreporter.CruiseControlMetricsReporter
```

b. Add the following configuration options and values:

```
cruise.control.metrics.topic.auto.create=true
cruise.control.metrics.topic.num.partitions=1
cruise.control.metrics.topic.replication.factor=1
```

These options enable the Cruise Control Metrics Reporter to create the **__CruiseControlMetrics** topic with a log cleanup policy of **DELETE**. For more information, see Auto-created topics and Log cleanup policy for Cruise Control Metrics topic .

3. Configure SSL, if required.

a. In the Kafka configuration properties file, configure SSL between the Cruise Control Metrics Reporter and the Kafka broker by setting the relevant client configuration properties.
The Metrics Reporter accepts all standard producer-specific configuration properties with the **cruise.control.metrics.reporter** prefix. For example: **cruise.control.metrics.reporter.ssl.truststore.password**.

b. In the Cruise Control properties file (**/opt/cruise-control/config/cruisecontrol.properties**) configure SSL between the Kafka broker and the Cruise Control server by setting the relevant client configuration properties.
Cruise Control inherits SSL client property options from Kafka and uses those properties for all Cruise Control server clients.

4. Restart the Kafka broker:

```
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
```

For information on restarting brokers in a multi-node cluster, see Section 3.6, “Performing a graceful rolling restart of Kafka brokers”.

5. Repeat steps 1-5 for the remaining brokers.

13.4. CONFIGURING AND STARTING CRUISE CONTROL

Configure the properties used by Cruise Control and then start the Cruise Control server using the **kafka-cruise-control-start.sh** script. The server is hosted on a single machine for the whole Kafka cluster.

Three topics are auto-created when Cruise Control starts. For more information, see Auto-created topics.

Prerequisites

- You are logged in to Red Hat Enterprise Linux as the **kafka** user.
- You have downloaded Cruise Control.
- You have deployed the Cruise Control Metrics Reporter .

Procedure

1. Edit the Cruise Control properties file (**/opt/cruise-control/config/cruisecontrol.properties**).
2. Configure the properties shown in the following example configuration:

```
# The Kafka cluster to control.
bootstrap.servers=localhost:9092 1

# The replication factor of Kafka metric sample store topic
sample.store.topic.replication.factor=2 2

# The configuration for the BrokerCapacityConfigFileResolver (supports JBOD, non-JBOD,
and heterogeneous CPU core capacities)
#capacity.config.file=config/capacity.json
#capacity.config.file=config/capacityCores.json
capacity.config.file=config/capacityJBOD.json 3

# The list of goals to optimize the Kafka cluster for with pre-computed proposals
default.goals={List of default optimization goals} 4

# The list of supported goals
goals={list of main optimization goals} 5

# The list of supported hard goals
hard.goals={List of hard goals} 6

# How often should the cached proposal be expired and recalculated if necessary
proposal.expiration.ms=60000 7

#Set failure detection to true
kafka.broker.failure.detection.enable=true 8
```

1. Host and port numbers of the Kafka broker (always port 9092).
2. Replication factor of the Kafka metric sample store topic. If you are evaluating Cruise Control in a single-node Kafka cluster, set this property to 1. For production use, set this property to 2 or more.
3. The configuration file that sets the maximum capacity limits for broker resources. Use the file that applies to your Kafka deployment configuration. For more information, see Capacity configuration.
4. Comma-separated list of default optimization goals, using fully-qualified domain names (FQDNs). A number of main optimization goals (see 5) are already set as default optimization goals; you can add or remove goals if desired. For more information, see Section 13.5, "Optimization goals overview".
5. Comma-separated list of main optimization goals, using FQDNs. To completely exclude goals from being used to generate optimization proposals, remove them from the list. For more information, see Section 13.5, "Optimization goals overview".
6. Comma-separated list of hard goals, using FQDNs. Seven of the main optimization goals are already set as hard goals; you can add or remove goals if desired. For more information, see Section 13.5, "Optimization goals overview".
7.

The interval, in milliseconds, for refreshing the cached optimization proposal that is generated from the default optimization goals. For more information, see Section 13.6,

8 Enables Cruise Control to use the Kafka API to detect broker failures.

3. Start the Cruise Control server. The server starts on port 9092 by default; optionally, specify a different port.

```
cd /opt/cruise-control/
./kafka-cruise-control-start.sh config/cruisecontrol.properties <port_number>
```

4. To verify that Cruise Control is running, send a GET request to the /**state** endpoint of the Cruise Control server:

```
curl -X GET 'http://<cc_host>:<cc_port>/kafkacruisecontrol/state'
```

Auto-created topics

The following table shows the three topics that are automatically created when Cruise Control starts. These topics are required for Cruise Control to work properly and must not be deleted or changed.

Table 13.1. Auto-created topics

Auto-created topic	Created by	Function
__CruiseControlMetrics	Cruise Control Metrics Reporter	Stores the raw metrics from the Metrics Reporter in each Kafka broker.
__KafkaCruiseControlPartitionMetricSamples	Cruise Control	Stores the derived metrics for each partition. These are created by the Metric Sample Aggregator.
__KafkaCruiseControlModelTrainingSamples	Cruise Control	Stores the metrics samples used to create the Cluster Workload Model

To ensure that log compaction is *disabled* in the auto-created topics, make sure that you configure the Cruise Control Metrics Reporter as described in Section 13.3, "Deploying the Cruise Control Metrics Reporter". Log compaction can remove records that are needed by Cruise Control and prevent it from working properly.

Additional resources

- Log cleanup policy for Cruise Control Metrics topic

13.5. OPTIMIZATION GOALS OVERVIEW

Optimization goals are constraints on workload redistribution and resource utilization across a Kafka cluster. To rebalance a Kafka cluster, Cruise Control uses optimization goals to generate optimization proposals.

13.5.1. Goals order of priority

Streams for Apache Kafka on Red Hat Enterprise Linux supports all the optimization goals developed in the Cruise Control project. The supported goals, in the default descending order of priority, are as follows:

1. Rack-awareness
2. Minimum number of leader replicas per broker for a set of topics
3. Replica capacity
4. Capacity: Disk capacity, Network inbound capacity, Network outbound capacity
5. CPU capacity
6. Replica distribution
7. Potential network output
8. Resource distribution: Disk utilization distribution, Network inbound utilization distribution, Network outbound utilization distribution
9. Leader bytes-in rate distribution
10. Topic replica distribution
11. CPU usage distribution
12. Leader replica distribution
13. Preferred leader election
14. Kafka Assigner disk usage distribution
15. Intra-broker disk capacity
16. Intra-broker disk usage

For more information on each optimization goal, see Goals in the Cruise Control Wiki.

13.5.2. Goals configuration in the Cruise Control properties file

You configure optimization goals in the **cruisecontrol.properties** file in the **cruise-control/config/** directory. Cruise Control has configurations for hard optimization goals that must be satisfied, as well as main, default, and user-provided optimization goals.

You can specify the following types of optimization goal in the following configuration:

- **Main goals** – **cruisecontrol.properties** file
- **Hard goals** – **cruisecontrol.properties** file
- **Default goals** – **cruisecontrol.properties** file
- **User-provided goals** – runtime parameters

Optionally, user-provided optimization goals are set at runtime as parameters in requests to the **/rebalance** endpoint.

Optimization goals are subject to any capacity limits on broker resources.

13.5.3. Hard and soft optimization goals

Hard goals are goals that *must* be satisfied in optimization proposals. Goals that are not configured as hard goals are known as *soft goals*. You can think of soft goals as *best effort* goals: they do not need to be satisfied in optimization proposals, but are included in optimization calculations.

Cruise Control will calculate optimization proposals that satisfy all the hard goals and as many soft goals as possible (in their priority order). An optimization proposal that does *not* satisfy all the hard goals is rejected by the Analyzer and is not sent to the user.

NOTE

For example, you might have a soft goal to distribute a topic's replicas evenly across the cluster (the topic replica distribution goal). Cruise Control will ignore this goal if doing so enables all the configured hard goals to be met.

In Cruise Control, the following main optimization goals are preset as hard goals:

```
RackAwareGoal; MinTopicLeadersPerBrokerGoal; ReplicaCapacityGoal; DiskCapacityGoal;
NetworkInboundCapacityGoal; NetworkOutboundCapacityGoal; CpuCapacityGoal
```

To change the hard goals, edit the **hard.goals** property of the **cruisecontrol.properties** file and specify the goals using their fully-qualified domain names.

Increasing the number of hard goals reduces the likelihood that Cruise Control will calculate and generate valid optimization proposals.

13.5.4. Main optimization goals

The main optimization goals are available to all users. Goals that are not listed in the main optimization goals are not available for use in Cruise Control operations.

The following main optimization goals are preset in the **goals** property of the **cruisecontrol.properties** file in descending priority order:

```
RackAwareGoal; MinTopicLeadersPerBrokerGoal; ReplicaCapacityGoal; DiskCapacityGoal;
NetworkInboundCapacityGoal; NetworkOutboundCapacityGoal; ReplicaDistributionGoal;
PotentialNwOutGoal; DiskUsageDistributionGoal; NetworkInboundUsageDistributionGoal;
NetworkOutboundUsageDistributionGoal; CpuUsageDistributionGoal; TopicReplicaDistributionGoal;
LeaderReplicaDistributionGoal; LeaderBytesInDistributionGoal; PreferredLeaderElectionGoal
```

To reduce complexity, we recommend that you do not change the preset main optimization goals, unless you need to completely exclude one or more goals from being used to generate optimization proposals. The priority order of the main optimization goals can be modified, if desired, in the configuration for default optimization goals.

To modify the preset main optimization goals, specify a list of goals in the **goals** property in descending priority order. Use fully-qualified domain names as shown in the **cruisecontrol.properties** file.

You must specify at least one main goal, or Cruise Control will crash.

NOTE

If you change the preset main optimization goals, you must ensure that the configured **hard.goals** are a subset of the main optimization goals that you configured. Otherwise, errors will occur when generating optimization proposals.

13.5.5. Default optimization goals

Cruise Control uses the *default optimization goals* list to generate the *cached optimization proposal*. For more information, see Section 13.6, "Optimization proposals overview" .

You can override the default optimization goals at runtime by setting user-provided optimization goals.

The following default optimization goals are preset in the **default.goals** property of the **cruisecontrol.properties** file in descending priority order:

```
RackAwareGoal; MinTopicLeadersPerBrokerGoal; ReplicaCapacityGoal; DiskCapacityGoal;
NetworkInboundCapacityGoal; NetworkOutboundCapacityGoal; CpuCapacityGoal;
ReplicaDistributionGoal; PotentialNwOutGoal; DiskUsageDistributionGoal;
NetworkInboundUsageDistributionGoal; NetworkOutboundUsageDistributionGoal;
CpuUsageDistributionGoal; TopicReplicaDistributionGoal; LeaderReplicaDistributionGoal;
LeaderBytesInDistributionGoal
```

You must specify at least one default goal, or Cruise Control will crash.

To modify the default optimization goals, specify a list of goals in the **default.goals** property in descending priority order. Default goals must be a subset of the main optimization goals; use fully-qualified domain names.

13.5.6. User-provided optimization goals

User-provided optimization goals narrow down the configured default goals for a particular optimization proposal. You can set them, as required, as parameters in HTTP requests to the **/rebalance** endpoint. For more information, see Section 13.9, "Generating optimization proposals" .

User-provided optimization goals can generate optimization proposals for different scenarios. For example, you might want to optimize leader replica distribution across the Kafka cluster without considering disk capacity or disk utilization. So, you send a request to the **/rebalance** endpoint containing a single goal for leader replica distribution.

User-provided optimization goals must:

- Include all configured hard goals, or an error occurs
- Be a subset of the main optimization goals

To ignore the configured hard goals in an optimization proposal, add the **skip_hard_goals_check=true** parameter to the request.

Additional resources

- Cruise Control configuration

- Configurations in the Cruise Control Wiki

13.6. OPTIMIZATION PROPOSALS OVERVIEW

An *optimization proposal* is a summary of proposed changes that would produce a more balanced Kafka cluster, with partition workloads distributed more evenly among the brokers.

Each optimization proposal is based on the set of optimization goals that was used to generate it, subject to any configured capacity limits on broker resources.

All optimization proposals are *estimates* of the impact of a proposed rebalance. You can approve or reject a proposal. You cannot approve a cluster rebalance without first generating the optimization proposal.

You can run the optimization proposal using one of the following endpoints:

- **/rebalance**
- **/add_broker**
- **/remove_broker**

13.6.1. Rebalancing endpoints

You specify a rebalancing endpoint when you send a POST request to generate an optimization proposal.

/rebalance

The **/rebalance** endpoint runs a full rebalance by moving replicas across all the brokers in the cluster.

/add_broker

The **add_broker** endpoint is used after scaling up a Kafka cluster by adding one or more brokers. Normally, after scaling up a Kafka cluster, new brokers are used to host only the partitions of newly created topics. If no new topics are created, the newly added brokers are not used and the existing brokers remain under the same load. By using the **add_broker** endpoint immediately after adding brokers to the cluster, the rebalancing operation moves replicas from existing brokers to the newly added brokers. You specify the new brokers as a **brokerid** list in the POST request.

/remove_broker

The **/remove_broker** endpoint is used before scaling down a Kafka cluster by removing one or more brokers. If you scale down a Kafka cluster, brokers are shut down even if they host replicas. This can lead to under-replicated partitions and possibly result in some partitions being under their minimum ISR (in-sync replicas). To avoid this potential problem, the **/remove_broker** endpoint moves replicas off the brokers that are going to be removed. When these brokers are not hosting replicas anymore, you can safely run the scaling down operation. You specify the brokers you're removing as a **brokerid** list in the POST request.

In general, use the **/rebalance** endpoint to rebalance a Kafka cluster by spreading the load across brokers. Use the **/add-broker** endpoint and **/remove_broker** endpoint only if you want to scale your cluster up or down and rebalance the replicas accordingly.

The procedure to run a rebalance is actually the same across the three different endpoints. The only difference is with listing brokers that have been added or will be removed to the request.

13.6.2. Approving or rejecting an optimization proposal

An optimization proposal summary shows the proposed scope of changes. The summary is returned in a response to a HTTP request through the Cruise Control API.

When you make a POST request to the **/rebalance** endpoint, an optimization proposal summary is returned in the response.

Returning an optimization proposal summary

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/rebalance'
```

Use the summary to decide whether to approve or reject an optimization proposal.

Approving an optimization proposal

You approve the optimization proposal by making a POST request to the **/rebalance** endpoint and setting the **dryrun** parameter to **false** (default **true**). Cruise Control applies the proposal to the Kafka cluster and starts a cluster rebalance operation.

Rejecting an optimization proposal

If you choose not to approve an optimization proposal, you can change the optimization goals or update any of the rebalance performance tuning options , and then generate another proposal. You can resend a request without the **dryrun** parameter to generate a new optimization proposal.

Use the optimization proposal to assess the movements required for a rebalance. For example, a summary describes inter-broker and intra-broker movements. Inter-broker rebalancing moves data between separate brokers. Intra-broker rebalancing moves data between disks on the same broker when you are using a JBOD storage configuration. Such information can be useful even if you don't go ahead and approve the proposal.

