

# RabbitMQ Stream Java Client

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The RabbitMQ Stream Java Client is a Java library to communicate with the [RabbitMQ Stream Plugin](#). It allows creating and deleting streams, as well as publishing to and consuming from these streams. Learn more in the [the client overview](#).

## What is a RabbitMQ Stream?

A RabbitMQ stream is a persistent and replicated data structure that models an [append-only log](#). It differs from the classical RabbitMQ queue in the way message consumption works. In a classical RabbitMQ queue, consuming removes messages from the queue. In a RabbitMQ stream, consuming leaves the stream intact. So the content of a stream can be read and re-read without impact or destructive effect.

None of the stream or classical queue data structure is better than the other, they are usually suited for different use cases.

## When to Use RabbitMQ Stream?

RabbitMQ Stream was developed to cover the following messaging use cases:

- *Large fan-outs*: when several consumer applications need to read the same messages.
- *Replay / Time-traveling*: when consumer applications need to read the whole history of data or from a given point in a stream.
- *Throughput performance*: when higher throughput than with other protocols (AMQP, STOMP, MQTT) is required.
- *Large logs*: when large amount of data need to be stored, with minimal in-memory overhead.

## Other Way to Use Streams in RabbitMQ

It is also possible to use the stream abstraction in RabbitMQ with the AMQP 0-9-1 protocol. Instead of consuming from a stream with the stream protocol, one consumes from a "stream-powered" queue with the AMQP 0-9-1 protocol. A "stream-powered" queue is a special type of queue that is backed up with a stream infrastructure layer and adapted to provide the stream semantics (mainly non-destructive reading).

Using such a queue has the advantage to provide the features inherent to the stream abstraction (append-only structure, non-destructive reading) with any AMQP 0-9-1 client library. This is clearly interesting when considering the maturity of AMQP 0-9-1 client libraries and the ecosystem around AMQP 0-9-1.

But by using it, one does not benefit from the performance of the stream protocol, which has been designed for performance in mind, whereas AMQP 0-9-1 is a more general-purpose protocol.

It is not possible to use "stream-powered" queues with the stream Java client, you need to use an AMQP 0-9-1 client library.

# Guarantees

RabbitMQ stream provides at-least-once guarantees thanks to the publisher confirm mechanism, which is supported by the stream Java client.

Message [deduplication](#) is also supported on the publisher side.

## Stream Client Overview

The RabbitMQ Stream Java Client implements the [RabbitMQ Stream protocol](#) and avoids dealing with low-level concerns by providing high-level functionalities to build fast, efficient, and robust client applications.

- *administrate streams (creation/deletion) directly from applications*. This can also be useful for development and testing.
- *adapt publishing throughput* thanks to the configurable batch size and flow control.
- *avoid publishing duplicate messages* thanks to message deduplication.
- *consume asynchronously from streams and resume where left off* thanks to automatic or manual offset tracking.
- *enforce [best practices](#) to create client connections* – to stream leaders for publishers to minimize inter-node traffic and to stream replicas for consumers to offload leaders.
- *optimize resources* thanks to automatic growing and shrinking of connections depending on the number of publishers and consumers.
- *let the client handle network failure* thanks to automatic connection recovery and automatic re-subscription for consumers.

## Versioning

The RabbitMQ Stream Java Client is in development and stabilization phase. When the stabilization phase ends, a 1.0.0 version will be cut, and [semantic versioning](#) is likely to be enforced.

Before reaching the stable phase, the client will use a versioning scheme of `[0.MINOR.PATCH]` where:

- `0` indicates the project is still in a stabilization phase.
- `MINOR` is a 0-based number incrementing with each new release cycle. It generally reflects significant changes like new features and potentially some programming interfaces changes.
- `PATCH` is a 0-based number incrementing with each service release, that is bug fixes.

Breaking changes between releases can happen but will be kept to a minimum. The next section provides more details about the evolution of programming interfaces.

# Stability of Programming Interfaces

The RabbitMQ Stream Java Client is in active development but its programming interfaces will remain as stable as possible. There is no guarantee though that they will remain completely stable, at least until it reaches version 1.0.0.

The client contains 2 sets of programming interfaces whose stability are of interest for application developers:

- Application Programming Interfaces (API): those are the ones used to write application logic. They include the interfaces and classes in the `com.rabbitmq.stream` package (e.g. `Producer`, `Consumer`, `Message`). These API constitute the main programming model of the client and will be kept as stable as possible.
- Service Provider Interfaces (SPI): those are interfaces to implement mainly technical behavior in the client. They are not meant to be used to implement application logic. Application developers may have to refer to them in the configuration phase and if they want to custom some internal behavior in the client. SPI include interfaces and classes in the `com.rabbitmq.stream.codec`, `com.rabbitmq.stream.compression`, `com.rabbitmq.stream.metrics` packages, among others. *These SPI are susceptible to change, but this should not impact the majority of applications*, as the changes would typically stay intern to the client.

## The Stream Java Client

The library requires Java 8 or later. Java 11 is recommended (CRC calculation uses methods available as of Java 9.)

## Setting up RabbitMQ

A RabbitMQ 3.9+ node with the stream plugin enabled is required. The easiest way to get up and running is to use Docker.

### With Docker

There are different ways to make the broker visible to the client application when running in Docker. The next sections show a couple of options suitable for local development.

#### NOTE

*Docker on macOS*

Docker runs on a virtual machine when using macOS, so do not expect high performance when using RabbitMQ Stream inside Docker on a Mac.

### With Docker Bridge Network Driver

This section shows how to start a broker instance for local development (the broker Docker container and the client application are assumed to run on the same host).

The following command creates a one-time Docker container to run RabbitMQ:

### *Running the stream plugin with Docker*

```
docker run -it --rm --name rabbitmq -p 5552:5552 \
  -e RABBITMQ_SERVER_ADDITIONAL_ERL_ARGS='-rabbitmq_stream advertised_host
localhost' \
  rabbitmq:3.9
```

The previous command exposes only the stream port (5552), you can expose ports for other protocols:

### *Exposing the AMQP 0.9.1 and management ports:*

```
docker run -it --rm --name rabbitmq -p 5552:5552 -p 5672:5672 -p 15672:15672 \
  -e RABBITMQ_SERVER_ADDITIONAL_ERL_ARGS='-rabbitmq_stream advertised_host
localhost' \
  rabbitmq:3.9-management
```

Refer to the official [RabbitMQ Docker image web page](#) to find out more about its usage.

Once the container is started, **the stream plugin must be enabled:**

### *Enabling the stream plugin:*

```
docker exec rabbitmq rabbitmq-plugins enable rabbitmq_stream
```

## **With Docker Host Network Driver**

This is the simplest way to run the broker locally. The container uses the [host network](#), this is perfect for experimenting locally.

### *Running RabbitMQ Stream with the host network driver*

```
docker run -it --rm --name rabbitmq --network host rabbitmq:3.9
```

Once the container is started, **the stream plugin must be enabled:**

### *Enabling the stream plugin:*

```
docker exec rabbitmq rabbitmq-plugins enable rabbitmq_stream
```

The container will use the following ports: 5552 (for stream) and 5672 (for AMQP.)

## **NOTE**

### *Docker Host Network Driver Support*

The host networking driver **only works on Linux hosts.**

## With a RabbitMQ Package Running on the Host

Using a package implies installing Erlang.

- Make sure to use [RabbitMQ 3.9 or more](#).
- Follow the steps to [install Erlang and the appropriate package](#)
- Enable the plugin `rabbitmq-plugins enable rabbitmq_stream`.
- The stream plugin listens on port 5552.

Refer to the [stream plugin documentation](#) for more information on configuration.

## Dependencies

Use your favorite build management tool to add the client dependencies to your project.

### Maven

*pom.xml*

```
<dependencies>

  <dependency>
    <groupId>com.rabbitmq</groupId>
    <artifactId>stream-client</artifactId>
    <version>0.5.0-SNAPSHOT</version>
  </dependency>

</dependencies>
```

Milestones and snapshots require to declare the [appropriate repository](#).

### Gradle

*build.gradle*

```
dependencies {
  compile "com.rabbitmq:stream-client:0.5.0-SNAPSHOT"
}
```

Milestones and snapshots require to declare the [appropriate repository](#).

## Milestones and Snapshots

Releases are available from Maven Central, which does not require specific declaration. Milestones and snapshots are available from repositories which must be declared in the dependency management configuration.



For milestones, with Maven:

*Milestone repository declaration for Maven*

```
<repositories>

  <repository>
    <id>packagecloud-rabbitmq-maven-milestones</id>
    <url>https://packagecloud.io/rabbitmq/maven-milestones/maven2</url>
    <releases><enabled>true</enabled></releases>
    <snapshots><enabled>false</enabled></snapshots>
  </repository>

</repositories>
```

For milestones, with Gradle:

*Milestone repository declaration for Gradle:*

```
repositories {
  maven { url "https://packagecloud.io/rabbitmq/maven-milestones/maven2" }
  mavenCentral()
}
```

For snapshots, with Maven:

*Snapshot repository declaration for Maven*

```
<repositories>

  <repository>
    <id>ossrh</id>
    <url>https://oss.sonatype.org/content/repositories/snapshots</url>
    <snapshots><enabled>true</enabled></snapshots>
    <releases><enabled>false</enabled></releases>
  </repository>

</repositories>
```

For snapshots, with Gradle:

*Snapshot repository declaration for Gradle:*

```
repositories {
  maven { url 'https://oss.sonatype.org/content/repositories/snapshots' }
  mavenCentral()
}
```

# Sample Application

This section covers the basics of the RabbitMQ Stream Java API by building a small publish/consume application. This is a good way to get an overview of the API. If you want a more comprehensive introduction, you can go to the [reference documentation section](#).

