Advanced topics

1. Messaging systems

Intro

- Messaging provides a mechanism for loosely-coupled integration of systems
- The central unit of processing in a message is a message which typically contains a **body** and a **header**
- Use cases include:
    - Log aggregation between systems
    - Event propagation between systems - някакви събития се fire-ват
    - Offloading log-running tasks to worker nodes - the result of the task then to be sent to a third systems for example
- Messaging solutions implement different protocols for transferring of messages such as **AMQP** (binary protocol), XMPP, MQTT and many more like XML, JSON, etc.
- The variety of protocols implies vendor lock-in when using a particular messaging solution (also called a messaging broker) - ако е специфичен протокола лошо. Т.е. протокола е добре да е такъв, че да може да се използва от различни message broker systems

- Message brokers
    - ActiveMQ - using JMS (Java Messaging System) Java EE
    - RabbitMQ
    - Qpid
    - TIBCO
    - WebSphere MQ
    - Msmq

- Messaging solutions provide means for:
    - Securing message transfer, authenticating and authorizing messaging endpoints
    - Routing messages between endpoints
    - Subscribing to the broker

- An **enterprise service bus (ESB)** is one layer of abstraction above a messaging solution that further provides:
    - Adapters for different messaging protocols
    - Translation of messages between the different types of protocols

I. RabbitMQ

Info

- An open source message broker written in Erlang
    - Заема малко ранм памет и процесор
    - при Erlang няма context switching като при JVM
    - reliability - дете ако не се изпълни, то родителят му го пуска за изпълнение наново
- **Implements the AMQP protocol** (Advanced Message Queueing Protocol)
- Has a pluggable architecture and provides extension for other protocols such as HTTP, STOMP and MQTT

- AMQP is a binary protocol that aims to standardize middleware communication
- The AMQP protocol derives its origins form the financial industry - processing of large volumes of financial data between different systems is a classic use case of messaging
- The AMQP protocol defines:
    - **Exchanges** - the message broker endpoints that receive messages
    - **Queues** - the message broker endpoints that store messages from exchanges and are used by subscribers for retrieval of messages. The Queue can also be persistent - messages can be saved.
    - **Bindings** - rules that bind exchanges and queues
- The AMQP protocol is programmable - which means that the above entities can be created/ modified/ deleted by applications

- The AMQP protocol defines multiple connection channels inside a single TCP connection in order to remove the overhead of opening a large number of TCP connections to the message broker

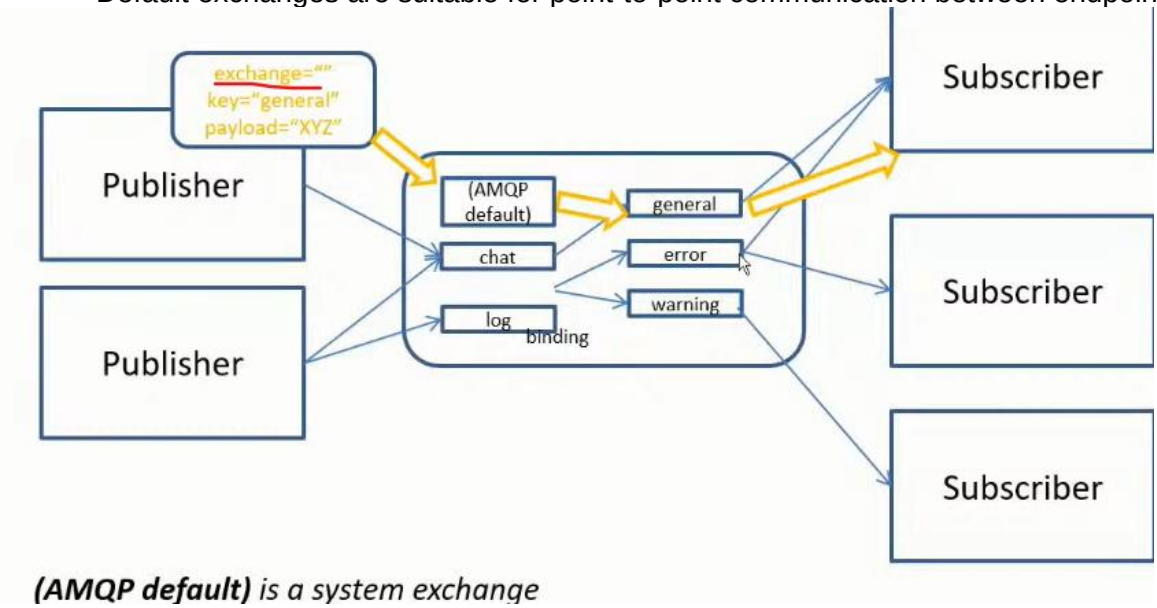
- Each message can be published with a **routing key**
- Each binding between an exchange and a queue has a **binding key**
- Routing of messages is determined based on matching between the **routing key** and the **binding key**

Messaging patterns with RabbitMQ

- Different types of messaging patterns are implemented by means of different types of exchanges
- RabbitMQ provides the following types of exchanges:
    - default - без име като търси съвпадение на **routing key** с **binding key**
    - direct - има име като търси съвпадение на **routing key** с **binding key**
    - fanout
    - topic
    - headers- на база мачинг по хедъри също