You might reject an optimization proposal, or delay its approval, because of the additional load on a Kafka cluster when rebalancing.

In the following example, the proposal suggests the rebalancing of data between separate brokers. The rebalance involves the movement of 55 partition replicas, totaling 12MB of data, across the brokers. Though the inter-broker movement of partition replicas has a high impact on performance, the total amount of data is not large. If the total data was much larger, you could reject the proposal, or time when to approve the rebalance to limit the impact on the performance of the Kafka cluster.

Rebalance performance tuning options can help reduce the impact of data movement. If you can extend the rebalance period, you can divide the rebalance into smaller batches. Fewer data movements at a single time reduces the load on the cluster.

Example optimization proposal summary

```
Optimization has 55 inter-broker replica (12 MB) moves, 0 intra-broker
replica (0 MB) moves and 24 leadership moves with a cluster model of 5
recent windows and 100.000% of the partitions covered.
Excluded Topics: [].
Excluded Brokers For Leadership: [].
Excluded Brokers For Replica Move: [].
Counts: 3 brokers 343 replicas 7 topics.
On-demand Balancedness Score Before (78.012) After (82.912).
Provision Status: RIGHT_SIZED.
```

The proposal will also move 24 partition leaders to different brokers, which has a low impact on performance.

The balancedness scores are measurements of the overall balance of the Kafka Cluster before and after the optimization proposal is approved. A balancedness score is based on optimization goals. If all goals are satisfied, the score is 100. The score is reduced for each goal that will not be met. Compare the balancedness scores to see whether the Kafka cluster is less balanced than it could be following a rebalance.

The provision status indicates whether the current cluster configuration supports the optimization goals. Check the provision status to see if you should add or remove brokers.

Table 13.2. Optimization proposal provision status

Status	Description
RIGHT_SIZED	The cluster has an appropriate number of brokers to satisfy the optimization goals.
UNDER_PROVISIONED	The cluster is under-provisioned and requires more brokers to satisfy the optimization goals.
OVER_PROVISIONED	The cluster is over-provisioned and requires fewer brokers to satisfy the optimization goals.
UNDECIDED	The status is not relevant or it has not yet been decided.

13.6.3. Optimization proposal summary properties

The following table describes the properties contained in an optimization proposal.

Table 13.3. Properties contained in an optimization proposal summary

Property	Description
n inter-broker replica (y MB) moves	**n**: The number of partition replicas that will be moved between separate brokers. **Performance impact during rebalance operation**: Relatively high. **y MB**: The sum of the size of each partition replica that will be moved to a separate broker. **Performance impact during rebalance operation**: Variable. The larger the number of MBs, the longer the cluster rebalance will take to complete.

Property	Description
n intra-broker replica (y MB) moves	**n**: The total number of partition replicas that will be transferred between the disks of the cluster's brokers. **Performance impact during rebalance operation**: Relatively high, but less than **inter-broker replica moves**. **y MB**: The sum of the size of each partition replica that will be moved between disks on the same broker. **Performance impact during rebalance operation**: Variable. The larger the number, the longer the cluster rebalance will take to complete. Moving a large amount of data between disks on the same broker has less impact than between separate brokers (see **inter-broker replica moves**).
n excluded topics	The number of topics excluded from the calculation of partition replica/leader movements in the optimization proposal. You can exclude topics in one of the following ways: In the **cruisecontrol.properties** file, specify a regular expression in the **topics.excluded.from.partition.movement** property. In a POST request to the /**rebalance** endpoint, specify a regular expression in the **excluded_topics** parameter. Topics that match the regular expression are listed in the response and will be excluded from the cluster rebalance.
n leadership moves	**n**: The number of partitions whose leaders will be switched to different replicas. **Performance impact during rebalance operation**: Relatively low.
n recent windows	**n**: The number of metrics windows upon which the optimization proposal is based.
n% of the partitions covered	**n%**: The percentage of partitions in the Kafka cluster covered by the optimization proposal.

Property	Description
On-demand Balancedness Score Before (nn.yyy) After (nn.yyy)	Measurements of the overall balance of a Kafka Cluster. Cruise Control assigns a **Balancedness Score** to every optimization goal based on several factors, including priority (the goal's position in the list of **default.goals** or user-provided goals). The **On-demand Balancedness Score** is calculated by subtracting the sum of the **Balancedness Score** of each violated soft goal from 100. The **Before** score is based on the current configuration of the Kafka cluster. The **After** score is based on the generated optimization proposal.

13.6.4. Cached optimization proposal

Cruise Control maintains a *cached optimization proposal* based on the configured default optimization goals. Generated from the workload model, the cached optimization proposal is updated every 15 minutes to reflect the current state of the Kafka cluster.

The most recent cached optimization proposal is returned when the following goal configurations are used:

- The default optimization goals
- User-provided optimization goals that can be met by the current cached proposal

To change the cached optimization proposal refresh interval, edit the **proposal.expiration.ms** setting in the **cruisecontrol.properties** file. Consider a shorter interval for fast changing clusters, although this increases the load on the Cruise Control server.

Additional resources

- Optimization goals overview
- Generating optimization proposals
- Initiating a cluster rebalance

13.7. REBALANCE PERFORMANCE TUNING OVERVIEW

You can adjust several performance tuning options for cluster rebalances. These options control how partition replicas and leadership movements in a rebalance are executed, as well as the bandwidth that is allocated to a rebalance operation.

Partition reassignment commands

Optimization proposals are composed of separate partition reassignment commands. When you initiate a proposal, the Cruise Control server applies these commands to the Kafka cluster.

A partition reassignment command consists of either of the following types of operations:

- **Partition movement** Involves transferring the partition replica and its data to a new location. Partition movements can take one of two forms:

    - Inter-broker movement: The partition replica is moved to a log directory on a different broker.
    - Intra-broker movement: The partition replica is moved to a different log directory on the same broker.

- **Leadership movement**: Involves switching the leader of the partition's replicas.

Cruise Control issues partition reassignment commands to the Kafka cluster in batches. The performance of the cluster during the rebalance is affected by the number of each type of movement contained in each batch.

To configure partition reassignment commands, see Rebalance tuning options.

Replica movement strategies

Cluster rebalance performance is also influenced by the *replica movement strategy* that is applied to the batches of partition reassignment commands. By default, Cruise Control uses the **BaseReplicaMovementStrategy**, which applies the commands in the order in which they were generated. However, if there are some very large partition reassignments early in the proposal, this strategy can slow down the application of the other reassignments.

Cruise Control provides three alternative replica movement strategies that can be applied to optimization proposals:

- **PrioritizeSmallReplicaMovementStrategy**: Order reassignments in ascending size.
- **PrioritizeLargeReplicaMovementStrategy**: Order reassignments in descending size.
- **PostponeUrpReplicaMovementStrategy**: Prioritize reassignments for replicas of partitions which have no out-of-sync replicas.

These strategies can be configured as a sequence. The first strategy attempts to compare two partition reassignments using its internal logic. If the reassignments are equivalent, then it passes them to the next strategy in the sequence to decide the order, and so on.

To configure replica movement strategies, see Rebalance tuning options.

Rebalance tuning options

Cruise Control provides several configuration options for tuning rebalance parameters. These options are set in the following ways:

- As properties, in the default Cruise Control configuration, in the **cruisecontrol.properties** file
- As parameters in POST requests to the /**rebalance** endpoint

The relevant configurations for both methods are summarized in the following table.

Table 13.4. Rebalance performance tuning configuration

Cruise Control properties	KafkaRebalance parameters	Default	Description

Cruise Control properties	KafkaRebalance parameters	Default	Description
num.concurrent.partition.movements.per.broker	**concurrent_partition_movements_per_broker**	5	The maximum number of inter-broker partition movements in each partition reassignment batch
num.concurrent.intra.broker.partition.movements	**concurrent_intra_broker_partition_movements**	2	The maximum number of intra-broker partition movements in each partition reassignment batch
num.concurrent.leader.movements	**concurrent_leader_movements**	1000	The maximum number of partition leadership changes in each partition reassignment batch
default.replication.throttle	**replication_throttle**	Null (no limit)	The bandwidth (in bytes per second) to assign to partition reassignment

Cruise Control properties	KafkaRebalance parameters	Defau lt	Description
default.replica.movement.strategies	**replica_movement_strategies**	**BaseReplicaMovementStrategy**	The list of strategies (in priority order) used to determine the order in which partition reassignment commands are executed for generated proposals. There are three strategies: **PrioritizeSmallReplicaMovementStrategy**, **PrioritizeLargeReplicaMovementStrategy**, and **PostponeUrpReplicaMovementStrategy**. For the server setting, use a comma-separated list with the fully qualified names of the strategy class (add **com.linkedin.kafka.cruisecontrol.executor.strategy.** to the start of each class name). For the rebalance parameters, use a comma-separated list of the class names of the replica movement strategies.

Changing the default settings affects the length of time that the rebalance takes to complete, as well as the load placed on the Kafka cluster during the rebalance. Using lower values reduces the load but increases the amount of time taken, and vice versa.

Additional resources

- Configurations in the Cruise Control Wiki
- REST APIs in the Cruise Control Wiki

13.8. CRUISE CONTROL CONFIGURATION

The **config/cruisecontrol.properties** file contains the configuration for Cruise Control. The file consists of properties in one of the following types:

- String
- Number
- Boolean

You can specify and configure all the properties listed in the Configurations section of the Cruise Control Wiki.

Capacity configuration

Cruise Control uses *capacity limits* to determine if certain resource-based optimization goals are being broken. An attempted optimization fails if one or more of these resource-based goals is set as a hard goal and then broken. This prevents the optimization from being used to generate an optimization proposal.

You specify capacity limits for Kafka broker resources in one of the following three **.json** files in **cruise-control/config**:

- **capacityJBOD.json**: For use in JBOD Kafka deployments (the default file).
- **capacity.json**: For use in non-JBOD Kafka deployments where each broker has the same number of CPU cores.
- **capacityCores.json**: For use in non-JBOD Kafka deployments where each broker has varying numbers of CPU cores.

Set the file in the **capacity.config.file** property in **cruisecontrol.properties**. The selected file will be used for broker capacity resolution. For example:

```
capacity.config.file=config/capacityJBOD.json
```

Capacity limits can be set for the following broker resources in the described units:

- **DISK**: Disk storage in MB
- **CPU**: CPU utilization as a percentage (0-100) or as a number of cores
- **NW_IN**: Inbound network throughput in KB per second
- **NW_OUT**: Outbound network throughput in KB per second

To apply the same capacity limits to every broker monitored by Cruise Control, set capacity limits for broker ID **-1**. To set different capacity limits for individual brokers, specify each broker ID and its capacity configuration.

Example capacity limits configuration

```
{
  "brokerCapacities":[
    {
      "brokerId": "-1",
      "capacity": {
        "DISK": "100000",
        "CPU": "100",
        "NW_IN": "10000",
        "NW_OUT": "10000"
      },
      "doc": "This is the default capacity. Capacity unit used for disk is in MB, cpu is in percentage,
network throughput is in KB."
    },
    {
      "brokerId": "0",
      "capacity": {
        "DISK": "500000",
        "CPU": "100",
        "NW_IN": "50000",
        "NW_OUT": "50000"
      },
      "doc": "This overrides the capacity for broker 0."
    }
  ]
}
```

For more information, see Populating the Capacity Configuration File in the Cruise Control Wiki.

Log cleanup policy for Cruise Control Metrics topic

It is important that the auto-created **__CruiseControlMetrics** topic (see auto-created topics) has a log cleanup policy of **DELETE** rather than **COMPACT**. Otherwise, records that are needed by Cruise Control might be removed.

As described in Section 13.3, "Deploying the Cruise Control Metrics Reporter", setting the following options in the Kafka configuration file ensures that the **COMPACT** log cleanup policy is correctly set:

- **cruise.control.metrics.topic.auto.create=true**
- **cruise.control.metrics.topic.num.partitions=1**
- **cruise.control.metrics.topic.replication.factor=1**

If topic auto-creation is *disabled* in the Cruise Control Metrics Reporter (**cruise.control.metrics.topic.auto.create=false**), but *enabled* in the Kafka cluster, then the **__CruiseControlMetrics** topic is still automatically created by the broker. In this case, you must change the log cleanup policy of the **__CruiseControlMetrics** topic to **DELETE** using the **kafka-configs.sh** tool.

1. Get the current configuration of the **__CruiseControlMetrics** topic:

```
opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_address> --entity-type topics --
entity-name __CruiseControlMetrics --describe
```

2. Change the log cleanup policy in the topic configuration:

```
/opt/kafka/bin/kafka-configs.sh --bootstrap-server <broker_address> --entity-type topics --
entity-name __CruiseControlMetrics --alter --add-config cleanup.policy=delete
```

If topic auto-creation is *disabled* in both the Cruise Control Metrics Reporter *and* the Kafka cluster, you must create the **__CruiseControlMetrics** topic manually and then configure it to use the **DELETE** log cleanup policy using the **kafka-configs.sh** tool.

For more information, see Section 7.9, "Modifying a topic configuration".

Logging configuration

Cruise Control uses **log4j1** for all server logging. To change the default configuration, edit the **log4j.properties** file in **/opt/cruise-control/config/log4j.properties**.

You must restart the Cruise Control server before the changes take effect.

13.9. GENERATING OPTIMIZATION PROPOSALS

When you make a POST request to the **/rebalance** endpoint, Cruise Control generates an optimization proposal to rebalance the Kafka cluster based on the optimization goals provided. You can use the results of the optimization proposal to rebalance your Kafka cluster.

You can run the optimization proposal using one of the following endpoints:

- **/rebalance**
- **/add_broker**
- **/remove_broker**

The endpoint you use depends on whether you are rebalancing across all the brokers already running in the Kafka cluster; or you want to rebalance after scaling up or before scaling down your Kafka cluster. For more information, see Rebalancing endpoints with broker scaling.

The optimization proposal is generated as a *dry run*, unless the **dryrun** parameter is supplied and set to **false**. In "dry run mode", Cruise Control generates the optimization proposal and the estimated result, but doesn't initiate the proposal by rebalancing the cluster.

You can analyze the information returned in the optimization proposal and decide whether to approve it.

Use the following parameters to make requests to the endpoints:

dryrun

type: boolean, default: true

Informs Cruise Control whether you want to generate an optimization proposal only (**true**), or generate an optimization proposal and perform a cluster rebalance (**false**).

When **dryrun=true** (the default), you can also pass the **verbose** parameter to return more detailed information about the state of the Kafka cluster. This includes metrics for the load on each Kafka broker before and after the optimization proposal is applied, and the differences between the before and after values.

excluded_topics

type: regex

A regular expression that matches the topics to exclude from the calculation of the optimization proposal.

goals

type: list of strings, default: the configured **default.goals** list

List of user-provided optimization goals to use to prepare the optimization proposal. If goals are not supplied, the configured **default.goals** list in the **cruisecontrol.properties** file is used.

skip_hard_goals_check

type: boolean, default: **false**

By default, Cruise Control checks that the user-provided optimization goals (in the **goals** parameter) contain all the configured hard goals (in **hard.goals**). A request fails if you supply goals that are not a subset of the configured **hard.goals**.