The sample application publishes some messages and then registers a consumer to make some computations out of them. The [source code is available on GitHub](#).

The sample class starts with a few imports:

*Imports for the sample application*

```
import com.rabbitmq.stream.*;
import java.util.UUID;
import java.util.concurrent.CountDownLatch;
import java.util.concurrent.TimeUnit;
import java.util.concurrent.atomic.AtomicLong;
import java.util.stream.IntStream;
```

The next step is to create the **Environment**. It is a management object used to manage streams and create producers as well as consumers. The next snippet shows how to create an **Environment** instance and create the stream used in the application:

*Creating the environment*

```
System.out.println("Connecting...");
Environment environment = Environment.builder().build(); ①
String stream = UUID.randomUUID().toString();
environment.streamCreator().stream(stream).create(); ②
```

① Use **Environment#builder** to create the environment

② Create the stream

Then comes the publishing part. The next snippet shows how to create a **Producer**, send messages, and handle publishing confirmations, to make sure the broker has taken outbound messages into account. The application uses a count down latch to move on once the messages have been confirmed.

```
System.out.println("Starting publishing...");
int messageCount = 10000;
CountDownLatch publishConfirmLatch = new CountDownLatch(messageCount);
Producer producer = environment.producerBuilder() ①
    .stream(stream)
    .build();
IntStream.range(0, messageCount)
    .forEach(i -> producer.send( ②
        producer.messageBuilder() ③
            .addData(String.valueOf(i).getBytes()) ③
            .build(), ③
        confirmationStatus -> publishConfirmLatch.countDown() ④
    ));
publishConfirmLatch.await(10, TimeUnit.SECONDS); ⑤
producer.close(); ⑥
System.out.printf("Published %,d messages%n", messageCount);
```

- ① Create the **Producer** with **Environment#producerBuilder**
- ② Send messages with **Producer#send(Message, ConfirmationHandler)**
- ③ Create a message with **Producer#messageBuilder**
- ④ Count down on message publishing confirmation
- ⑤ Wait for all publishing confirmations to have arrived
- ⑥ Close the producer

It is now time to consume the messages. The **Environment** lets us create a **Consumer** and provide some logic on each incoming message by implementing a **MessageHandler**. The next snippet does this to calculate a sum and output it once all the messages have been received:

## Consuming messages

```
System.out.println("Starting consuming...");
AtomicLong sum = new AtomicLong(0);
CountDownLatch consumeLatch = new CountDownLatch(messageCount);
Consumer consumer = environment.consumerBuilder() ①
    .stream(stream)
    .offset(OffsetSpecification.first()) ②
    .messageHandler((offset, message) -> { ③
        sum.addAndGet(Long.parseLong(new String(message.getBodyAsBinary()))); ④
        consumeLatch.countDown(); ⑤
    })
    .build();

consumeLatch.await(10, TimeUnit.SECONDS); ⑥

System.out.println("Sum: " + sum.get()); ⑦

consumer.close(); ⑧
```

① Create the `Consumer` with `Environment#consumerBuilder`

② Start consuming from the beginning of the stream

③ Set up the logic to handle messages

④ Add the value in the message body to the sum

⑤ Count down on each message

⑥ Wait for all messages to have arrived

⑦ Output the sum

⑧ Close the consumer

The application has some cleaning to do before terminating, that is deleting the stream and closing the environment:

### *Cleaning before terminating*

```
environment.deleteStream(stream); ①
environment.close(); ②
```

① Delete the stream

② Close the environment

You can run the sample application from the root of the project (you need a running local RabbitMQ node with the stream plugin enabled):

```
$ ./mvnw -q test-compile exec:java -Dexec.classpathScope="test" \
  -Dexec.mainClass="com.rabbitmq.stream.docs.SampleApplication"
Starting publishing...
Published 10000 messages
Starting consuming...
Sum: 49995000
```

You can remove the `-q` flag if you want more insight on the execution of the build.

## RabbitMQ Stream Java API

### Overview

This section describes the API to connect to the RabbitMQ Stream Plugin, publish messages, and consume messages. There are 3 main interfaces:

- `com.rabbitmq.stream.Environment` for connecting to a node and optionally managing streams.
- `com.rabbitmq.stream.Producer` to publish messages.
- `com.rabbitmq.stream.Consumer` to consume messages.

### Environment

#### Creating the Environment

The environment is the main entry point to a node or a cluster of nodes. `Producer` and `Consumer` instances are created from an `Environment` instance. Here is the simplest way to create an `Environment` instance:

*Creating an environment with all the defaults*

```
Environment environment = Environment.builder().build(); ①
// ...
environment.close(); ②
```

① Create an environment that will connect to localhost:5552

② Close the environment after usage

Note the environment must be closed to release resources when it is no longer needed.

Consider the environment like a long-lived object. An application will usually create one `Environment` instance when it starts up and close it when it exits.

It is possible to use a URI to specify all the necessary information to connect to a node:

### Creating an environment with a URI

```
Environment environment = Environment.builder()
    .uri("rabbitmq-stream://guest:guest@localhost:5552/%2f") ①
    .build();
```

① Use the `uri` method to specify the URI to connect to

The previous snippet uses a URI that specifies the following information: host, port, username, password, and virtual host (`/`, which is encoded as `%2f`). The URI follows the same rules as the [AMQP 0.9.1 URI](#), except the protocol must be `rabbitmq-stream`. [TLS is enabled](#) by using the `rabbitmq-stream+tls` scheme in the URI.

When using one URI, the corresponding node will be the main entry point to connect to. The `Environment` will then use the stream protocol to find out more about streams topology (leaders and replicas) when asked to create `Producer` and `Consumer` instances. The `Environment` may become blind if this node goes down though, so it may be more appropriate to specify several other URIs to try in case of failure of a node:

### Creating an environment with several URIs

```
Environment environment = Environment.builder()
    .uris(Arrays.asList(
        "rabbitmq-stream://host1:5552",
        "rabbitmq-stream://host2:5552",
        "rabbitmq-stream://host3:5552")
    )
    .build(); ①
```

① Use the `uris` method to specify several URIs

By specifying several URIs, the environment will try to connect to the first one, and will pick a new URI randomly in case of disconnection.

## Understanding Connection Logic

Creating the environment to connect to a cluster node works usually seamlessly. Creating publishers and consumers can cause problems as the client uses hints from the cluster to locate the nodes where stream leaders and replicas are located to connect to the appropriate nodes.

These connection hints can be accurate or less appropriate depending on the infrastructure. If you hit some connection problems at some point – like hostnames impossible to resolve for client applications - this [blog post](#) should help you understand what is going on and fix the issues.

## Enabling TLS

TLS can be enabled by using the `rabbitmq-stream+tls` scheme in the URI. The default TLS port is 5551.

Use the `EnvironmentBuilder#tls` method to configure TLS. The most important setting is a

`io.netty.handler.ssl.SslContext` instance, which is created and configured with the `io.netty.handler.ssl.SslContext#forClient` method. Note hostname verification is enabled by default.

The following snippet shows a common configuration, whereby the client is instructed to trust servers with certificates signed by the configured certificate authority (CA).

#### *Creating an environment that uses TLS*

```
X509Certificate certificate;
try (FileInputStream inputStream =
    new FileInputStream("/path/to/ca_certificate.pem")) {
    CertificateFactory fact = CertificateFactory.getInstance("X.509");
    certificate = (X509Certificate) fact.generateCertificate(inputStream); ❶
}
SslContext sslContext = SslContextBuilder
    .forClient()
    .trustManager(certificate) ❷
    .build();

Environment environment = Environment.builder()
    .uri("rabbitmq-stream+tls://guest:guest@localhost:5551/%2f") ❸
    .tls().sslContext(sslContext) ❹
    .environmentBuilder()
    .build();
```

❶ Load certificate authority (CA) certificate from PEM file

❷ Configure Netty `SslContext` to trust CA certificate

❸ Use TLS scheme in environment URI

❹ Set `SslContext` in environment configuration

It is sometimes handy to trust any server certificates in development environments. `EnvironmentBuilder#tls` provides the `trustEverything` method to do so. **This should not be used in a production environment.**

#### *Creating a TLS environment that trusts all server certificates for development*

```
Environment environment = Environment.builder()
    .uri("rabbitmq-stream+tls://guest:guest@localhost:5551/%2f")
    .tls().trustEverything() ❶
    .environmentBuilder()
    .build();
```

❶ Trust all server certificates

### **Configuring the Environment**

The following table sums up the main settings to create an `Environment`:

Parameter Name	Description	Default
<code>uri</code>	The URI of the node to connect to (single node).	<code>rabbitmq-stream://guest:guest@localhost:5552/%2f</code>
<code>uris</code>	The URI of the nodes to try to connect to (cluster).	<code>rabbitmq-stream://guest:guest@localhost:5552/%2f</code> singleton list
<code>host</code>	Host to connect to.	<code>localhost</code>
<code>port</code>	Port to use.	<code>5552</code>
<code>username</code>	Username to use to connect.	<code>guest</code>
<code>password</code>	Password to use to connect.	<code>guest</code>
<code>virtualHost</code>	Virtual host to connect to.	<code>/</code>
<code>rpcTimeout</code>	Timeout for RPC calls.	<code>Duration.ofSeconds(10)</code>
<code>recoveryBackOffDelayPolicy</code>	Delay policy to use for backoff on connection recovery.	Fixed delay of 5 seconds
<code>topologyUpdateBackOffDelayPolicy</code>	Delay policy to use for backoff on topology update, e.g. when a stream replica moves and a consumer needs to connect to another node.	Initial delay of 5 seconds then delay of 1 second.
<code>scheduledExecutorService</code>	Executor used to schedule infrastructure tasks like background publishing, producers and consumers migration after disconnection or topology update. If a custom executor is provided, it is the developer's responsibility to close it once it is no longer necessary.	<div> Executors <pre> .newScheduledThreadPool(     Runtime         .getRuntime()         .availableProcessors()     ); </pre> </div>
<code>maxProducersByConnection</code>	The maximum number of <code>Producer</code> instances a single connection can maintain before a new connection is open. The value must be between 1 and 255.	255
<code>maxTrackingConsumersByConnection</code>	The maximum number of <code>Consumer</code> instances that store their offset a single connection can maintain before a new connection is open. The value must be between 1 and 255.	50



Parameter Name	Description	Default
<code>maxConsumersByConnection</code>	The maximum number of <code>Consumer</code> instances a single connection can maintain before a new connection is open. The value must be between 1 and 255.	255
<code>lazyInitialization</code>	To delay the connection opening until necessary.	false
<code>tls</code>	Configuration helper for TLS.	TLS is enabled if a <code>rabbitmq-stream+tls</code> URI is provided.
<code>tls#hostnameVerification</code>	Enable or disable hostname verification.	Enabled by default.
<code>tls#sslContext</code>	Set the <code>io.netty.handler.ssl.SslContext</code> used for the TLS connection. Use <code>io.netty.handler.ssl.SslContextBuilder#forClient</code> to configure it. The server certificate chain and the client private key are the typical elements that need to be configured.	The JDK trust manager and no client private key.
<code>tls#trustEverything</code>	Helper to configure a <code>SslContext</code> that trusts all server certificates and does not use a client private key. <b>Only for development.</b>	Disabled by default.

## Managing Streams

Streams are usually long-lived, centrally-managed entities, that is, applications are not supposed to create and delete them. It is nevertheless possible to create and delete stream with the `Environment`. This comes in handy for development and testing purposes.

Streams are created with the `Environment#streamCreator()` method:

*Creating a stream*

```
environment.streamCreator().stream("my-stream").create(); ①
```

① Create the `my-stream` stream

`StreamCreator#create` is idempotent: trying to re-create a stream with the same name and same properties (e.g. maximum size, see below) will not throw an exception. In other words, you can be sure the stream has been created once `StreamCreator#create` returns. Note it is not possible to create

a stream with the same name as an existing stream but with different properties. Such a request will result in an exception.

Streams can be deleted with the `Environment#delete(String)` method:

#### *Deleting a stream*

```
environment.deleteStream("my-stream"); ①
```

① Delete the `my-stream` stream

Note you should avoid stream churn (creating and deleting streams repetitively) as their creation and deletion imply some significant housekeeping on the server side (interactions with the file system, communication between nodes of the cluster).

It is also possible to limit the size of a stream when creating it. A stream is an append-only data structure and reading from it does not remove data. This means a stream can grow indefinitely. RabbitMQ Stream supports a size-based and time-based retention policies: once the stream reaches a given size or a given age, it is truncated (starting from the beginning).

#### **IMPORTANT**

*Limit the size of streams if appropriate!*

Make sure to set up a retention policy on potentially large streams if you don't want to saturate the storage devices of your servers. Keep in mind that this means some data will be erased!

It is possible to set up the retention policy when creating the stream:

#### *Setting the retention policy when creating a stream*

```
environment.streamCreator()  
    .stream("my-stream")  
    .maxLengthBytes(ByteCapacity.GB(10)) ①  
    .maxSegmentSizeBytes(ByteCapacity.MB(500)) ②  
    .create();
```

① Set the maximum size to 10 GB

② Set the segment size to 500 MB

The previous snippet mentions a segment size. RabbitMQ Stream does not store a stream in a big, single file, it uses segment files for technical reasons. A stream is truncated by deleting whole segment files (and not part of them) so the maximum size of a stream is usually significantly higher than the size of segment files. 500 MB is a reasonable segment file size to begin with.

#### **NOTE**

*When does the broker enforce the retention policy?*

The broker enforces the retention policy when the segments of a stream roll over, that is when the current segment has reached its maximum size and is closed in favor of a new one. This means the maximum segment size is a critical setting in the retention mechanism.

RabbitMQ Stream also supports a time-based retention policy: segments get truncated when they reach a certain age. The following snippet illustrates how to set the time-based retention policy:

*Setting a time-based retention policy when creating a stream*

```
environment.streamCreator()
    .stream("my-stream")
    .maxAge(Duration.ofHours(6)) ①
    .maxSegmentSizeBytes(ByteCapacity.MB(500)) ②
    .create();
```

① Set the maximum age to 6 hours

② Set the segment size to 500 MB

## Producer

### Creating a Producer

A **Producer** instance is created from the **Environment**. The only mandatory setting to specify is the stream to publish to:

*Creating a producer from the environment*

```
Producer producer = environment.producerBuilder() ①
    .stream("my-stream") ②
    .build(); ③
// ...
producer.close(); ④
```

① Use `Environment#producerBuilder()` to define the producer

② Specify the stream to publish to

③ Create the producer instance with `build()`

④ Close the producer after usage

Consider a **Producer** instance like a long-lived object, do not create one to send just one message.

#### NOTE

##### *Producer thread safety*

Producer instances are thread-safe. **Deduplication** imposes **restrictions on the usage of threads** though.

Internally, the **Environment** will query the broker to find out about the topology of the stream and will create or re-use a connection to publish to the leader node of the stream.

The following table sums up the main settings to create a **Producer**:

Parameter Name	Description	Default
<code>stream</code>	The stream to publish to.	No default, mandatory setting.

Parameter Name	Description	Default
<code>name</code>	The logical name of the producer. Specify a name to enable <a href="#">message deduplication</a> .	<code>null</code> (no deduplication)
<code>batchSize</code>	The maximum number of messages to accumulate before sending them to the broker.	100
<code>subEntrySize</code>	The number of messages to put in a sub-entry. A sub-entry is one "slot" in a publishing frame, meaning outbound messages are not only batched in publishing frames, but in sub-entries as well. Use this feature to increase throughput at the cost of increased latency and potential duplicated messages even when deduplication is enabled.	1 (meaning no use of sub-entry batching)
<code>maxUnconfirmedMessages</code>	The maximum number of unconfirmed outbound messages. <code>Producer#send</code> will start blocking when the limit is reached.	10,000
<code>batchPublishingDelay</code>	Period to send a batch of messages.	100 ms
<code>confirmTimeout</code>	Time before the client calls the confirm callback to signal outstanding unconfirmed messages timed out.	30 seconds
<code>enqueueTimeout</code>	Time before enqueueing of a message fail when the maximum number of unconfirmed is reached. The callback of the message will be called with a negative status. Set the value to <code>Duration.ZERO</code> if there should be no timeout.	10 seconds.

## Sending Messages

Once a `Producer` has been created, it is possible to send a message with the `Producer#send(Message, ConfirmationHandler)` method. The following snippet shows how to publish a message with a byte array payload:

```
byte[] messagePayload = "hello".getBytes(StandardCharsets.UTF_8); ①
producer.send(
    producer.messageBuilder().addData(messagePayload).build(), ②
    confirmationStatus -> { ③
        if (confirmationStatus.isConfirmed()) {
            // the message made it to the broker
        } else {
            // the message did not make it to the broker
        }
    }
});
```

① The payload of a message is an array of bytes

② Create the message with `Producer#messageBuilder()`

③ Define the behavior on publish confirmation

Messages are not only made of a `byte[]` payload, we will see in [the next section](#) they can also carry pre-defined and application properties.

#### NOTE

*Use a `MessageBuilder` instance only once*

A `MessageBuilder` instance is meant to create only one message. You need to create a new instance of `MessageBuilder` for every message you want to create.

The `ConfirmationHandler` defines an asynchronous callback invoked when the client received from the broker the confirmation the message has been taken into account. The `ConfirmationHandler` is the place for any logic on publishing confirmation, including re-publishing the message if it is negatively acknowledged.

#### WARNING

*Keep the confirmation callback as short as possible*

The confirmation callback should be kept as short as possible to avoid blocking the connection thread. Not doing so can make the `Environment`, `Producer`, `Consumer` instances sluggish or even block them. Any long processing should be done in a separate thread (e.g. with an asynchronous `ExecutorService`).

## Working with Complex Messages

The publishing example above showed that messages are made of a byte array payload, but it did not go much further. Messages in RabbitMQ Stream can actually be more sophisticated, as they comply to the [AMQP 1.0 message format](#).

In a nutshell, a message in RabbitMQ Stream has the following structure:

- properties: a defined set of standard properties of the message (e.g. message ID, correlation ID, content type, etc).
- application properties: a set of arbitrary key/value pairs.
- body: typically an array of bytes.

- message annotations: a set of key/value pairs (aimed at the infrastructure).