Default exchange

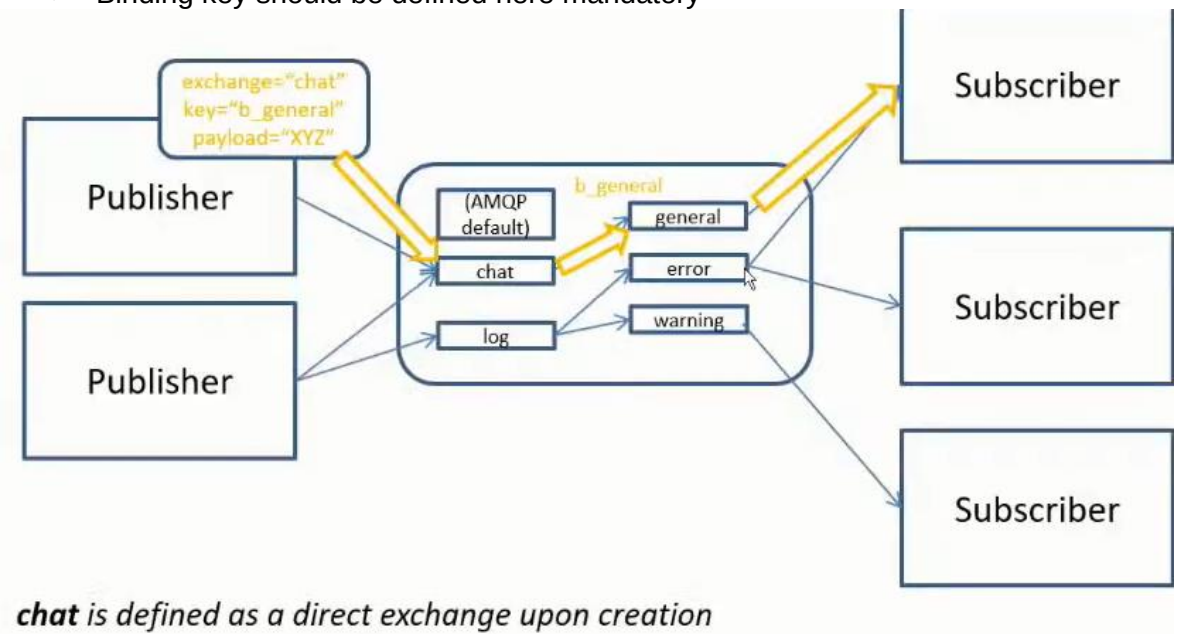
- A default exchange has **the empty string as a name** and routes messages to a queue if the routing key of the message matches the queue name (no binding needs to be declared between a default exchange and a queue)
- Default exchanges are suitable for point-to-point communication between endpoints



***(AMQP default)** is a system exchange*

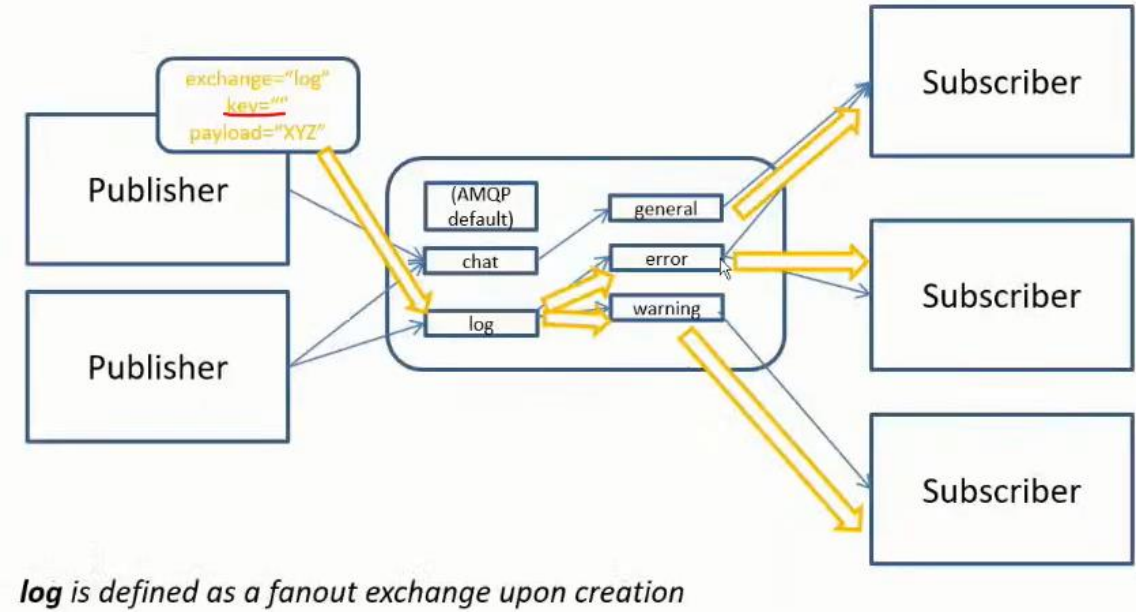
Direct exchange

- A direct exchange routes messages to a queue if the routing key of the message matches the binding key between the direct exchange and the queue
- Direct exchanges are suitable for point-to-point communication between endpoints
- Binding key should be defined here mandatory



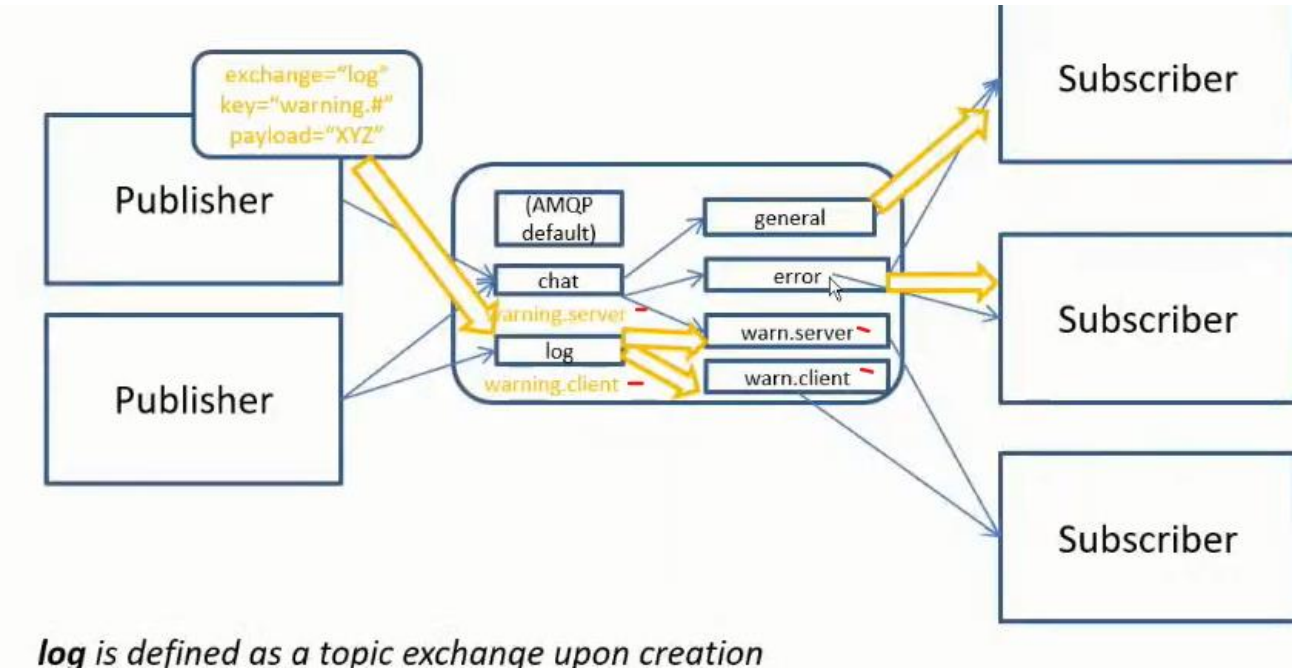
Fanout exchange

- A fanout exchange routes (broadcasts) messages to all queues that are bound to it (the binding key is not used)
- Fanout exchanges are suitable for publish-subscribe communication between endpoints



