# Pivotal RabbitMQ

## 3 Day Course

Version 3.6.1b

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# Pivotal RabbitMQ Course Introduction

Objectives and Prerequisites

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## Logistics

- Participants list / registration
- Courseware / Internet access
- Working hours
- Lunch and breaks
- Toilets / Fire alarms / Emergency exits
- Other questions?
- Introductions

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## Course Objectives

- After this class, you should be able to do the following:
  - Describe messaging and asynchronous systems.
  - Describe AMQP (Advanced Message Queuing Protocol).
  - Install and administer RabbitMQ.
  - Access RabbitMQ from applications, using the Java binding to send and consume messages.
  - Describe reliable messaging development by using RabbitMQ APIs.
  - Describe RabbitMQ cluster and high availability.
  - Describe RabbitMQ's performance and security.

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## Course Introduction

- Course designed for Windows and Linux
  - 50% theory
  - 50% labs
- Memory keys:
  - Lab materials and documentation

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## Course Prerequisites

- Basic knowledge of core Java
- Working knowledge in Spring Tool Suite (STS) / Eclipse
- This is not an advanced course – no knowledge of RabbitMQ or AMQP is expected

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## Course Outline – Day 1

| Module | Description |
|---|---|
| Introduction to Messaging and AMQP | Advantages of messaging in IT systems, overview of the AMQP model. |
| RabbitMQ Installation | The RabbitMQ project and its main features, how to install and setup an instance, main configuration settings, plugin mechanism. Lab. |
| Development and Integration | Accessing RabbitMQ from applications, using the Java client to send and consume messages. Lab. |

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# Course Outline – Day 2

| Module | Description |
|---|---|
| Reliable Messaging Development | What can go wrong in messaging applications, how to safely send and receive messages using persistence, transactions, and acknowledgments. Lab. |
| Clustering | Understanding RabbitMQ clustering, setting up a cluster, load balancing, network partition handling strategies. Lab. |
| High Availability | Node failures, mirrored queues, slaves synchronization, failover handling for the client. Lab. |

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# Course Outline – Day 3

| Module | Description |
|---|---|
| Plugins | Federation and shovel, using LDAP for authentication, the STOMP plugin. |
| Performance | Factors that impact performance, flow control, message paging, best practices. Lab. |
| Spring AMQP | Using Spring AMQP for application development. Lab. |
| Security | Virtual hosts, securing communications between client and broker, protecting exchanges and queues. Lab. |
| Operations and Monitoring | Production settings and tuning.<br>Tips and techniques to monitor your RabbitMQ cluster. |

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# Let’s Get Started!


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# Introduction to Messaging and AMQP

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## Agenda

- **Messaging and Asynchronous Systems**
- Why JMS isn't enough
- Introduction to AMQP
- RabbitMQ case studies

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# What is Messaging?

- Messaging is a way to make applications / systems communicate
- Messaging is sometimes called an "integration style"
- Messaging eases decoupling between applications
  - Applications can evolve independently.
- Messaging is often referred to as "Message Oriented Middleware" (MoM)
- Messaging server typically called a *broker*
  - Broker ensures reliable dispatching of messages

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# What is a Message?

- Messages consist of a payload and multiple headers
- Payload is the actual content to exchange
  - Can be a string, a byte array (binary serialized object)
  - Often serialized with data exchange format (JSON, XML)
- Headers are metadata
  - Key/value pairs
  - Can be technology-specific or custom
  - E.g., routing (where to go, whom to answer to, etc.) ...
- Messaging technologies usually come with their subtleties
  - An AMQP message can have several kinds of metadata (header, properties, delivery annotations), a body, and even a footer!

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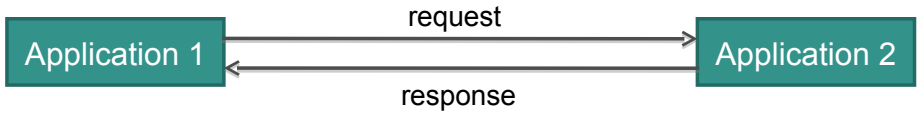
# Synchronous vs. Asynchronous

- When an application wants to talk to another application, it can send a message to it …
  - Synchronously




  - Asynchronously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# Synchronous vs. Asynchronous

- Real-world comparison:
  - Synchronous = phone
  - Asynchronous = SMS

**NOTE** Asynchronous messaging decouples the senders and receivers, more than synchronous remote method calls.

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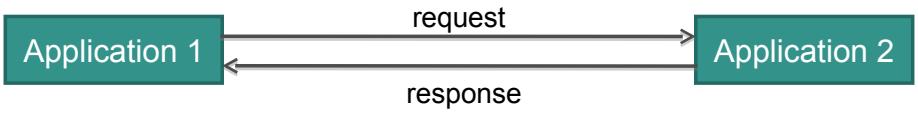
# Synchronous Messaging




- Sending application must know about receiving application
  - Host, port, protocol, endpoint
- Sending application is blocked until receiving application answers
- What happens if the receiving application doesn't respond?
  - Wait?
  - Crash?
- HTTP is an example of synchronous messaging

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# Asynchronous Messaging


- Sending application knows only about the broker
- Sending application can "fire and forget" if it doesn't need a response
  - Request / reply also supported
- Receiving application consumes messages whenever it wants
  - Constant polling, notification, batch de-queuing
  - It consumes messages rather than receives them
- JMS and AMQP are examples of asynchronous messaging

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# Decoupling

- The broker decouples the sender and the receiver…
  - Spatially
    - They don't need to be co-located
  - Temporally
    - No need of immediate responses
    - Processing can happen in the background
    - Receiver doesn't have to be up when message is sent
  - Logically
    - Sender and receiver don't know about each other
    - Broker can use advanced routing

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# Use Cases

- Simple producer – consumer
  - Send message for further processing
  - E.g., a web app places an order for further processing
- Request / reply
  - Send message and wait for response
  - E.g., to throttle or scale processing on the consumer side
- Publish / subscribe
  - Send message for multiple consumption
  - E.g., order sent to inventory and billing systems

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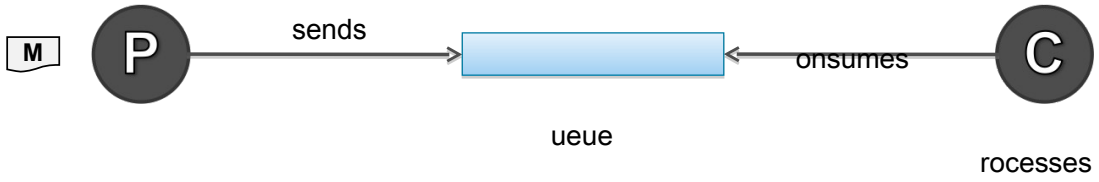
# Simple Producer - Consumer

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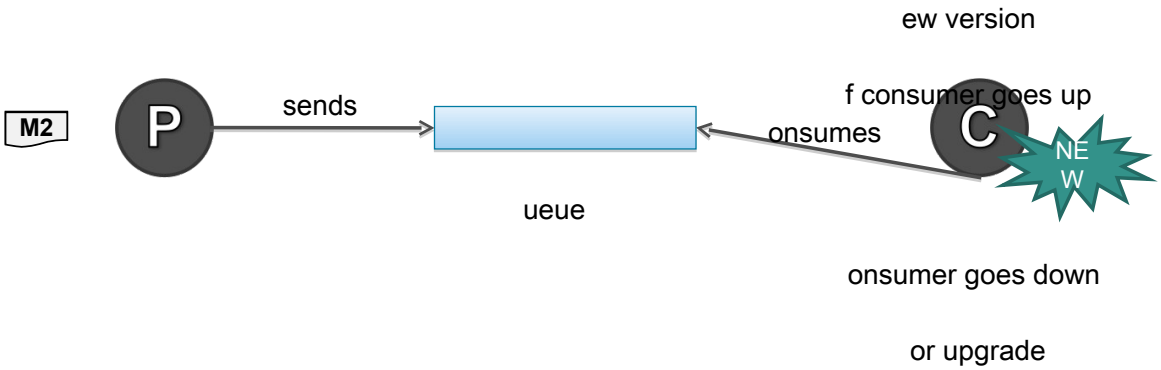
# Simple Producer – Consumer

## Temporal Decoupling

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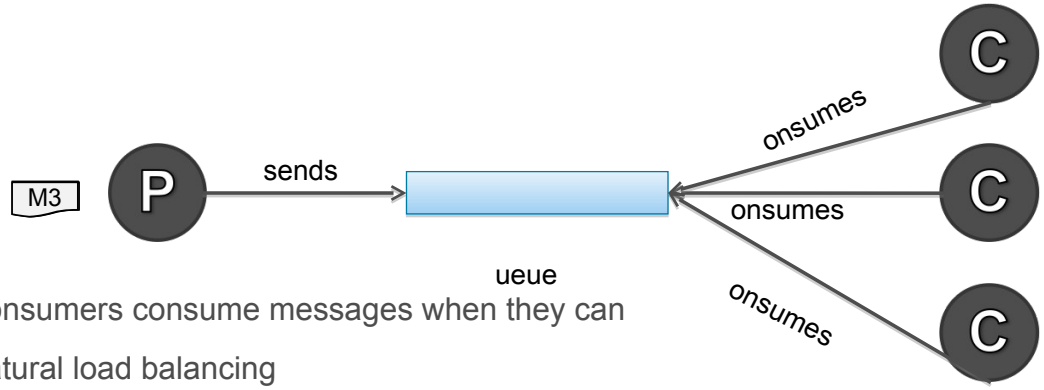
# Simple Producer – Multiple Consumers




- Consumers consume messages when they can
- Natural load balancing

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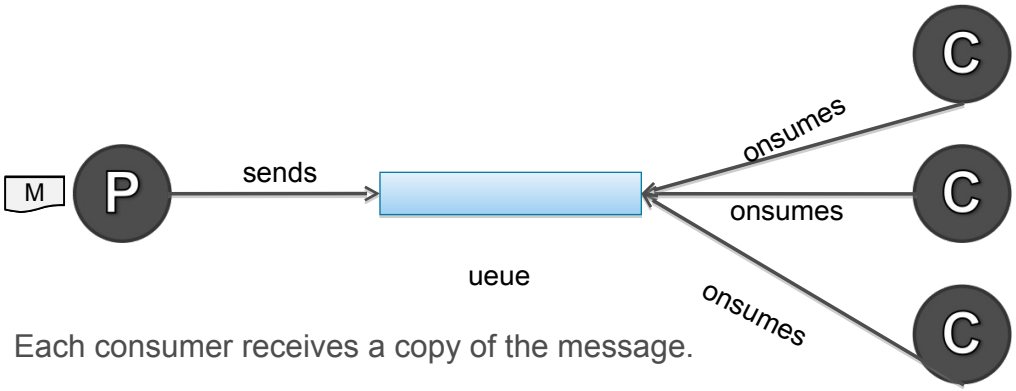
# Publish / Subscribe




- Each consumer receives a copy of the message.

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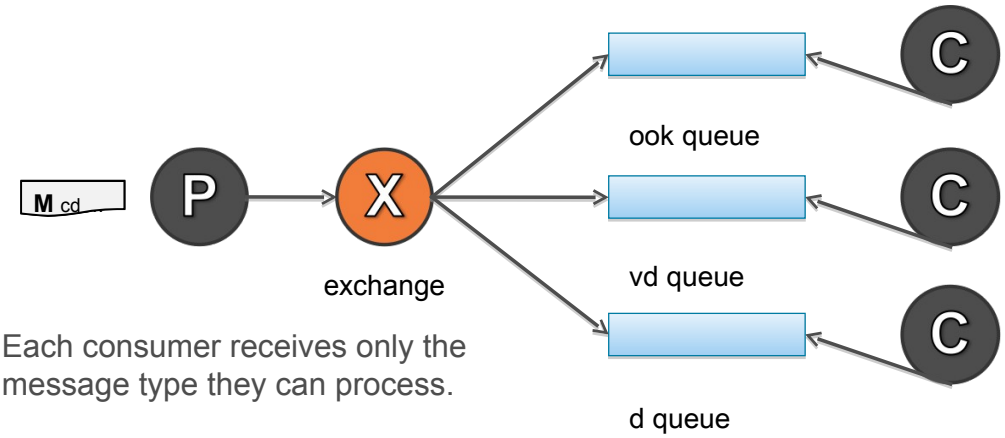
# Routing




- Each consumer receives only the message type they can process.

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# Pros and Cons of Messaging

- Pros
  - Scalability
  - Loose coupling
- Cons
  - Complexity
  - Broker can be a single point of failure

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## Messaging in the Cloud

- Asynchronous messaging is an ideal integration tool for cloud deployments
  - Elastic
  - Scalable
  - Robust
  - Decoupled
- RabbitMQ is the preferred mechanism for integrating Pivotal Cloud Foundry applications



Cloud
AMQP

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## Agenda

- Messaging and Asynchronous Systems
- **Why JMS isn't enough**
- Introduction to AMQP
- RabbitMQ case studies

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## JMS

- JMS stands for Java Message Service
- JMS is part of Java Enterprise Edition
- JMS is a Java API.
- JMS solves the vendor lock-in for Java apps
- JMS supports
  - persistent messages
  - reliable messaging
  - distributed transactions (through JTA and XA)
- JMS doesn't provide advanced routing rules
  - One can use selectors on a destination

**NOTE** JMS doesn't standardize the network communication, brokers do whatever they want on the wire.

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## Why JMS Isn't Enough

- JMS = Java Message Service
- Everything is in the name: Java
- Sender and receiver become coupled through the language
- Limitation is manageable in one enterprise system
- Limits interoperability between different companies' systems

**NOTE** Support for other languages/platforms is broker specific.

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## Giving Up On JMS?