The RabbitMQ Stream Java client uses the `Message` interface to abstract a message and the recommended way to create `Message` instances is to use the `Producer#messageBuilder()` method. To publish a `Message`, use the `Producer#send(Message, ConfirmationHandler)`:

#### Creating a message with properties

```
Message message = producer.messageBuilder() ①
    .properties() ②
        .messageId(UUID.randomUUID())
        .correlationId(UUID.randomUUID())
        .contentType("text/plain")
    .messageBuilder() ③
        .addData("hello".getBytes(StandardCharsets.UTF_8)) ④
    .build(); ⑤
producer.send(message, confirmationStatus -> { }); ⑥
```

- ① Get the message builder from the producer
- ② Get the properties builder and set some properties
- ③ Go back to message builder
- ④ Set byte array payload
- ⑤ Build the message instance
- ⑥ Publish the message

#### Is RabbitMQ Stream based on AMQP 1.0?

AMQP 1.0 is a standard that defines *an efficient binary peer-to-peer protocol for transporting messages between two processes over a network*. It also defines *an abstract message format, with concrete standard encoding*. This is only the latter part that RabbitMQ Stream uses. The AMQP 1.0 protocol is not used, only AMQP 1.0 encoded messages are wrapped into the RabbitMQ Stream binary protocol.

#### NOTE

The actual AMQP 1.0 message encoding and decoding happen on the client side, the RabbitMQ Stream plugin stores only bytes, it has no idea that AMQP 1.0 message format is used.

AMQP 1.0 message format was chosen because of its flexibility and its advanced type system. It provides good interoperability, which allows streams to be accessed as AMQP 0-9-1 queues, without data loss.

## Message Deduplication

RabbitMQ Stream provides publisher confirms to avoid losing messages: once the broker has persisted a message it sends a confirmation for this message. But this can lead to duplicate messages: imagine the connection closes because of a network glitch after the message has been persisted but *before* the confirmation reaches the producer. Once reconnected, the producer will retry to send the same message, as it never received the confirmation. So the message will be

persisted twice.

Luckily RabbitMQ Stream can detect and filter out duplicated messages, based on 2 client-side elements: the *producer name* and the *message publishing ID*.

#### WARNING

*Deduplication is not guaranteed when using sub-entries batching*

It is not possible to guarantee deduplication when [sub-entry batching](#) is in use. Sub-entry batching is disabled by default and it does not prevent from batching messages in a single publish frame, which can already provide very high throughput.

#### WARNING

*Deduplication is not guaranteed when publishing on several threads*

We'll see below that deduplication works using a strictly increasing sequence for messages. This means messages must be published in order and the preferred way to do this is usually *within a single thread*. Even if messages are *created* in order, with the proper sequence ID, if they are published in several threads, they can get out of order, e.g. message 5 can be *published* before message 2. The deduplication mechanism will then filter out message 2 in this case.

So you have to be very careful about the way your applications publish messages when deduplication is in use. If you worry about performance, note it is possible to publish hundreds of thousands of messages in a single thread with RabbitMQ Stream.

### Setting the Name of a Producer

The producer name is set when creating the producer instance, which automatically enables deduplication:

*Naming a producer to enable message deduplication*

```
Producer producer = environment.producerBuilder()
    .name("my-app-producer") ①
    .confirmTimeout(Duration.ZERO) ②
    .stream("my-stream")
    .build();
```

① Set a name for the producer

② Disable confirm timeout check

Thanks to the name, the broker will be able to track the messages it has persisted on a given stream for this producer. If the producer connection unexpectedly closes, it will automatically recover and retry outstanding messages. The broker will then filter out messages it has already received and persisted. No more duplicates!

## IMPORTANT

Why setting `confirmTimeout` to 0 when using deduplication?

The point of deduplication is to avoid duplicates when retrying unconfirmed messages. But why retrying in the first place? To avoid *losing* messages, that is enforcing *at-least-once* semantics. If the client does not stubbornly retry messages and gives up at some point, messages can be lost, which maps to *at-most-once* semantics. This is why the deduplication examples set the `confirmTimeout` setting to `Duration.ZERO`: to disable the background task that calls the confirmation callback for outstanding messages that time out. This way the client will do its best to retry messages until they are confirmed.

Consider the producer name a logical name. It should not be a random sequence that changes when the producer application is restarted. Names like `online-shop-order` or `online-shop-invoice` are better names than `3d235e79-047a-46a6-8c80-9d159d3e1b05`. There should be only one living instance of a producer with a given name on a given stream at the same time.

### Understanding Publishing ID

The producer name is only one part of the deduplication mechanism, the other part is the *message publishing ID*. If the producer has a name, the client automatically assigns a publishing ID to each outbound message for the producer. The publishing ID is a strictly increasing sequence, starting at 0 and incremented for each message. The default publishing sequence is good enough for deduplication, but it is possible to assign a publishing ID to each message:

#### Using an explicit publishing ID

```
Message message = producer.messageBuilder()
    .publishingId(1) ①
    .addData("hello".getBytes(StandardCharsets.UTF_8))
    .build();
producer.send(message, confirmationStatus -> { });
```

① Set a publishing ID on a message

There are a few rules to follow when using a custom publishing ID sequence:

- the sequence should start at 0
- the sequence must be strictly increasing
- there can be gaps in the sequence (e.g. 0, 1, 2, 3, 6, 7, 9, 10, etc)

A custom publishing ID sequence has usually a meaning: it can be the line number of a file or the primary key in a database.

Note the publishing ID is not part of the message: it is not stored with the message and so is not available when consuming the message. It is still possible to store the value in the AMQP 1.0 message application properties or in an appropriate properties (e.g. `messageId`).



## IMPORTANT

*Do not mix client-assigned and custom publishing ID*

As soon as a producer name is set, message deduplication is enabled. It is then possible to let the producer assign a publishing ID to each message or assign custom publishing IDs. **Do one or the other, not both!**

### Restarting a Producer Where It Left Off

Using a custom publishing sequence is even more useful to restart a producer where it left off. Imagine a scenario whereby the producer is sending a message for each line in a file and the application uses the line number as the publishing ID. If the application restarts because of some necessary maintenance or even a crash, the producer can restart from the beginning of the file: there would no duplicate messages because the producer has a name and the application sets publishing IDs appropriately. Nevertheless, this is far from ideal, it would be much better to restart just after the last line the broker successfully confirmed. Fortunately this is possible thanks to the `Producer#getLastPublishing()` method, which returns the last publishing ID for a given producer. As the publishing ID in this case is the line number, the application can easily scroll to the next line and restart publishing from there.

The next snippet illustrates the use of `Producer#getLastPublishing()`:

*Setting a producer where it left off*

```
Producer producer = environment.producerBuilder()
    .name("my-app-producer") ①
    .confirmTimeout(Duration.ZERO) ②
    .stream("my-stream")
    .build();
long nextPublishingId = producer.getLastPublishingId() + 1; ③
while (moreContent(nextPublishingId)) {
    byte[] content = getContent(nextPublishingId); ④
    Message message = producer.messageBuilder()
        .publishingId(nextPublishingId) ⑤
        .addData(content)
        .build();
    producer.send(message, confirmationStatus -> {});
    nextPublishingId++;
}
```

- ① Set a name for the producer
- ② Disable confirm timeout check
- ③ Query last publishing ID for this producer and increment it
- ④ Scroll to the content for the next publishing ID
- ⑤ Set the message publishing

## Consumer

`Consumer` is the API to consume messages from a stream.

## Creating a Consumer

A `Consumer` instance is created with `Environment#consumerBuilder()`. The main settings are the stream to consume from, the place in the stream to start consuming from (the *offset*), and a callback when a message is received (the `MessageHandler`). The next snippet shows how to create a `Consumer`:

### Creating a consumer

```
Consumer consumer = environment.consumerBuilder() ①
    .stream("my-stream") ②
    .offset(OffsetSpecification.first()) ③
    .messageHandler((offset, message) -> {
        message.getBodyAsBinary(); ④
    })
    .build(); ⑤
// ...
consumer.close(); ⑥
```

① Use `Environment#consumerBuilder()` to define the consumer

② Specify the stream to consume from

③ Specify where to start consuming from

④ Define behavior on message consumption

⑤ Build the consumer

⑥ Close consumer after usage

The broker start sending messages as soon as the `Consumer` instance is created.

### WARNING

*Keep the message processing callback as short as possible*

The message processing callback should be kept as short as possible to avoid blocking the connection thread. Not doing so can make the `Environment`, `Producer`, `Consumer` instances sluggish or even block them. Any long processing should be done in a separate thread (e.g. with an asynchronous `ExecutorService`).

The following table sums up the main settings to create a `Consumer`:

Parameter Name	Description	Default
<code>stream</code>	The stream to consume from.	No default, mandatory setting.
<code>offset</code>	The offset to start consuming from.	<code>OffsetSpecification#next()</code>
<code>messageHandler</code>	The callback for inbound messages.	No default, mandatory setting.
<code>name</code>	The consumer name (for <code>offset tracking</code> .)	<code>null</code> (no offset tracking)

Parameter Name	Description	Default
<code>AutoTrackingStrategy</code>	Enable and configure the <a href="#">auto-tracking strategy</a> .	This is the default tracking strategy if a consumer <code>name</code> is provided.
<code>AutoTrackingStrategy#messageCountBeforeStorage</code>	Number of messages before storing.	10,000
<code>AutoTrackingStrategy#flushInterval</code>	Interval to check and store the last received offset in case of inactivity.	<code>Duration.ofSeconds(5)</code>
<code>ManualTrackingStrategy</code>	Enable and configure the <a href="#">manual tracking strategy</a> .	Disabled by default.
<code>ManualTrackingStrategy#checkInterval</code>	Interval to check if the last requested stored offset has been actually stored.	<code>Duration.ofSeconds(5)</code>

#### NOTE

*Why is my consumer not consuming?*

A consumer starts consuming at the very end of a stream by default (`next` offset). This means the consumer will receive messages as soon as a producer publishes to the stream. *This also means that if no producers are currently publishing to the stream, the consumer will stay idle, waiting for new messages to come in.* Use the `ConsumerBuilder#offset(OffsetSpecification)` to change the default behavior and see the [offset section](#) to find out more about the different types of offset specification.