Topic exchange

- A topic exchange routes (multicasts) messages to all queues that have a binding key (can be a pattern) that matches the routing key of the message
- Topic exchanges are suitable for routing messages to different queues based on the type of message
- Диеса след *warning.* може да е всякаква дума

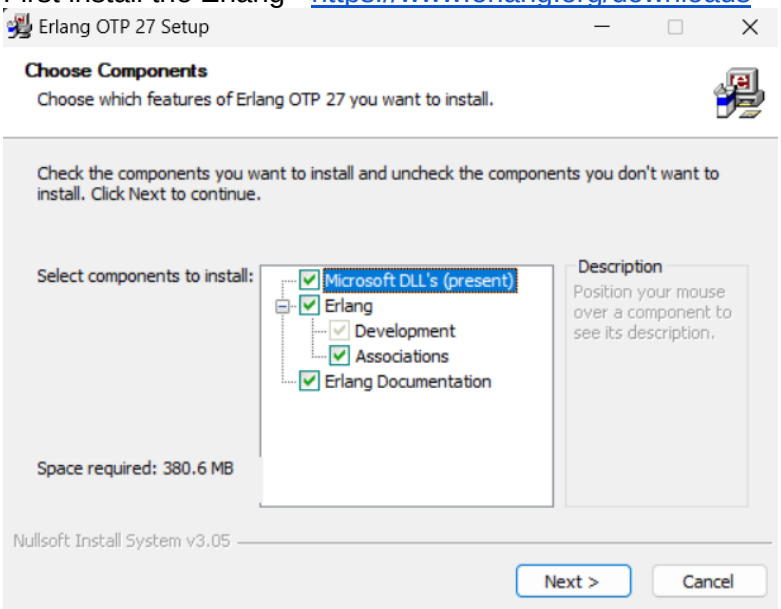


Headers exchange

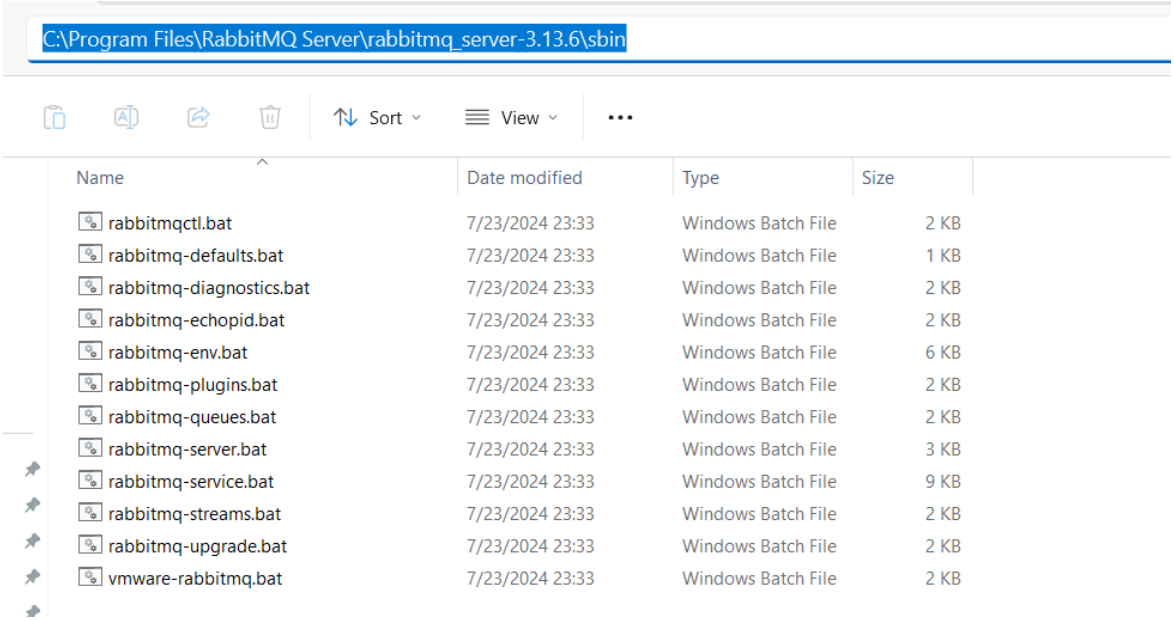
- A headers exchange routes messages based on a custom message header
- Header exchanges are suitable for routing messages to different queues based on more than one attribute

Installation of the RabbitMQ server

First install the Erlang - https://www.erlang.org/downloads



Then install the RabbitMQ server - https://www.rabbitmq.com/docs/download
rabbitmq-service.bat
rabbitmq-service.bat



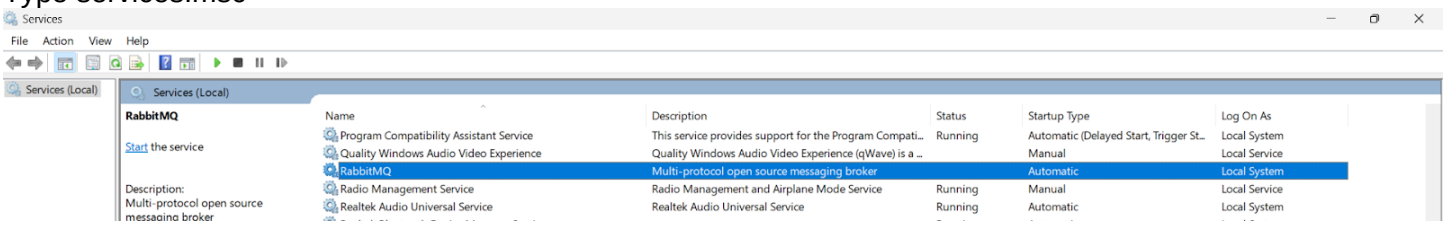
C:\Program Files\RabbitMQ Server\rabbitmq_server-3.13.6\sbin>**rabbitmq-plugins.bat enable** rabbitmq_management
Enabling plugins on node rabbit@SVILKATA:
rabbitmq_management
The following plugins have been configured:
  rabbitmq_management
  rabbitmq_management_agent
  rabbitmq_web_dispatch
Applying plugin configuration to rabbit@SVILKATA...
The following plugins have been enabled:
  rabbitmq_management
  rabbitmq_management_agent
  rabbitmq_web_dispatch

set 3 plugins.
Offline change; changes will take effect at broker restart.