- JMS is a mature, stable, and reliable standard
- JMS is Java specific
- AMQP is standardized at the protocol level ...
- ... and AMQP broker usually provides JMS bridges!
  - Can help upgrade to AMQP by keeping the same application code

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## Agenda

- Messaging and Asynchronous Systems
- Why JMS isn't enough
- **Introduction to AMQP**
- RabbitMQ case studies

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# AMQP

- AMQP stands for Advanced Message Queuing Protocol
- AMQP
  - Aims to provide an open standard for messaging
  - Enables complete interoperability for messaging middleware
  - Defines the network protocol and the semantics of broker services
- AMQP is open, interoperable, and platform agnostic

**NOTE** AMQP is an application protocol, like HTTP and SMTP.

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# History of AMQP

- Development started in 2004 by JP Morgan and iMatix
- AMQP Working Group was born when other companies joined the effort
  - See members at http://www.amqp.org/about/members
- Specification version 1.0 final in October 2011
  - Downloadable at http://www.amqp.org/resources/download
- AMQP originated in the finance industry …
- … but it addresses a large range of middleware problems

**NOTE** This training focuses on AMQP 0.9.1, the most popular and widespread version.

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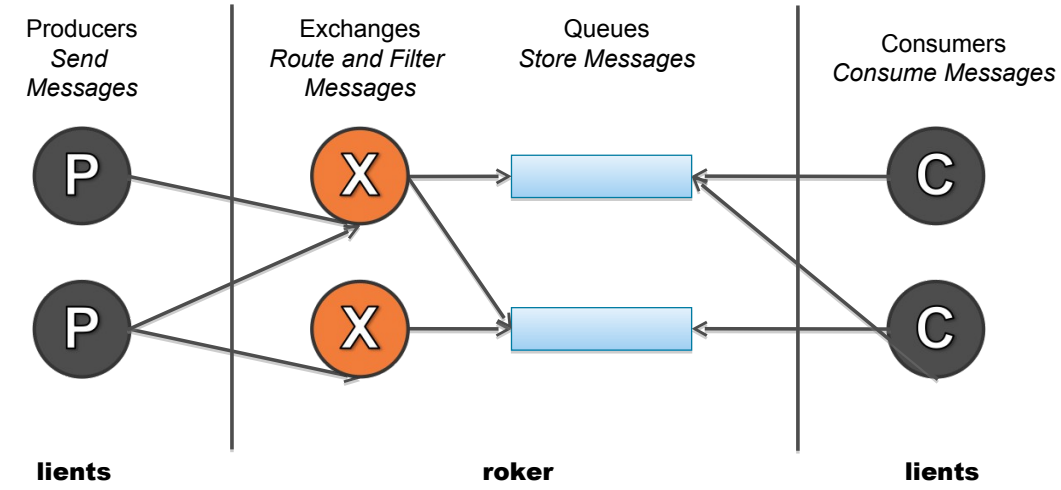
# The AMQP Model (v0.9.1)

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# JMS / AMQP Comparison

| | JMS | AMQP |
|---|---|---|
| Defined by | Java Community Process | AMQP Working Group |
| Scope | Java API | Application protocol |
| API | Yes | No |
| Interoperable | No (broker specific) | Yes |
| Distributed transactions | Yes | Yes* |
| Routing | No | Yes |

**NOTE** * RabbitMQ implements AMQP but doesn't support distributed transactions.

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## Agenda

- Messaging and Asynchronous Systems
- Why JMS isn't enough
- Introduction to AMQP
- **RabbitMQ case studies**

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## RabbitMQ case study: New York Times

- System provides subscription services for news, video feeds, etc.
- Dozens of RabbitMQ instances
- Deployment across 6 AWS zones
- Upon launch, the system autoscaled to 500 K users
- Connection times stayed stable around 200 ms

***Source*** http://lists.rabbitmq.com/pipermail/rabbitmq-discuss/2014-January/032920.html

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## RabbitMQ case study: Travis CI

- Hosted continuous integration service
- Build logs are forwarded to RabbitMQ for live display
- Messages contain an incrementing counter to identify ordering
- RabbitMQ clusters are hosted on CloudAMQP
- Tracvis CI handles 74 K builds per day

**Source** https://blog.pivotal.io/pivotal/case-studies/continuous-integration-scaling-to-74000-builds-per-day-with-travis-ci-rabbitmq

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## Summary

- Asynchronous messaging facilitates decoupling between systems
- Common messaging patterns:
  - Simple producer/consumer
  - Request/reply
  - Publish-subscribe
- AMQP is an open standard for messaging
  - A binary network protocol specification
  - Not just a Java interface specification like JMS!

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# RabbitMQ Installation

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## Agenda

- **RabbitMQ Installation**
- Basic Administration

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## Capabilities

- The most popular AMQP implementation
  - Implements AMQP 0-8, AMQP 0-9-1, AMQP 1.0
  - Implements STOMP, MQTT
- Written in Erlang using OTP (Open Telecom Platform)
  - Designed for scale and fault tolerance
- Fully open-source under the MPL (Mozilla Public License)
- Consists of:
  - An AMQP message broker
  - Client libraries for multiple languages and platforms

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## Installation overview

- Use official RabbitMQ packages
  - Not OS default packages, they can be old
- Erlang VM is required
  - You may have to install it yourself, e.g. CentOS family
- For latest instructions, refer to http://www.rabbitmq.com/download.html

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# Installation on Fedora / RedHat

- Install a recent Erlang runtime system, e.g. from Erlang Solutions

```
$ wget http://packages.erlang-solutions.com/erlang-solutions-1.0-1.noarch.rpm
$ sudo rpm -Uvh erlang-solutions-1.0-1.noarch.rpm
$ sudo yum install erlang
```

- Install RabbitMQ
  - Get the most recent RPM directly from the official site http://www.rabbitmq.com/download.html

```
$ wget http://www.rabbitmq.com/releases/rabbitmq-server/v3.6.1/rabbitmq-server-3.6.1-
1.noarch.rpm
$ sudo rpm --import https://www.rabbitmq.com/rabbitmq-signing-key-public.asc
$ sudo yum install rabbitmq-server-3.6.1-1.noarch.rpm
```

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# Installation on Debian / Ubuntu

- Add the RabbitMQ official repository to your /etc/apt/sources.list:

```
$ echo 'deb http://www.rabbitmq.com/debian/ testing main' |
       sudo tee /etc/apt/sources.list.d/rabbitmq.list
```

- Add the public key to your trusted key list using apt-key(8):

```
$ wget -O- https://www.rabbitmq.com/rabbitmq-signing-key-public.asc |
       sudo apt-key add -
```

- Update the packages list and install RabbitMQ (use sudo if needed)

```
$ sudo apt-get update
$ sudo apt-get install rabbitmq-server
```

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## Installation on Windows

- Download and install Erlang from http://www.erlang.org/download.html
- Download and install RabbitMQ from http://www.rabbitmq.com/install-windows.html
- The installer will install the broker as a service, and create a “RabbitMQ Server” folder in the Start menu.

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## Installation on Mac OS X

- Installation package includes Erlang.
- Download and install RabbitMQ from http://www.rabbitmq.com/install-standalone-mac.html
- MacPorts and Homebrew packages also available.

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# Starting and Stopping RabbitMQ

- Running RabbitMQ is straightforward
  - Assuming the bin directory is in the PATH

```
$ rabbitmq-server
```

- Running the daemon in the background:

```
$ rabbitmq-server -detached
```

- Stopping RabbitMQ
  - Assuming the bin directory is in the PATH

```
$ rabbitmqctl stop
```

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# RabbitMQ Startup Log Sample (first lines)

```
=INFO REPORT==== 6-Apr-2016::12:07:36 ===
Starting RabbitMQ 3.6.1 on Erlang 18.3
Copyright (C) 2007-2016 Pivotal Software, Inc.
Licensed under the MPL.  See http://www.rabbitmq.com/

=INFO REPORT==== 6-Apr-2016::12:07:36 ===
node           : rabbit@vm-master1
home dir       : /var/lib/rabbitmq
config file(s) : /etc/rabbitmq/rabbitmq.config (not found)
cookie hash    : 2k4H5hGmec0OT+6wzMtLhQ==
log            : /var/log/rabbitmq/rabbit@vm-master1.log
sasl log       : /var/log/rabbitmq/rabbit@vm-master1-sasl.log
database dir   : /var/lib/rabbitmq/mnesia/rabbit@vm-master1

=INFO REPORT==== 6-Apr-2016::12:07:37 ===
Memory limit set to 397MB of 993MB total.

=INFO REPORT==== 6-Apr-2016::12:07:37 ===
Disk free limit set to 50MB

=INFO REPORT==== 6-Apr-2016::12:07:37 ===
Limiting to approx 924 file handles (829 sockets)
```

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## Running RabbitMQ on Boot in RedHat

- Installing the RabbitMQ init script in the different runlevels

```
$ chkconfig rabbitmq-server on
```

- Starting the daemon manually:

```
$ service rabbitmq-server start
```

- Stopping the daemon manually:

```
$ service rabbitmq-server stop
```

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## Running RabbitMQ on Boot in Debian

- Installing the RabbitMQ init script in the different runlevels

```
$ update-rc.d rabbitmq-server defaults
```

- Starting the daemon manually:

```
$ /etc/init.d/rabbitmq-server start
```

- Stopping the daemon manually:

```
$ /etc/init.d/rabbitmq-server stop
```

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# Checking RabbitMQ Status

- To check the status of the RabbitMQ server:

```
$ rabbitmqctl status
```

- Should produce output similar to the following:

```
Status of node 'rabbit@vm-master1' ...
[{pid,14400},
 {running_applications,[{rabbit,"RabbitMQ","3.6.1"},
                        {mnesia,"MNESIA  CXC 138 12","4.13.3"},
                        {os_mon,"CPO  CXC 138 46","2.4"},
                        {xmerl,"XML parser","1.3.10"},
                        {rabbit_common,[],"3.6.1"},
                        {ranch,"Socket acceptor pool for TCP protocols.",
                               "1.2.1"},
                        {sasl,"SASL  CXC 138 11","2.7"},
                        {stdlib,"ERTS  CXC 138 10","2.8"},
                        {kernel,"ERTS  CXC 138 10","4.2"}]},
 {os,{unix,linux}},
 {erlang_version,"Erlang/OTP 18 [erts-7.3] [source-d2a6d81] [64-bit] [async-threads:64] [hipe]
   [kernel-poll:true]\n"},
 ...
```

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# Lab

Installation and Management

"Installation"

(Up to and including section 2.2)

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# Agenda

- RabbitMQ Installation
- **Basic Administration**

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# Customizing the RabbitMQ Installation

- Customized by 2 configuration files
  - `rabbitmq-env.conf`
  - `rabbitmq.config`

- Location of configuration files is distribution specific
  - Generic UNIX - `$RABBITMQ_HOME/etc/rabbitmq/`
  - Debian - `/etc/rabbitmq/`
  - RPM - `/etc/rabbitmq/`
  - Mac OS X (Macports) - `${install_prefix}/etc/rabbitmq/`, the Macports prefix is usually `/opt/local`
  - Mac OS X (Homebrew) - `/usr/local/etc/rabbitmq`
  - Windows - `%APPDATA%\RabbitMQ\`

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# Environment

- Environment variables are sourced
  - In the **`rabbitmq-env`** shell script
  - From the file **`/etc/rabbitmq/rabbitmq-env.conf`** (recommended – does not exist after install, you must create it)
- **`rabbitmq-env.conf`** is not used on Windows
- Variables are listed at http://www.rabbitmq.com/configure.html
  - See also the **`rabbitmq-env.conf`** manpage for your version

```
$ man rabbitmq-env.conf
```

- Examples
  - RABBITMQ_NODE_IP_ADDRESS: network interfaces binding
  - RABBITMQ_MNESIA_BASE: database files location

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# Configuration File

- Formatted as an Erlang configuration file
  - Options are listed at http://www.rabbitmq.com/configure.html
  - Example is shown below.

```
[
  {rabbit, [
    {heartbeat, 30},
    {tcp_listeners, [5673]},
    {default_user,<<"guest2">>},
    {default_pass,<<"guest2">>}
  ]}
].
```

TCP keepalive heartbeat interval

List of AMQP listener ports

Default username/password

Don't forget the closing "period"!

**NOTE** These are sample settings to show the various options formats. Note the syntax for strings.

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# Classic Configuration

- RabbitMQ works great out-of-the-box!
- Use configuration for:
  - Changing ports
  - Setting TCP keepalive heartbeat interval
  - Changing logging levels
  - SSL
  - LDAP integration
  - etc.

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# Logging

- Logs are written to
  - `/var/log/rabbitmq` (UNIX platforms)
  - `$USER_HOME\AppData\Roaming\RabbitMQ\log` (Windows)
- Logs are rotated using standard logrotate mechanism in Unix
  - By default, logs are rotated weekly
  - Configuration in `/etc/logrotate.d/rabbitmq-server`
- Up to 6 log files are created:
  - `startup_log`
  - `startup_err`
  - `<nodename>@<hostname>.log (eg. "rabbit@centos4.log")`
  - `<nodename>@<hostname>-sasl.log (eg. "rabbit@centos4-sasl.log")`
  - `shutdown_log`
  - `shutdown_err`

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## Logging

- **`startup_log`**: Messages related to server startup.
- **`startup_err`**: Errors on server startup.
- **`<nodename>@<hostname>.log`** (eg. "**`rabbit@centos4.log`**"): Main server log file.
- **`<nodename>@<hostname>-sasl.log`** (eg. **`rabbit@centos4-sasl.log`**): Contains Erlang process crash reports.
- **`shutdown_log`**: Server shutdown log file.
- **`shutdown_err`**: Errors on server shutdown

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## Data Files

- RabbitMQ uses the Erlang Mnesia distributed database to persist state.
  - A distributed key-value Erlang database
  - Designed for high availability
- Mnesia stores system state (exchange, queue metadata)
  - Does ***not*** store message content (is stored separately in a persistency log file)
- Data is by default kept in
  - **`/var/lib/rabbitmq/mnesia`** (UNIX platforms)
  - **`$USER_HOME\AppData\Roaming\RabbitMQ\db`** (Windows)
- Structure
  - **`$DB_ROOT/<nodename>/`** (Mnesia DB)
  - **`$DB_ROOT/<nodename>.pid`** (pidfile)
  - **`$DB_ROOT/<nodename>-plugins-expand/`** (generated launcher scripts)

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# RabbitMQ Plugins

- Plugins extend the functionality of the RabbitMQ servers. Examples include:
  - Management
  - LDAP
  - Federation
- A list of official plugins can be found at http://www.rabbitmq.com/plugins.html
- Most (including Management plugin) are disabled by default, must be enabled.

```
$ rabbitmq-plugins enable rabbitmq_management
```

- Server must be restarted for changes to take effect.
- Available plugins are displayed using the “rabbitmq-plugins” list command.
  - Dependent plugins automatically enabled when a parent is enabled are indicated by a lower-case “e”.

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# RabbitMQ Plugins

- Broker will log number of enabled plugins on startup:

```
$ sbin/rabbitmq-server

            RabbitMQ 3.6.1. Copyright (C) 2007-2016 Pivotal Software, Inc.
  ##  ##    Licensed under the MPL.  See http://www.rabbitmq.com/
  ##  ##
  ##########  Logs: /…/var/log/rabbitmq/rabbit@MacBook-Pro.log
  ######  ##        /…/var/log/rabbitmq/rabbit@MacBook-Pro-sasl.log
  ##########
            Starting broker... completed with 6 plugins.
```

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# Management Plugin

- A web application
  - With administration capabilities
  - Graphical monitoring (queue depths, throughput ,etc.)
- Default port is 15672
- Default login credentials are user “guest”, password “guest”

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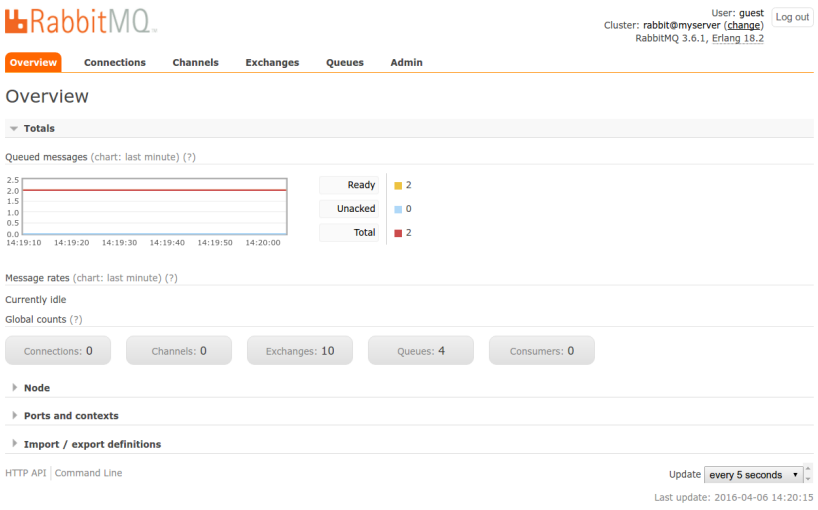
# Management Plugin Screenshot

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# Management Using the CLI

- Statistics for exchanges and queues accessible from the CLI

```
$ rabbitmqctl list_queues [-p <vhostpath>] [<infos>...]
$ rabbitmqctl list_exchanges [-p <vhostpath>] [<infos>...]
$ rabbitmqctl list_bindings [-p <vhostpath>] [<infos>...]
$ rabbitmqctl list_connections [<infos>...]
$ rabbitmqctl list_channels [<infos>...]
$ rabbitmqctl list_consumers [-p <vhostpath>]
$ rabbitmqctl
```

Running without args displays options

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# Management Using the CLI

```
$ rabbitmqctl list_queues name durable messages_ready
Listing queues ...
quot    true    0
quotes  true    0
test.queue      true    76
...done.
$
$ rabbitmqctl list_exchanges name type durable
Listing exchanges ...
amq.direct      direct  true
amq.fanout      fanout  true
amq.headers     headers true
amq.match       headers true
amq.rabbitmq.log        topic   true
amq.rabbitmq.trace      topic   true
amq.topic       topic   true
quotations      fanout  true
quotes  fanout  true
test.exchange   direct  true
...done.
```