Set **skip_hard_goals_check** to **true** if you want to generate an optimization proposal with user-provided optimization goals that do not include all the configured **hard.goals**.

json

type: boolean, default: **false**

Controls the type of response returned by the Cruise Control server. If not supplied, or set to **false**, then Cruise Control returns text formatted for display on the command line. If you want to extract elements of the returned information programmatically, set **json=true**. This will return JSON formatted text that can be piped to tools such as **jq**, or parsed in scripts and programs.

verbose

type: boolean, default: **false**

Controls the level of detail in responses that are returned by the Cruise Control server. Can be used with **dryrun=true**.

NOTE

Other parameters are available. For more information, see REST APIs in the Cruise Control Wiki.

Prerequisites

- Kafka is running.
- You have configured Cruise Control.
- (Optional for scaling up) You have installed new brokers on hosts to include in the rebalance.

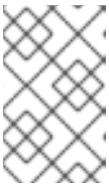
Procedure

1. Generate an optimization proposal using a POST request to the **/rebalance**, **/add_broker**, or **/remove_broker** endpoint.

Example request to /rebalance using default goals

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/rebalance'
```

The cached optimization proposal is immediately returned.



NOTE

If **NotEnoughValidWindows** is returned, Cruise Control has not yet recorded enough metrics data to generate an optimization proposal. Wait a few minutes and then resend the request.

Example request to /rebalance using specified goals

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/rebalance?
goals=RackAwareGoal,ReplicaCapacityGoal'
```

If the request satisfies the supplied goals, the cached optimization proposal is immediately returned. Otherwise, a new optimization proposal is generated using the supplied goals; this takes longer to calculate. You can enforce this behavior by adding the **ignore_proposal_cache=true** parameter to the request.

Example request to /rebalance using specified goals without hard goals

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/rebalance?
goals=RackAwareGoal,ReplicaCapacityGoal,ReplicaDistributionGoal&skip_hard_goal_check=tr
ue'
```

Example request to /add_broker that includes specified brokers

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/add_broker?brokerid=3,4'
```

The request includes the IDs of the new brokers only. For example, this request adds brokers with the IDs **3** and **4**. Replicas are moved to the new brokers from existing brokers when rebalancing.

Example request to /remove_broker that excludes specified brokers

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/remove_broker?brokerid=3,4'
```

The request includes the IDs of the brokers being excluded only. For example, this request excludes brokers with the IDs **3** and **4**. Replicas are moved from the brokers being removed to other existing brokers when rebalancing.

NOTE

If a broker that is being removed has excluded topics, replicas are still moved.

2. Review the optimization proposal contained in the response. The properties describe the pending cluster rebalance operation.

The proposal contains a high level summary of the proposed optimization, followed by summaries for each default optimization goal, and the expected cluster state after the proposal has executed.

Pay particular attention to the following information:

- The **Cluster load after rebalance** summary. If it meets your requirements, you should assess the impact of the proposed changes using the high level summary.
- **n inter-broker replica (y MB) moves** indicates how much data will be moved across the network between brokers. The higher the value, the greater the potential performance impact on the Kafka cluster during the rebalance.
- **n intra-broker replica (y MB) moves** indicates how much data will be moved within the brokers themselves (between disks). The higher the value, the greater the potential performance impact on individual brokers (although less than that of **n inter-broker replica (y MB) moves**).
- The number of leadership moves. This has a negligible impact on the performance of the cluster during the rebalance.

Asynchronous responses

The Cruise Control REST API endpoints timeout after 10 seconds by default, although proposal generation continues on the server. A timeout might occur if the most recent cached optimization proposal is not ready, or if user-provided optimization goals were specified with **ignore_proposal_cache=true**.

To allow you to retrieve the optimization proposal at a later time, take note of the request's unique identifier, which is given in the header of responses from the **/rebalance** endpoint.

To obtain the response using **curl**, specify the verbose (**-v**) option:

```
curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/rebalance'
```

Here is an example header:

```
* Connected to cruise-control-server (::1) port 9090 (#0)
> POST /kafkacruisecontrol/rebalance HTTP/1.1
> Host: cc-host:9090
> User-Agent: curl/7.70.0
> Accept: /
>
* Mark bundle as not supporting multiuse
< HTTP/1.1 200 OK
< Date: Mon, 01 Jun 2023 15:19:26 GMT
< Set-Cookie: JSESSIONID=node01wk6vjzjj12go13m81o7no5p7h9.node0; Path=/
< Expires: Thu, 01 Jan 1970 00:00:00 GMT
< User-Task-ID: 274b8095-d739-4840-85b9-f4cfaaf5c201
< Content-Type: text/plain;charset=utf-8
< Cruise-Control-Version: 2.0.103.redhat-00002
< Cruise-Control-Commit_Id: 58975c9d5d0a78dd33cd67d4bcb497c9fd42ae7c
< Content-Length: 12368
< Server: Jetty(9.4.26.v20200117-redhat-00001)
```

If an optimization proposal is not ready within the timeout, you can re-submit the POST request, this time including the **User-Task-ID** of the original request in the header:

```
curl -v -X POST -H 'User-Task-ID: 274b8095-d739-4840-85b9-f4cfaaf5c201' 'cruise-control-server:9090/kafkacruisecontrol/rebalance'
```

What to do next

Section 13.10, "Approving an optimization proposal"

13.10. APPROVING AN OPTIMIZATION PROPOSAL

If you are satisfied with your most recently generated optimization proposal, you can instruct Cruise Control to initiate a cluster rebalance and begin reassigning partitions.

Leave as little time as possible between generating an optimization proposal and initiating the cluster rebalance. If some time has passed since you generated the original optimization proposal, the cluster state might have changed. Therefore, the cluster rebalance that is initiated might be different to the one you reviewed. If in doubt, first generate a new optimization proposal.

Only one cluster rebalance, with a status of "Active", can be in progress at a time.

Prerequisites

- You have generated an optimization proposal from Cruise Control.

Procedure

1. Send a POST request to the **/rebalance**, **/add_broker**, or **/remove_broker** endpoint with the **dryrun=false** parameter:
   If you used the **/add_broker** or **/remove_broker** endpoint to generate a proposal that included or excluded brokers, use the same endpoint to perform the rebalance with or without the specified brokers.

   Example request to /rebalance

   ```
   curl -X POST 'cruise-control-server:9090/kafkacruisecontrol/rebalance?dryrun=false'
   ```

   Example request to /add_broker

   ```
   curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/add_broker?dryrun=false&brokerid=3,4'
   ```

   Example request to /remove_broker

   ```
   curl -v -X POST 'cruise-control-server:9090/kafkacruisecontrol/remove_broker?dryrun=false&brokerid=3,4'
   ```

   Cruise Control initiates the cluster rebalance and returns the optimization proposal.

2. Check the changes that are summarized in the optimization proposal. If the changes are not what you expect, you can stop the rebalance.

3. Check the progress of the cluster rebalance using the **/user_tasks** endpoint. The cluster rebalance in progress has a status of "Active".
   To view all cluster rebalance tasks executed on the Cruise Control server:

```
curl 'cruise-control-server:9090/kafkacruisecontrol/user_tasks'

USER TASK ID      CLIENT ADDRESS  START TIME     STATUS  REQUEST URL
c459316f-9eb5-482f-9d2d-97b5a4cd294d  0:0:0:0:0:0:0:1       2020-06-01_16:10:29 UTC
Active      POST /kafkacruisecontrol/rebalance?dryrun=false
445e2fc3-6531-4243-b0a6-36ef7c5059b4  0:0:0:0:0:0:0:1       2020-06-01_14:21:26 UTC
Completed   GET /kafkacruisecontrol/state?json=true
05c37737-16d1-4e33-8e2b-800dee9f1b01  0:0:0:0:0:0:0:1       2020-06-01_14:36:11 UTC
Completed   GET /kafkacruisecontrol/state?json=true
aebae987-985d-4871-8cfb-6134ecd504ab  0:0:0:0:0:0:0:1       2020-06-01_16:10:04 UTC
```

4. To view the status of a particular cluster rebalance task, supply the **user-task-ids** parameter and the task ID:

```
curl 'cruise-control-server:9090/kafkacruisecontrol/user_tasks?user_task_ids=c459316f-9eb5-482f-9d2d-97b5a4cd294d'
```

(Optional) Removing brokers when scaling down

After a successful rebalance you can stop any brokers you excluded in order to scale down the Kafka cluster.

1. Check that each broker being removed does not have any live partitions in its log (**log.dirs**).

```
ls -l <LogDir> | grep -E '^d' | grep -vE '[a-zA-Z0-9.-]+\.[a-z0-9]+-delete$'
```

   If a log directory does not match the regular expression **\.[a-z0-9]-delete$**, active partitions are still present. If you have active partitions, check the rebalance has finished or the configuration for the optimization proposal. You can run the proposal again. Make sure that there are no active partitions before moving on to the next step.

2. Stop the broker.

```
su - kafka
/opt/kafka/bin/kafka-server-stop.sh
```

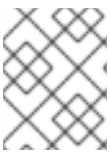
3. Confirm that the broker has stopped.

```
jcmd | grep kafka
```

13.11. STOPPING AN ACTIVE CLUSTER REBALANCE

You can stop the cluster rebalance that is currently in progress.

This instructs Cruise Control to finish the current batch of partition reassignments and then stop the rebalance. When the rebalance has stopped, completed partition reassignments have already been applied; therefore, the state of the Kafka cluster is different when compared to before the start of the rebalance operation. If further rebalancing is required, you should generate a new optimization proposal.



NOTE

The performance of the Kafka cluster in the intermediate (stopped) state might be worse than in the initial state.

Prerequisites

- A cluster rebalance is in progress (indicated by a status of "Active").

Procedure

- Send a POST request to the /**stop_proposal_execution** endpoint:

```
curl -X POST 'cruise-control-server:9090/kafkacruisecontrol/stop_proposal_execution'
```

Additional resources

- Generating optimization proposals

CHAPTER 14. USING CRUISE CONTROL TO MODIFY TOPIC REPLICATION FACTOR

Make requests to the **/topic_configuration** endpoint of the Cruise Control REST API to modify topic configurations, including the replication factor.

Prerequisites

- You are logged in to Red Hat Enterprise Linux as the **kafka** user.
- You have configured Cruise Control.
- You have deployed the Cruise Control Metrics Reporter .

Procedure

1. Start the Cruise Control server. The server starts on port 9092 by default; optionally, specify a different port.

```
cd /opt/cruise-control/
./kafka-cruise-control-start.sh config/cruisecontrol.properties <port_number>
```

2. To verify that Cruise Control is running, send a GET request to the **/state** endpoint of the Cruise Control server:

```
curl -X GET 'http://<cc_host>:<cc_port>/kafkacruisecontrol/state'
```

3. Run the **bin/kafka-topics.sh** command with the **--describe** option and to check the current replication factor of the target topic:

```
/opt/kafka/bin/kafka-topics.sh \
  --bootstrap-server localhost:9092 \
  --topic <topic_name> \
  --describe
```

4. Update the replication factor for the topic:

```
curl -X POST 'http://<cc_host>:<cc_port>/kafkacruisecontrol/topic_configuration?topic=
<topic_name>&replication_factor=<new_replication_factor>&dryrun=false'
```

   For example, **curl -X POST 'localhost:9090/kafkacruisecontrol/topic_configuration?topic=topic1&replication_factor=3&dryrun=false'**.

5. Run the **bin/kafka-topics.sh** command with the **--describe** option, as before, to see the results of the change to the topic.

CHAPTER 15. USING THE PARTITION REASSIGNMENT TOOL

When scaling a Kafka cluster, you may need to add or remove brokers and update the distribution of partitions or the replication factor of topics. To update partitions and topics, you can use the **kafka-reassign-partitions.sh** tool.

You can change the replication factor of a topic using the **kafka-reassign-partitions.sh** tool. The tool can also be used to reassign partitions and balance the distribution of partitions across brokers to improve performance. However, it is recommended to use Cruise Control for automated partition reassignments and cluster rebalancing and changing the topic replication factor . Cruise Control can move topics from one broker to another without any downtime, and it is the most efficient way to reassign partitions.

15.1. PARTITION REASSIGNMENT TOOL OVERVIEW

The partition reassignment tool provides the following capabilities for managing Kafka partitions and brokers:

Redistributing partition replicas

Scale your cluster up and down by adding or removing brokers, and move Kafka partitions from heavily loaded brokers to under-utilized brokers. To do this, you must create a partition reassignment plan that identifies which topics and partitions to move and where to move them. Cruise Control is recommended for this type of operation as it automates the cluster rebalancing process.

Scaling topic replication factor up and down

Increase or decrease the replication factor of your Kafka topics. To do this, you must create a partition reassignment plan that identifies the existing replication assignment across partitions and an updated assignment with the replication factor changes.

Changing the preferred leader

Change the preferred leader of a Kafka partition. This can be useful if the current preferred leader is unavailable or if you want to redistribute load across the brokers in the cluster. To do this, you must create a partition reassignment plan that specifies the new preferred leader for each partition by changing the order of replicas.

Changing the log directories to use a specific JBOD volume

Change the log directories of your Kafka brokers to use a specific JBOD volume. This can be useful if you want to move your Kafka data to a different disk or storage device. To do this, you must create a partition reassignment plan that specifies the new log directory for each topic.

15.1.1. Generating a partition reassignment plan

The partition reassignment tool (**kafka-reassign-partitions.sh**) works by generating a partition assignment plan that specifies which partitions should be moved from their current broker to a new broker.

If you are satisfied with the plan, you can execute it. The tool then does the following:

- Migrates the partition data to the new broker
- Updates the metadata on the Kafka brokers to reflect the new partition assignments
- Triggers a rolling restart of the Kafka brokers to ensure that the new assignments take effect

The partition reassignment tool has three different modes:

--generate

Takes a set of topics and brokers and generates a *reassignment JSON file* which will result in the partitions of those topics being assigned to those brokers. Because this operates on whole topics, it cannot be used when you only want to reassign some partitions of some topics.

--execute

Takes a *reassignment JSON file* and applies it to the partitions and brokers in the cluster. Brokers that gain partitions as a result become followers of the partition leader. For a given partition, once the new broker has caught up and joined the ISR (in-sync replicas) the old broker will stop being a follower and will delete its replica.

--verify

Using the same *reassignment JSON file* as the **--execute** step, **--verify** checks whether all the partitions in the file have been moved to their intended brokers. If the reassignment is complete, **--verify** also removes any traffic throttles (**--throttle**) that are in effect. Unless removed, throttles will continue to affect the cluster even after the reassignment has finished.

It is only possible to have one reassignment running in a cluster at any given time, and it is not possible to cancel a running reassignment. If you must cancel a reassignment, wait for it to complete and then perform another reassignment to revert the effects of the first reassignment. The **kafka-reassign-partitions.sh** will print the reassignment JSON for this reversion as part of its output. Very large reassignments should be broken down into a number of smaller reassignments in case there is a need to stop in-progress reassignment.

15.1.2. Specifying topics in a partition reassignment JSON file

The **kafka-reassign-partitions.sh** tool uses a reassignment JSON file that specifies the topics to reassign. You can generate a reassignment JSON file or create a file manually if you want to move specific partitions.

A basic reassignment JSON file has the structure presented in the following example, which describes three partitions belonging to two Kafka topics. Each partition is reassigned to a new set of replicas, which are identified by their broker IDs. The **version**, **topic**, **partition**, and **replicas** properties are all required.

Example partition reassignment JSON file structure