През CommandPrompt като администратор:
C:\Program Files\RabbitMQ Server\rabbitmq_server-3.13.6\sbin>rabbitmq-plugins.bat list
Listing plugins with pattern ".*" ...
 Configured: E = explicitly enabled; e = implicitly enabled
 | Status: [failed to contact rabbit@SVILKATA - status not shown]
 |/
[ ] rabbitmq_amqp1_0 3.13.6
[ ] rabbitmq_auth_backend_cache 3.13.6
[ ] rabbitmq_auth_backend_http 3.13.6
[ ] rabbitmq_auth_backend_ldap 3.13.6
[ ] rabbitmq_auth_backend_oauth2 3.13.6
[ ] rabbitmq_auth_mechanism_ssl 3.13.6
[ ] rabbitmq_consistent_hash_exchange 3.13.6
[ ] rabbitmq_event_exchange 3.13.6
[ ] rabbitmq_federation 3.13.6
[ ] rabbitmq_federation_management 3.13.6
[ ] rabbitmq_jms_topic_exchange 3.13.6
[*] rabbitmq_management 3.13.6
[*] rabbitmq_management_agent 3.13.6
[ ] rabbitmq_mqtt 3.13.6

```
[  ] rabbitmq_peer_discovery_aws     3.13.6
[  ] rabbitmq_peer_discovery_common        3.13.6
[  ] rabbitmq_peer_discovery_consul 3.13.6
[  ] rabbitmq_peer_discovery_etcd    3.13.6
[  ] rabbitmq_peer_discovery_k8s     3.13.6
[  ] rabbitmq_prometheus             3.13.6
[  ] rabbitmq_random_exchange        3.13.6
[  ] rabbitmq_recent_history_exchange  3.13.6
[  ] rabbitmq_sharding               3.13.6
[  ] rabbitmq_shovel            3.13.6
[  ] rabbitmq_shovel_management      3.13.6
[  ] rabbitmq_stomp             3.13.6
[  ] rabbitmq_stream            3.13.6
[  ] rabbitmq_stream_management            3.13.6
[  ] rabbitmq_top               3.13.6
[  ] rabbitmq_tracing           3.13.6
[  ] rabbitmq_trust_store            3.13.6
[*] rabbitmq_web_dispatch            3.13.6
[  ] rabbitmq_web_mqtt               3.13.6
[  ] rabbitmq_web_mqtt_examples      3.13.6
[  ] rabbitmq_web_stomp              3.13.6
[  ] rabbitmq_web_stomp_examples           3.13.6
```

Type services.msc

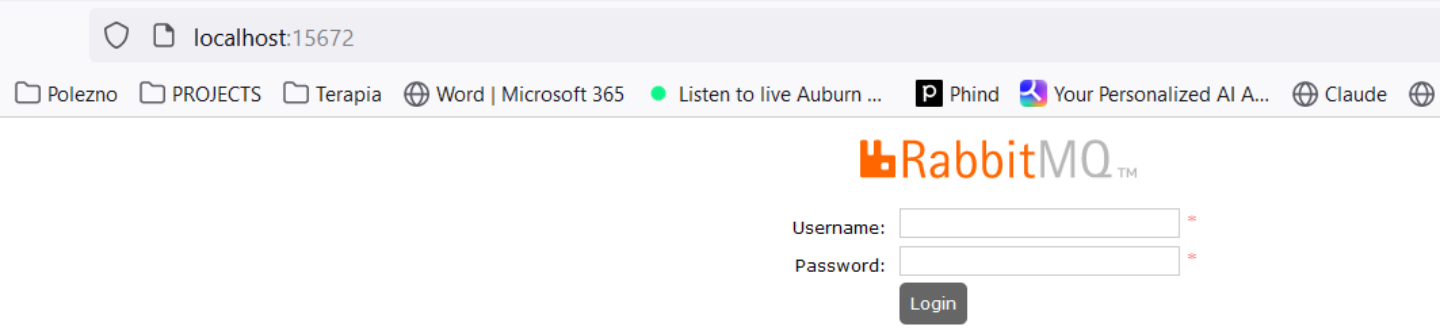



```
C:\Program Files\RabbitMQ Server\rabbitmq_server-3.13.6\sbin>rabbitmq-server.bat
2024-07-31 11:52:47.571000+03:00 [warning] <0.134.0> Using RABBITMQ_ADVANCED_CONFIG_FILE:
c:/Users/svilk/AppData/Roaming/RabbitMQ/advanced.config
2024-07-31 11:52:52.145000+03:00 [notice] <0.45.0> Application syslog exited with reason: stopped
2024-07-31 11:52:52.145000+03:00 [notice] <0.213.0> Logging: switching to configured handler(s); following
messages may not be visible in this log output

  ##  ##      RabbitMQ 3.13.6
  ##  ##
  ##########  Copyright (c) 2007-2024 Broadcom Inc and/or its subsidiaries
  ######  ##
  ##########  Licensed under the MPL 2.0. Website: https://rabbitmq.com

  Erlang:      27.0.1 [jit]
  TLS Library: OpenSSL - OpenSSL 3.1.0 14 Mar 2023
  Release series support status: see https://www.rabbitmq.com/release-information

  Doc guides:  https://www.rabbitmq.com/docs
  Support:     https://www.rabbitmq.com/docs/contact
  Tutorials:   https://www.rabbitmq.com/tutorials
  Monitoring:  https://www.rabbitmq.com/docs/monitoring
  Upgrading:   https://www.rabbitmq.com/docs/upgrade

  Logs: <stdout>
```