## Specifying an Offset

The offset is the place in the stream where the consumer starts consuming from. The possible values for the offset parameter are the following:

- `OffsetSpecification.first()`: starting from the first available offset. If the stream has not been [truncated](#), this means the beginning of the stream (offset 0).
- `OffsetSpecification.last()`: starting from the end of the stream and returning the last [chunk](#) of messages immediately (if the stream is not empty).
- `OffsetSpecification.next()`: starting from the next offset to be written. Contrary to `OffsetSpecification.last()`, consuming with `OffsetSpecification.next()` will not return anything if no-one is publishing to the stream. The broker will start sending messages to the consumer when messages are published to the stream.
- `OffsetSpecification.offset(offset)`: starting from the specified offset. 0 means consuming from the beginning of the stream (first messages). The client can also specify any number, for example the offset where it left off in a previous incarnation of the application.
- `OffsetSpecification.timestamp(timestamp)`: starting from the messages stored after the specified timestamp.

*What is a chunk of messages?*

**NOTE**

A chunk is simply a batch of messages. This is the storage and transportation unit used in RabbitMQ Stream, that is messages are stored contiguously in a chunk and they are delivered as part of a chunk. A chunk can be made of one to several thousands of messages, depending on the ingress.

The following figure shows the different offset specifications in a stream made of 2 chunks:

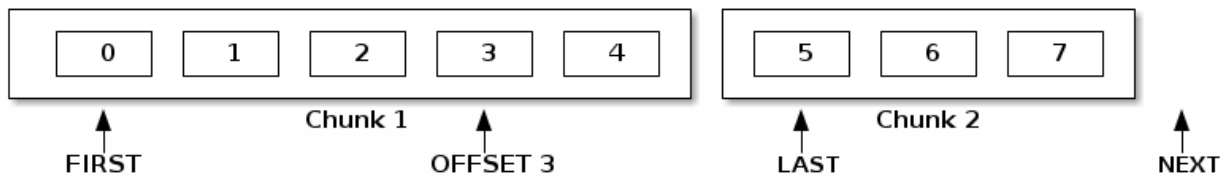


Figure 1. Offset specifications in a stream made of 2 chunks

### Tracking the Offset for a Consumer

A consumer can track the offset it has reached in a stream. This allows a new incarnation of the consumer to restart consuming where it left off. Offset tracking works in 2 steps:

- the consumer must have a **name**. The name is set with `ConsumerBuilder#name(String)`. The name can be any value (under 256 characters) and is expected to be unique (from the application point of view). Note neither the client library, nor the broker enforces uniqueness of the name: if 2 `Consumer` Java instances share the same name, their offset tracking will likely be interleaved, which applications usually do not expect.
- the consumer must periodically **store the offset** it has reached so far. The way offsets are stored depends on the tracking strategy: automatic or manual.

Whatever tracking strategy you use, **a consumer must have a name to be able to store offsets**.

#### Automatic Offset Tracking

The following snippet shows how to enable automatic tracking with the defaults:

*Using automatic tracking strategy with the defaults*

```
Consumer consumer =
    environment.consumerBuilder()
        .stream("my-stream")
        .name("application-1") ①
        .autoTrackingStrategy() ②
        .builder()
        .messageHandler((context, message) -> {
            // message handling code...
        })
        .build();
```

① Set the consumer name (mandatory for offset tracking)

## ② Use automatic tracking strategy with defaults

The automatic tracking strategy has the following available settings:

- **message count before storage:** the client will store the offset after the specified number of messages, right after the execution of the message handler. *The default is every 10,000 messages.*
- **flush interval:** the client will make sure to store the last received offset at the specified interval. This avoids having pending, not stored offsets in case of inactivity. *The default is 5 seconds.*

Those settings are configurable, as shown in the following snippet:

### Configuring the automatic tracking strategy

```
Consumer consumer =
    environment.consumerBuilder()
        .stream("my-stream")
        .name("application-1") ①
        .autoTrackingStrategy() ②
            .messageCountBeforeStorage(50_000) ③
            .flushInterval(Duration.ofSeconds(10)) ④
        .builder()
        .messageHandler((context, message) -> {
            // message handling code...
        })
        .build();
```

① Set the consumer name (mandatory for offset tracking)

② Use automatic tracking strategy

③ Store every 50,000 messages

④ Make sure to store offset at least every 10 seconds

Note the automatic tracking is the default tracking strategy, so if you are fine with its defaults, it is enabled as soon as you specify a name for the consumer:

### Setting only the consumer name to enable automatic tracking

```
Consumer consumer =
    environment.consumerBuilder()
        .stream("my-stream")
        .name("application-1") ①
        .messageHandler((context, message) -> {
            // message handling code...
        })
        .build();
```

① Set only the consumer name to enable automatic tracking with defaults

Automatic tracking is simple and provides good guarantees. It is nevertheless possible to have more fine-grained control over offset tracking by using manual tracking.

## Manual Offset Tracking

The manual tracking strategy lets the developer in charge of storing offsets whenever they want, not only after a given number of messages has been received and supposedly processed, like automatic tracking does.

The following snippet shows how to enable manual tracking and how to store the offset at some point:

*Using manual tracking with defaults*

```
Consumer consumer =
    environment.consumerBuilder()
        .stream("my-stream")
        .name("application-1") ①
        .manualTrackingStrategy() ②
        .builder()
        .messageHandler((context, message) -> {
            // message handling code...

            if (conditionToStore()) {
                context.storeOffset(); ③
            }
        })
        .build();
```

- ① Set the consumer name (mandatory for offset tracking)
- ② Use manual tracking with defaults
- ③ Store at the current offset on some condition

Manual tracking has only one setting: the **check interval**. The client checks that the last requested stored offset has been actually stored at the specified interval. *The default check interval is 5 seconds.*

The following snippet shows the configuration of manual tracking:

```
Consumer consumer =
    environment.consumerBuilder()
        .stream("my-stream")
        .name("application-1") ①
        .manualTrackingStrategy() ②
            .checkInterval(Duration.ofSeconds(10)) ③
        .builder()
        .messageHandler((context, message) -> {
            // message handling code...

            if (conditionToStore()) {
                context.storeOffset(); ④
            }
        })
        .build();
```

- ① Set the consumer name (mandatory for offset tracking)
- ② Use manual tracking with defaults
- ③ Check last requested offset every 10 seconds
- ④ Store the current offset on some condition

The snippet above uses `MessageHandler.Context#storeOffset()` to store at the offset of the current message, but it is possible to store anywhere in the stream with `MessageHandler.Context#consumer().store(long)` or simply `Consumer#store(long)`.

### Considerations On Offset Tracking

*When to store offsets?* Avoid storing offsets too often or, worse, for each message. Even though offset tracking is a small and fast operation, it will make the stream grow unnecessarily, as the broker persists offset tracking entries in the stream itself.

A good rule of thumb is to store the offset every few thousands of messages. Of course, when the consumer will restart consuming in a new incarnation, the last tracked offset may be a little behind the very last message the previous incarnation actually processed, so the consumer may see some messages that have been already processed.

A solution to this problem is to make sure processing is idempotent or filter out the last duplicated messages.

---

*Is the offset a reliable absolute value?* Message offsets may not be contiguous. This implies that the message at offset 500 in a stream may not be the 501 message in the stream (offsets start at 0). There can be different types of entries in a stream storage, a message is just one of them. For example, storing an offset creates an offset tracking entry, which has its own offset.

This means one must be careful when basing some decision on offset values, like a modulo to perform an operation every X messages. As the message offsets have no guarantee to be contiguous,

the operation may not happen exactly every X messages.

### Subscription Listener

The client provides a `SubscriptionListener` interface callback to add behavior before a subscription is created. This callback can be used to customize the offset the client library computed for the subscription. The callback is called when the consumer is first created and when the client has to re-subscribe (e.g. after a disconnection or a topology change).

#### WARNING

*Experimental*

This API is experimental, it is subject to change.

It is possible to use the callback to get the last processed offset from an external store, that is not using the server-side offset tracking feature RabbitMQ Stream provides. The following code snippet shows how this can be done (note the interaction with the external store is not detailed):

*Using an external store for offset tracking with a subscription listener*

```
Consumer consumer = environment.consumerBuilder()
    .stream("my-stream")
    .subscriptionListener(subscriptionContext -> { ①
        long offset = getOffsetFromExternalStore(); ②
        subscriptionContext.offsetSpecification(OffsetSpecification.offset(offset));
    }) ③
    .messageHandler((context, message) -> {
        // message handling code...

        storeOffsetInExternalStore(context.offset()); ④
    })
    .build();
```

- ① Set subscription listener
- ② Get offset from external store
- ③ Set offset to use for the subscription
- ④ Store the offset in the external store after processing

When using an external store for offset tracking, it is no longer necessary to set a name and an offset strategy, as these only apply when server-side offset tracking is in use.