```
{
  "version": 1, 1
  "partitions": [ 2
    {
      "topic": "example-topic-1", 3
      "partition": 0, 4
      "replicas": [1, 2, 3] 5
    },
    {
      "topic": "example-topic-1",
      "partition": 1,
      "replicas": [2, 3, 4]
    },
    {
      "topic": "example-topic-2",
      "partition": 0,
      "replicas": [3, 4, 5]
```

```
    }
  ]
}
```

1. The version of the reassignment JSON file format. Currently, only version 1 is supported, so this should always be 1.
2. An array that specifies the partitions to be reassigned.
3. The name of the Kafka topic that the partition belongs to.
4. The ID of the partition being reassigned.
5. An ordered array of the IDs of the brokers that should be assigned as replicas for this partition. The first broker in the list is the leader replica.

NOTE

Partitions not included in the JSON are not changed.

If you specify only topics using a **topics** array, the partition reassignment tool reassigns all the partitions belonging to the specified topics.

Example reassignment JSON file structure for reassigning all partitions for a topic

```
{
  "version": 1,
  "topics": [
    { "topic": "my-topic"}
  ]
}
```

15.1.3. Reassigning partitions between JBOD volumes

When using JBOD storage in your Kafka cluster, you can reassign the partitions between specific volumes and their log directories (each volume has a single log directory).

To reassign a partition to a specific volume, add **log_dirs** values for each partition in the reassignment JSON file. Each **log_dirs** array contains the same number of entries as the **replicas** array, since each replica should be assigned to a specific log directory. The **log_dirs** array contains either an absolute path to a log directory or the special value **any**. The **any** value indicates that Kafka can choose any available log directory for that replica, which can be useful when reassigning partitions between JBOD volumes.

Example reassignment JSON file structure with log directories

```
{
  "version": 1,
  "partitions": [
    {
      "topic": "example-topic-1",
      "partition": 0,
      "replicas": [1, 2, 3]
```

```
      "log_dirs": ["/var/lib/kafka/data-0/kafka-log1", "any", "/var/lib/kafka/data-1/kafka-log2"]
    },
    {
      "topic": "example-topic-1",
      "partition": 1,
      "replicas": [2, 3, 4]
      "log_dirs": ["any",  "/var/lib/kafka/data-2/kafka-log3", "/var/lib/kafka/data-3/kafka-log4"]
    },
    {
      "topic": "example-topic-2",
      "partition": 0,
      "replicas": [3, 4, 5]
      "log_dirs": ["/var/lib/kafka/data-4/kafka-log5", "any",  "/var/lib/kafka/data-5/kafka-log6"]
    }
  ]
}
```

15.1.4. Throttling partition reassignment

Partition reassignment can be a slow process because it involves transferring large amounts of data between brokers. To avoid a detrimental impact on clients, you can throttle the reassignment process. Use the **--throttle** parameter with the **kafka-reassign-partitions.sh** tool to throttle a reassignment. You specify a maximum threshold in bytes per second for the movement of partitions between brokers. For example, **--throttle 5000000** sets a maximum threshold for moving partitions of 50 MBps.

Throttling might cause the reassignment to take longer to complete.

- If the throttle is too low, the newly assigned brokers will not be able to keep up with records being published and the reassignment will never complete.
- If the throttle is too high, clients will be impacted.

For example, for producers, this could manifest as higher than normal latency waiting for acknowledgment. For consumers, this could manifest as a drop in throughput caused by higher latency between polls.

15.2. REASSIGNING PARTITIONS AFTER ADDING BROKERS

Use a reassignment file generated by the **kafka-reassign-partitions.sh** tool to reassign partitions after increasing the number of brokers in a Kafka cluster. The reassignment file should describe how partitions are reassigned to brokers in the enlarged Kafka cluster. You apply the reassignment specified in the file to the brokers and then verify the new partition assignments.

This procedure describes a secure scaling process that uses TLS. You'll need a Kafka cluster that uses TLS encryption and mTLS authentication.

NOTE

Though you can use the **kafka-reassign-partitions.sh** tool, Cruise Control is recommended for automated partition reassignments and cluster rebalancing . Cruise Control can move topics from one broker to another without any downtime, and it is the most efficient way to reassign partitions.

Prerequisites

- An existing Kafka cluster.
- A new machine with the additional AMQ broker installed.
- You have created a JSON file to specify how partitions should be reassigned to brokers in the enlarged cluster.
  In this procedure, we are reassigning all partitions for a topic called **my-topic**. A JSON file named **topics.json** specifies the topic, and is used to generate a **reassignment.json** file.

Example JSON file specifies my-topic

```
{
  "version": 1,
  "topics": [
    { "topic": "my-topic"}
  ]
}
```

Procedure

1. Create a configuration file for the new broker using the same settings as for the other brokers in your cluster, except for **broker.id**, which should be a number that is not already used by any of the other brokers.
2. Start the new Kafka broker passing the configuration file you created in the previous step as the argument to the **kafka-server-start.sh** script:

```
su - kafka
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
```

3. Verify that the Kafka broker is running.

```
jcmd | grep Kafka
```

4. Repeat the above steps for each new broker.
5. If you haven't done so, generate a reassignment JSON file named **reassignment.json** using the **kafka-reassign-partitions.sh** tool.

   ### Example command to generate the reassignment JSON file

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --topics-to-move-json-file topics.json \ 1
  --broker-list 0,1,2,3,4 \ 2
  --generate
```

   1 The JSON file that specifies the topic.

   2 Brokers IDs in the kafka cluster to include in the operation. This assumes broker **4** has been added.

Example reassignment JSON file showing the current and proposed replica assignment

```
Current partition replica assignment
{"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[0,1,2],"log_dirs":
["any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[1,2,3],"log_dirs":
["any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[2,3,0],"log_dirs":
["any","any","any"]}]}

Proposed partition reassignment configuration
{"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[0,1,2,3],"log_dirs":
["any","any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[1,2,3,4],"log_dirs":
["any","any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[2,3,4,0],"log_dirs":
["any","any","any","any"]}]}
```

Save a copy of this file locally in case you need to revert the changes later on.

6. Run the partition reassignment using the **--execute** option.

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --reassignment-json-file reassignment.json \
  --execute
```

If you are going to throttle replication you can also pass the **--throttle** option with an inter-broker throttled rate in bytes per second. For example:

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --reassignment-json-file reassignment.json \
  --throttle 5000000 \
  --execute
```

7. Verify that the reassignment has completed using the **--verify** option.

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --reassignment-json-file reassignment.json \
  --verify
```

The reassignment has finished when the **--verify** command reports that each of the partitions being moved has completed successfully. This final **--verify** will also have the effect of removing any reassignment throttles.

15.3. REASSIGNING PARTITIONS BEFORE REMOVING BROKERS

Use a reassignment file generated by the **kafka-reassign-partitions.sh** tool to reassign partitions before decreasing the number of brokers in a Kafka cluster. The reassignment file must describe how partitions are reassigned to the remaining brokers in the Kafka cluster. You apply the reassignment specified in the file to the brokers and then verify the new partition assignments. Brokers in the highest numbered pods are removed first.

This procedure describes a secure scaling process that uses TLS. You'll need a Kafka cluster that uses TLS encryption and mTLS authentication.

NOTE

Though you can use the **kafka-reassign-partitions.sh** tool, Cruise Control is recommended for automated partition reassignments and cluster rebalancing . Cruise Control can move topics from one broker to another without any downtime, and it is the most efficient way to reassign partitions.

Prerequisites

- An existing Kafka cluster.
- You have created a JSON file to specify how partitions should be reassigned to brokers in the reduced cluster.
  In this procedure, we are reassigning all partitions for a topic called **my-topic**. A JSON file named **topics.json** specifies the topic, and is used to generate a **reassignment.json** file.

Example JSON file specifies my-topic

```
{
  "version": 1,
  "topics": [
    { "topic": "my-topic"}
  ]
}
```

Procedure

1. If you haven't done so, generate a reassignment JSON file named **reassignment.json** using the **kafka-reassign-partitions.sh** tool.

   #### Example command to generate the reassignment JSON file

   ```
   /opt/kafka/bin/kafka-reassign-partitions.sh \
     --bootstrap-server localhost:9092 \
     --topics-to-move-json-file topics.json \ 1
     --broker-list 0,1,2,3 \ 2
     --generate
   ```

   1 The JSON file that specifies the topic.

   2 Brokers IDs in the kafka cluster to include in the operation. This assumes broker **4** has been removed.

   #### Example reassignment JSON file showing the current and proposed replica assignment

   ```
   Current partition replica assignment
   {"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[3,4,2,0],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[0,2,3,1],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[1,3,0,4],"log_dirs":
   ["any","any","any","any"]}]}

   Proposed partition reassignment configuration
   ```

```
{"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[0,1,2],"log_dirs":
["any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[1,2,3],"log_dirs":
["any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[2,3,0],"log_dirs":
["any","any","any"]}]}
```

Save a copy of this file locally in case you need to revert the changes later on.

2. Run the partition reassignment using the **--execute** option.

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --reassignment-json-file reassignment.json \
  --execute
```

If you are going to throttle replication you can also pass the **--throttle** option with an inter-broker throttled rate in bytes per second. For example:

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --reassignment-json-file reassignment.json \
  --throttle 5000000 \
  --execute
```

3. Verify that the reassignment has completed using the **--verify** option.

```
/opt/kafka/bin/kafka-reassign-partitions.sh \
  --bootstrap-server localhost:9092 \
  --reassignment-json-file reassignment.json \
  --verify
```

The reassignment has finished when the **--verify** command reports that each of the partitions being moved has completed successfully. This final **--verify** will also have the effect of removing any reassignment throttles.

4. Check that each broker being removed does not have any live partitions in its log (**log.dirs**).

```
ls -l <LogDir> | grep -E '^d' | grep -vE '[a-zA-Z0-9.-]+\.[a-z0-9]+-delete$'
```

If a log directory does not match the regular expression **\.[a-z0-9]-delete$**, active partitions are still present. If you have active partitions, check the reassignment has finished or the configuration in the reassignment JSON file. You can run the reassignment again. Make sure that there are no active partitions before moving on to the next step.

5. Stop the broker.

```
su - kafka
/opt/kafka/bin/kafka-server-stop.sh
```

6. Confirm that the Kafka broker has stopped.

```
jcmd | grep kafka
```

15.4. CHANGING THE REPLICATION FACTOR OF TOPICS

Use the **kafka-reassign-partitions.sh** tool to change the replication factor of topics in a Kafka cluster. This can be done using a reassignment file to describe how the topic replicas should be changed.

Prerequisites

- An existing Kafka cluster.
- You have created a JSON file to specify the topics to include in the operation.
  In this procedure, a topic called **my-topic** has 4 replicas and we want to reduce it to 3. A JSON file named **topics.json** specifies the topic, and is used to generate a **reassignment.json** file.

Example JSON file specifies my-topic

```
{
  "version": 1,
  "topics": [
    { "topic": "my-topic"}
  ]
}
```

Procedure

1. If you haven't done so, generate a reassignment JSON file named **reassignment.json** using the **kafka-reassign-partitions.sh** tool.

   #### Example command to generate the reassignment JSON file

   ```
   /opt/kafka/bin/kafka-reassign-partitions.sh \
     --bootstrap-server localhost:9092 \
     --topics-to-move-json-file topics.json \ 1
     --broker-list 0,1,2,3,4 \ 2
     --generate
   ```

   1 The JSON file that specifies the topic.

   2 Brokers IDs in the kafka cluster to include in the operation.

   #### Example reassignment JSON file showing the current and proposed replica assignment

   ```
   Current partition replica assignment
   {"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[3,4,2,0],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[0,2,3,1],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[1,3,0,4],"log_dirs":
   ["any","any","any","any"]}]}