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## Virtual Hosts

- Use virtual hosts (“vhosts”) to isolate sets of producers-consumers i.e. provides different namespaces
- Prevents exchange and queue name clashes across multiple applications.
- Default vhost is “/”
- Adding, deleting, and listing vhosts

```
$ rabbitmqctl add_vhost <vhostpath>
$ rabbitmqctl delete_vhost <vhostpath>
$ rabbitmqctl list_vhosts
```

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## User Management

- Create a user:

```
$ rabbitmqctl add_user <username> <password>
```

- Delete a user:

```
$ rabbitmqctl delete_user <username>
```

- List users:

```
$ rabbitmqctl list_users
```

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# Tracing

- RabbitMQ provides the “firehose tracer”
  - Fine-grained logs
  - Details on what happens in the server
- The firehose tracer
  - Has a performance penalty
  - Must be explicitly activated

```
$ rabbitmqctl trace_on [-p <vhost>]
$ rabbitmqctl trace_off [-p <vhost>]
```

- Consumable using AMQP from the amq.rabbitmq.trace exchange
  - ‘publish.<exchangename>’ as routing key for inbound messages
  - ‘deliver.<queuename>’ as routing key for outbound messages
- Headers and body are copies of the original

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# Troubleshooting

- Check the status of the broker with rabbitmqctl status
- If the broker doesn’t start
  - Check the log files: **`startup_log`**, **`startup_err`**, and server log files
  - Check **`erl_crash.dump`** file in the directory where the broker was started
  - Often caused by the wrong formatting of the config file
- If plugin won’t activate, run rabbitmq-plugins list
- To verify AMQP traffic, use the firehose
- Check the mailing list
  - https://groups.google.com/forum/#!forum/rabbitmq-users

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## Summary

- RabbitMQ can be installed on various platforms including Windows, Mac OSX, and Linux
- Installation customized by 2 configuration files
  - **`rabbitmq-env.conf`**
  - **`rabbitmq.config`**
- Server management can be performed using the `rabbitmqctl` CLI or the web management plugin GUI

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## Lab

Installation and Management

"Using the Management Plugin”

(Section 2.3)

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# RabbitMQ Development and Integration

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## Agenda

- **Development Basics**
  - Clients
  - Java Client Basics
- Client AMQP Resource Management
  - Routing Messages
  - Exchanges
  - Message Ordering
- Use cases and patterns

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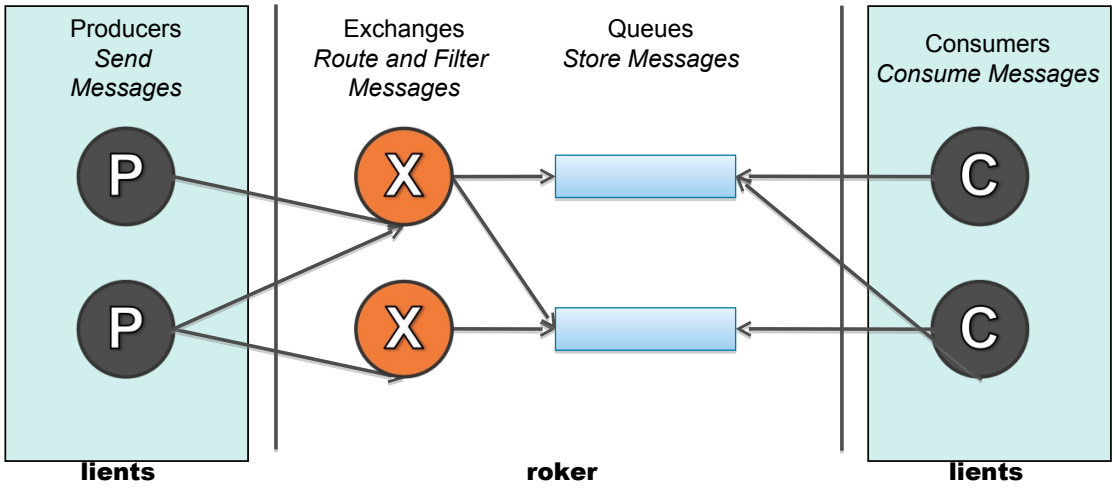
# The AMQP Model

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# Clients

- Official clients are:
  - Java
  - C# (.NET)
  - Erlang
  - JMS (only available in Pivotal commercial release)
- Community-maintained clients include:
  - Python, Perl, Ruby
  - PHP
  - C/C++
  - JavaScript
  - Lisp, OCaml, and many more…
- For a full list go to http://www.rabbitmq.com/devtools.html

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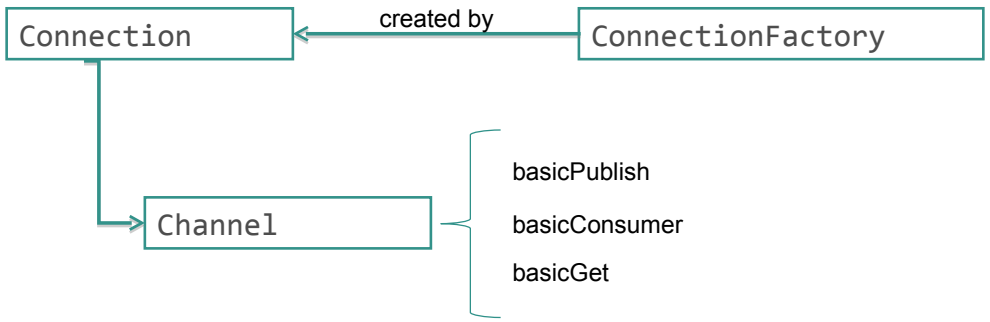
# Java Client Hierarchy

- Java client provides a simple interface.
- `Channel` class is the main component.

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# Creating an AMQP Connection (Java Client)

- The `Connection` interface represents an AMQP connection.
  - All connection parameters have a default value
  - Override as necessary using setters

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

{…}

ConnectionFactory factory = new ConnectionFactory();
factory.setUsername("guest");
factory.setPassword("guest");
factory.setVirtualHost("/");
factory.setHost("localhost");
factory.setPort(5672);

Connection connection = factory.newConnection();
```

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# Creating an AMQP Connection (Java Client)

- AMQP URI's may also be used

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

{…}

ConnectionFactory factory = new ConnectionFactory();
factory.setUri("amqp://username:password@hostname:port/vhost");

Connection connection = factory.newConnection();
```

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# Creating an AMQP Channel

- The connection will be used to create a `Channel`
- The channel object is used to produce and consume messages.
- Channels are thread-safe, but the recommendation is to use one channel per thread in a multi-threaded application.

```
import com.rabbitmq.client.Channel;

{…}

Channel channel = connection.createChannel();
```

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# Closing Resources

- Connection must be closed, channel can be closed also.
- Closing the connection also closes the open channels.

```
{…}

channel.close();
connection.close();
```

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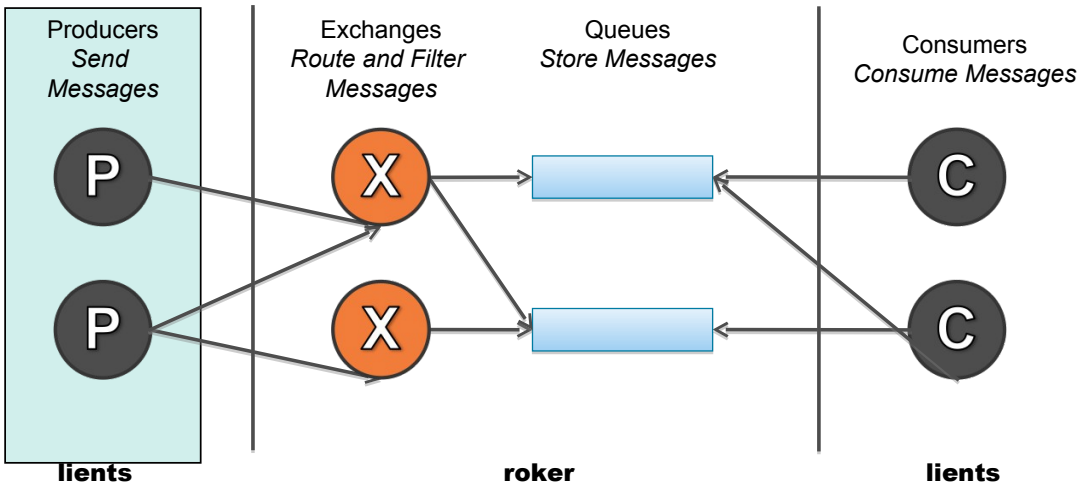
# The AMQP Model

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# Publishing Messages

- AMQP messages are published to an exchange
- The `Channel.basicPublish()` method is used
- A simple publisher:


- `AMQP.BasicProperties` defines all the properties of your message
  - contentType, encoding, headers, correlationId, deliveryMode, expiration, messageId, replyTo, etc.

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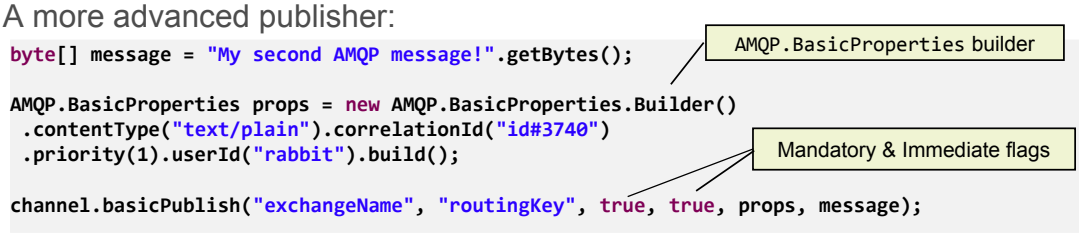
# Publishing Messages

- A more advanced publisher:




- Mandatory flag
  - the message will be sent back to the sender if it cannot be routed to at least one queue (use Channel.setReturnListener to be notified)
- Immediate flag
  - the message will be handled as unroutable if at least one of the queues that would receive the message has no subscription on it. RabbitMQ does not currently support this flag.

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# Pre-Defined Properties

- The `MessageProperties` class contains pre-defined properties.

```
byte[] message = "My second AMQP message!".getBytes();

AMQP.BasicProperties props = MessageProperties.TEXT_PLAIN;

channel.basicPublish("exchangeName", "routingKey", true, true, props, message);
```

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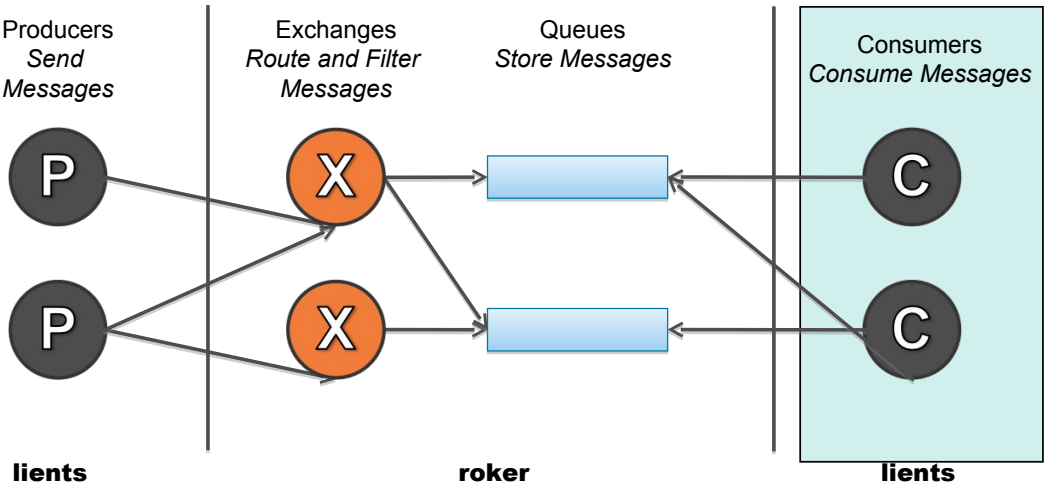
# The AMQP Model

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# Receiving Messages

- Two different ways to receive AMQP messages
  - Asynchronously (subscription)
    - `Channel.basicConsume()`
    - Consumer callback mechanism
    - Non-blocking
  - Synchronously (polling)
    - `Channel.basicGet()`
    - Message is explicitly requested by caller

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# Receiving Messages Asynchronously

- The callback is achieved with the `Consumer` interface
- Important methods are:
  - `handleCancel()`
  - `handleCancelOk()`
  - `handleConsumeOk()`
  - `handleDelivery()`
  - `handleRecoverOk()`
  - `handleShutdownSignal`
- Implement them when you want your consumers to be notified of delivery, cancel, shutdown, or consume events

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## `DefaultConsumer` Class

- Java client provides a `DefaultConsumer` class
- Mostly empty, developers override required methods
  - Avoids implementing all the methods from `Consumer`
- `Consumer` implementations typically extend this class

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## Receiving Messages Asynchronously

- `Channel.basicConsumer()` example:

```
boolean autoAck = true;

channel.basicConsume("queue", autoAck,

        new DefaultConsumer(channel) {

        @Override
        public void handleDelivery( String consumerTag,
                                    Envelope envelope,
                                    AMQP.BasicProperties properties,
                                    byte[] body) throws IOException {

                    String contentType = properties.getContentType();
                    String routingKey = envelope.getRoutingKey();

              // process message here ...
            }
      });
```

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# Receiving Messages Synchronously (Polling)

- `Channel.basicGet()` example:

```
boolean autoAck = true;

GetResponse response = channel.basicGet("queueName", autoAck);

if (response != null) {
    AMQP.BasicProperties props = response.getProps();
    byte[] body = response.getBody();
    Envelope envelope = response.getEnvelope();

    // process message here ...
}
```

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# Lab

"Java Message Sender and Receiver"

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# Agenda

- Development Basics
  - Clients
  - Java Client Basics
- **Client AMQP Resource Management**
  - Routing Messages
  - Exchanges
  - Message Ordering
- Use cases and patterns

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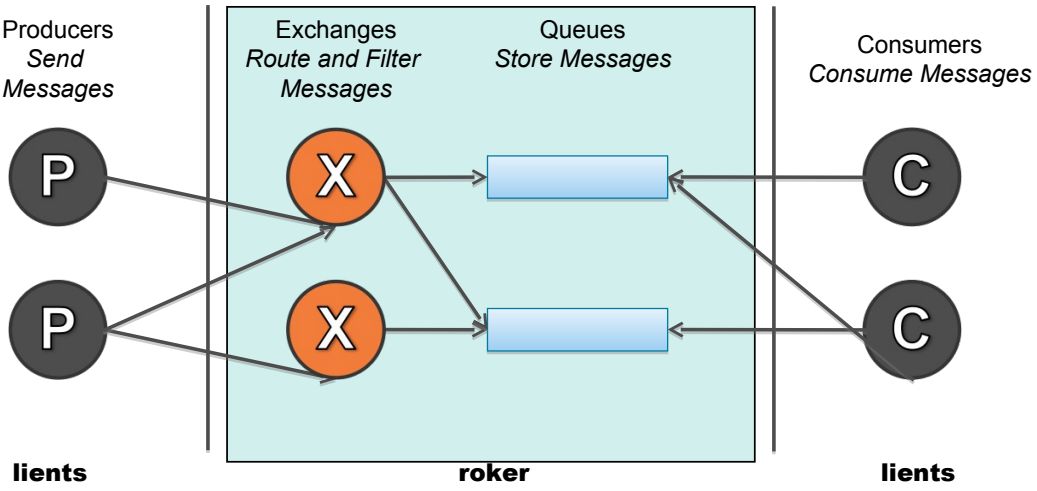
# The AMQP Model

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# Managing and Creating AMQP Resources

- Queues, exchanges and bindings
  - They always exist on the broker, when they exist at all
  - They can be created on the fly by clients
  - They can be durable (i.e. can survive broker restarts)
- Clients can create and manage AMQP resources on the broker side
  - Exchange creation / deletion
  - Queue creation / purge / deletion
  - Binding creation / deletion

**NOTE** Resource creation is idempotent, as long as the already-existing resource has the exact same attributes (durability, auto-deletion, etc.)