Using a subscription listener can also be useful to have more accurate offset tracking on re-subscription, at the cost of making the application code slightly more complex. This requires a good understanding on how and when subscription occurs in the client, and so when the subscription listener is called:

- for a consumer with no name (server-side offset tracking *disabled*)
  - on the first subscription (when the consumer is created): the offset specification is the one specified with `ConsumerBuilder#offset(OffsetSpecification)`, the default being



`OffsetSpecification#next()`

- on re-subscription (after a disconnection or topology change): the offset specification is the offset of the last dispatched message
- for a consumer with a name (server-side offset tracking *enabled*)
  - on the first subscription (when the consumer is created): the server-side stored offset (if any) overrides the value specified with `ConsumerBuilder#offset(OffsetSpecification)`
  - on re-subscription (after a disconnection or topology change): the server-side stored offset is used

The subscription listener comes in handy on re-subscription. The application can track the last processed offset in-memory, with an `AtomicLong` for example. The application knows exactly when a message is processed and updates its in-memory tracking accordingly, whereas the value computed by the client may not be perfectly appropriate on re-subscription.

Let's take the example of a named consumer with an offset tracking strategy that is lagging because of bad timing and a long flush interval. When a glitch happens and triggers the re-subscription, the server-side stored offset can be quite behind what the application actually processed. Using this server-side stored offset can lead to duplicates, whereas using the in-memory, application-specific offset tracking variable is more accurate. A custom `SubscriptionListener` lets the application developer uses what's best for the application if the computed value is not optimal.

## Super Streams (Partitioned Streams)

### WARNING

*Experimental*

Super streams are an experimental feature, they are subject to change.

A super stream is a logical stream made of several individual streams. In essence, a super stream is a partitioned stream that brings scalability compared to a single stream.

The stream Java client uses the same programming model for super streams as with individual streams, that is the `Producer`, `Consumer`, `Message`, etc API are still valid when super streams are in use. Application code should not be impacted whether it uses individual or super streams.

### Topology

A super stream is made of several individual streams, so it can be considered a logical entity rather than an actual physical entity. The topology of a super stream is based on the [AMQP 0.9.1 model](#), that is exchange, queues, and bindings between them. This does not mean AMQP resources are used to transport or store stream messages, it means that they are used to *describe* the super stream topology, that is the streams it is made of.

Let's take the example of an `invoices` super stream made of 3 streams (i.e. partitions):

- an `invoices` exchange represents the super stream
- the `invoices-0`, `invoices-1`, `invoices-2` streams are the partitions of the super stream (streams are also AMQP queues in RabbitMQ)
- 3 bindings between the exchange and the streams link the super stream to its partitions and

represent *routing rules*

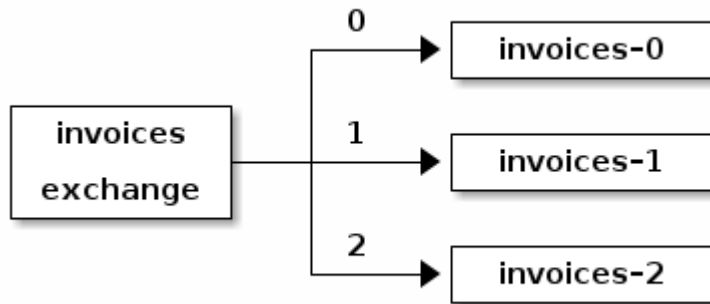


Figure 2. The topology of a super stream is defined with bindings between an exchange and queues

When a super stream is in use, the stream Java client queries this information to find out about the partitions of a super stream and the routing rules. From the application code point of view, using a super stream is mostly configuration-based. Some logic must also be provided to extract routing information from messages.

### Publishing to a Super Stream

When the topology of a super stream like the one described above has been set, creating a producer for it is straightforward:

#### Creating a Producer for a Super Stream

```
Producer producer = environment.producerBuilder()
    .stream("invoices") ①
    .routing(message -> message.getProperties().getMessageIdAsString()) ②
    .producerBuilder()
    .build(); ③

// ...
producer.close(); ④
```

- ① Use the super stream name
- ② Provide the logic to get the routing key from a message
- ③ Create the producer instance
- ④ Close the producer when it's no longer necessary

Note that even though the `invoices` super stream is not an actual stream, its name must be used to declare the producer. Internally the client will figure out the streams that compose the super stream. The application code must provide the logic to extract a routing key from a message as a `Function<Message, String>`. The client will hash the routing key to determine the stream to send the message to (using partition list and a modulo operation).

The client uses 32-bit `MurmurHash3` by default to hash the routing key. This hash function provides good uniformity, performance, and portability, making it a good default choice, but it is possible to specify a custom hash function:

```
Producer producer = environment.producerBuilder()
    .stream("invoices")
    .routing(message -> message.getProperties().getMessageIdAsString())
    .hash(rk -> rk.hashCode()) ①
    .producerBuilder()
    .build();
```

① Use `String#hashCode()` to hash the routing key

Note using Java's `hashCode()` method is a debatable choice as potential producers in other languages are unlikely to implement it, making the routing different between producers in different languages.

### Resolving Routes with Bindings

Hashing the routing key to pick a partition is only one way to route messages to the appropriate streams. The stream Java client provides another way to resolve streams, based on the routing key *and* the bindings between the super stream exchange and the streams.

This routing strategy makes sense when the partitioning has a business meaning, e.g. with a partition for a region in the world, like in the diagram below:



Figure 3. A super stream with a partition for a region in a world

In such a case, the routing key will be a property of the message that represents the region:

### Enabling the "key" routing strategy

```
Producer producer = environment.producerBuilder()
    .stream("invoices")
    .routing(msg -> msg.getApplicationProperties().get("region").toString()) ①
    .key() ②
    .producerBuilder()
    .build();
```

① Extract the routing key

② Enable the "key" routing strategy

Internally the client will query the broker to resolve the destination streams for a given routing key, making the routing logic from any exchange type available to streams. Note the client caches results, it does not query the broker for every message.

### Using a Custom Routing Strategy

The solution that provides the most control over routing is using a custom routing strategy. This should be needed only for specific cases.

The following code sample shows how to implement a simplistic round-robin `RoutingStrategy` and use it in the producer. Note this implementation should not be used in production as the modulo operation is not sign-safe for simplicity's sake.

#### *Setting a round-robin routing strategy*

```
AtomicLong messageCount = new AtomicLong(0);
RoutingStrategy routingStrategy = (message, metadata) -> {
    List<String> partitions = metadata.partitions();
    String stream = partitions.get(
        (int) messageCount.getAndIncrement() % partitions.size()
    );
    return Collections.singletonList(stream);
};
Producer producer = environment.producerBuilder()
    .stream("invoices")
    .routing(null) ①
    .strategy(routingStrategy) ②
    .producerBuilder()
    .build();
```

① No need to set the routing key extraction logic

② Set the custom routing strategy

### Deduplication

Deduplication for a super stream producer works the same way as with a [single stream producer](#). The publishing ID values are spread across the streams but this does affect the mechanism.

### Consuming From a Super Stream

A super stream consumer is not much different from a single stream consumer. The `ConsumerBuilder#superStream(String)` must be used to set the super stream to consume from:

```
Consumer consumer = environment.consumerBuilder()
    .superStream("invoices") ①
    .messageHandler((context, message) -> {
        // message processing
    })
    .build();
// ...
consumer.close(); ②
```

① Set the super stream name

② Close the consumer when it is no longer necessary

A super stream consumer is a composite consumer: it will look up the super stream partitions and create a consumer for each of them.

### Offset Tracking

The semantic of offset tracking for a super stream consumer are roughly the same as for an individual stream consumer. There are still some subtle differences, so a good understanding of [offset tracking](#) in general and of the [automatic](#) and [manual](#) offset tracking strategies is recommended.

Here are the main differences for the automatic/manual offset tracking strategies between single and super stream consuming:

- **automatic offset tracking:** internally, *the client divides the `messageCountBeforeStorage` setting by the number of partitions for each individual consumer*. Imagine a 3-partition super stream, `messageCountBeforeStorage` set to 10,000, and 10,000 messages coming in, perfectly balanced across the partitions (that is about 3,333 messages for each partition). In this case, the automatic offset tracking strategy will not kick in, because the expected count message has not been reached on any partition. Making the client divide `messageCountBeforeStorage` by the number of partitions can be considered "more accurate" if the message are well balanced across the partitions. A good rule of thumb is to then multiply the expected per-stream `messageCountBeforeStorage` by the number of partitions, to avoid storing offsets too often. So the default being 10,000, it can be set to 30,000 for a 3-partition super stream.
- **manual offset tracking:** the `MessageHandler.Context#storeOffset()` method must be used, the `Consumer#store(long)` will fail, because an offset value has a meaning only in one stream, not in other streams. A call to `MessageHandler.Context#storeOffset()` will store the current message offset in *its* stream, but also the offset of the last dispatched message for the other streams of the super stream.

## Building the Client

You need JDK 1.8 or more installed.

To build the JAR file:

```
./mvnw clean package -DskipITs -DskipTests
```

To launch the test suite (requires a local RabbitMQ node with stream plugin enabled):

```
./mvnw verify -Drabbitmqctl.bin=/path/to/rabbitmqctl
```

## The Performance Tool

The library contains also a performance tool to test the RabbitMQ Stream plugin. It is usable as an uber JAR [downloadable from GitHub Release](#) or as a [Docker image](#). It can be built separately as well.