   Proposed partition reassignment configuration
   {"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[0,1,2,3],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[1,2,3,4],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[2,3,4,0],"log_dirs":
   ["any","any","any","any"]}]}
   ```

   Save a copy of this file locally in case you need to revert the changes later on.

2. Edit the **reassignment.json** to remove a replica from each partition.
   For example use **jq** to remove the last replica in the list for each partition of the topic:

   Removing the last topic replica for each partition

   ```
   jq '.partitions[].replicas |= del(.[-1])' reassignment.json > reassignment.json
   ```

   Example reassignment file showing the updated replicas

   ```
   {"version":1,"partitions":[{"topic":"my-topic","partition":0,"replicas":[0,1,2],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":1,"replicas":[1,2,3],"log_dirs":
   ["any","any","any","any"]},{"topic":"my-topic","partition":2,"replicas":[2,3,4],"log_dirs":
   ["any","any","any","any"]}]}
   ```

3. Make the topic replica change using the **--execute** option.

   ```
   /opt/kafka/bin/kafka-reassign-partitions.sh \
     --bootstrap-server localhost:9092 \
     --reassignment-json-file reassignment.json \
     --execute
   ```

   NOTE

   Removing replicas from a broker does not require any inter-broker data movement, so there is no need to throttle replication. If you are adding replicas, then you may want to change the throttle rate.

4. Verify that the change to the topic replicas has completed using the **--verify** option.

   ```
   /opt/kafka/bin/kafka-reassign-partitions.sh \
     --bootstrap-server localhost:9092 \
     --reassignment-json-file reassignment.json \
     --verify
   ```

   The reassignment has finished when the **--verify** command reports that each of the partitions being moved has completed successfully. This final **--verify** will also have the effect of removing any reassignment throttles.

5. Run the **bin/kafka-topics.sh** command with the **--describe** option to see the results of the change to the topics.

   ```
   /opt/kafka/bin/kafka-topics.sh \
     --bootstrap-server localhost:9092 \
     --describe
   ```

   Results of reducing the number of replicas for a topic

   ```
   my-topic  Partition: 0  Leader: 0  Replicas: 0,1,2 Isr: 0,1,2
   my-topic  Partition: 1  Leader: 2  Replicas: 1,2,3 Isr: 1,2,3
   my-topic  Partition: 2  Leader: 3  Replicas: 2,3,4 Isr: 2,3,4
   ```

CHAPTER 16. SETTING UP DISTRIBUTED TRACING

Distributed tracing allows you to track the progress of transactions between applications in a distributed system. In a microservices architecture, tracing tracks the progress of transactions between services. Trace data is useful for monitoring application performance and investigating issues with target systems and end-user applications.

In Streams for Apache Kafka, tracing facilitates the end-to-end tracking of messages: from source systems to Kafka, and then from Kafka to target systems and applications. It complements the metrics that are available to view in JMX metrics, as well as the component loggers.

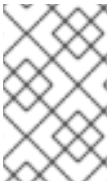
Support for tracing is built in to the following Kafka components:

- Kafka Connect
- MirrorMaker
- MirrorMaker 2
- Streams for Apache Kafka Bridge

Tracing is not supported for Kafka brokers.

You add tracing configuration to the properties file of the component.

To enable tracing, you set environment variables and add the library of the tracing system to the Kafka classpath. For Jaeger tracing, you can add tracing artifacts for OpenTelemetry with the Jaeger Exporter.



NOTE

Streams for Apache Kafka no longer supports OpenTracing. If you were previously using OpenTracing with Jaeger, we encourage you to transition to using OpenTelemetry instead.

To enable tracing in Kafka producers, consumers, and Kafka Streams API applications, you *instrument* application code. When instrumented, clients generate trace data; for example, when producing messages or writing offsets to the log.

NOTE

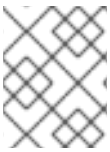
Setting up tracing for applications and systems beyond Streams for Apache Kafka is outside the scope of this content.

16.1. OUTLINE OF PROCEDURES

To set up tracing for Streams for Apache Kafka, follow these procedures in order:

- Set up tracing for Kafka Connect, MirrorMaker 2, and MirrorMaker:
  - Enable tracing for Kafka Connect
  - Enable tracing for MirrorMaker 2
  - Enable tracing for MirrorMaker

- Set up tracing for clients:
  - Initialize a Jaeger tracer for Kafka clients
- Instrument clients with tracers:
  - Instrument producers and consumers for tracing
  - Instrument Kafka Streams applications for tracing



NOTE

For information on enabling tracing for the Kafka Bridge, see Using the Streams for Apache Kafka Bridge.

16.2. TRACING OPTIONS

Use OpenTelemetry with the Jaeger tracing system.

OpenTelemetry provides an API specification that is independent from the tracing or monitoring system.

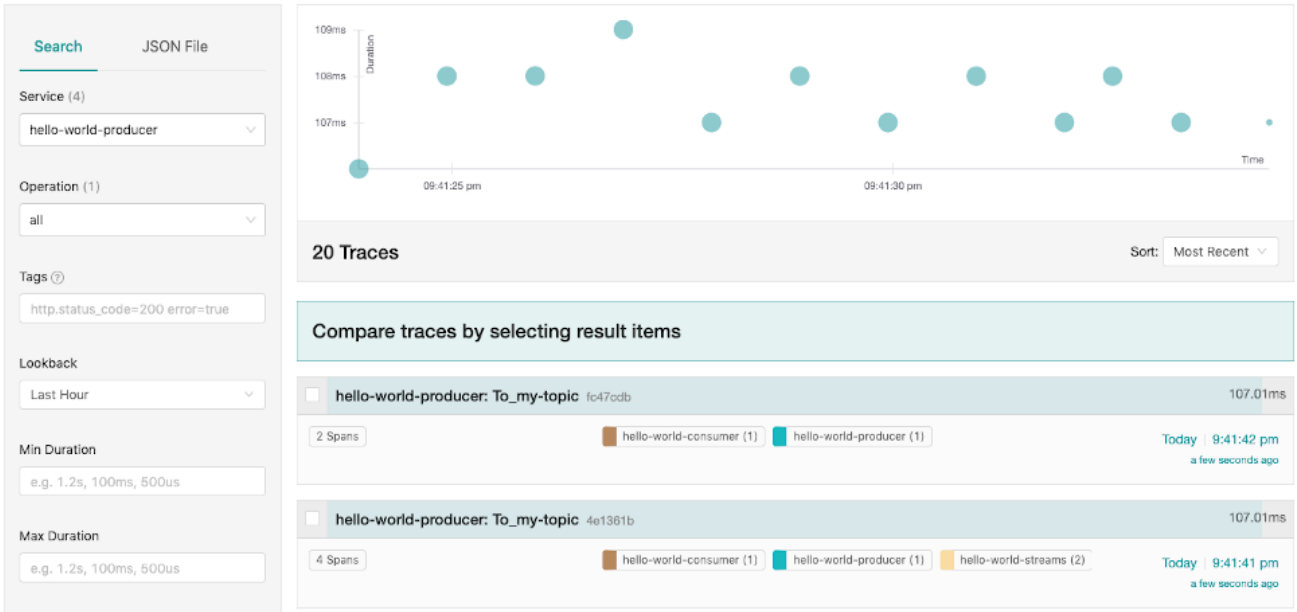
You use the APIs to instrument application code for tracing.

- Instrumented applications generate *traces* for individual requests across the distributed system.
- Traces are composed of *spans* that define specific units of work over time.

Jaeger is a tracing system for microservices-based distributed systems.

- The Jaeger user interface allows you to query, filter, and analyze trace data.

The Jaeger user interface showing a simple query



Additional resources

- Jaeger documentation

- OpenTelemetry documentation

16.3. ENVIRONMENT VARIABLES FOR TRACING

Use environment variables when you are enabling tracing for Kafka components or initializing a tracer for Kafka clients.

Tracing environment variables are subject to change. For the latest information, see the OpenTelemetry documentation.

The following tables describe the key environment variables for setting up a tracer.

Table 16.1. OpenTelemetry environment variables

Property	Required	Description
OTEL_SERVICE_NAME	Yes	The name of the Jaeger tracing service for OpenTelemetry.
OTEL_EXPORTER_JAEGER_ENDPOINT	Yes	The exporter used for tracing.
OTEL_TRACES_EXPORTER	Yes	The exporter used for tracing. Set to **otlp** by default. If using Jaeger tracing, you need to set this environment variable as **jaeger**. If you are using another tracing implementation, specify the exporter used.

16.4. ENABLING TRACING FOR KAFKA CONNECT

Enable distributed tracing for Kafka Connect using configuration properties. Only messages produced and consumed by Kafka Connect itself are traced. To trace messages sent between Kafka Connect and external systems, you must configure tracing in the connectors for those systems.

You can enable tracing that uses OpenTelemetry.

Procedure

1. Add the tracing artifacts to the **opt/kafka/libs** directory.
2. Configure producer and consumer tracing in the relevant Kafka Connect configuration file.
   - If you are running Kafka Connect in standalone mode, edit the **/opt/kafka/config/connect-standalone.properties** file.
   - If you are running Kafka Connect in distributed mode, edit the **/opt/kafka/config/connect-distributed.properties** file.

   Add the following tracing interceptor properties to the configuration file:

   Properties for OpenTelemetry

```
producer.interceptor.classes=io.opentelemetry.instrumentation.kafkaclients.TracingProducerInte
rceptor
consumer.interceptor.classes=io.opentelemetry.instrumentation.kafkaclients.TracingConsumerI
nterceptor
```

With tracing enabled, you initialize tracing when you run the Kafka Connect script.

3. Save the configuration file.
4. Set the environment variables for tracing.
5. Start Kafka Connect in standalone or distributed mode with the configuration file as a parameter (plus any connector properties):

Running Kafka Connect in standalone mode

```
su - kafka
/opt/kafka/bin/connect-standalone.sh \
/opt/kafka/config/connect-standalone.properties \
connector1.properties \
[connector2.properties ...]
```

Running Kafka Connect in distributed mode

```
su - kafka
/opt/kafka/bin/connect-distributed.sh /opt/kafka/config/connect-distributed.properties
```

The internal consumers and producers of Kafka Connect are now enabled for tracing.

16.5. ENABLING TRACING FOR MIRRORMAKER 2

Enable distributed tracing for MirrorMaker 2 by defining the Interceptor properties in the MirrorMaker 2 properties file. Messages are traced between Kafka clusters. The trace data records messages entering and leaving the MirrorMaker 2 component.

You can enable tracing that uses OpenTelemetry.

Procedure

1. Add the tracing artifacts to the **opt/kafka/libs** directory.
2. Configure producer and consumer tracing in the **opt/kafka/config/connect-mirror-maker.properties** file.
   Add the following tracing interceptor properties to the configuration file:

Properties for OpenTelemetry

```
header.converter=org.apache.kafka.connect.converters.ByteArrayConverter
producer.interceptor.classes=io.opentelemetry.instrumentation.kafkaclients.TracingProducerInte
rceptor
consumer.interceptor.classes=io.opentelemetry.instrumentation.kafkaclients.TracingConsumerI
nterceptor
```

ByteArrayConverter prevents Kafka Connect from converting message headers (containing trace IDs) to base64 encoding. This ensures that messages are the same in both the source and the target clusters.

With tracing enabled, you initialize tracing when you run the Kafka MirrorMaker 2 script.

3. Save the configuration file.
4. Set the environment variables for tracing.
5. Start MirrorMaker 2 with the producer and consumer configuration files as parameters:

```
su - kafka
/opt/kafka/bin/connect-mirror-maker.sh \
/opt/kafka/config/connect-mirror-maker.properties
```

The internal consumers and producers of MirrorMaker 2 are now enabled for tracing.

16.6. ENABLING TRACING FOR MIRRORMAKER

Enable distributed tracing for MirrorMaker by passing the Interceptor properties as consumer and producer configuration parameters. Messages are traced from the source cluster to the target cluster. The trace data records messages entering and leaving the MirrorMaker component.

You can enable tracing that uses OpenTelemetry.

Procedure

1. Add the tracing artifacts to the **opt/kafka/libs** directory.
2. Configure producer tracing in the **/opt/kafka/config/producer.properties** file.
   Add the following tracing interceptor property:

   #### Producer property for OpenTelemetry

   ```
   producer.interceptor.classes=io.opentelemetry.instrumentation.kafkaclients.TracingProducerInte
   rceptor
   ```

3. Save the configuration file.
4. Configure consumer tracing in the **/opt/kafka/config/consumer.properties** file.
   Add the following tracing interceptor property:

   #### Consumer property for OpenTelemetry

   ```
   consumer.interceptor.classes=io.opentelemetry.instrumentation.kafkaclients.TracingConsumerI
   nterceptor
   ```

   With tracing enabled, you initialize tracing when you run the Kafka MirrorMaker script.

5. Save the configuration file.
6. Set the environment variables for tracing.
7. Start MirrorMaker with the producer and consumer configuration files as parameters:

```
su - kafka
/opt/kafka/bin/kafka-mirror-maker.sh \
--producer.config /opt/kafka/config/producer.properties \
--consumer.config /opt/kafka/config/consumer.properties \
--num.streams=2
```

The internal consumers and producers of MirrorMaker are now enabled for tracing.

16.7. INITIALIZING TRACING FOR KAFKA CLIENTS

Initialize a tracer for OpenTelemetry, then instrument your client applications for distributed tracing. You can instrument Kafka producer and consumer clients, and Kafka Streams API applications.

Configure and initialize a tracer using a set of tracing environment variables.

Procedure

In each client application add the dependencies for the tracer:

1. Add the Maven dependencies to the **pom.xml** file for the client application:

Dependencies for OpenTelemetry

```
<dependency>
  <groupId>io.opentelemetry.semconv</groupId>
  <artifactId>opentelemetry-semconv</artifactId>
  <version>1.21.0-alpha</version>
</dependency>
<dependency>
  <groupId>io.opentelemetry</groupId>
  <artifactId>opentelemetry-exporter-otlp</artifactId>
  <version>1.34.1</version>
  <exclusions>
    <exclusion>
      <groupId>io.opentelemetry</groupId>
      <artifactId>opentelemetry-exporter-sender-okhttp</artifactId>
    </exclusion>
  </exclusions>
</dependency>
<dependency>
  <groupId>io.opentelemetry</groupId>
  <artifactId>opentelemetry-exporter-sender-grpc-managed-channel</artifactId>
  <version>1.34.1</version>
  <scope>runtime</scope>
</dependency>
<dependency>
  <groupId>io.opentelemetry</groupId>
  <artifactId>opentelemetry-sdk-extension-autoconfigure</artifactId>
  <version>1.34.1</version>
</dependency>
<dependency>
  <groupId>io.opentelemetry.instrumentation</groupId>
  <artifactId>opentelemetry-kafka-clients-2.6</artifactId>
  <version>1.32.0-alpha</version>
</dependency>
```

```
<dependency>
    <groupId>io.opentelemetry</groupId>
    <artifactId>opentelemetry-sdk</artifactId>
    <version>1.34.1</version>
</dependency>
<dependency>
    <groupId>io.opentelemetry</groupId>
    <artifactId>opentelemetry-exporter-sender-jdk</artifactId>
    <version>1.34.1-alpha</version>
    <scope>runtime</scope>
</dependency>
<dependency>
    <groupId>io.grpc</groupId>
    <artifactId>grpc-netty-shaded</artifactId>
    <version>1.61.0</version>
</dependency>
```

2. Define the configuration of the tracer using the tracing environment variables.
3. Create a tracer, which is initialized with the environment variables:

   Creating a tracer for OpenTelemetry

   ```
   OpenTelemetry ot = GlobalOpenTelemetry.get();
   ```

4. Register the tracer as a global tracer:

   ```
   GlobalTracer.register(tracer);
   ```

5. Instrument your client:
   - Section 16.8, “Instrumenting producers and consumers for tracing”
   - Section 16.9, “Instrumenting Kafka Streams applications for tracing”

16.8. INSTRUMENTING PRODUCERS AND CONSUMERS FOR TRACING

Instrument application code to enable tracing in Kafka producers and consumers. Use a decorator pattern or interceptors to instrument your Java producer and consumer application code for tracing. You can then record traces when messages are produced or retrieved from a topic.

OpenTelemetry instrumentation project provides classes that support instrumentation of producers and consumers.

Decorator instrumentation

For decorator instrumentation, create a modified producer or consumer instance for tracing.

Interceptor instrumentation

For interceptor instrumentation, add the tracing capability to the consumer or producer configuration.

Prerequisites

- You have initialized tracing for the client.

You enable instrumentation in producer and consumer applications by adding the tracing JARs as dependencies to your project.

Procedure

Perform these steps in the application code of each producer and consumer application. Instrument your client application code using either a decorator pattern or interceptors.

- To use a decorator pattern, create a modified producer or consumer instance to send or receive messages.
  You pass the original **KafkaProducer** or **KafkaConsumer** class.

  #### Example decorator instrumentation for OpenTelemetry

  ```
  // Producer instance
  Producer < String, String > op = new KafkaProducer < > (
     configs,
     new StringSerializer(),
     new StringSerializer()
     );
     Producer < String, String > producer = tracing.wrap(op);
  KafkaTracing tracing = KafkaTracing.create(GlobalOpenTelemetry.get());
  producer.send(...);

  //consumer instance
  Consumer<String, String> oc = new KafkaConsumer<>(
     configs,
     new StringDeserializer(),
     new StringDeserializer()
     );
     Consumer<String, String> consumer = tracing.wrap(oc);
  consumer.subscribe(Collections.singleton("mytopic"));
  ConsumerRecords<Integer, String> records = consumer.poll(1000);
  ConsumerRecord<Integer, String> record = ...
  SpanContext spanContext = TracingKafkaUtils.extractSpanContext(record.headers(), tracer);
  ```

- To use interceptors, set the interceptor class in the producer or consumer configuration.
  You use the **KafkaProducer** and **KafkaConsumer** classes in the usual way. The **TracingProducerInterceptor** and **TracingConsumerInterceptor** interceptor classes take care of the tracing capability.

  #### Example producer configuration using interceptors