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# Using Queues and Exchanges

- Clients can declare queues and exchanges
- Declaring a resource ensures it exists, creating it if necessary
  - Exchange declaration is realized on a channel
  - Example is shown below.

```
channel.exchangeDeclare("exchangeName", "direct", true);
```

Exchange type

Durability flag

**NOTE** Exchange types are described in the next slides.

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# Using Queues and Exchanges

- Queue declaration is realized on a channel

```
channel.queueDeclare("queueName", true, false, false, null);
```

Durability flag | Exclusive flag | Auto-delete flag | Arguments

- Durability
  - Message can survive broker restarts (more on this in next module)
- Exclusive
  - Only the current client can connect to this queue
  - Exclusive queues will be deleted when the client closes the connection
- Auto-delete
  - The queue will be deleted after the last subscription is removed from it

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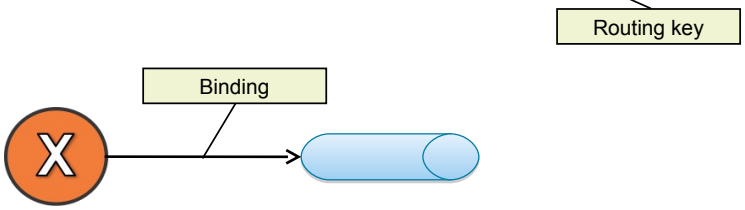
# Binding Queues and Exchanges

- Clients need to bind queues and exchanges on channel
- Routing key needs to be provided in order to bind the exchange and the queue t

```
channel.queueBind("queueName", "exchangeName", "widget");
```

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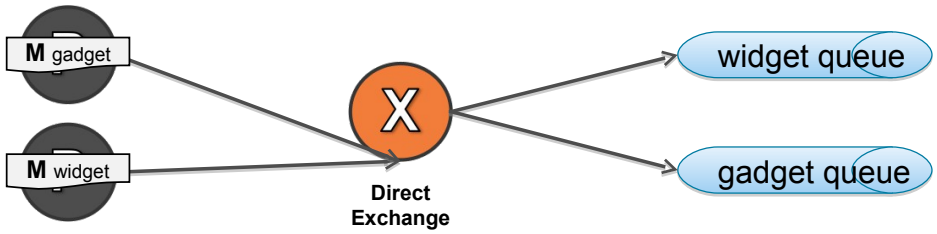
# Routing Logic to Queues

- AMQP embeds routing logic using exchange types and bindings.
- Messages are published with a special header: "`routingkey`"
  - Pattern matching is performed between the message `routingkey` and the exchange bindings
  - Based on the match results, in combination with the type of exchange, the message is routed to the appropriate queue(s).

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# Removing Bindings and Purging Queues

- To remove a binding:

```
channel.queueUnbind("queueName", "exchangeName", "widget");
```

- To purge all messages from a queue (note this does not delete the queue):

```
channel.queuePurge("queueName");
```

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# Deleting Resources

- To delete a queue:

```
channel.queueDelete(“queueName");
```

- To delete an exchange:

```
channel.exchangeDelete(“exchangeName”);
```

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# Exchange Types

- 4 AMQP default exchange types:
  - Fanout
  - Direct
  - Headers
  - Topic
- Each type of exchange has different routing capabilities.
- It is also possible to write your own custom exchange.
- RabbitMQ includes a custom consistent hash exchange as part of the installation.

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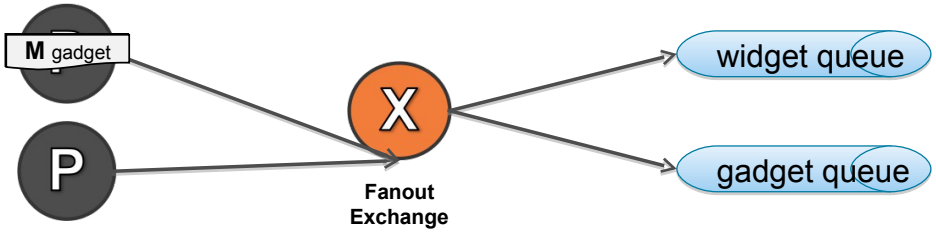
# Fanout Exchanges

- Think “broadcast” or “publish-subscribe”
- No routing key evaluation
- Bindings don’t need routing key criteria
- Always matches
- Sends messages to all the bound queues

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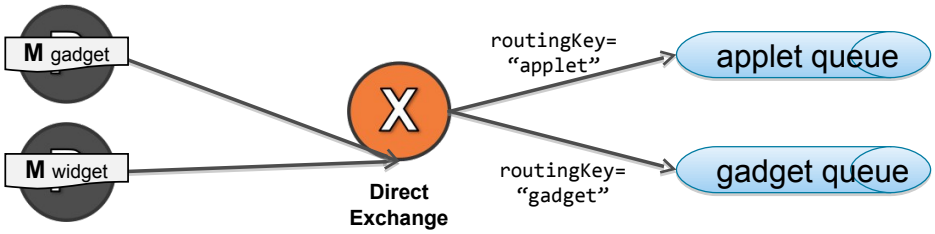
# Direct Exchanges

- Routing key is mandatory
- Otherwise, message is not routed and is discarded
- Sends messages to all the bound queues where the routing key matches the binding.

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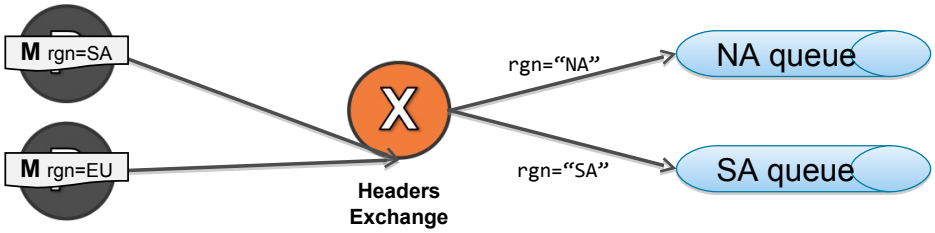
# Headers Exchanges

- No routing key evaluation
- Message headers are key/value pairs
- Like the direct exchange, but matches on headers and not on message routing key
- Can match on any or all key-value pairs specified in the binding
- Again, message is discarded if no matching binding is found

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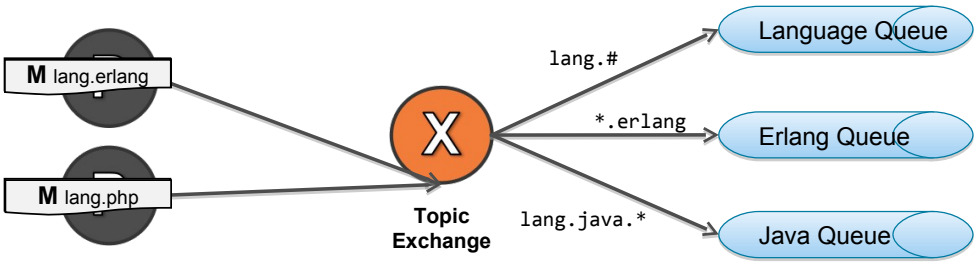
# Topic Exchanges

- Topic exchange matches the message routing key on binding-defined pattern
- The binding pattern supports wildcards
  - * (star) can substitute for exactly one word
  - # (hash) can substitute for zero or more words

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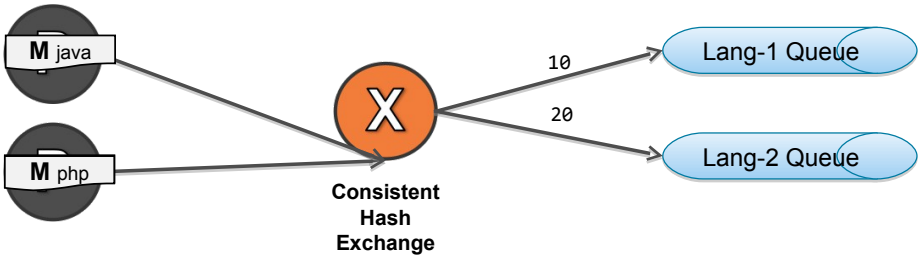
# Consistent Hash Exchange

- Consistent hash exchange routes messages to bound queues based on hashed value of routing key
- Each queue essentially represents a "bucket" of the hash
- The routingKey binding value is an integer that specifies the weighting for each queue
  - In example below, the "Lang-2 Queue" will receive twice as many messages as the "Lang-1 Queue"

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# Message ordering guarantees

- RabbitMQ provides strong message ordering guarantees
- Messages are always held in publication order in *one* queue
- Nevertheless, relying too much on message ordering in consumers is fragile
  - Limits the processing to a single consumer, it's not scalable
  - With multiple consumers, processing messages in strict order doesn't make much sense
- It's still possible to observe out of order messages
  - If the queue has multiple consumers
  - If some consumers *requeue* messages

**NOTE** A consumer can requeue a message for various reasons (bad format, rejection). The reliability module covers the requeuing mechanisms.

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# Priority queues

- RabbitMQ can prioritize the delivery of messages to consumers
  - Messages with high priority are delivered *before* other messages
  - Priority takes over publication order
- Use priority when some messages are more urgent than others
  - E.g. messages coming from “premium” customers vs “standard” customers
- How to use priority in RabbitMQ?
  - Declare a queue with a max priority level (e.g. 10)
  - Send messages with the priority property set to the priority level (e.g. 8)
- Priority semantics:
  - Messages with a high priority level are delivered first
  - Messages with no priority property set are treated as if their priority level were 0

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# Setting up priority

```
Map<String,Object> arguments = new HashMap<>();
arguments.put("x-max-priority", 10);
channel.queueDeclare("queueWithPriority", true, false, false, arguments);
```

Use the x-max-priority argument when creating the queue

```
byte[] message = "This message should be processed quickly!".getBytes();

AMQP.BasicProperties props = new AMQP.BasicProperties.Builder()
 .priority(8)
 .build();

channel.basicPublish("exchangeName", "routingKey", true, true, props, message);
```

Use the priority property when sending the message to set the priority level

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# Priority queues, more details

- Priority queues cannot change the number of priorities they support
- The priority level can be between 0 and 255
  - Pick a reasonable max level, like 10
- Each level of priority has some in-memory and on-disk cost
  - Another good reason to set a reasonable max level!

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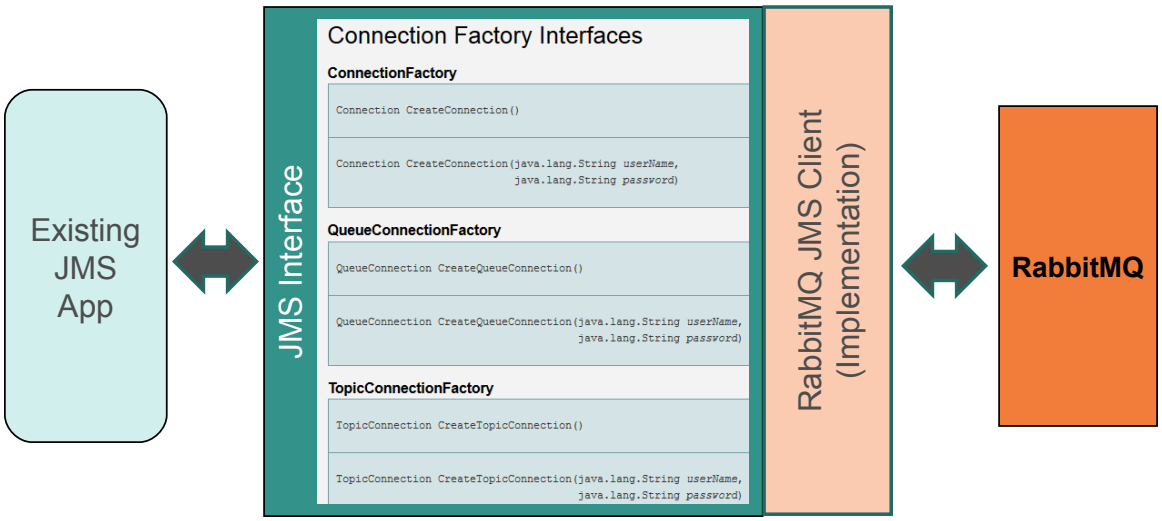
# JMS Client

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# Higher Level Abstractions

- Client API's are modeled on the AMQP specification
  - Low-level
- Higher-level abstractions are often required
  - Automatic reconnection
  - Failover
  - Built-in mechanism for marshalling/unmarshalling payloads
  - Uniform error handling

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# Higher Level Abstractions

- Java
  - Spring AMQP
  - Spring Integration
- Spring AMQP
  - Minimize boilerplate code with an AmqpTemplate
  - Encode and decode payloads with MessageConverter
  - Provide resilience mechanisms (retry…)
  - Similar to the JMS support in Spring Framework
- Spring Integration
  - Provide unidirectional calls (one-way) over AMQP
  - Provide bidirectional calls (request-reply) over AMQP

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## Even Higher Level Abstractions

- Need to do it yourself
- De-duplication if needed for consumers
- Buffering while disconnected for producers
  - Cyclic buffers for holding unsent messages
  - Sender thread(s) with failover on a set of broker nodes

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## Lab

Message Routing

(Part 1: "Exchange Types and Bindings")

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# Agenda

- Development Basics
  - Clients
  - Java Client Basics
- Client AMQP Resource Management
  - Routing Messages
  - Exchanges
  - Message Ordering
- **Use cases and patterns**

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# Use Cases and Patterns

- In messaging, there are lots of common patterns and use cases
  - They are often called Enterprise Integration Patterns (EIP)
  - http://www.eaipatterns.com/
  - Enterprise Integration Patterns book by Gregor Hohpe and Bobby Woolf
- AMQP and RabbitMQ provide a foundation to use these patterns in messaging applications
  - RPC: request / reply communications
  - Work queue: distribute tasks among consumers
  - Publish / subscribe: send message to many consumers at once

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# RPC – Remote Procedure Call

- This pattern is also known as request-reply
  - An initial message is sent to a consumer (request)
  - Timeout in case the response takes too long to come
  - A message is sent back to the original producer (reply)
- Hidden mechanisms play a role in this request-reply pattern
  - The request needs to be sent with extra headers
    - reply_to in order to know on which queue reply should be sent back
    - correlation_id in order to correlate the response and the reply
  - The reply also has extra headers
    - correlation_id has to be the same as the request to be able to correlate both messages

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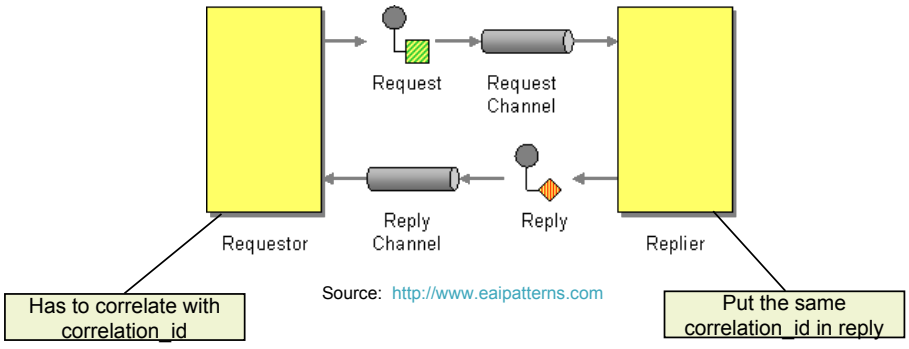
# RPC – Remote Procedure Call