Snapshots are on [GitHub release](#) as well. Use the `pivotalrabbitmq/stream-perf-test:dev` image to use the latest snapshot in Docker.

## Using the Performance Tool

### With Docker

The performance tool is available as a [Docker image](#). You can use the Docker image to list the available options:

*Listing the available options of the performance tool*

```
docker run -it --rm pivotalrabbitmq/stream-perf-test --help
```

There are all sorts of options, if none is provided, the tool will start publishing to and consuming from a stream created only for the test.

When using Docker, the container running the performance tool must be able to connect to the broker, so you have to figure out the appropriate Docker configuration to make this possible. You can have a look at the [Docker network documentation](#) to find out more.

#### NOTE

##### *Docker on macOS*

Docker runs on a virtual machine when using macOS, so do not expect high performance when using RabbitMQ Stream and the performance tool inside Docker on a Mac.

We show next a couple of options to easily use the Docker image.

### With Docker Host Network Driver

This is the simplest way to run the image locally, with a local broker running in Docker as well. The containers use the [host network](#), this is perfect for experimenting locally.

```
# run the broker
docker run -it --rm --name rabbitmq --network host rabbitmq:3.9
# open another terminal and enable the stream plugin
docker exec rabbitmq rabbitmq-plugins enable rabbitmq_stream
# run the performance tool
docker run -it --rm --network host pivotalrabbitmq/stream-perf-test
```

#### *Docker Host Network Driver Support*

#### **NOTE**

According to Docker's documentation, the host networking driver **only works on Linux hosts**. Nevertheless, the commands above work on some Mac hosts.

### **With Docker Bridge Network Driver**

Containers need to be able to communicate with each other with the [bridge network driver](#), this can be done by defining a network and running the containers in this network.

#### *Running the broker and performance tool with the bridge network driver*

```
# create a network
docker network create stream-perf-test
# run the broker
docker run -it --rm --network stream-perf-test --name rabbitmq rabbitmq:3.9
# open another terminal and enable the stream plugin
docker exec rabbitmq rabbitmq-plugins enable rabbitmq_stream
# run the performance tool
docker run -it --rm --network stream-perf-test pivotalrabbitmq/stream-perf-test \
    --uris rabbitmq-stream://rabbitmq:5552
```

### **With the Java Binary**

The Java binary is available on [GitHub Release](#). [Snapshots](#) are available as well. To use the latest snapshot:

```
wget https://github.com/rabbitmq/rabbitmq-java-tools-binaries-dev/releases/download/v-
stream-perf-test-latest/stream-perf-test-latest.jar
```

To launch a run:

```

$ java -jar stream-perf-test-latest.jar
17:51:26.207 [main] INFO  c.r.stream.perf.StreamPerfTest - Starting producer
1, published 560277 msg/s, confirmed 554088 msg/s, consumed 556983 msg/s, latency
min/median/75th/95th/99th 2663/9799/13940/52304/57995 µs, chunk size 1125
2, published 770722 msg/s, confirmed 768209 msg/s, consumed 768585 msg/s, latency
min/median/75th/95th/99th 2454/9599/12206/23940/55519 µs, chunk size 1755
3, published 915895 msg/s, confirmed 914079 msg/s, consumed 916103 msg/s, latency
min/median/75th/95th/99th 2338/8820/11311/16750/52985 µs, chunk size 2121
4, published 1004257 msg/s, confirmed 1003307 msg/s, consumed 1004981 msg/s, latency
min/median/75th/95th/99th 2131/8322/10639/14368/45094 µs, chunk size 2228
5, published 1061380 msg/s, confirmed 1060131 msg/s, consumed 1061610 msg/s, latency
min/median/75th/95th/99th 2131/8247/10420/13905/37202 µs, chunk size 2379
6, published 1096345 msg/s, confirmed 1095947 msg/s, consumed 1097447 msg/s, latency
min/median/75th/95th/99th 2131/8225/10334/13722/33109 µs, chunk size 2454
7, published 1127791 msg/s, confirmed 1127032 msg/s, consumed 1128039 msg/s, latency
min/median/75th/95th/99th 1966/8150/10172/13500/23940 µs, chunk size 2513
8, published 1148846 msg/s, confirmed 1148086 msg/s, consumed 1149121 msg/s, latency
min/median/75th/95th/99th 1966/8079/10135/13248/16771 µs, chunk size 2558
9, published 1167067 msg/s, confirmed 1166369 msg/s, consumed 1167311 msg/s, latency
min/median/75th/95th/99th 1966/8063/9986/12977/16757 µs, chunk size 2631
10, published 1182554 msg/s, confirmed 1181938 msg/s, consumed 1182804 msg/s, latency
min/median/75th/95th/99th 1966/7963/9949/12632/16619 µs, chunk size 2664
11, published 1197069 msg/s, confirmed 1196495 msg/s, consumed 1197291 msg/s, latency
min/median/75th/95th/99th 1966/7917/9955/12503/15386 µs, chunk size 2761
12, published 1206687 msg/s, confirmed 1206176 msg/s, consumed 1206917 msg/s, latency
min/median/75th/95th/99th 1966/7893/9975/12503/15280 µs, chunk size 2771
...
^C
Summary: published 1279444 msg/s, confirmed 1279019 msg/s, consumed 1279019 msg/s,
latency 95th 12161 µs, chunk size 2910

```

The previous command will start publishing to and consuming from a **stream** stream that will be created. The tool outputs live metrics on the console and write more detailed metrics in a **stream-perf-test-current.txt** file that get renamed to **stream-perf-test-yyyy-MM-dd-HHmmss.txt** when the run ends.

To see the options:

```
java -jar stream-perf-test-latest.jar --help
```

The performance tool comes also with a [completion script](#). You can download it and enable it in your **~/.zshrc** file:

```
alias stream-perf-test='java -jar target/stream-perf-test.jar'
source ~/.zsh/stream-perf-test_completion
```

Note the activation requires an alias which must be **stream-perf-test**. The command can be



anything though.

## Common Usage

### Connection

The performance tool connects by default to localhost, on port 5552, with default credentials (`guest` / `guest`), on the default / virtual host. This can be changed with the `--uris` option:

```
java -jar stream-perf-test.jar --uris rabbitmq-stream://rabbitmq-1:5552
```

The URI follows the same rules as the [AMQP 0.9.1 URI](#), except the protocol must be `rabbitmq-stream`. The next command shows how to set up the different elements of the URI:

```
java -jar stream-perf-test.jar \  
  --uris rabbitmq-stream://guest:guest@localhost:5552/%2f
```

The option accepts several values, separated by commas. By doing so, the tool will be able to pick another URI for its "locator" connection, in case a node crashes:

```
java -jar stream-perf-test.jar \  
  --uris rabbitmq-stream://rabbitmq-1:5552,rabbitmq-stream://rabbitmq-2:5552
```

Note the tool uses those URIs only for management purposes, it does not use them to distribute publishers and consumers across a cluster.

It is also possible to enable [TLS](#) by using the `rabbitmq-stream+tls` scheme:

```
java -jar stream-perf-test.jar \  
  --uris rabbitmq-stream+tls://guest:guest@localhost:5551/%2f
```

Note the performance tool will automatically configure the client to trust all server certificates and to not use a private key (for client authentication).

Have a look at the [connection logic section](#) in case of connection problem.

### Publishing Rate

It is possible to limit the publishing rate with the `--rate` option:

```
java -jar stream-perf-test.jar --rate 10000
```

RabbitMQ Stream can easily saturate the resources of the hardware, it can especially max out the storage IO. Reasoning when a system is under severe constraints can be difficult, so setting a low publishing rate can be a good idea to get familiar with the performance tool and the semantics of

streams.

## Number of Producers and Consumers

You can set the number of producers and consumers with the `--producers` and `--consumers` options, respectively:

```
java -jar stream-perf-test.jar --producers 5 --consumers 5
```

With the previous command, you should see a higher consuming rate than publishing rate. It is because the 5 producers publish as fast as they can and each consumer consume the messages from the 5 publishers. In theory the consumer rate should be 5 times the publishing rate, but as stated previously, the performance tool may put the broker under severe constraints, so the numbers may not add up.

You can set a low publishing rate to verify this theory:

```
java -jar stream-perf-test.jar --producers 5 --consumers 5 --rate 10000
```

With the previous command, each publisher should publish 10,000 messages per second, that is 50,000 messages per second overall. As each consumer consumes each published messages, the consuming rate should be 5 times the publishing rate, that is 250,000 messages per second. Using a small publishing rate should let plenty of resources to the system, so the rates should tend towards those values.

## Streams

The performance tool uses a `stream` stream by default, the `--streams` option allows specifying streams that the tool will try to create. Note producer and consumer counts must be set accordingly, as they are not spread across the stream automatically. The following command will run a test with 3 streams, with a producer and a consumer on each of them:

```
java -jar stream-perf-test.jar --streams stream1,stream2,stream3 \  
--producers 3 --consumers 3
```

The stream creation process has the following semantics:

- the tool always tries to create streams.
- if the target streams already exist and have the exact same properties as the ones the tool uses (see [retention](#) below), the run will start normally as stream creation is idempotent.
- if the target streams already exist but do not have the exact same properties as the ones the tool uses, the run will start normally as well, the tool will output a warning.
- for any other errors during creation, the run will stop.
- the streams are not deleted after the run.