  ```
  senderProps.put(ProducerConfig.INTERCEPTOR_CLASSES_CONFIG,
     TracingProducerInterceptor.class.getName());

  KafkaProducer<Integer, String> producer = new KafkaProducer<>(senderProps);
  producer.send(...);
  ```

  #### Example consumer configuration using interceptors

  ```
  consumerProps.put(ConsumerConfig.INTERCEPTOR_CLASSES_CONFIG,
     TracingConsumerInterceptor.class.getName());

  KafkaConsumer<Integer, String> consumer = new KafkaConsumer<>(consumerProps);
  ```

```
consumer.subscribe(Collections.singletonList("messages"));
ConsumerRecords<Integer, String> records = consumer.poll(1000);
ConsumerRecord<Integer, String> record = ...
SpanContext spanContext = TracingKafkaUtils.extractSpanContext(record.headers(), tracer);
```

16.9. INSTRUMENTING KAFKA STREAMS APPLICATIONS FOR TRACING

Instrument application code to enable tracing in Kafka Streams API applications. Use a decorator pattern or interceptors to instrument your Kafka Streams API applications for tracing. You can then record traces when messages are produced or retrieved from a topic.

Decorator instrumentation

For decorator instrumentation, create a modified Kafka Streams instance for tracing. For OpenTelemetry, you need to create a custom **TracingKafkaClientSupplier** class to provide tracing instrumentation for Kafka Streams.

Interceptor instrumentation

For interceptor instrumentation, add the tracing capability to the Kafka Streams producer and consumer configuration.

Prerequisites

- You have initialized tracing for the client.
  You enable instrumentation in Kafka Streams applications by adding the tracing JARs as dependencies to your project.
- To instrument Kafka Streams with OpenTelemetry, you'll need to write a custom **TracingKafkaClientSupplier**.
- The custom **TracingKafkaClientSupplier** can extend Kafka's **DefaultKafkaClientSupplier**, overriding the producer and consumer creation methods to wrap the instances with the telemetry-related code.

  Example custom TracingKafkaClientSupplier

```
private class TracingKafkaClientSupplier extends DefaultKafkaClientSupplier {
    @Override
    public Producer<byte[], byte[]> getProducer(Map<String, Object> config) {
        KafkaTelemetry telemetry = KafkaTelemetry.create(GlobalOpenTelemetry.get());
        return telemetry.wrap(super.getProducer(config));
    }

    @Override
    public Consumer<byte[], byte[]> getConsumer(Map<String, Object> config) {
        KafkaTelemetry telemetry = KafkaTelemetry.create(GlobalOpenTelemetry.get());
        return telemetry.wrap(super.getConsumer(config));
    }

    @Override
    public Consumer<byte[], byte[]> getRestoreConsumer(Map<String, Object> config) {
        return this.getConsumer(config);
    }
```

```
    @Override
    public Consumer<byte[], byte[]> getGlobalConsumer(Map<String, Object> config) {
        return this.getConsumer(config);
    }
}
```

Procedure

Perform these steps for each Kafka Streams API application.

- To use a decorator pattern, create an instance of the **TracingKafkaClientSupplier** supplier interface, then provide the supplier interface to **KafkaStreams**.

  #### Example decorator instrumentation

  ```
  KafkaClientSupplier supplier = new TracingKafkaClientSupplier(tracer);
  KafkaStreams streams = new KafkaStreams(builder.build(), new StreamsConfig(config),
  supplier);
  streams.start();
  ```

- To use interceptors, set the interceptor class in the Kafka Streams producer and consumer configuration.
  The **TracingProducerInterceptor** and **TracingConsumerInterceptor** interceptor classes take care of the tracing capability.

  #### Example producer and consumer configuration using interceptors

  ```
  props.put(StreamsConfig.PRODUCER_PREFIX +
  ProducerConfig.INTERCEPTOR_CLASSES_CONFIG,
  TracingProducerInterceptor.class.getName());
  props.put(StreamsConfig.CONSUMER_PREFIX +
  ConsumerConfig.INTERCEPTOR_CLASSES_CONFIG,
  TracingConsumerInterceptor.class.getName());
  ```

16.10. SPECIFYING TRACING SYSTEMS WITH OPENTELEMETRY

Instead of the default Jaeger system, you can specify other tracing systems that are supported by OpenTelemetry.

If you want to use another tracing system with OpenTelemetry, do the following:

1. Add the library of the tracing system to the Kafka classpath.
2. Add the name of the tracing system as an additional exporter environment variable.

   #### Additional environment variable when not using Jaeger

   ```
   OTEL_SERVICE_NAME=my-tracing-service
   OTEL_TRACES_EXPORTER=zipkin (1)
   OTEL_EXPORTER_ZIPKIN_ENDPOINT=http://localhost:9411/api/v2/spans (2)
   ```

   (1) The name of the tracing system. In this example, Zipkin is specified.

   (2) The endpoint of the specific selected exporter that listens for spans. In this example, a Zipkin endpoint is specified.

Zipkin endpoint is specified.

Additional resources

- OpenTelemetry exporter values

16.11. SPECIFYING CUSTOM SPAN NAMES FOR OPENTELEMETRY

A tracing *span* is a logical unit of work in Jaeger, with an operation name, start time, and duration. Spans have built-in names, but you can specify custom span names in your Kafka client instrumentation where used.

Specifying custom span names is optional and only applies when using a decorator pattern in producer and consumer client instrumentation or Kafka Streams instrumentation.

Custom span names cannot be specified directly with OpenTelemetry. Instead, you retrieve span names by adding code to your client application to extract additional tags and attributes.

Example code to extract attributes

```
//Defines attribute extraction for a producer
private static class ProducerAttribExtractor implements AttributesExtractor < ProducerRecord < ? , ? >
, Void > {
    @Override
    public void onStart(AttributesBuilder attributes, ProducerRecord < ? , ? > producerRecord) {
        set(attributes, AttributeKey.stringKey("prod_start"), "prod1");
    }
    @Override
    public void onEnd(AttributesBuilder attributes, ProducerRecord < ? , ? > producerRecord,
@Nullable Void unused, @Nullable Throwable error) {
        set(attributes, AttributeKey.stringKey("prod_end"), "prod2");
    }
}
//Defines attribute extraction for a consumer
private static class ConsumerAttribExtractor implements AttributesExtractor < ConsumerRecord < ? ,
? > , Void > {
    @Override
    public void onStart(AttributesBuilder attributes, ConsumerRecord < ? , ? > producerRecord) {
        set(attributes, AttributeKey.stringKey("con_start"), "con1");
    }
    @Override
    public void onEnd(AttributesBuilder attributes, ConsumerRecord < ? , ? > producerRecord,
@Nullable Void unused, @Nullable Throwable error) {
        set(attributes, AttributeKey.stringKey("con_end"), "con2");
    }
}
//Extracts the attributes
public static void main(String[] args) throws Exception {
        Map < String, Object > configs = new HashMap < >
(Collections.singletonMap(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092"));
        System.setProperty("otel.traces.exporter", "jaeger");
        System.setProperty("otel.service.name", "myapp1");
        KafkaTracing tracing = KafkaTracing.newBuilder(GlobalOpenTelemetry.get())
```

```
        .addProducerAttributesExtractors(new ProducerAttribExtractor())
        .addConsumerAttributesExtractors(new ConsumerAttribExtractor())
        .build();
```

CHAPTER 17. USING KAFKA EXPORTER

Kafka Exporter is an open source project to enhance monitoring of Apache Kafka brokers and clients.

Kafka Exporter is provided with Streams for Apache Kafka for deployment with a Kafka cluster to extract additional metrics data from Kafka brokers related to offsets, consumer groups, consumer lag, and topics.

The metrics data is used, for example, to help identify slow consumers.

Lag data is exposed as Prometheus metrics, which can then be presented in Grafana for analysis.

If you are already using Prometheus and Grafana for monitoring of built-in Kafka metrics, you can configure Prometheus to also scrape the Kafka Exporter Prometheus endpoint.

Kafka exposes metrics through JMX, which can then be exported as Prometheus metrics. For more information, see Monitoring your cluster using JMX .

17.1. CONSUMER LAG

Consumer lag indicates the difference in the rate of production and consumption of messages. Specifically, consumer lag for a given consumer group indicates the delay between the last message in the partition and the message being currently picked up by that consumer. The lag reflects the position of the consumer offset in relation to the end of the partition log.

This difference is sometimes referred to as the *delta* between the producer offset and consumer offset, the read and write positions in the Kafka broker topic partitions.

Suppose a topic streams 100 messages a second. A lag of 1000 messages between the producer offset (the topic partition head) and the last offset the consumer has read means a 10-second delay.

The importance of monitoring consumer lag

For applications that rely on the processing of (near) real-time data, it is critical to monitor consumer lag to check that it does not become too big. The greater the lag becomes, the further the process moves from the real-time processing objective.

Consumer lag, for example, might be a result of consuming too much old data that has not been purged, or through unplanned shutdowns.

Reducing consumer lag

Typical actions to reduce lag include:

- Scaling-up consumer groups by adding new consumers
- Increasing the retention time for a message to remain in a topic
- Adding more disk capacity to increase the message buffer

Actions to reduce consumer lag depend on the underlying infrastructure and the use cases Streams for Apache Kafka is supporting. For instance, a lagging consumer is less likely to benefit from the broker being able to service a fetch request from its disk cache. And in certain cases, it might be acceptable to automatically drop messages until a consumer has caught up.

17.2. KAFKA EXPORTER ALERTING RULE EXAMPLES

The sample alert notification rules specific to Kafka Exporter are as follows:

UnderReplicatedPartition

An alert to warn that a topic is under-replicated and the broker is not replicating enough partitions. The default configuration is for an alert if there are one or more under-replicated partitions for a topic. The alert might signify that a Kafka instance is down or the Kafka cluster is overloaded. A planned restart of the Kafka broker may be required to restart the replication process.

TooLargeConsumerGroupLag

An alert to warn that the lag on a consumer group is too large for a specific topic partition. The default configuration is 1000 records. A large lag might indicate that consumers are too slow and are falling behind the producers.

NoMessageForTooLong

An alert to warn that a topic has not received messages for a period of time. The default configuration for the time period is 10 minutes. The delay might be a result of a configuration issue preventing a producer from publishing messages to the topic.

You can adapt alerting rules according to your specific needs.

Additional resources

For more information about setting up alerting rules, see Configuration in the Prometheus documentation.

17.3. KAFKA EXPORTER METRICS

Lag information is exposed by Kafka Exporter as Prometheus metrics for presentation in Grafana.

Kafka Exporter exposes metrics data for brokers, topics, and consumer groups.

Table 17.1. Broker metrics output

Name	Information
kafka_brokers	Number of brokers in the Kafka cluster

Table 17.2. Topic metrics output

Name	Information
kafka_topic_partitions	Number of partitions for a topic
kafka_topic_partition_current_offset	Current topic partition offset for a broker
kafka_topic_partition_oldest_offset	Oldest topic partition offset for a broker
kafka_topic_partition_in_sync_replica	Number of in-sync replicas for a topic partition
kafka_topic_partition_leader	Leader broker ID of a topic partition

Name	Information
kafka_topic_partition_leader_is_preferred	Shows **1** if a topic partition is using the preferred broker
kafka_topic_partition_replicas	Number of replicas for this topic partition
kafka_topic_partition_under_replicated_partition	Shows **1** if a topic partition is under-replicated

Table 17.3. Consumer group metrics output

Name	Information
kafka_consumergroup_current_offset	Current topic partition offset for a consumer group
kafka_consumergroup_lag	Current approximate lag for a consumer group at a topic partition

17.4. RUNNING KAFKA EXPORTER

Run Kafka Exporter to expose Prometheus metrics for presentation in a Grafana dashboard.

Download and install the Kafka Exporter package to use the Kafka Exporter with Streams for Apache Kafka. You need a Streams for Apache Kafka subscription to be able to download and install the package.

Prerequisites

- Streams for Apache Kafka is installed on each host, and the configuration files are available.
- You have a subscription to Streams for Apache Kafka .

This procedure assumes you already have access to a Grafana user interface and Prometheus is deployed and added as a data source.

Procedure

1. Install the Kafka Exporter package:

```
dnf install kafka_exporter
```

2. Verify the package has installed:

```
dnf info kafka_exporter
```

3. Run the Kafka Exporter using appropriate configuration parameter values:

```
kafka_exporter --kafka.server=<kafka_bootstrap_address>:9092 --kafka.version=3.7.0 --<my_other_parameters>
```

The parameters require a double-hyphen convention, such as **--kafka.server**.

Table 17.4. Kafka Exporter configuration parameters

Option	Description	Default
kafka.server	Host/post address of the Kafka server.	**kafka:9092**
kafka.version	Kafka broker version.	**1.0.0**
group.filter	A regular expression to specify the consumer groups to include in the metrics.	**.*** (all)
topic.filter	A regular expression to specify the topics to include in the metrics.	**.*** (all)
sasl.<*parameter*>	Parameters to enable and connect to the Kafka cluster using SASL/PLAIN authentication, with user name and password.	**false**
tls.<*parameter*>	Parameters to enable connect to the Kafka cluster using TLS authentication, with optional certificate and key.	**false**
web.listen-address	Port address to expose the metrics.	**:9308**
web.telemetry-path	Path for the exposed metrics.	/**metrics**
log.level	Logging configuration, to log messages with a given severity (debug, info, warn, error, fatal) or above.	**info**
log.enable-sarama	Boolean to enable Sarama logging, a Go client library used by the Kafka Exporter.	**false**
legacy.partitions	Boolean to enable metrics to be fetched from inactive topic partitions as well as from active partitions. If you want Kafka Exporter to return metrics for inactive partitions, set to **true**.	**false**

You can use **kafka_exporter --help** for information on the properties.

4. Configure Prometheus to monitor the Kafka Exporter metrics.
   For more information on configuring Prometheus, see the Prometheus documentation.

5. Enable Grafana to present the Kafka Exporter metrics data exposed by Prometheus.
   For more information, see Presenting Kafka Exporter metrics in Grafana .

Updating Kafka Exporter

Use the latest version of Kafka Exporter with your Streams for Apache Kafka installation.

To check for updates, use:

```
dnf check-update
```

To update Kafka Exporter, use:

```
dnf update kafka_exporter
```

17.5. PRESENTING KAFKA EXPORTER METRICS IN GRAFANA

Using Kafka Exporter Prometheus metrics as a data source, you can create a dashboard of Grafana charts.

For example, from the metrics you can create the following Grafana charts:

- Message in per second (from topics)
- Message in per minute (from topics)
- Lag by consumer group
- Messages consumed per minute (by consumer groups)

When metrics data has been collected for some time, the Kafka Exporter charts are populated.

Use the Grafana charts to analyze lag and to check if actions to reduce lag are having an impact on an affected consumer group. If, for example, Kafka brokers are adjusted to reduce lag, the dashboard will show the *Lag by consumer group* chart going down and the *Messages consumed per minute* chart going up.

Additional resources

- Example dashboard for Kafka Exporter
- Grafana documentation

CHAPTER 18. UPGRADING STREAMS FOR APACHE KAFKA AND KAFKA

Upgrade your Kafka cluster with no downtime. Streams for Apache Kafka 2.7 supports and uses Apache Kafka version 3.7.0. Kafka 3.6.0 is supported only for the purpose of upgrading to Streams for Apache Kafka 2.7. You upgrade to the latest supported version of Kafka when you install the latest version of Streams for Apache Kafka.

18.1. UPGRADE PREREQUISITES

Before you begin the upgrade process, make sure you are familiar with any upgrade changes described in the Streams for Apache Kafka 2.7 on Red Hat Enterprise Linux Release Notes .

18.2. STRATEGIES FOR UPGRADING CLIENTS

Upgrading Kafka clients ensures that they benefit from the features, fixes, and improvements that are introduced in new versions of Kafka. Upgraded clients maintain compatibility with other upgraded Kafka components. The performance and stability of the clients might also be improved.

Consider the best approach for upgrading Kafka clients and brokers to ensure a smooth transition. The chosen upgrade strategy depends on whether you are upgrading brokers or clients first. Since Kafka 3.0, you can upgrade brokers and client independently and in any order. The decision to upgrade clients or brokers first depends on several factors, such as the number of applications that need to be upgraded and how much downtime is tolerable.

If you upgrade clients before brokers, some new features may not work as they are not yet supported by brokers. However, brokers can handle producers and consumers running with different versions and supporting different log message versions.

18.3. UPGRADING KAFKA CLUSTERS

Upgrade a KRaft-based Kafka cluster to a newer supported Kafka version and KRaft metadata version. You update the installation files, then configure and restart all Kafka nodes. After performing these steps, data is transmitted between the Kafka brokers according to the new metadata version.

WARNING

When downgrading a KRaft-based Strimzi Kafka cluster to a lower version, like moving from 3.7.0 to 3.6.0, ensure that the metadata version used by the Kafka cluster is a version supported by the Kafka version you want to downgrade to. The metadata version for the Kafka version you are downgrading from must not be higher than the version you are downgrading to.

Prerequisites

- You are logged in to Red Hat Enterprise Linux as the **kafka** user.
- Streams for Apache Kafka is installed on each host , and the configuration files are available.

- You have downloaded the installation files.

Procedure

For each Kafka node in your Streams for Apache Kafka cluster, starting with controller nodes and then brokers, and one at a time:

1. Download the Streams for Apache Kafka archive from the Streams for Apache Kafka software downloads page.

   NOTE

   If prompted, log in to your Red Hat account.

2. On the command line, create a temporary directory and extract the contents of the **amq-streams-<version>-bin.zip** file.

   ```
   mkdir /tmp/kafka
   unzip amq-streams-<version>-bin.zip -d /tmp/kafka
   ```

3. If running, stop the Kafka broker running on the host.

   ```
   /opt/kafka/bin/kafka-server-stop.sh
   jcmd | grep kafka
   ```

   If you are running Kafka on a multi-node cluster, see Section 3.6, “Performing a graceful rolling restart of Kafka brokers”.

4. Delete the **libs** and **bin** directories from your existing installation:

   ```
   rm -rf /opt/kafka/libs /opt/kafka/bin
   ```

5. Copy the **libs** and **bin** directories from the temporary directory:

   ```
   cp -r /tmp/kafka/kafka_<version>/libs /opt/kafka/
   cp -r /tmp/kafka/kafka_<version>/bin /opt/kafka/
   ```

6. If required, update the configuration files in the **config** directory to reflect any changes in the new Kafka version.

7. Delete the temporary directory.

   ```
   rm -r /tmp/kafka
   ```

8. Restart the updated Kafka node:

   #### Restarting nodes with combined roles

   ```
   /opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/server.properties
   ```

   #### Restarting controller nodes

   ```
   /opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/controller.properties
   ```

Restarting nodes with broker roles

```
/opt/kafka/bin/kafka-server-start.sh -daemon /opt/kafka/config/kraft/broker.properties
```

The Kafka broker starts using the binaries for the latest Kafka version.

For information on restarting brokers in a multi-node cluster, see Section 3.6, "Performing a graceful rolling restart of Kafka brokers".

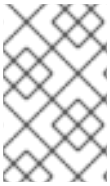
9. Check that Kafka is running:

```
jcmd | grep kafka
```

10. Update the Kafka metadata version:

```
./bin/kafka-features.sh --bootstrap-server <broker_host>:<port> upgrade --metadata 3.7
```

Use the correct version for the Kafka version you are upgrading to.



NOTE

Verify that a restarted Kafka broker has caught up with the partition replicas it is following using the **kafka-topics.sh** tool to ensure that all replicas contained in the broker are back in sync. For instructions, see Listing and describing topics.

Upgrading client applications

Ensure all Kafka client applications are updated to use the new version of the client binaries as part of the upgrade process and verify their compatibility with the Kafka upgrade. If needed, coordinate with the team responsible for managing the client applications.

TIP

To check that a client is using the latest message format, use the **kafka.server:type=BrokerTopicMetrics,name={Produce|Fetch}MessageConversionsPerSec** metric. The metric shows **0** if the latest message format is being used.

18.4. UPGRADING KAFKA COMPONENTS

Upgrade Kafka components on a host machine to use the latest version of Streams for Apache Kafka. You can use the Streams for Apache Kafka installation files to upgrade the following components:

- Kafka Connect
- MirrorMaker
- Kafka Bridge (separate ZIP file)

Prerequisites

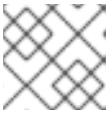
- You are logged in to Red Hat Enterprise Linux as the **kafka** user.
- You have downloaded the installation files.

- You have upgraded Kafka.
  If a Kafka component is running on the same host as Kafka, you'll also need to stop and start Kafka when upgrading.

Procedure

For each host running an instance of the Kafka component:

1. Download the Streams for Apache Kafka or Kafka Bridge installation files from the Streams for Apache Kafka software downloads page.

   NOTE

   If prompted, log in to your Red Hat account.

2. On the command line, create a temporary directory and extract the contents of the **amq-streams-<version>-bin.zip** file.

   ```
   mkdir /tmp/kafka
   unzip amq-streams-<version>-bin.zip -d /tmp/kafka
   ```

   For Kafka Bridge, extract the **amq-streams-<version>-bridge-bin.zip** file.

3. If running, stop the Kafka component running on the host.

4. Delete the **libs** and **bin** directories from your existing installation:

   ```
   rm -rf /opt/kafka/libs /opt/kafka/bin
   ```

5. Copy the **libs** and **bin** directories from the temporary directory:

   ```
   cp -r /tmp/kafka/kafka_<version>/libs /opt/kafka/
   cp -r /tmp/kafka/kafka_<version>/bin /opt/kafka/
   ```

6. If required, update the configuration files in the **config** directory to reflect any changes in the new versions.

7. Delete the temporary directory.

   ```
   rm -r /tmp/kafka
   ```

8. Start the Kafka component using the appropriate script and properties files.

   #### Starting Kafka Connect in standalone mode

   ```
   /opt/kafka/bin/connect-standalone.sh \
   /opt/kafka/config/connect-standalone.properties <connector1>.properties
   [<connector2>.properties ...]
   ```

   #### Starting Kafka Connect in distributed mode

   ```
   /opt/kafka/bin/connect-distributed.sh \
   /opt/kafka/config/connect-distributed.properties
   ```

Starting MirrorMaker 2 in dedicated mode

```
/opt/kafka/bin/connect-mirror-maker.sh \
/opt/kafka/config/connect-mirror-maker.properties
```

Starting Kafka Bridge

```
su - kafka
./bin/kafka_bridge_run.sh \
--config-file=<path>/application.properties
```

9. Verify that the Kafka component is running, and producing or consuming data as expected.

Verifying Kafka Connect in standalone mode is running

```
jcmd | grep ConnectStandalone
```

Verifying Kafka Connect in distributed mode is running

```
jcmd | grep ConnectDistributed
```

Verifying MirrorMaker 2 in dedicated mode is running

```
jcmd | grep mirrorMaker
```

Verifying Kafka Bridge is running by checking the log

```
HTTP-Kafka Bridge started and listening on port 8080
HTTP-Kafka Bridge bootstrap servers localhost:9092
```

CHAPTER 19. MONITORING YOUR CLUSTER USING JMX

Collecting metrics is critical for understanding the health and performance of your Kafka deployment. By monitoring metrics, you can actively identify issues before they become critical and make informed decisions about resource allocation and capacity planning. Without metrics, you may be left with limited visibility into the behavior of your Kafka deployment, which can make troubleshooting more difficult and time-consuming. Setting up metrics can save you time and resources in the long run, and help ensure the reliability of your Kafka deployment.

Kafka components use Java Management Extensions (JMX) to share management information through metrics. These metrics are crucial for monitoring a Kafka cluster's performance and overall health. Like many other Java applications, Kafka employs Managed Beans (MBeans) to supply metric data to monitoring tools and dashboards. JMX operates at the JVM level, allowing external tools to connect and retrieve management information from Kafka components. To connect to the JVM, these tools typically need to run on the same machine and with the same user privileges by default.

19.1. ENABLING THE JMX AGENT

Enable JMX monitoring of Kafka components using JVM system properties. Use the **KAFKA_JMX_OPTS** environment variable to set the JMX system properties required for enabling JMX monitoring. The scripts that run the Kafka component use these properties.

Procedure

1. Set the **KAFKA_JMX_OPTS** environment variable with the JMX properties for enabling JMX monitoring.

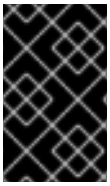
```
export KAFKA_JMX_OPTS=-Dcom.sun.management.jmxremote=true
  -Dcom.sun.management.jmxremote.port=<port>
  -Dcom.sun.management.jmxremote.authenticate=false
  -Dcom.sun.management.jmxremote.ssl=false
```

   Replace <port> with the name of the port on which you want the Kafka component to listen for JMX connections.

2. Add **org.apache.kafka.common.metrics.JmxReporter** to **metric.reporters** in the **server.properties** file.

```
metric.reporters=org.apache.kafka.common.metrics.JmxReporter
```

3. Start the Kafka component using the appropriate script, such as **bin/kafka-server-start.sh** for a broker or **bin/connect-distributed.sh** for Kafka Connect.



IMPORTANT

It is recommended that you configure authentication and SSL to secure a remote JMX connection. For more information about the system properties needed to do this, see the Oracle documentation.

19.2. DISABLING THE JMX AGENT

Disable JMX monitoring for Kafka components by updating the **KAFKA_JMX_OPTS** environment variable.

Procedure

1. Set the **KAFKA_JMX_OPTS** environment variable to disable JMX monitoring.

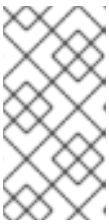
```
export KAFKA_JMX_OPTS=-Dcom.sun.management.jmxremote=false
```

NOTE

Other JMX properties, like port, authentication, and SSL properties do not need to be specified when disabling JMX monitoring.

2. Set **auto.include.jmx.reporter** to **false** in the Kafka **server.properties** file.

```
auto.include.jmx.reporter=false
```



NOTE

The **auto.include.jmx.reporter** property is deprecated. From Kafka 4, the JMXReporter is only enabled if **org.apache.kafka.common.metrics.JmxReporter** is added to the **metric.reporters** configuration in the properties file.

3. Start the Kafka component using the appropriate script, such as **bin/kafka-server-start.sh** for a broker or **bin/connect-distributed.sh** for Kafka Connect.

19.3. METRICS NAMING CONVENTIONS

When working with Kafka JMX metrics, it's important to understand the naming conventions used to identify and retrieve specific metrics. Kafka JMX metrics use the following format:

Metrics format

```
<metric_group>:type=<type_name>,name=<metric_name><other_attribute>=<value>
```

- <metric_group> is the name of the metric group
- <type_name> is the name of the type of metric
- <metric_name> is the name of the specific metric
- <other_attribute> represents zero or more additional attributes

For example, the **BytesInPerSec** metric is a **BrokerTopicMetrics** type in the **kafka.server** group:

```
kafka.server:type=BrokerTopicMetrics,name=BytesInPerSec
```

In some cases, metrics may include the ID of an entity. For instance, when monitoring a specific client, the metric format includes the client ID:

Metrics for a specific client

```
kafka.consumer:type=consumer-fetch-manager-metrics,client-id=<client_id>
```

Similarly, a metric can be further narrowed down to a specific client and topic:

Metrics for a specific client and topic

```
kafka.consumer:type=consumer-fetch-manager-metrics,client-id=<client_id>,topic=<topic_id>
```

Understanding these naming conventions will allow you to accurately specify the metrics you want to monitor and analyze.

NOTE

To view the full list of available JMX metrics for a Strimzi installation, you can use a graphical tool like JConsole. JConsole is a Java Monitoring and Management Console that allows you to monitor and manage Java applications, including Kafka. By connecting to the JVM running the Kafka component using its process ID, the tool's user interface allows you to view the list of metrics.

19.4. ANALYZING KAFKA JMX METRICS FOR TROUBLESHOOTING

JMX provides a way to gather metrics about Kafka brokers for monitoring and managing their performance and resource usage. By analyzing these metrics, common broker issues such as high CPU usage, memory leaks, thread contention, and slow response times can be diagnosed and resolved. Certain metrics can pinpoint the root cause of these issues.

JMX metrics also provide insights into the overall health and performance of a Kafka cluster. They help monitor the system's throughput, latency, and availability, diagnose issues, and optimize performance. This section explores the use of JMX metrics to help identify common issues and provides insights into the performance of a Kafka cluster.

Collecting and graphing these metrics using tools like Prometheus and Grafana allows you to visualize the information returned. This can be particularly helpful in detecting issues or optimizing performance. Graphing metrics over time can also help with identifying trends and forecasting resource consumption.

19.4.1. Checking for under-replicated partitions

A balanced Kafka cluster is important for optimal performance. In a balanced cluster, partitions and leaders are evenly distributed across all brokers, and I/O metrics reflect this. As well as using metrics, you can use the **kafka-topics.sh** tool to get a list of under-replicated partitions and identify the problematic brokers. If the number of under-replicated partitions is fluctuating or many brokers show high request latency, this typically indicates a performance issue in the cluster that requires investigation. On the other hand, a steady (unchanging) number of under-replicated partitions reported by many of the brokers in a cluster normally indicates that one of the brokers in the cluster is offline.

Use the **describe --under-replicated-partitions** option from the **kafka-topics.sh** tool to show information about partitions that are currently under-replicated in the cluster. These are the partitions that have fewer replicas than the configured replication factor.

If the output is blank, the Kafka cluster has no under-replicated partitions. Otherwise, the output shows replicas that are not in sync or available.

In the following example, only 2 of the 3 replicas are in sync for each partition, with a replica missing from the ISR (in-sync replica).

Returning information on under-replicated partitions from the command line

-

```
bin/kafka-topics.sh --bootstrap-server :9092 --describe --under-replicated-partitions