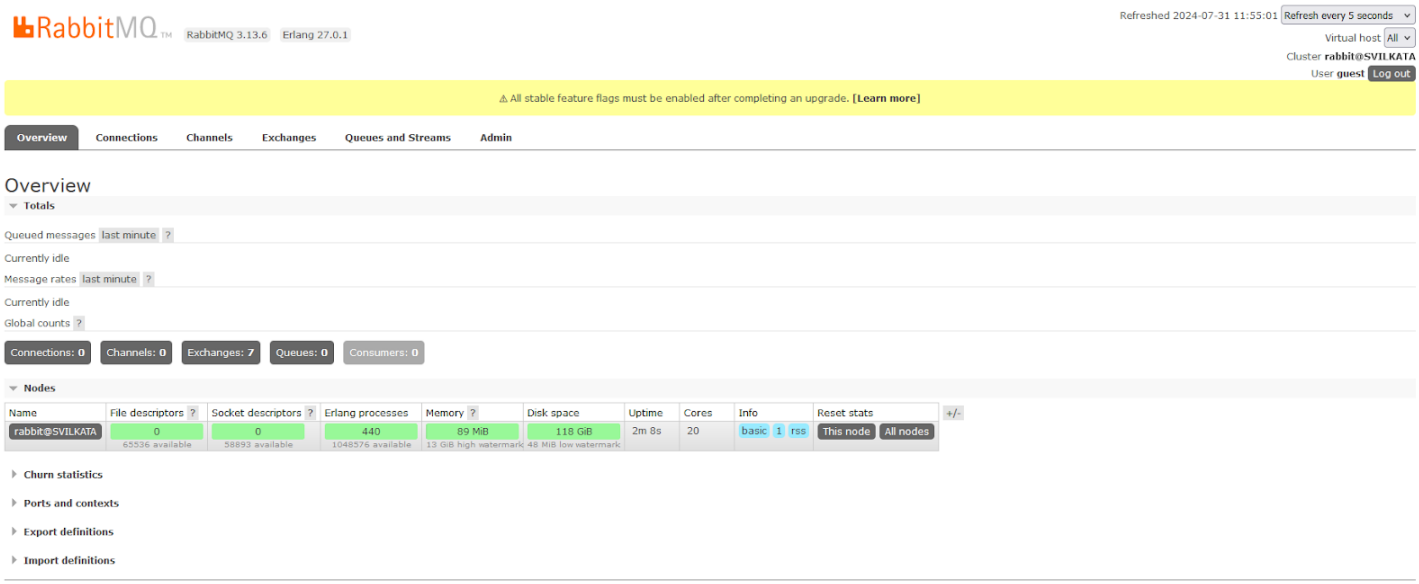
c:/Users/svilk/AppData/Roaming/RabbitMQ/log/rabbit@SVILKATA.log

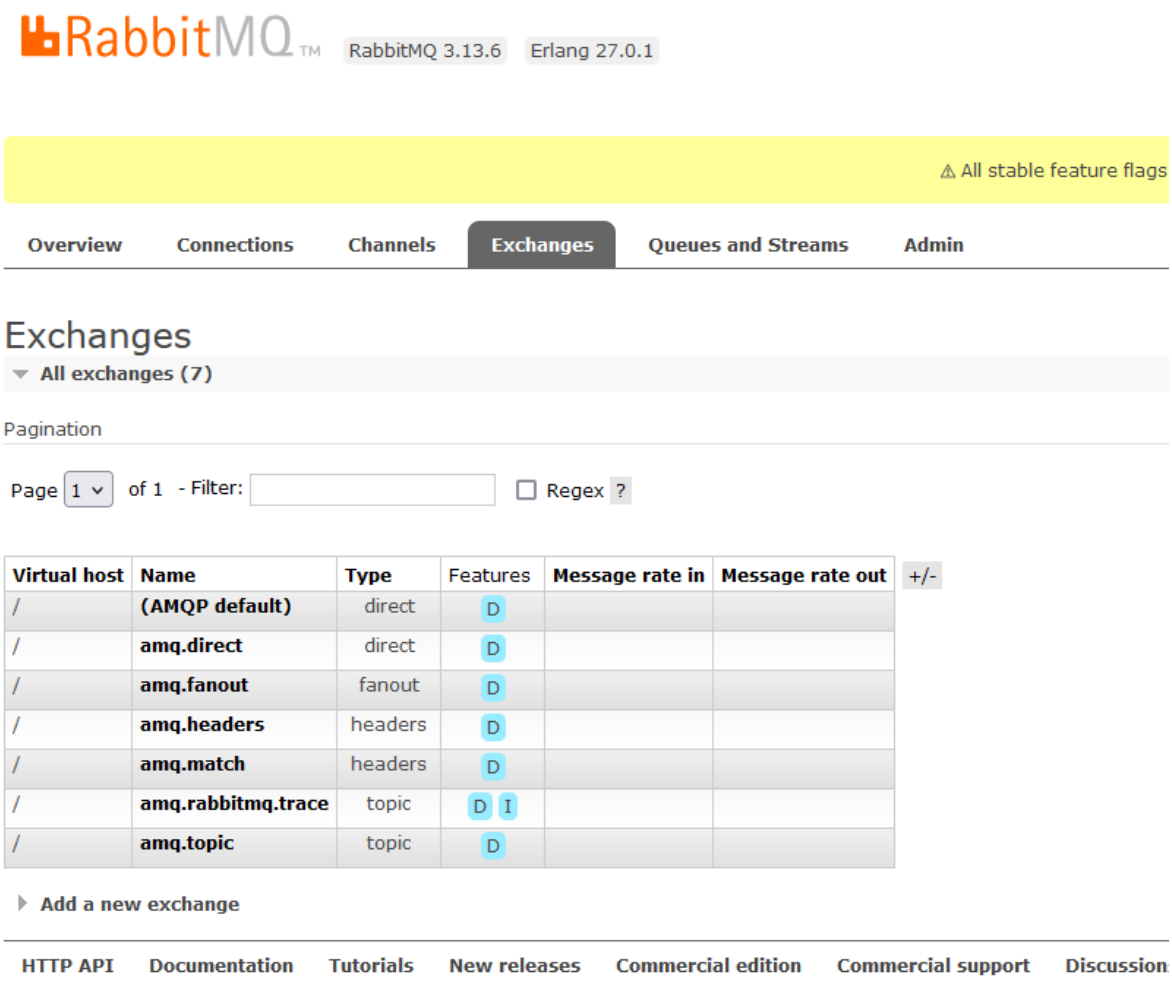
Config file(s): c:/Users/svilk/AppData/Roaming/RabbitMQ/advanced.config