- if you want the tool to delete the streams after a run, use the `--delete-streams` flag.

Specifying streams one by one can become tedious as their number grows, so the `--stream-count` option can be combined with the `--streams` option to specify a number or a range and a stream name pattern, respectively. The following table shows the usage of these 2 options and the resulting exercised streams. Do not forget to also specify the appropriate number of producers and consumers if you want all the declared streams to be used.

Options	Computed Streams	Details
<code>--stream-count 5 --streams stream</code>	stream-1,stream-2,stream-3,stream-4,stream-5	Stream count starts at 1.
<code>--stream-count 5 --streams stream-%d</code>	stream-1,stream-2,stream-3,stream-4,stream-5	Possible to specify a <a href="#">Java printf-style format string</a> .
<code>--stream-count 10 --streams stream-%d</code>	stream-1,stream-2,stream-3,...,stream-10	Not bad, but not correctly sorted alphabetically.
<code>--stream-count 10 --streams stream-%02d</code>	stream-01,stream-02,stream-03,...,stream-10	Better for sorting.
<code>--stream-count 10 --streams stream</code>	stream-01,stream-02,stream-03,...,stream-10	The default format string handles the sorting issue.
<code>--stream-count 50-500 --streams stream-%03d</code>	stream-050,stream-051,stream-052,...,stream-500	Ranges are accepted.
<code>--stream-count 50-500</code>	stream-050,stream-051,stream-052,...,stream-500	Default format string.

## Publishing Batch Size

The default publishing batch size is 100, that is a publishing frame is sent every 100 messages. The following command sets the batch size to 50 with the `--batch-size` option:

```
java -jar stream-perf-test.jar --batch-size 50
```

There is no ideal batch size, it is a tradeoff between throughput and latency. High batch size values should increase throughput (usually good) and latency (usually not so good), whereas low batch size should decrease throughput (usually not good) and latency (usually good).

## Unconfirmed Messages

A publisher can have at most 10,000 unconfirmed messages at some point. If it reaches this value, it has to wait until the broker confirms some messages. This avoids fast publishers overwhelming the broker. The `--confirms` option allows changing the default value:

```
java -jar stream-perf-test.jar --confirms 20000
```

High values should increase throughput at the cost of consuming more memory, whereas low values should decrease throughput and memory consumption.

## Message Size

The default size of a message is 10 bytes, which is rather small. The `--size` option lets you specify a different size, usually higher, to have a value close to your use case. The next command sets a size of 1 KB:

```
java -jar stream-perf-test.jar --size 1024
```

Note the message body size cannot be smaller than 8 bytes, as the performance tool stores a long in each message to calculate the latency. Note also the actual size of a message will be slightly higher, as the body is wrapped in an [AMQP 1.0 message](#).

## Advanced Usage

### Retention

If you run performance tests for a long time, you might be interested in setting a [retention strategy](#) for the streams the performance tool creates for a run. This would typically avoid saturating the storage devices of your servers. The default values are 20 GB for the maximum size of a stream and 500 MB for each segment files that composes a stream. You can change these values with the `--max-length-bytes` and `--stream-max-segment-size-bytes` options:

```
java -jar stream-perf-test.jar --max-length-bytes 10gb \  
                                --stream-max-segment-size-bytes 250mb
```

Both options accept units (`kb`, `mb`, `gb`, `tb`), as well as no unit to specify a number of bytes.

It is also possible to use the time-based retention strategy with the `--max-age` option. This can be less predictable than `--max-length-bytes` in the context of performance tests though. The following command shows how to set the maximum age of segments to 5 minutes with a maximum segment size of 250 MB:

```
java -jar stream-perf-test.jar --max-age PT5M \  
                                --stream-max-segment-size-bytes 250mb
```

The `--max-age` option uses the [ISO 8601 duration format](#).

### Offset (Consumer)

Consumers start by default at the very end of a stream (offset `next`). It is possible to specify an [offset](#) to start from with the `--offset` option, if you have existing streams, and you want to consume from them at a specific offset. The following command sets the consumer to start consuming at the beginning of a stream:

```
java -jar stream-perf-test.jar --offset first
```

The accepted values for `--offset` are `first`, `last`, `next` (the default), an unsigned long for a given offset, and an ISO 8601 formatted timestamp (eg. `2020-06-03T07:45:54Z`).

## Offset Tracking (Consumer)

A consumer can [track the point](#) it has reached in a stream to be able to restart where it left off in a new incarnation. The performance tool has the `--store-every` option to tell consumers to store the offset every `x` messages to be able to measure the impact of offset tracking in terms of throughput and storage. This feature is disabled by default. The following command shows how to store the offset every 100,000 messages:

```
java -jar stream-perf-test.jar --store-every 100000
```

## Consumer Names

When using `--store-every` (see above) for [offset tracking](#), the performance tool uses a default name using the pattern `{stream-name}-{consumer-number}`. So the default name of a single tracking consumer consuming from `stream` will be `stream-1`.

The consumer names pattern can be set with the `--consumer-names` option, which uses the [Java printf-style format string](#). The stream name and the consumer number are injected as arguments, in this order.

The following table illustrates some examples for the `--consumer-names` option for a `s1` stream and a second consumer:

Option	Computed Name	Details
<code>%s-%d</code>	<code>s1-2</code>	Default pattern.
<code>stream-%s-consumer-%d</code>	<code>stream-s1-consumer-2</code>	
<code>consumer-%2\$d-on-stream-%1\$s</code>	<code>consumer-2-on-stream-s1</code>	The argument indexes ( <code>1\$</code> for the stream, <code>2\$</code> for the consumer number) must be used as the pattern uses the consumer number first, which is not the pre-defined order of arguments.
<code>uuid</code>	<code>7cc75659-ea67-4874-96ef-151a505e1a55</code>	<a href="#">Random UUID</a> that changes for every run.

Note you can use `--consumer-names uuid` to change the consumer names for every run. This can be useful when you want to use tracking consumers in different runs but you want to force the offset they start consuming from. With consumer names that do not change between runs, tracking consumers would ignore the specified offset and would start where they left off (this is the purpose of offset tracking).

## Producer Names

You can use the `--producer-names` option to set the producer names pattern and therefore enable

[message deduplication](#) (using the default publishing sequence starting at 0 and incremented for each message). The same naming options apply as above in [consumer names](#) with the only difference that the default pattern is empty (i.e. no deduplication).

Here is an example of the usage of the `--producer-names` option:

```
java -jar stream-perf-test.jar --producer-names %s-%d
```

The run will start one producer and will use the `stream-1` producer reference (default stream is `stream` and the number of the producer is 1.)

## Monitoring

The tool can expose some runtime information on HTTP. The default port is 8080. The following options are available:

- `--monitoring`: add a `threaddump` endpoint to display a thread dump of the process. This can be useful to inspect threads if the tool seems blocked.
- `--prometheus`: add a `metrics` endpoint to expose metrics using the Prometheus format. The endpoint can then be declared in a Prometheus instance to scrape the metrics.
- `--monitoring-port`: set the port to use for the web server.

## Using Environment Variables as Options

Environment variables can sometimes be easier to work with than command line options. This is especially true when using a manifest file for configuration (with Docker Compose or Kubernetes) and the number of options used grows.

The performance tool automatically uses environment variables that match the snake case version of its long options. E.g. it automatically picks up the value of the `BATCH_SIZE` environment variable for the `--batch-size` option, but only if the environment variable is defined.

You can list the environment variables that the tool picks up with the following command:

```
java -jar stream-perf-test.jar --environment-variables
```

The short version of the option is `-env`.

To avoid collisions with environment variables that already exist, it is possible to specify a prefix for the environment variables that the tool looks up. This prefix is defined with the `RABBITMQ_STREAM_PERF_TEST_ENV_PREFIX` environment variable, e.g.:

```
RABBITMQ_STREAM_PERF_TEST_ENV_PREFIX="STREAM_PERF_TEST_"
```

With `RABBITMQ_STREAM_PERF_TEST_ENV_PREFIX="STREAM_PERF_TEST_"` defined, the tool looks for the `STREAM_PERF_TEST_BATCH_SIZE` environment variable, not `BATCH_SIZE`.

## Logging

The performance tool binary uses Logback with an internal configuration file. The default log level is **warn** with a console appender.

It is possible to define loggers directly from the command line, this is useful for quick debugging. Use the **rabbitmq.streamperfest.loggers** system property with **name=level** pairs, e.g.:

```
java -Drabbitmq.streamperfest.loggers=com.rabbitmq.stream=debug -jar stream-perf-test.jar
```

It is possible to define several loggers by separating them with commas, e.g. **-Drabbitmq.streamperfest.loggers=com.rabbitmq.stream=debug,com.rabbitmq.stream.perf=info**.

It is also possible to use an environment variable:

```
export RABBITMQ_STREAM_PERF_TEST_LOGGERS=com.rabbitmq.stream=debug
```

The system property takes precedence over the environment variable.

Use the environment variable with the Docker image:

```
docker run -it --rm --network host \  
  --env RABBITMQ_STREAM_PERF_TEST_LOGGERS=com.rabbitmq.stream=debug \  
  pivotalrabbitmq/stream-perf-test
```

## Building the Performance Tool

To build the uber JAR:

```
./mvnw clean package -Dmaven.test.skip -P performance-tool
```

Then run the tool:

```
java -jar target/stream-perf-test.jar
```