- The requestor can implement the timer process
  - This is optional, but risky if not implemented

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# RPC - RpcClient

- Java client comes with two convenient classes to manage client and server side

```
try {
        RpcClient rpcClient = new RpcClient(channel, "exchangeName", "key", 500);

        byte[] request = "my request".getBytes();
        byte[] reply = rpcClient.primitiveCall(request);

        // do business with reply message

} catch (TimeoutException e) {

        // manage timeout here
```

Specify channel, exchange, routing key, and timeout (ms)

This method call returns either
-reply
-TimeoutException

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# RPC - RpcServer

- Need to override one method to specify behaviour

Specify channel and queue name

Override the handleCall() method

```
RpcServer rpcServer = new RpcServer(channel, "queueName") {

    @Override
    public byte[] handleCall(byte[] request, BasicProperties replyProperties) {

                    // do business to create reply message
                    return "reply!!".getBytes();
    }

};
rpcServer.mainloop();
```

Create the reply message

Start the looping process

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# RPC – RabbitMQ optimization

- The RPC client usually waits for the response on a dedicated queue
  - Do this if there's nothing better in your messaging infrastructure…
  - But this is inefficient
- RabbitMQ provides the *direct reply-to* feature to make RPC faster
  - By providing the `amq.rabbitmq.reply-to` special queue
- The Java `RpcClient` and `RpcServer` classes use this special queue
  - No need to worry about optimization if you're using them
- Any custom RPC mechanism should use the special queue
  - In case the used client doesn't already implement RPC this way

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# Work Queue – Predictable Dispatching

- With AMQP and RabbitMQ, you can of course run several consumers on the same queue
- Contrary to some other messaging brokers, AMQP messages are round-robin dispatched
  - For example, if you have two consumers connected to a queue
  - The queue has 10 messages
  - Both consumers will receive exactly five messages
    - Consumer 1 : the first, third, fifth, seventh, ninth
    - Consumer 2 : the second, fourth, sixth, eighth, tenth
- In JMS, you cannot predict which consumer will get the next message (random, based on the consumer's load and speed)

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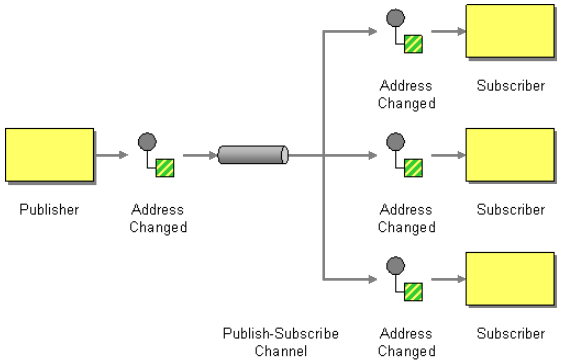
# Publish / Subscribe

- This pattern allows us to send a message (or copy of message) to many consumers at the same time
  - All active consumers at a given time will receive the same copy of the message




Source: http://www.eaipatterns.com

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# Publish / Subscribe

- Implemented using topic destinations in JMS.
- In AMQP, fanout exchanges are used to implement the publish-subscribe pattern.
- Alternatively, exchange types with multiple identical bindings can be used to route copies to multiple queues.

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## Summary

- Numerous clients supported in various languages
- RabbitMQ Java client has robust support for managing server resources, and publishing and consuming messages
- 4 different exchange types dictate message routing
- It is possible to implement common messaging patterns in RabbitMQ

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## Lab

Message Routing

(Part 2: "Patterns")

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# RabbitMQ and Reliable Messaging Development

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## Agenda

- **Durability and persistence**
- AMQP Transactions
- AMQP Acknowledgements
- Dead letter exchanges
- Multiple transactional resources

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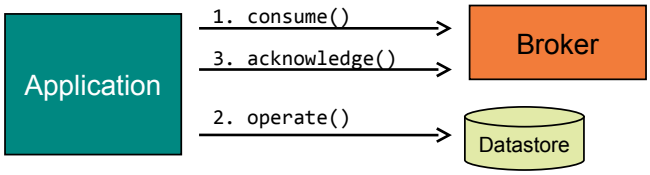
# Messaging and Reliability

- Messaging is rarely isolated
- Messaging is usually interleaved with business processing
- Typical reception workflow:




- "Acknowledge" means a message has been properly processed
- Once acknowledged, the message is removed from the queue

**NOTE** The acknowledgement is sent to the broker, not to the producer of the message!

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# RabbitMQ and reliability

- Many things can go wrong during message publication or reception
- AMQP specifies how to exchange messages in a reliable manner
- RabbitMQ implements these reliable mechanisms

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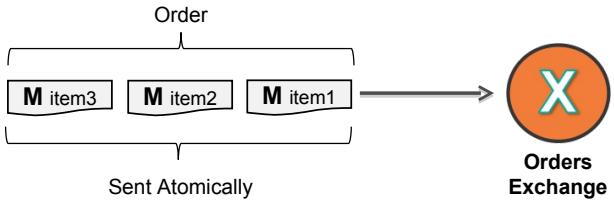
# What Can Go Wrong?

- The broker crashes; sent but not-yet-consumed messages are lost!
  - The broker can provide *persistence*
- Business processing after reception times out, or is temporarily down
  - The broker can *redeliver* the message
- Messages must be sent as a group, but the application fails in the middle
  - Thanks to transactions, the broker can provide *atomic operations*

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# Durability and Persistence

- Durability is the 'D' in ACID, eg.
  - surviving a server restart
  - surviving a broker crash
- Durability happens at three different levels:
  - Exchange
  - Queue
  - Message (referred to as “persistence”)
- Durability only works if queues are durable and messages are persistent.

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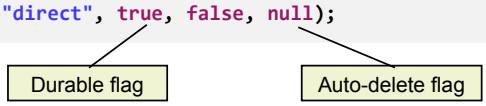
# Durable Exchanges

- Setting up a durable exchange:

```
ConnectionFactory factory = new ConnectionFactory();
factory.setHost("localhost");
Connection connection = factory.newConnection();
Channel channel = connection.createChannel();

// declare the durable exchange
channel.exchangeDeclare("my-exchange", "direct", true, false, null);
```




- Consequences:
  - The exchange definition (i.e. metadata) is written to disk
  - If the broker crashes or shuts down, the exchange is still there when the broker is restarted
  - There's no need to re-declare the exchange between restarts

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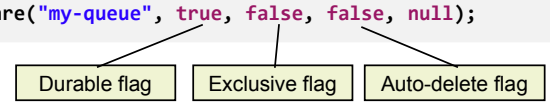
# Durable Queues

- Setting up a durable queue:

```
ConnectionFactory factory = new ConnectionFactory();
factory.setHost("localhost");
Connection connection = factory.newConnection();
Channel channel = connection.createChannel();

// declare the durable queue
channel.queueDeclare("my-queue", true, false, false, null);
```




- Consequences:
  - The queue definition (i.e. metadata) is written to disk
  - If the broker crashes or shuts down, the queue is still there when the broker is restarted
  - There's no need to re-declare the queue between restarts

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# Persistent Messages

- Creating a persistent message:

```
ConnectionFactory factory = new ConnectionFactory();
factory.setHost("localhost");
Connection connection = factory.newConnection();
Channel channel = connection.createChannel();

// set the message as persistent (deliveryMode = 2)
AMQP.BasicProperties.Builder builder = new AMQP.BasicProperties.Builder();
AMQP.BasicProperties props = builder.deliveryMode(2).build();

String message = "Hello World!";
channel.basicPublish("my-exchange", "key", props, message.getBytes());
System.out.println("Sent '" + message + "'");
```

Set message as persistent

- Consequences:
  - Persists the message to the file system (in persistency log file)
  - If stored in durable queue, the message will still be there between restarts

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# Agenda

- Durability and persistence
- **AMQP Transactions**
- AMQP Acknowledgements
- Dead letter exchanges
- Multiple transactional resources

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# Transactions in AMQP

- AMQP specifies transaction semantics
- RabbitMQ implements part of the semantics
  - More on the limitations later
- AMQP transactions are pretty similar to JMS transactions but they do differ in the following ways:
  - Acknowledgment (ack) of received messages
    - Can be on a group of messages
  - Transaction to publish and acknowledge messages
    - Commit and Rollback
    - Can be on a group of messages

**NOTE** There's no acknowledgment for publishing in AMQP. RabbitMQ has "Publisher Confirms" extension to ensure message(s) make it to the broker.

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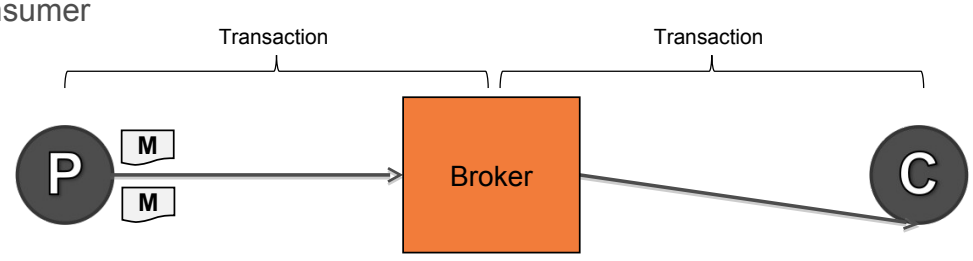
# Transactions Across Senders and Consumers

- Transactions don't span the sender and the consumer
- A common transaction would couple the sender to the consumer
- Messaging is all about decoupling!
- Transaction semantics are only between the sender-broker and broker-consumer

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# AMQP Transactions

- Acknowledgment doesn't exist on the publisher side in AMQP
  - RabbitMQ has a publisher confirms extension
- Transaction is managed at the channel level
  - `Channel.txSelect()`
    - Set this channel as transacted
  - `Channel.txCommit()`
    - Commit all the published messages since the last `txSelect`
    - A new transaction starts immediately after committing
  - `Channel.txRollback()`
    - Rollback all the published messages since the last `txSelect`
    - Cancel all the acknowledgments since the last `txSelect`
    - A new transaction starts immediately after rollback

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# AMQP Transactions

- Transaction usage for publishers:

```
try {
  channel.txSelect();

  byte[] msg = "NASDAQ".getBytes();
  channel.basicPublish(stockExchange, stockCategory, null, msg);

  channel.txCommit();

} catch (Exception e) {

  channel.txRollback();

}
```

Set this channel as transactional (do it once)

Publish the message

Commit the transaction (a new transaction starts)

Rollback the transaction in case of problem (a new transaction starts)

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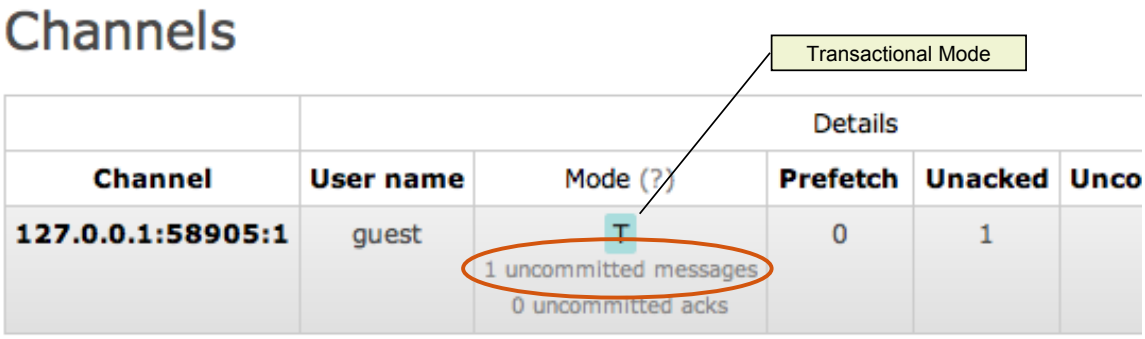
# AMQP Transactions

- In the RabbitMQ Management Console:




- Messages stay in uncommitted state
  - Until the transaction is committed or rolled back

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# AMQP Transactions

- Publishing messages in batch mode, all messages will be committed together

```
channel.txSelect();

byte[] msgNasdaq = "NASDAQ".getBytes();
byte[] msgDJ = "DOWJONES".getBytes();
byte[] msgSP500 = "SP500".getBytes();

channel.basicPublish(stockExchange, stockCategory, null, msgNasdaq);
channel.basicPublish(stockExchange, stockCategory, null, msgDJ);
channel.basicPublish(stockExchange, stockCategory, null, msgSP500);

channel.txCommit();
```


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# AMQP Transactions

- Rolling back published messages
  - All the messages will be rolled back and will not reach the exchange

```
channel.txSelect();

byte[] msgNasdaq = "NASDAQ".getBytes();
byte[] msgDJ = "DOWJONES".getBytes();

channel.basicPublish(stockExchange, stockCategory, null, msgNasdaq);
channel.basicPublish(stockExchange, stockCategory, null, msgDJ);

// business exception is thrown here!
// must cancel all publications

channel.txRollback();
```

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# Agenda

- Durability and persistence
- AMQP Transactions
- **AMQP Acknowledgements**
- Dead letter exchanges
- Multiple transactional resources

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# Did Message Reach the Broker?

- Without transactions:
  - Client uses fire-and-forget
  - They can't know whether the message(s) reached the broker or not
- With transactions:
  - When `txCommit()` returns, it means the broker got the message(s)
- With publisher confirms:
  - When the sequence number of the message is returned in the `handleAck()` callback method

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# Receiving Messages

- How does the broker know that the consumer processed the message?


- The consumer can:
  - Have the broker acknowledge messages automatically on delivery ("auto-ack")
  - Receive, process, and explicitly send the acknowledgement
  - Start a transaction, receive messages, acknowledge messages, and commit acknowledged messages

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# AMQP Acknowledgements

- Acknowledgments are for receivers only
- Receiver
  - Can acknowledge one or a group of messages
  - Gets the delivery tag from the message and uses it to acknowledge on the channel
- Messages that are not acknowledged are put back in the queue

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# AMQP Acknowledgements

- If fetching messages synchronously:
  - Envelope is an argument of the handleDelivery() method

```
boolean autoAck = false;
GetResponse response = channel.basicGet("queueName", autoAck);

if (response != null) {

  AMQP.BasicProperties props = response.getProps();
  byte[] body = response.getBody();
  long deliveryTag = response.getEnvelope().getDeliveryTag();

  // do business logic here

  boolean multiple = false;
  channel.basicAck(deliveryTag, multiple);

}
```

Set auto-ack to false

Get the delivery tag from the envelope

Single acknowledgement

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# AMQP Acknowledgements

- If using asynchronous callbacks
  - Specify acknowledgement mode in the `basicConsume()` method

```
boolean autoAck = false;
channel.basicConsume("queueName", autoAck, listener);
```

Explicit acknowledgements

  - Envelope is passed in as an argument of the handleDelivery() method

```
public void handleDelivery(String consumerTag,
            Envelope envelope,
            AMQP.BasicProperties properties,
            byte[] body) throws java.io.IOException {

  // Process message here

  // Ack the message
  this.getChannel().basicAck(envelope.getDeliveryTag(), false);
}
```

Get the delivery tag from the envelope

Do not acknowledge multiple messages

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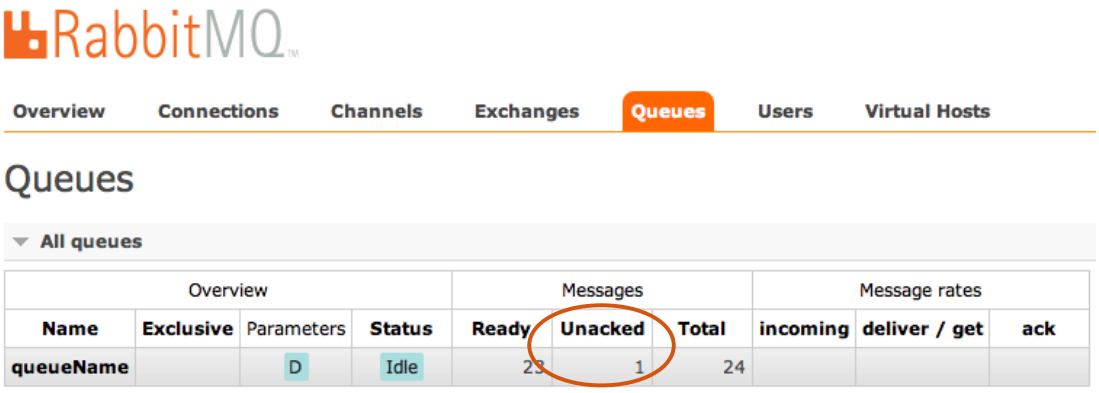
# AMQP Acknowledgements

- Until the message is acknowledged by the client
  - There will be some unacknowledged messages

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# No Acknowledgement?