Starting broker... **completed with 3 plugins.**



username: guest
password: guest

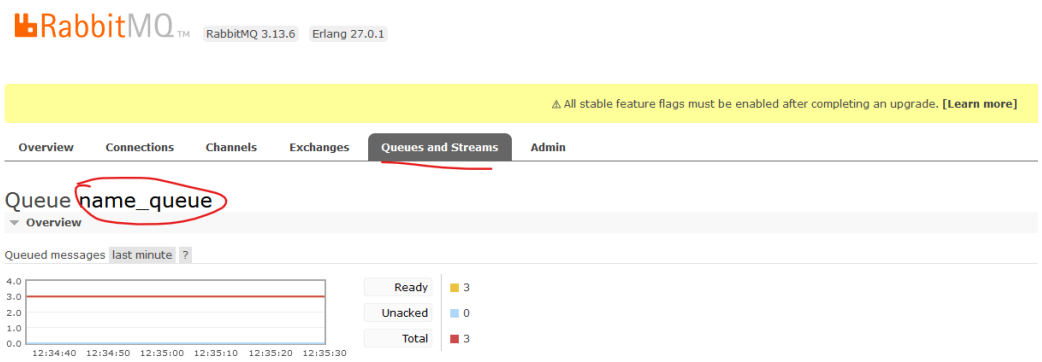




Using the Java Client

```
<dependency>
 <groupId>com.rabbitmq</groupId>
 <artifactId>amqp-client</artifactId>
 <version>5.20.0</version>
</dependency>

import com.rabbitmq.client.Channel;
import com.rabbitmq.client.Connection;
import com.rabbitmq.client.ConnectionFactory;

import java.io.IOException;
import java.nio.charset.StandardCharsets;
import java.util.concurrent.TimeoutException;

public class Publisher {
   public static void main(String[] args) throws IOException, TimeoutException {
       Connection connection = null;
       Channel channel = null;

       try {
           ConnectionFactory connectionFactory = new ConnectionFactory();
           connectionFactory.setHost("localhost"); //by default on port 15672
           connection = connectionFactory.newConnection();
           channel = connection.createChannel();
```

```
            channel.exchangeDeclare("name_exchange", "direct"); //created only once on
the RabbitMQ server
            channel.queueDeclare("name_queue", false, false, false, null); //created
only once on the RabbitMQ server
            channel.queueBind("name_queue", "name_exchange", "routing_key_test");

            channel.basicPublish("name_exchange", "routing_key_test", null,
                    "Hello RabbitMQ from Java
client".getBytes(StandardCharsets.UTF_8));
        } finally {
            if (channel != null) {
                channel.close();
            }
            if (connection != null) {
                connection.close();
            }
        }
    }
}
```



RabbitMQ™ RabbitMQ 3.13.6 Erlang 27.0.1

⚠ All stable feature flags must be e

Overview | Connections | Channels | Exchanges | Queues and Streams | Admin

Bindings (2)

Publish message

Get messages

Warning: getting messages from a queue is a destructive action. ?

Ack Mode: Nack message requeue true

Encoding: Auto string / base64 ?

Messages: 10

Get Message(s)

Message 1

The server reported 2 messages remaining.

Exchange	name_exchange
Routing Key	routing_key_test
Redelivered	•
Properties	
Payload 31 bytes Encoding: string	Hello RabbitMQ from Java client

Message 2

The server reported 1 messages remaining.

Exchange	name_exchange
Routing Key	routing_key_test
Redelivered	○
Properties	
Payload 31 bytes Encoding: string	Hello RabbitMQ from Java client

Message 3

```java
import com.rabbitmq.client.AMQP;
import com.rabbitmq.client.Channel;
import com.rabbitmq.client.Connection;
import com.rabbitmq.client.ConnectionFactory;
import com.rabbitmq.client.DefaultConsumer;
import com.rabbitmq.client.Envelope;

import java.io.IOException;
import java.util.concurrent.TimeoutException;

public class Subscriber {
   public static void main(String[] args) throws IOException, TimeoutException,
InterruptedException {
       Connection connection = null;
       Channel channel = null;

       try {
           ConnectionFactory connectionFactory = new ConnectionFactory();
           connectionFactory.setHost("localhost"); //by default on port 15672
           connection = connectionFactory.newConnection();
           channel = connection.createChannel();
```

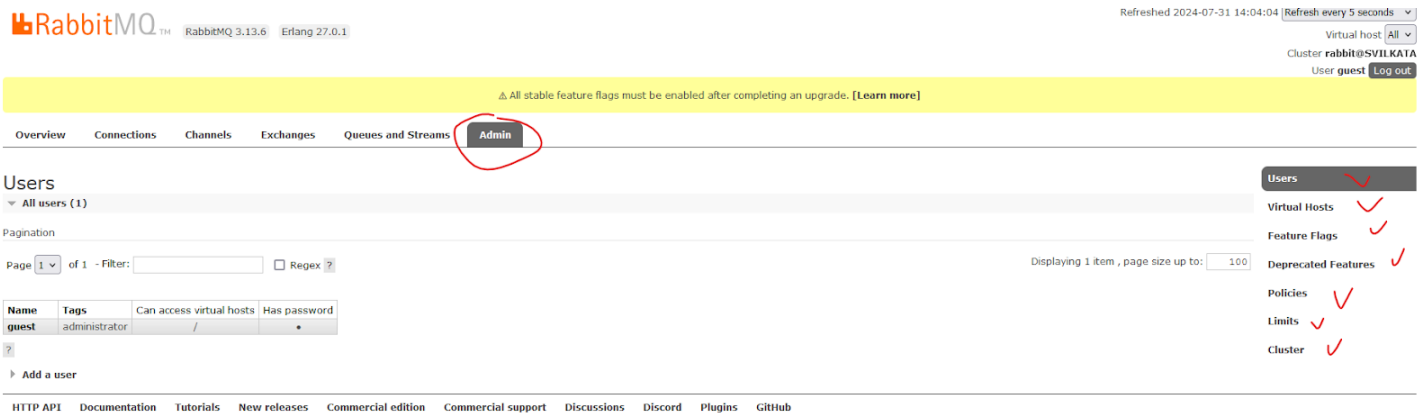
```
            channel.exchangeDeclare("name_exchange", "direct"); //created only once on
the RabbitMQ server
            channel.queueDeclare("name_queue", false, false, false, null); //created
only once on the RabbitMQ server
            channel.queueBind("name_queue", "name_exchange", "routing_key_test");

            while (true) {
                channel.basicConsume("name_queue", true, new DefaultConsumer(channel)
{
                    @Override
                    public void handleDelivery(String consumerTag, Envelope envelope,
AMQP.BasicProperties properties, byte[] body) throws IOException {
                        // super.handleDelivery(consumerTag, envelope, properties,
body);  no-op no work to do
                        System.out.println(new String(body));
                    }
                });

                Thread.sleep(3000);
            }
        } finally {
            if (channel != null) {
                channel.close();
            }
            if (connection != null) {
                connection.close();
            }
        }
    }
}
```