Topic: topic-1 Partition: 0 Leader: 4 Replicas: 4,2,3 Isr: 4,3
Topic: topic-1 Partition: 1 Leader: 3 Replicas: 2,3,4 Isr: 3,4
Topic: topic-1 Partition: 2 Leader: 3 Replicas: 3,4,2 Isr: 3,4
```

Here are some metrics to check for I/O and under-replicated partitions:

Metrics to check for under-replicated partitions

```
kafka.server:type=ReplicaManager,name=PartitionCount 1
kafka.server:type=ReplicaManager,name=LeaderCount 2
kafka.server:type=BrokerTopicMetrics,name=BytesInPerSec 3
kafka.server:type=BrokerTopicMetrics,name=BytesOutPerSec 4
kafka.server:type=ReplicaManager,name=UnderReplicatedPartitions 5
kafka.server:type=ReplicaManager,name=UnderMinIsrPartitionCount 6
```

1. Total number of partitions across all topics in the cluster.
2. Total number of leaders across all topics in the cluster.
3. Rate of incoming bytes per second for each broker.
4. Rate of outgoing bytes per second for each broker.
5. Number of under-replicated partitions across all topics in the cluster.
6. Number of partitions below the minimum ISR.

If topic configuration is set for high availability, with a replication factor of at least 3 for topics and a minimum number of in-sync replicas being 1 less than the replication factor, under-replicated partitions can still be usable. Conversely, partitions below the minimum ISR have reduced availability. You can monitor these using the **kafka.server:type=ReplicaManager,name=UnderMinIsrPartitionCount** metric and the **under-min-isr-partitions** option from the **kafka-topics.sh** tool.

TIP

Use Cruise Control to automate the task of monitoring and rebalancing a Kafka cluster to ensure that the partition load is evenly distributed. For more information, see Chapter 13, *Using Cruise Control for cluster rebalancing*.

19.4.2. Identifying performance problems in a Kafka cluster

Spikes in cluster metrics may indicate a broker issue, which is often related to slow or failing storage devices or compute restraints from other processes. If there is no issue at the operating system or hardware level, an imbalance in the load of the Kafka cluster is likely, with some partitions receiving disproportionate traffic compared to others in the same Kafka topic.

To anticipate performance problems in a Kafka cluster, it's useful to monitor the **RequestHandlerAvgIdlePercent** metric. **RequestHandlerAvgIdlePercent** provides a good overall indicator of how the cluster is behaving. The value of this metric is between 0 and 1. A value below 0.7

indicates that threads are busy 30% of the time and performance is starting to degrade. If the value drops below 50%, problems are likely to occur, especially if the cluster needs to scale or rebalance. At 30%, a cluster is barely usable.

Another useful metric is **kafka.network:type=Processor,name=IdlePercent**, which you can use to monitor the extent (as a percentage) to which network processors in a Kafka cluster are idle. The metric helps identify whether the processors are over or underutilized.

To ensure optimal performance, set the **num.io.threads** property equal to the number of processors in the system, including hyper-threaded processors. If the cluster is balanced, but a single client has changed its request pattern and is causing issues, reduce the load on the cluster or increase the number of brokers.

It's important to note that a single disk failure on a single broker can severely impact the performance of an entire cluster. Since producer clients connect to all brokers that lead partitions for a topic, and those partitions are evenly spread over the entire cluster, a poorly performing broker will slow down produce requests and cause back pressure in the producers, slowing down requests to all brokers. A RAID (Redundant Array of Inexpensive Disks) storage configuration that combines multiple physical disk drives into a single logical unit can help prevent this issue.

Here are some metrics to check the performance of a Kafka cluster:

Metrics to check the performance of a Kafka cluster

```
kafka.server:type=KafkaRequestHandlerPool,name=RequestHandlerAvgIdlePercent 1
# attributes: OneMinuteRate, FifteenMinuteRate
kafka.server:type=socket-server-metrics,listener=([-.\w]+),networkProcessor=([\d]+) 2
# attributes: connection-creation-rate
kafka.network:type=RequestChannel,name=RequestQueueSize 3
kafka.network:type=RequestChannel,name=ResponseQueueSize 4
kafka.network:type=Processor,name=IdlePercent,networkProcessor=([-.\w]+) 5
kafka.server:type=KafkaServer,name=TotalDiskReadBytes 6
kafka.server:type=KafkaServer,name=TotalDiskWriteBytes 7
```

1. Average idle percentage of the request handler threads in the Kafka broker's thread pool. The **OneMinuteRate** and **FifteenMinuteRate** attributes show the request rate of the last one minute and fifteen minutes, respectively.
2. Rate at which new connections are being created on a specific network processor of a specific listener in the Kafka broker. The **listener** attribute refers to the name of the listener, and the **networkProcessor** attribute refers to the ID of the network processor. The **connection-creation-rate** attribute shows the rate of connection creation in connections per second.
3. Current size of the request queue.
4. Current sizes of the response queue.
5. Percentage of time the specified network processor is idle. The **networkProcessor** specifies the ID of the network processor to monitor.
6. Total number of bytes read from disk by a Kafka server.
7. Total number of bytes written to disk by a Kafka server.

19.4.3. Identifying performance problems with a Kafka controller

The Kafka controller is responsible for managing the overall state of the cluster, such as broker registration, partition reassignment, and topic management. Problems with the controller in the Kafka cluster are difficult to diagnose and often fall into the category of bugs in Kafka itself. Controller issues might manifest as broker metadata being out of sync, offline replicas when the brokers appear to be fine, or actions on topics like topic creation not happening correctly.

There are not many ways to monitor the controller, but you can monitor the active controller count and the controller queue size. Monitoring these metrics gives a high-level indicator if there is a problem. Although spikes in the queue size are expected, if this value continuously increases, or stays steady at a high value and does not drop, it indicates that the controller may be stuck. If you encounter this problem, you can move the controller to a different broker, which requires shutting down the broker that is currently the controller.

Here are some metrics to check the performance of a Kafka controller:

Metrics to check the performance of a Kafka controller

```
kafka.controller:type=KafkaController,name=ActiveControllerCount 1
kafka.controller:type=KafkaController,name=OfflinePartitionsCount 2
kafka.controller:type=ControllerEventManager,name=EventQueueSize 3
```

1. Number of active controllers in the Kafka cluster. A value of 1 indicates that there is only one active controller, which is the desired state.
2. Number of partitions that are currently offline. If this value is continuously increasing or stays at a high value, there may be a problem with the controller.
3. Size of the event queue in the controller. Events are actions that must be performed by the controller, such as creating a new topic or moving a partition to a new broker. if the value continuously increases or stays at a high value, the controller may be stuck and unable to perform the required actions.

19.4.4. Identifying problems with requests

You can use the **RequestHandlerAvgIdlePercent** metric to determine if requests are slow. Additionally, request metrics can identify which specific requests are experiencing delays and other issues.

To effectively monitor Kafka requests, it is crucial to collect two key metrics: count and 99th percentile latency, also known as tail latency.

The count metric represents the number of requests processed within a specific time interval. It provides insights into the volume of requests handled by your Kafka cluster and helps identify spikes or drops in traffic.

The 99th percentile latency metric measures the request latency, which is the time taken for a request to be processed. It represents the duration within which 99% of requests are handled. However, it does not provide information about the exact duration for the remaining 1% of requests. In other words, the 99th percentile latency metric tells you that 99% of the requests are handled within a certain duration, and the remaining 1% may take even longer, but the precise duration for this remaining 1% is not known. The choice of the 99th percentile is primarily to focus on the majority of requests and exclude outliers that can skew the results.

This metric is particularly useful for identifying performance issues and bottlenecks related to the majority of requests, but it does not give a complete picture of the maximum latency experienced by a small fraction of requests.

By collecting and analyzing both count and 99th percentile latency metrics, you can gain an understanding of the overall performance and health of your Kafka cluster, as well as the latency of the requests being processed.

Here are some metrics to check the performance of Kafka requests:

Metrics to check the performance of requests

```
# requests: EndTxn, Fetch, FetchConsumer, FetchFollower, FindCoordinator, Heartbeat,
InitProducerId,
# JoinGroup, LeaderAndIsr, LeaveGroup, Metadata, Produce, SyncGroup, UpdateMetadata (1)
kafka.network:type=RequestMetrics,name=RequestsPerSec,request=([\w]+) (2)
kafka.network:type=RequestMetrics,name=RequestQueueTimeMs,request=([\w]+) (3)
kafka.network:type=RequestMetrics,name=TotalTimeMs,request=([\w]+) (4)
kafka.network:type=RequestMetrics,name=LocalTimeMs,request=([\w]+) (5)
kafka.network:type=RequestMetrics,name=RemoteTimeMs,request=([\w]+) (6)
kafka.network:type=RequestMetrics,name=ThrottleTimeMs,request=([\w]+) (7)
kafka.network:type=RequestMetrics,name=ResponseQueueTimeMs,request=([\w]+) (8)
kafka.network:type=RequestMetrics,name=ResponseSendTimeMs,request=([\w]+) (9)
# attributes: Count, 99thPercentile (10)
```

(1) Request types to break down the request metrics.

(2) Rate at which requests are being processed by the Kafka broker per second.

(3) Time (in milliseconds) that a request spends waiting in the broker's request queue before being processed.

(4) Total time (in milliseconds) that a request takes to complete, from the time it is received by the broker to the time the response is sent back to the client.

(5) Time (in milliseconds) that a request spends being processed by the broker on the local machine.

(6) Time (in milliseconds) that a request spends being processed by other brokers in the cluster.

(7) Time (in milliseconds) that a request spends being throttled by the broker. Throttling occurs when the broker determines that a client is sending too many requests too quickly and needs to be slowed down.

(8) Time (in milliseconds) that a response spends waiting in the broker's response queue before being sent back to the client.

(9) Time (in milliseconds) that a response takes to be sent back to the client after it has been generated by the broker.

(10) For all of the requests metrics, the **Count** and **99thPercentile** attributes show the total number of requests that have been processed and the time it takes for the slowest 1% of requests to complete, respectively.

19.4.5. Using metrics to check the performance of clients

By analyzing client metrics, you can monitor the performance of the Kafka clients (producers and consumers) connected to a broker. This can help identify issues highlighted in broker logs, such as consumers being frequently kicked off their consumer groups, high request failure rates, or frequent disconnections.

Here are some metrics to check the performance of Kafka clients:

Metrics to check the performance of client requests

```
kafka.consumer:type=consumer-metrics,client-id=([-.\w]+) 1
# attributes: time-between-poll-avg, time-between-poll-max
kafka.consumer:type=consumer-coordinator-metrics,client-id=([-.\w]+) 2
# attributes: heartbeat-response-time-max, heartbeat-rate, join-time-max, join-rate, rebalance-rate-per-hour
kafka.producer:type=producer-metrics,client-id=([-.\w]+) 3
# attributes: buffer-available-bytes, bufferpool-wait-time, request-latency-max, requests-in-flight
# attributes: txn-init-time-ns-total, txn-begin-time-ns-total, txn-send-offsets-time-ns-total, txn-commit-time-ns-total, txn-abort-time-ns-total
# attributes: record-error-total, record-queue-time-avg, record-queue-time-max, record-retry-rate, record-retry-total, record-send-rate, record-send-total
```

1. (Consumer) Average and maximum time between poll requests, which can help determine if the consumers are polling for messages frequently enough to keep up with the message flow. The **time-between-poll-avg** and **time-between-poll-max** attributes show the average and maximum time in milliseconds between successive polls by a consumer, respectively.
2. (Consumer) Metrics to monitor the coordination process between Kafka consumers and the broker coordinator. Attributes relate to the heartbeat, join, and rebalance process.
3. (Producer) Metrics to monitor the performance of Kafka producers. Attributes relate to buffer usage, request latency, in-flight requests, transactional processing, and record handling.

19.4.6. Using metrics to check the performance of topics and partitions

Metrics for topics and partitions can also be helpful in diagnosing issues in a Kafka cluster. You can also use them to debug issues with a specific client when you are unable to collect client metrics.

Here are some metrics to check the performance of a specific topic and partition:

Metrics to check the performance of topics and partitions

```
#Topic metrics
kafka.server:type=BrokerTopicMetrics,name=BytesInPerSec,topic=([-.\w]+) 1
kafka.server:type=BrokerTopicMetrics,name=BytesOutPerSec,topic=([-.\w]+) 2
kafka.server:type=BrokerTopicMetrics,name=FailedFetchRequestsPerSec,topic=([-.\w]+) 3
kafka.server:type=BrokerTopicMetrics,name=FailedProduceRequestsPerSec,topic=([-.\w]+) 4
kafka.server:type=BrokerTopicMetrics,name=MessagesInPerSec,topic=([-.\w]+) 5
kafka.server:type=BrokerTopicMetrics,name=TotalFetchRequestsPerSec,topic=([-.\w]+) 6
kafka.server:type=BrokerTopicMetrics,name=TotalProduceRequestsPerSec,topic=([-.\w]+) 7
#Partition metrics
kafka.log:type=Log,name=Size,topic=([-.\w]+),partition=([\d]+)) 8
```

```
kafka.log:type=Log,name=NumLogSegments,topic=([-.\w]+),partition=([\d]+)) 9
kafka.log:type=Log,name=LogEndOffset,topic=([-.\w]+),partition=([\d]+)) 10
kafka.log:type=Log,name=LogStartOffset,topic=([-.\w]+),partition=([\d]+)) 11
```

1. Rate of incoming bytes per second for a specific topic.
2. Rate of outgoing bytes per second for a specific topic.
3. Rate of fetch requests that failed per second for a specific topic.
4. Rate of produce requests that failed per second for a specific topic.
5. Incoming message rate per second for a specific topic.
6. Total rate of fetch requests (successful and failed) per second for a specific topic.
7. Total rate of fetch requests (successful and failed) per second for a specific topic.
8. Size of a specific partition's log in bytes.
9. Number of log segments in a specific partition.
10. Offset of the last message in a specific partition's log.
11. Offset of the first message in a specific partition's log

Additional resources

- Apache Kafka documentation for a full list of available metrics
- Prometheus documentation
- Grafana documentation

APPENDIX A. USING YOUR SUBSCRIPTION

Streams for Apache Kafka is provided through a software subscription. To manage your subscriptions, access your account at the Red Hat Customer Portal.

Accessing Your Account

1. Go to access.redhat.com.
2. If you do not already have an account, create one.
3. Log in to your account.

Activating a Subscription

1. Go to access.redhat.com.
2. Navigate to **My Subscriptions**.
3. Navigate to **Activate a subscription** and enter your 16-digit activation number.

Downloading Zip and Tar Files

To access zip or tar files, use the customer portal to find the relevant files for download. If you are using RPM packages, this step is not required.

1. Open a browser and log in to the Red Hat Customer Portal **Product Downloads** page at access.redhat.com/downloads.
2. Locate the **Streams for Apache Kafka for Apache Kafka**entries in the **INTEGRATION AND AUTOMATION** category.
3. Select the desired Streams for Apache Kafka product. The **Software Downloads** page opens.
4. Click the **Download** link for your component.

Installing packages with DNF

To install a package and all the package dependencies, use:

```
dnf install <package_name>
```

To install a previously-downloaded package from a local directory, use:

```
dnf install <path_to_download_package>
```

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