- There's no timeout in AMQP
  - If the processing takes a long time, and the ack doesn't come, then the broker won't resend the messages
- When a client quits, the unacked messages are redelivered
  - Client quits = client closes connection
- Broker can't release unacked messages
  - Not good for memory!
- Use rabbitmqctl or the management plugin to track unacked messages

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# Acknowledging Multiple Messages

- Only one call to `Channel.basicAck()`, with parameters:
  - the tag of a delivered message (this message and all previous unacknowledged messages are acknowledged)
  - multiple flag set to true

```
boolean autoAck = false;
GetResponse response1 = channel.basicGet("queueName", autoAck);
// do business with response1

GetResponse response2 = channel.basicGet("queueName", autoAck);
// do business with response2

GetResponse response3 = channel.basicGet("queueName", autoAck);
// do business with response3

long latestDeliveryTag = response3.getEnvelope().getDeliveryTag();
boolean multiple = true;
channel.basicAck(deliveryTag, multiple);
```

Multiple acknowledgement

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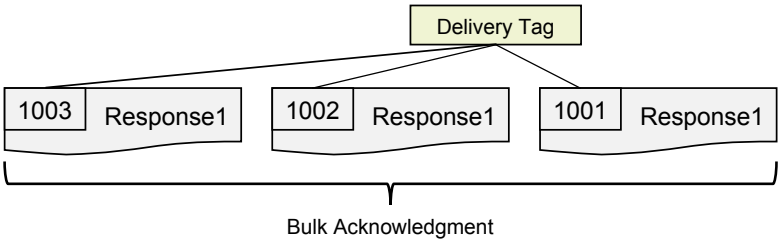
# Acknowledging Multiple Messages

- All the messages that match the criteria below will be acknowledged in the same call to `basicAck()`:
  - Messages received on the same channel
  - Messages not yet acknowledged
  - Messages with a delivery tag less than or equal to the delivery tag given to the basicAck() method




```
channel.basicAck(1003, true);
```

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# AMQP Rejections

- Instead of acknowledging, consumers can also reject messages
  - Message can be requeued if needed (requeue flag)
  - The `basicReject()` method doesn't discard multiple messages
- Best practices:
  - Try to avoid requeuing messages that are likely to be repeatedly rejected by the consumer (poison messages)
  - Messages that cause the consumer to crash are likely to do so again.

```
public void handleDelivery(String consumerTag, Envelope envelope,
  AMQP.BasicProperties properties, byte[] body) throws java.io.IOException {

  long deliveryTag = envelope.getDeliveryTag();

  // something went wrong...
  boolean requeue = true;
  this.getChannel().basicReject(deliveryTag, requeue);
}
```

Requeue flag

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# AMQP Rejections – RabbitMQ Extension

- RabbitMQ offers one method to reject messages
- It is done by calling the `Channel.basicNack()` method
  - This is not part of the AMQP specification
  - Can reject all previous unacknowledged messages

```
public void handleDelivery(String consumerTag, Envelope envelope,
  AMQP.BasicProperties properties, byte[] body) throws java.io.IOException {

  long deliveryTag = envelope.getDeliveryTag();

  // something went wrong...
  boolean requeue = true;
  boolean multiple = true;
  this.getChannel().basicNack(deliveryTag, multiple, requeue);
}
```

Multiple flag

Requeue flag

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# AMQP Transactions Over Acknowledgements

- Messages can be acknowledged inside a transaction
- Typical workflow:
  - `txSelect()` before receiving
  - Business processing (can be message sending), ack
  - `txCommit()`
- Useful to make sending an acknowledgment atomic
  - E.g., consume, send, ack, commit everything

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# AMQP Transactions Over Acknowledgements

- The message is acknowledged after the `basicAck()`
- But the acknowledgment isn't committed before the `txCommit()`

```
channel.txSelect();

boolean autoAck = false;
GetResponse response = channel.basicGet("queueName", autoAck);

// do business logic here

long deliveryTag = response.getEnvelope().getDeliveryTag();
channel.basicAck(deliveryTag, false);

channel.txCommit();
```

Start the transaction

Use explicit acknowledgements

Acknowledge the message

Commit the transaction

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# AMQP Transactions Over Acknowledgements

- Before acknowledgement:

Channels

| | Details | | | | | |
|---|---|---|---|---|---|---|
| **Channel** | **User name** | Mode (?) | **Prefetch** | **Unacked** | **Unconfirmed** | **Status** |
| **127.0.0.1:59832:1** | guest | T<br>0 uncommitted messages<br>0 uncommitted acks | 0 | 1 | 0 | Idle |

Queues

**All queues**

| Overview | | | | Messages | | |
|---|---|---|---|---|---|---|
| **Name** | **Exclusive** | Parameters | **Status** | **Ready** | **Unacked** | **Total** |
| **queueName** | | D | Idle | 22 | 1 | 23 |

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# AMQP Transactions Over Acknowledgements

- After acknowledgment but before commit:

Channels

| | Details | | | | | |
|---|---|---|---|---|---|---|
| **Channel** | **User name** | Mode (?) | **Prefetch** | **Unacked** | **Unconfirmed** | **Status** |
| **127.0.0.1:59874:1** | guest | T<br>0 uncommitted messages<br>1 uncommitted acks | 0 | 0 | 0 | Idle |

Queues

**All queues**

| Overview | | | | Messages | | |
|---|---|---|---|---|---|---|
| **Name** | **Exclusive** | Parameters | **Status** | **Ready** | **Unacked** | **Total** |
| **queueName** | | D | Idle | 22 | 1 | 23 |

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# AMQP Transactions Over Acknowledgements

- After commit:

Queues

**All queues**

| Overview | | | | Messages | | |
|---|---|---|---|---|---|---|
| **Name** | **Exclusive** | Parameters | **Status** | **Ready** | **Unacked** | **Total** |
| **queueName** | | D | Idle | 22 | 0 | 22 |

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## Reception: Acknowledgement or Transaction?

- For simple cases, prefer acknowledgment
  - It's simpler and fits most of the cases
  - Performs better than transactions
- Fine-grained control with transactions
  - Can make reception/acknowledgement AND sending atomic!

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## Agenda

- Durability and persistence
- AMQP Transactions
- AMQP Acknowledgements
- Dead letter exchanges
- Multiple transactional resources

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# Dead Letter Exchanges

- What should I do with rejected, not requeued messages?
  - They're usually "poisonous", but worth keeping track of
- A queue can specify a dead letter exchange
- Rejected, not requeued messages are sent to this dead letter exchange
  - The exchange must exist when the first message is dead-lettered
  - It's a "normal" exchange (any type, any binding)
- Dead letter queuing can lead to a human intervention
  - Last chance processing
- RabbitMQ adds information to dead-lettered messages
  - Queue, reason, time, routing keys

**NOTE** A message is also sent to the queue dead letter exchange when its TTL expires or when the queue length limit is exceeded.

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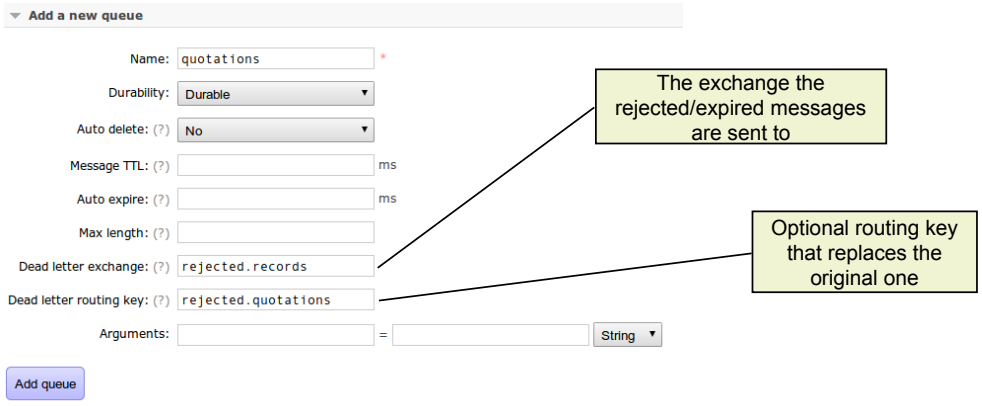
# Dead letter exchanges

- Declare dead letter exchange at queue creation
  - x-dead-letter-exchange and x-dead-letter-routing-key arguments

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# Lab

Implementing a Reliable Message Flow
(Part 1: "Durability and Persistence,
Acknowledgements, and Transactions")

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# Agenda

- Durability and persistence
- AMQP Transactions
- AMQP Acknowledgements
- Dead letter exchanges
- Multiple transactional resources

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# Multiple Transactional Resources

- Message processing is usually interleaved with business processing
  - E.g., on message reception, update the database
- Two transactional resources!
  - Broker (with message acknowledgment)
  - Database (commit the changes)
- All of this needs to be atomic
  - No partial failures!

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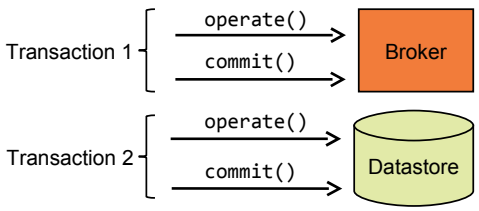
# Local Transactions on Multiple Resources

- Two transactional resources (database, broker)
  - Each resource transaction has to be committed individually
  - A rollback on a single transaction doesn't affect any other transaction
  - Cannot enlist transactions
- Referred to as *local* transactions

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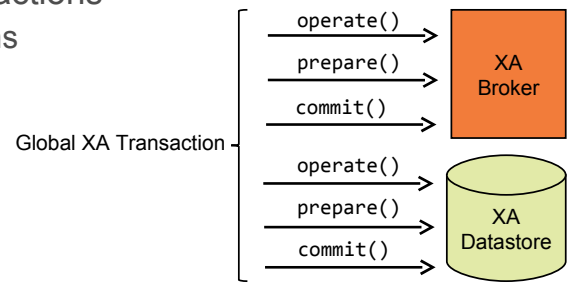
# Global Transactions

- Two transactional resources (database, broker)
  - A transaction can be committed/rolled back atomically
  - Resources has to support XA protocol
  - Resources are coordinated by a dedicated transaction manager
- Referred to as global transactions
  - Or *distributed* transactions

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# Local Transactions in Java

- Local Java transactions are managed:
- Directly by the developer
  - Calling the `beginTX()` and `commitTX()` or `rollbackTX()` method
  - Either by directly using the client resource API, or JTA
  - Have to write the technical code inside the business code
- By the container / lightweight container
  - Spring automatically manages TX, hiding them for the developer
  - Through some helper classes, or by configuration / annotations
  - By creating a Java EE Resource managed by the container

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## Global Transactions in Java

- JTA has support for global transactions
- A dedicated JTA transaction manager handles global transactions
- The JTA transaction manager is usually part of a full blown Java EE application server
  - Standalone JTA transaction managers also exist

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## XA Drawbacks

- XA Transactions have limitations and drawbacks
  - It is generally costly and impacts performance
  - It can be difficult to set-up
  - It is not 100% reliable (there is still a window where things can go wrong)

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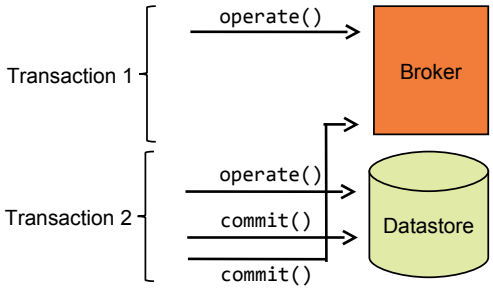
# Best Effort Pattern (1-Phase Commit)

- The workaround to XA is to use the best effort pattern
  - It is very close to the XA model without drawbacks
  - The critical window is very short (two operations for two commits)
  - When compared to local TX, the best effort pattern has no performance overhead
  - But it's not real XA

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# Transactions in AMQP

- AMQP supports both local and global transactions
- RabbitMQ supports *only local transactions*
  - 1-Phase Commit of the best effort pattern is well suited for AMQP / RabbitMQ
- Spring AMQP supports best effort pattern out of the box

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## Transactions in AMQP

- Best effort pattern can lead to duplicate messages
  - If something goes wrong between the DB and the broker commits
  - Message goes back to the queue and is redelivered
  - Business processing can happen twice!
- Processing must be idempotent
  - Processing must be idempotent
  - Certain types of processing are idempotent (e.g., update a flag to true)
  - Otherwise, must make processing idempotent (detect duplicate, ignore it, and send ack)

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## Summary

- Durability and persistence protect against message loss
- AMQP transactions improve reliability
- AMQP acknowledgements should be used by consumers to inform the broker when processing has completed
- Dead letter exchanges can be useful for handling rejected messages
- Best-effort pattern is recommended when there are multiple transactional resources

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# Lab

## Implementing a Reliable Message Flow
## (Part 2: "Multiple Transactional Resources and Best Effort")

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# RabbitMQ Clustering

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## Agenda

- **Clustering overview**
- Setting up clustering
- Network partitions

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# Clustering

- Clustering means using multiple nodes to construct a single *logical* broker
  - All nodes behave identically to clients
  - Clients see same exchanges, queues, users, vhosts
- Clustering enables scalability and high availability
- Scalability: scale messaging throughput by adding nodes
  - Several nodes to publish to and consume from
- High availability: no interruption of service if a node fails
  - No single point of failure

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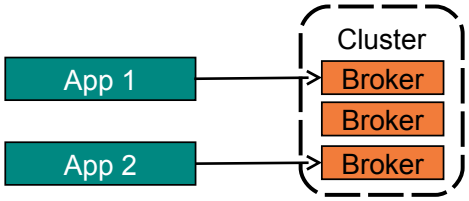
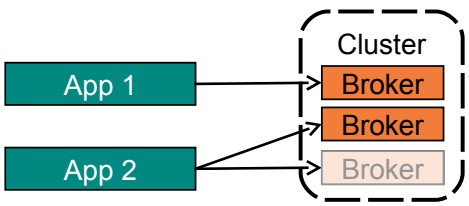
# Clustering




- Scalability:
  - Load is balanced across nodes
  - Is not automatic, must be designed accordingly




- High Availability (HA):
  - If node fails, client can connect to another one
  - Is only one part of an HA solution, clustering by itself is not inherently HA

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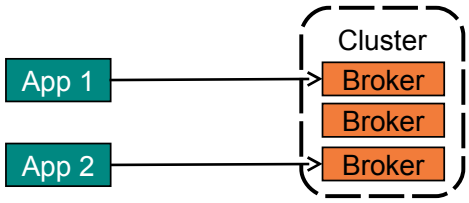
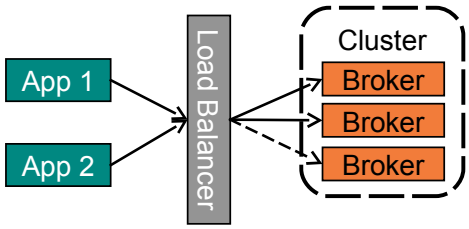
# Clustering Client Connectivity