Administration

- Administration of the broker includes a number of activities such as:
  - Updating the broker
  - Backing up the broker database
  - installing/uninstalling and configuring plug-ins
  - Configuring the various components of the broker

- Apart from queues, exchanges and bindings we can also manage the following types of components:
  - vhosts (virtual hosts) - for logical separation of broker components
  - users
  - Parameters - defining upstream links to another brokers
  - Policies - for queue mirroring

- Administration of single instance or an entire cluster can be performed in several ways:
  - Using the management Web interface



- Using the management HTTP API - rest API
- Using the **rabbitmq-admin.py / rabbitmqadmin.py** script - written on Python
- Using the **rabbitmqctl** utility

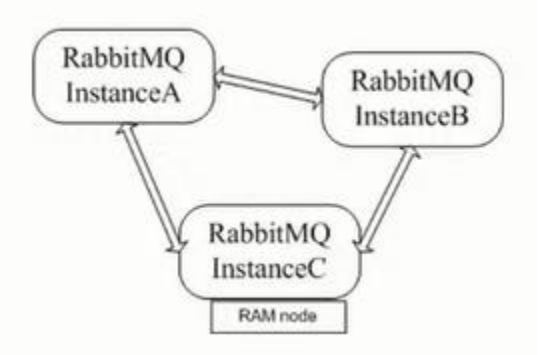
Scalability and High Availability in RabbitMQ

Basic default configuration

- RabbitMQ provides clustering support that allows new RabbitMQ nodes to be added on the fly
- Clustering by default does not guarantee that message loss may or may not occur - ако дадена инстанция примерно падне

- Nodes in a RabbitMQ cluster can be:
  - DISK - data is persisted in the node database
  - RAM - data is buffered only in-memory - когато не е критично да се запазват данните след рестарт например
- **Nodes share only broker metadata - messages are not replicated among nodes!! - съобщението не се репликира в останалите node-ве**

Example:
A и B са DISK nodes, а C е Ram node.



Instance A node DISK

```
set RABBITMQ_NODENAME=instanceA &
set RABBITMQ_NODE_PORT=5770 &
set RABBITMQ_SERVER_START_ARGS=
      -rabbitmq_management listener [{port,33333}] &
rabbitmq-server.bat -detached
```

Instance B node DISK

Пускаме инстанция B, спираме я, присъединяваме я след това

```
set RABBITMQ_NODENAME=instanceB &
set RABBITMQ_NODE_PORT=5771 &
rabbitmq-server.bat -detached
rabbitmqctl.bat -n instanceB stop_app
rabbitmqctl.bat -n instanceB join_cluster instanceA@MARTIN
rabbitmqctl.bat -n instanceB start_app
```

Instance C node RAM

Пускаме инстанция C, спираме я, присъединяваме я след това

```
set RABBITMQ_NODENAME=instanceC &
set RABBITMQ_NODE_PORT=5772 &
rabbitmq-server.bat -detached
rabbitmqctl.bat -n instanceC stop_app
rabbitmqctl.bat -n instanceC join_cluster -ram instanceA@MARTIN
rabbitmqctl.bat -n instanceC start_app
```

- If a node that hosts a queue buffers unprocessed messages goes down, then messages are lost
- Default clustering mechanism provides scalability in terms of queues rather than high availability

Mirrored queues

- **Mirrored queues** are an extension to the default clustering mechanism that can be used to establish **high availability** at the broker level
- Mirrored queues provide queue replication over different nodes that allows a message to survive node failure
- Queue mirroring is establishing by means of a mirroring policy that specifies:
  - Number of nodes to use for queue replication
  - Particular nodes designated by name for queue replication
  - All nodes for queue replication

- The node where the queue is created is the master node - all other nodes are slaves
- A new master node can be promoted in case the original one goes down
- A slave node is promoted to/as the new master in case it is fully synchronized with the old master

Example:

Let's define the test queue in the cluster and mirror it over all other nodes:

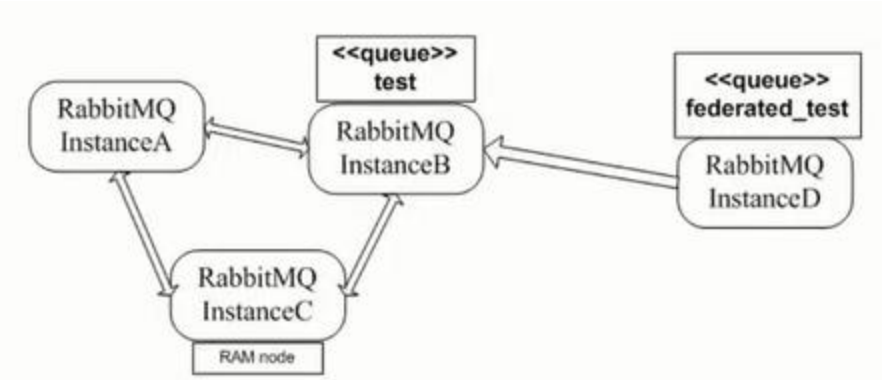
```
rabbitmqadmin.py -N instanceA declare queue name=test
durable=false
rabbitmqctl -n instanceA set_policy ha-all "test" "{""ha-
mode"":""all""}"
```

Federation and Shovel plugins

- The RabbitMQ clustering mechanism uses Erlang message passing along with a message cookie in order to establish communication between the nodes…….. which is **not reliable** over the Wide Area Networks!!
- In order to establish high availability among nodes in different geographic locations you can use the **federation, federation_management** and **shovel** plug-ins
- The shovel plug-in works at a lower level than the federation plug-in

Federation

- Ако искаме да репликираме опашката на отдалечена инстанция D:




```
set RABBITMQ_NODENAME=instanceD &
set RABBITMQ_NODE_PORT=6001 &
set RABBITMQ_SERVER_START_ARGS=
       -rabbitmq_management listener [{port,44444}] &
rabbitmq-server.bat -detached

rabbitmq-plugins -n instanceD enable rabbitmq_federation
rabbitmq-plugins -n instanceD enable
rabbitmq_federation_management
```

- Declare the **federated_test** queue

```
rabbitmqadmin.py -N instanceD -P 44444 declare queue
name=federated_test durable=false
```

Declare the upstream to the initial cluster and set a federation link to the **test** queue:

```
rabbitmqctl -n instanceD set_parameter federation-upstream
upstream
"{""uri"":""amqp://localhost:5770"","""expires"":3600000,
""queue"":""test""}"

rabbitmqctl -n instanceD set_policy federate-queue
--apply-to queues "federated_test"
"{""federation-upstream"":""upstream""}"
```