- Option 1:
  - Clients have list of nodes to connect to, iterate over list until they connect successfully
  - Advantages: no additional components required
  - Disadvantages: clients must be aware of the cluster membership, and update configurations when the cluster changes




- Option 2:
  - Clients connect through a software or hardware load balancer
  - Advantages: clients always connect to a single virtual IP, do not need to be aware of cluster membership
  - Disadvantages: single point of failure, additional component required

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# Load Balancer

- The load balancer connects client to a node as selected by the specified algorithm eg. least connections, round robin, etc.
- Clients don't have to know all the nodes and deal with failures
- Load balancing can be at the TCP-level, no knowledge of AMQP necessary
- All classical solutions work
  - HAProxy – http://haproxy.1wt.eu/
  - IPVS – http://www.linuxvirtualserver.org/software/ipvs.html
  - Other software solutions
  - Hardware solutions

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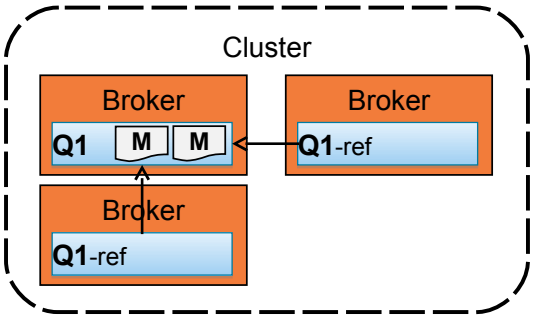
# Clustering does *not* equal full HA

- Standard default queues are not replicated across nodes in the cluster
- A single node in the cluster contains the queue messages
- Other nodes simply hold pointers to the node with the actual messages

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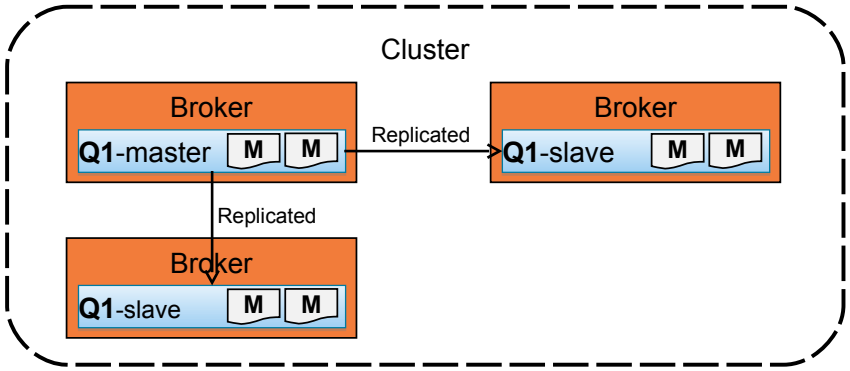
# Clustering + Mirrored Queues = Full HA

- Mirrored queues replicate the messages to other node(s) in the cluster.
- In the event of the node hosting the master copy going down, another node can take over

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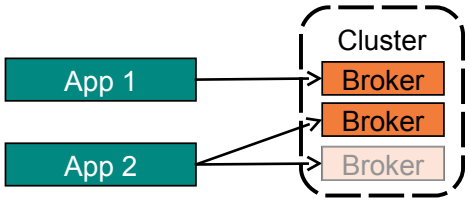
# Client Side Failover

- Clients must be aware of node failures
- Clients must handle reconnections

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# Clustering

- It is important to understand the concepts behind RabbitMQ clustering, since:
  - A failure isn't fully transparent for a client (especially a consumer)
  - Messages in a queue can be lost after a failure

**NOTE** Some components can help to cope with these concerns (e.g., a load balancer to make reconnection simpler for clients).

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# What's Inside a Cluster?

- A single or cluster RabbitMQ node stores metadata on
  - Users
  - Queues
  - Bindings
  - Exchanges
  - Virtual hosts
- A cluster node also stores metadata about the other nodes
- Any declaration on a node is replicated to the other nodes  i.e. the metadata is replicated to all nodes in the cluster

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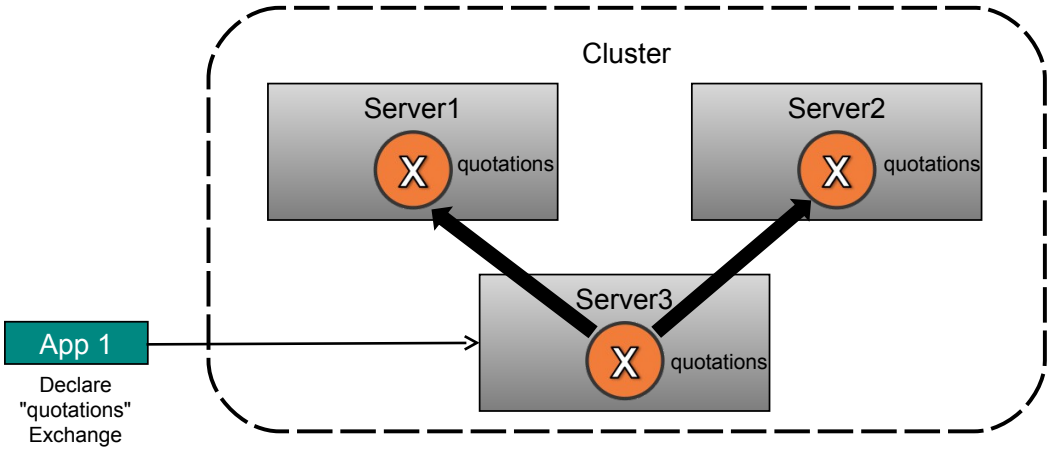
# Cluster Behavior for an Exchange Declaration

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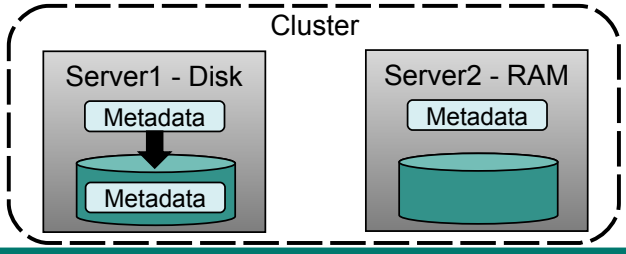
# RAM vs Disk Nodes

- A node can store metadata in RAM or on disk
  - RAM storage allows fast access (but metadata is lost in case of a restart)
  - Disk storage is slower but metadata will survive a restart
- A cluster node can be either a RAM or a disk node
- A single RabbitMQ node can only be a disk node
  - You don't want to lose durable definitions between restarts!

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# RAM vs Disk Nodes

- General rule: always use disk nodes
  - This is safer
  - A cluster of only RAM nodes would result in data loss if the cluster crashed
- RAM node are faster, but only for resource management
  - E.g., creating a queue
- Disk nodes are rarely a source of bad performance
  - Instead, investigate other potential root causes such as persistent messages, acknowledgments, etc.

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# Behind the Scenes

- Clustering exchanges and bindings
  - Just a routing table
  - Clustering them means distributing them on the nodes
  - Each node can make routing decisions without network calls
- Clustering users and virtual hosts
  - Clustering them means distributing them on the nodes
  - In classic cases, doesn't account for much replication traffic
- Clustering a queue
  - All nodes replicate the queue metadata
  - But only one node stores the queue's content (messages)
  - RabbitMQ sets up pointers on all other nodes, to the node with the queue contents

**NOTE** RabbitMQ provides mirrored queues to replicate queue messages on multiple nodes. The high availability module covers mirrored queues.

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# Queue Creation

- Creating a standard (non-mirrored) queue on a cluster
  - All nodes will see it (cluster)
  - (n – 1) nodes will just have a pointer to the real queue on a node
  - 1 node will have the physical storage
  - RabbitMQ puts the physical queue on the node the client declaring the queue was connected to at the time the queue was declared
  - No rebalancing is done

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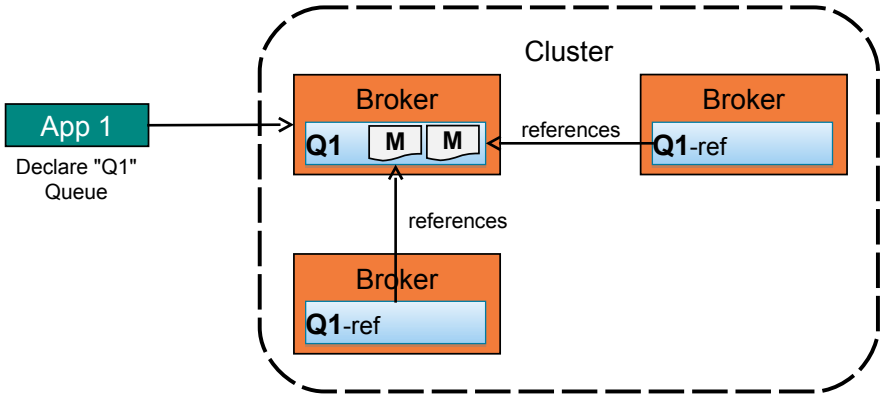
# Standard Non-Mirrored Queue in a Cluster

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# Agenda

- Clustering overview
- **Setting up clustering**
- Network partitions

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# Creating a Cluster (overview)

- Prerequisites
  - Must be the same RabbitMQ and Erlang versions on all nodes
  - A special file must be copied to all cluster nodes for RabbitMQ to communicate between nodes (next slide)
- Creating a cluster on three machines
  - server1, server2, server3 in the next slides
- Start RabbitMQ on all nodes
  - For all nodes except the first:
  - Stop the RabbitMQ application, leaving Erlang running
  - Run the RabbitMQ clustering, telling it where to find the other cluster nodes
  - Restart the RabbitMQ application

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# Erlang Cookie

- RabbitMQ's clustering builds on top of Erlang OTP
  - Open Telecom Platform
- OTP requires nodes to share the same cookie to communicate
- It's just a text file to copy between nodes, eg:

```
CGUKYMYPRRNFOSUYVXPE
```

- User running RabbitMQ needs read permissions on the file

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## Step 1: Copy the Erlang Cookie

- Start the server on one of the nodes

```
server1$ service rabbitmq-server start
```

- It creates the Erlang cookie if it doesn't already exist:
  - `/var/lib/rabbitmq/.erlang.cookie` (UNIX)
  - `C:\Users\Current User\.erlang.cookie` or `C:\Documents and Settings\Current User\.erlang.cookie` (Windows)
- Copy the Erlang cookie to the correct location on all the other nodes you want to cluster
  - User running RabbitMQ needs read permissions on the file!

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## Step 2: Start The Other Servers

- Login to all the other servers
- Start RabbitMQ on all the other servers

```
server2$ service rabbitmq-server start
```

```
server3$ service rabbitmq-server start
```

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# Step 2: Start The Other Servers

- Confirm the RabbitMQ servers are running by checking their status
- Confirm the RabbitMQ servers are all standalone
  - i.e. not in a cluster already

```
server1$ rabbitmqctl cluster_status
Cluster status of node rabbit@server1 ...
[{nodes,[{disc,[rabbit@server1]}]},{running_nodes,[rabbit@server1]}]
...done.
```

```
server2$ rabbitmqctl cluster_status
Cluster status of node rabbit@server2 ...
[{nodes,[{disc,[rabbit@server2]}]},{running_nodes,[rabbit@server2]}]
...done.
```

```
server3$ rabbitmqctl cluster_status
Cluster status of node rabbit@server3 ...
[{nodes,[{disc,[rabbit@server3]}]},{running_nodes,[rabbit@server3]}]
...done.
```

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# Step 3: Stop the joining nodes

- Choose a server that will be the first cluster node
  - Don't touch it; leave it running
  - You can also stop it (stop_app) and reset it, to be sure to start from a clean state
- On all other servers
  - Stop the RabbitMQ application

**NOTE** A reset removes the node from any cluster it belongs to, removes all metadata, and deletes all persistent messages. Do it only if you want a fresh cluster!

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# Step 3: Stop the joining nodes

```
server2$ rabbitmqctl stop_app
Stopping node rabbit@server2 ...
...done.
```

Leaves the Erlang VM running.

```
server3$ rabbitmqctl stop_app
Stopping node rabbit@server3 ...
...done.
```

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# Step 4: Join the Node to the Cluster

- On all servers that have undergone step 3
  - Join the cluster by specifying the other nodes
- Starting with server2

Join as a RAM node

Specify the node to join

```
server2$ rabbitmqctl join_cluster --ram rabbit@server1
Clustering node rabbit@server2 with [rabbit@server1] ...
...done.
server2$ rabbitmqctl start_app
Starting node rabbit@server2 ...
...done.
```

**NOTE** Joining a cluster resets the joining node.

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# Step 5: Check the Cluster Status

- Confirm the status on the newly clustered nodes

```
server1$ rabbitmqctl cluster_status
Cluster status of node rabbit@server1 ...
[{nodes,[{disc,[rabbit@server1]},{ram,[rabbit@server2]}]},
 {running_nodes,[rabbit@server2,rabbit@server1]}]
...done.
```

A 2-node cluster

```
server2$ rabbitmqctl cluster_status
Cluster status of node rabbit@server2 ...
[{nodes,[{disc,[rabbit@server1]},{ram,[rabbit@server2]}]},
 {running_nodes,[rabbit@server1,rabbit@server2]}]
...done.
```

Both nodes are up

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# Step 5: RAM vs. Disk Nodes

- Going back to the cluster status:

```
server1$ rabbitmqctl cluster_status
Cluster status of node rabbit@server1 ...
[{nodes,[{disc,[rabbit@server1]},{ram,[rabbit@server2]}]},
 {running_nodes,[rabbit@server2,rabbit@server1]}]
...done.
```

rabbit@server1 is a disk node

rabbit@server2 is a RAM node

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# Step 5: RAM vs. Disk Nodes

- How can we specify if a node is a RAM or disk?
- Going back to what we executed:

```
server2$ rabbitmqctl join_cluster --ram rabbit@server1
Clustering node rabbit@server2 with [rabbit@server1] ...
...done.
server2$ rabbitmqctl start_app
Starting node rabbit@server2 ...
...done.
```

- For a disk node, exclude the "--ram" parameter

```
server2$ rabbitmqctl join_cluster rabbit@server1
Clustering node rabbit@server2 with [rabbit@server1] ...
...done.
server2$ rabbitmqctl start_app
Starting node rabbit@server2 ...
...done.
```

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# Step 6: Join the Node to the Cluster

- On all servers that have undergone step 3
- Join the cluster by excluding the "--ram" parameter
- Let's do that again with server3, as a disk node

server3 will join as a disk node

```
server3$ rabbitmqctl join_cluster rabbit@server1
Clustering node rabbit@server3 with [rabbit@server1, rabbit@server3] ...
...done.
server3$ rabbitmqctl start_app
Starting node rabbit@server3 ...
...done.
```

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# Step 7: Check the Cluster Status

- Confirm the status on the newly clustered nodes

```
server1$ rabbitmqctl cluster_status
Cluster status of node rabbit@server1 ...
[{nodes,[{disc,[rabbit@server3, rabbit@server1]}, {ram,[rabbit@server2]}]},
 {running_nodes,[rabbit@server3, rabbit@server2, rabbit@server1]}]
...done.
```

A 3-node cluster

```
server2$ rabbitmqctl cluster_status
Cluster status of node rabbit@server2 ...
[{nodes,[{disc,[rabbit@server3, rabbit@server1]}, {ram,[rabbit@server2]}]},
 {running_nodes,[rabbit@server3, rabbit@server1, rabbit@server2]}]
...done.
```

```
server3$ rabbitmqctl cluster_status
Cluster status of node rabbit@server3 ...
[{nodes,[{disc,[rabbit@server3, rabbit@server1]}, {ram,[rabbit@server2]}]},
 {running_nodes,[rabbit@server1, rabbit@server2, rabbit@server3]}]
...done.
```