Shovel

The shovel plug-in provides two variants:

- **static** - all links between the source/destination nodes/clusters are defined statically in the RabbitMQ configuration file
- **dynamic** - all links between the source/destination nodes/clusters are defined dynamically via the RabbitMQ parameters

destination / source	exchange	queue
exchange	federation dynamic shovel	dynamic shovel
queue	static shovel dynamic shovel	federation dynamic shovel

Integrations

Info

- RabbitMQ provides integrations with other protocols such as STOMP, MQTT and LDAP by means of RabbitMQ plug-ins
- Using the Java Client - already discussed above
- The Spring framework provides integration with AMQP protocol and RabbitMQ in particular
- The **Spring AMQP framework** provides:
    - **RabbitAdmin** class for automatically declaring queues, exchanges and bindings
    - **Listener container** for asynchronous processing of inbound messages
    - **RabbitTemplate** class for sending and receiving messages

- Utilities of the Spring AMQP framework can be used directly in Java or preconfigured in the Spring configuration
- The **Spring Integration framework** to **Spring Boot** provides adapters for the AMQP protocol

- Integration with Quarkus framework

Spring AMQP framework

```
<dependencies>
    <dependency>
        <groupId>org.springframework.amqp</groupId>
        <artifactId>spring-rabbit</artifactId>
        <version>1.4.5.RELEASE</version>
    </dependency>
</dependencies>
```

The **RabbitAdmin** class:

```
CachingConnectionFactory factory = new
       CachingConnectionFactory("localhost");
RabbitAdmin admin = new RabbitAdmin(factory);
Queue queue = new Queue("sample-queue");
admin.declareQueue(queue);
TopicExchange exchange = new TopicExchange("sample-topic-
       exchange");
admin.declareExchange(exchange);
admin.declareBinding(BindingBuilder.bind(queue).to(exchange)
       .with("sample-key"));
factory.destroy();
```

Listener container

```
CachingConnectionFactory factory =
       new CachingConnectionFactory(
"localhost");
SimpleMessageListenerContainer container = new
SimpleMessageListenerContainer(
       factory);
Object listener = new Object() {
    public void handleMessage(String message) {
    System.out.println("Message received: " +
    message);
}};
MessageListenerAdapter adapter = new
       MessageListenerAdapter(listener);
container.setMessageListener(adapter);
container.setQueueNames("sample-queue");
container.start();
```

The **RabbitTemplate** class:

```
CachingConnectionFactory factory =
       new CachingConnectionFactory("localhost");
RabbitTemplate template = new
RabbitTemplate(factory);
template.convertAndSend("", "sample-queue",
        "sample-queue test message!");
```

- All of the above Spring AMQP framework examples can be configured using the Spring configuration - so that to be cleaner and to decouple RabbitMQ configuration from the business logic/Java code

For example within a **configuration.xml** file:

```
7 public class RabbitAdminSpringExample {
8
9     public static void main(String[] args) {
10
11         AbstractApplicationContext context = new ClassPathXmlApplicationContext(
12                 "configuration.xml");
13         RabbitAdmin admin = context.getBean(RabbitAdmin.class);
14     }
15
16 }
```

```
http://www.springframework.org/schema/beans/spring-beans.xsd (xsi:schemaLocation)
1 <beans xmlns="http://www.springframework.org/schema/beans"
2     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:rabbit="http://ww
3     xsi:schemaLocation="http://www.springframework.org/schema/rabbit
4             http://www.springframework.org/schema/rabbit/spring-rabbit.xsd
5             http://www.springframework.org/schema/beans
6             http://www.springframework.org/schema/beans/spring-beans.xsd">
7
8     <rabbit:connection-factory id="connectionFactory" host="localhost" />
9
10    <rabbit:template id="amqpTemplate" connection-factory="connectionFactory"
11        exchange="" routing-key="sample-queue-spring"/>
12    <rabbit:admin connection-factory="connectionFactory" />
13
14    <rabbit:queue name="sample-queue-spring" />
```

Spring Boot Starter AMQP - Spring Integration framework

In gradle

Implementation ‘org.springframework.boot:**spring-boot-starter-amqp**’

Предоставя ни бийнове за **RabbitAdmin** class, **Listener container** and **RabbitTemplate** class.

Посредством дефиниране на бийнове - можем да си декларираме **exchange, queue** или **queueBinding**

```
10 @Component
11 public class EventingServiceImpl implements EventingService {
12
13     private final RabbitTemplate template;
14
15     public EventingServiceImpl(RabbitTemplate template) {
16         this.template = template;
17     }
18
19     @Bean
20     public Queue createExchangeQueue() {
21         return new Queue("exchange_rate_queue");
4     @Override
5     public void publish(String message) {
6         template.convertAndSend("exchange_rate_queue", message);
7     }
8
9 }
```

Quarkus framework

```
<dependency>
 <groupId>io.quarkus</groupId>
 <artifactId>quarkus-smallrye-reactive-messaging-rabbitmq</artifactId>
</dependency>
```

In application.properties file

```
mp.messaging.outgoing.bi.use-ssl=true
mp.messaging.outgoing.bi.connector=smallrye-rabbitmq
mp.messaging.outgoing.bi.exchange.type=direct
mp.messaging.outgoing.bi.port=5672

import io.smallrye.reactive.messaging.rabbitmq.OutgoingRabbitMQMetadata;

@Inject
@Channel("asd")  //from Microprofile
Emitter<String> emitter;  //from Microprofile

public void emmitMessage(RabbitMqPayload payload) {
   String messagePayload = JsonUtils.toJsonString(List.of(payload));
   LOGGER.debugf("Emitting Bi message to RabbitMQ %s", messagePayload);
   OutgoingRabbitMQMetadata metadata = new OutgoingRabbitMQMetadata.Builder()
           .withRoutingKey(payload.routingKey())
           .build();

   Message<String> message = Message.of(messagePayload, Metadata.of(metadata));
   biEmitter.send(message); //from Microprofile
   LOGGER.infof("Bi message emitted to route %s", payload.routingKey());
}
```

Security

- RabbitMQ uses SASL Simple Authentication Security Layer for authentication (SASL PLAIN used by default)
- RabbitMQ uses access control lists (permissions) for authorization
- SSL/TLS support can be enabled for the AMQP communication channels
- SSL/TLS support can be enabled for node communication between nodes in a cluster
- SSL/TLS support can be enabled for the federation and shovel plug-ins

II. Apache Kafka