All nodes are up

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# Changing a Node Type (RAM – Disk)

- To change the type of the node
  - Stop the application
  - Change the type with `change_cluster_node_type <new_type>`
  - Start the application

```
server2$ rabbitmqctl stop_app
server2$ rabbitmqctl change_cluster_node_type disk
server2$ rabbitmqctl start_app
```

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# Removing a Cluster Node

- Stop the application and reset the node

```
server1$ rabbitmqctl stop_app
Stopping node rabbit@server1 ...done.
server1$ rabbitmqctl reset
Resetting node rabbit@server1 ...done.
server1$ rabbitmqctl start_app
Starting node rabbit@server1 ...done
```

- server1 is now an independent broker
- Don't stop the only disk node in a cluster!
  - Change the type of another node from RAM to disk first

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# Upgrading a cluster

- 2 scenarios
  - The cluster can run during the upgrade
  - The cluster must be taken down
- When must the cluster be taken down?
  - When upgrading Erlang
  - When from major/minor RabbitMQ version to another
  - E.g. from 3.0.x to 3.1.x, from 2.x.x to 3.x.x

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## Upgrading a cluster (scenario 1)

- If the cluster can run
  - Just stop and upgrade nodes one after the other

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## Upgrading a cluster (scenario 2)

- All nodes must be stopped
  - Stop a disk node last (a.k.a. the “upgrader”)
- Change the RabbitMQ version (and Erlang if appropriate)
- Start the upgrader first
- The upgrader automatically updates the metadata structure if needed
- Start the other nodes

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# Clustering on a Single Machine

- A cluster can run on a single machine
- Very useful for experimenting failure scenarios
- Just need to avoid port collisions!

```
$ RABBITMQ_NODE_PORT=5672 RABBITMQ_NODENAME=server1 rabbitmq-server start
$ RABBITMQ_NODE_PORT=5673 RABBITMQ_NODENAME=server2 rabbitmq-server start
```

- To stop:

```
$ rabbitmqctl -n server1 stop
$ rabbitmqctl -n server2 stop
```

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# Clustering on a Single Machine

- Specify port for the management plugin if it's enabled:

```
RABBITMQ_NODE_PORT=5672 RABBITMQ_NODENAME=server1 \
RABBITMQ_SERVER_START_ARGS="-rabbitmq_management listener [{port,15672}]" \
rabbitmq-server start
```

***NOTE*** Remove any port settings the rabbitmq.config file contains.

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# Lab

Setting Up A RabbitMQ Cluster

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# Agenda

- Clustering overview
- Setting up clustering
- **Network partitions**

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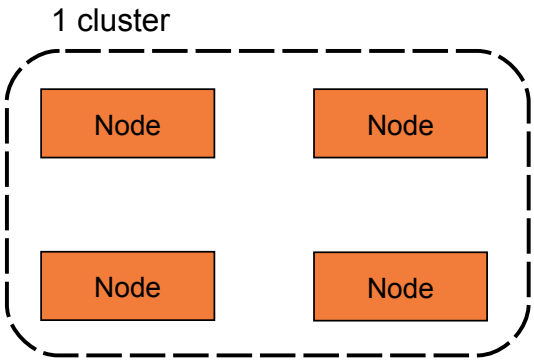
# Network Partitions

- What happens when cluster nodes can't reach each other?

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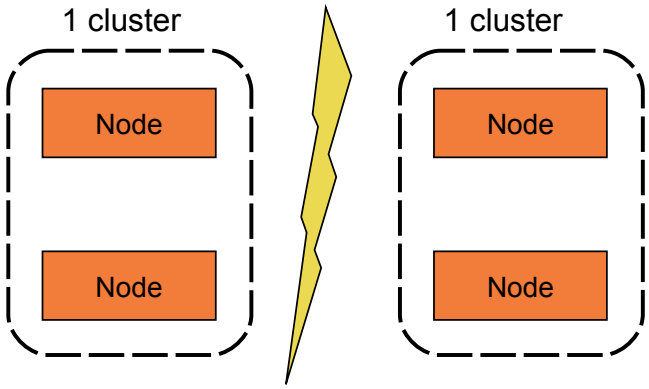
# Network Partitions

- Default behavior in case of network partition: 2 independent clusters

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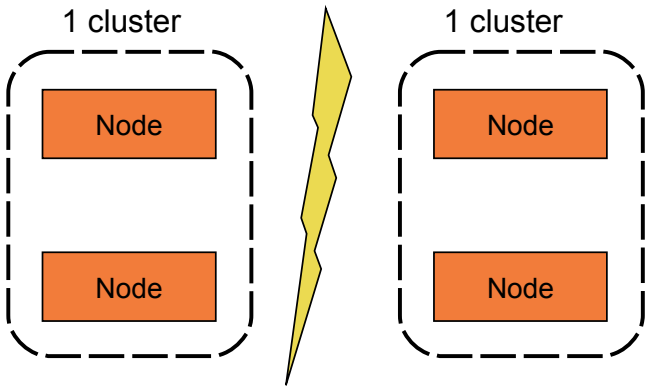
# Network Partitions

- When network connectivity is restored, still 2 independent clusters
- This is the default behavior (a.k.a. “ignore”) : no explicit action after the partition

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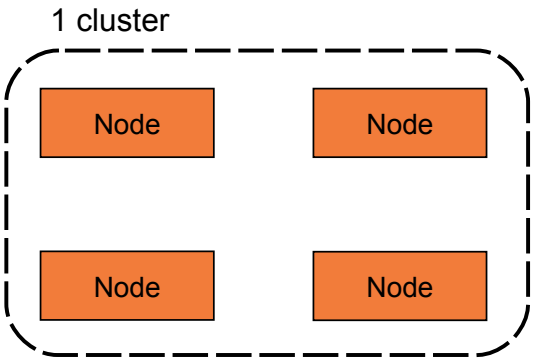
# Network Partitions Recovery

- Choose one “winning” partition/cluster
- Stop and start all nodes in the “losing” cluster, they’ll rejoin the cluster
- Everything in the losing cluster is lost

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# Network Partitions Detection

- Partition happens after `net_ticktime` seconds of non-connectivity
  - Default is 60 seconds
- Nodes report the partition in the log (when connectivity is restored)

```
=ERROR REPORT==== 24-Mar-2016::18:02:30 ===
Mnesia(rabbit@server1): ** ERROR ** mnesia_event got
    {inconsistent_database, running_partitioned_network, rabbit@server2}
```

- Information also available from the command line

```
$ rabbitmqctl cluster_status
Cluster status of node rabbit@server1 ...
[{nodes,[{disc,[rabbit@server2,rabbit@server1]}]},
 {running_nodes,[rabbit@server1,rabbit@server2]},
 {partitions,[{rabbit@server1,[rabbit@server2]},
              {rabbit@server2,[rabbit@server1]}]}]
...done.
```

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# Network Partitions Handling

- Default behavior: RabbitMQ doesn't do anything
  - "ignore" mode
- Other modes are available, they can intervene:
  - When the partition is detected
  - When connectivity is restored
- Modes:
  - pause_minority: automatically stop nodes in a minority cluster
  - pause_if_all_down: automatically stop nodes that cannot reach a given list of other nodes
  - autoheal: on connectivity recovery, choose automatically a winning partition and restart the node in the losing partition

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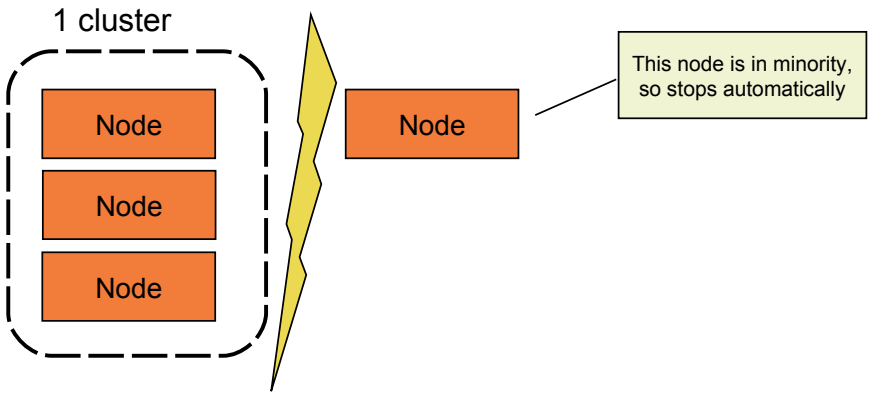
# Network Partitions – pause_minority

- Nodes in a minority partition stop
  - Minority = fewer or equal than half the total number of nodes

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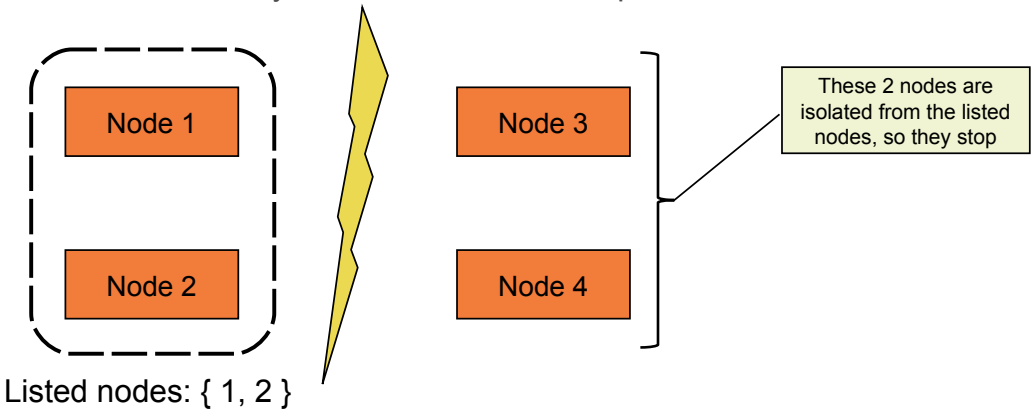
# Network Partitions – pause_if_all_down

- List of “important” nodes at configuration time
- If one node loses connectivity with those nodes, it stops

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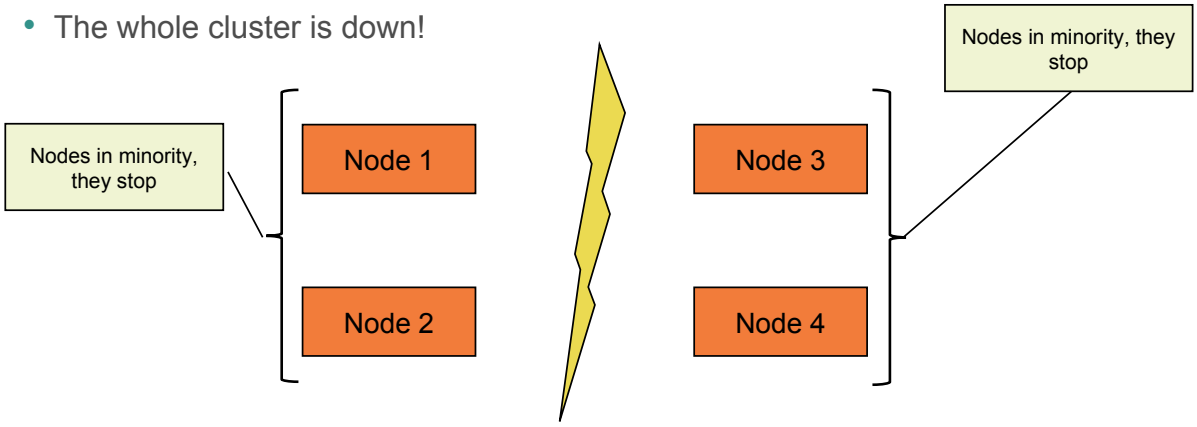
# pause_minority vs. pause_if_all_down

- With pause_minority
- The whole cluster is down!

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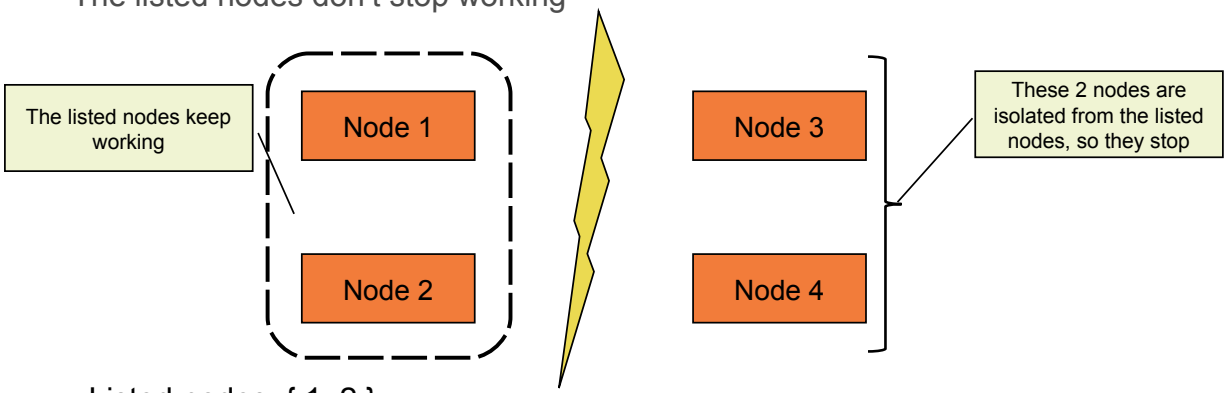
# pause_minority vs. pause_if_all_down

- With pause_if_all_down
- The listed nodes don't stop working




Listed nodes: { 1, 2 }

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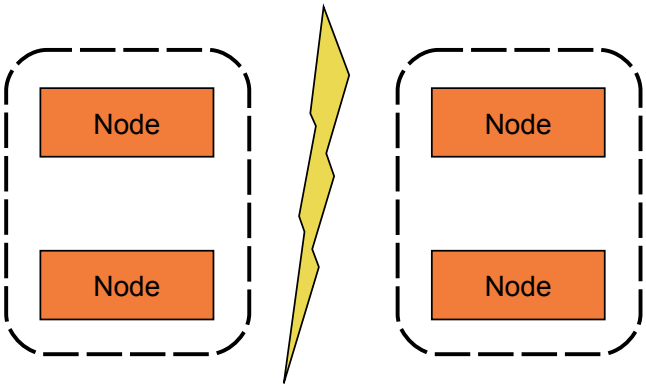
# Network Partitions – autoheal

- RabbitMQ chooses a winning partition when connectivity is restored
- How?
  - Partition with the most clients connected
  - In case of draw, partition with the most nodes
  - In case of draw, random choice

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# Network Partitions Handling Configuration

- In RabbitMQ configuration file

ignore | pause_minority | autoheal

```
[
{rabbit, [
  {cluster_partition_handling, ignore }
]}
].
```

- With pause_if_all_down

ignore | autoheal
(because listed nodes can also lose connectivity)

```
[
{rabbit, [
  {cluster_partition_handling,
  {pause_if_all_down, ['rabbit@server1', 'rabbit@server2'], ignore }
]}
].
```

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## Network Partitions Handling

- Use ignore
  - If you have a very reliable network and plan to recover manually
- Use pause_minority / pause_if_all_down
  - If your network is less reliable
  - If you want minimal manual intervention once connectivity is restored
- Use autoheal
  - If you favor availability over consistency
  - If you can afford to lose some data

**NOTE** The complete reference: http://www.rabbitmq.com/partitions.html

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## Summary

- RabbitMQ clusters form a single logical server
- Important to understand underlying clustering concepts
- Creating a cluster is easy
- RabbitMQ offers several options for handling network partitions

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# High Availability

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## Agenda

- **Cluster node failures and consequences**
- Mirrored queues
- Slaves synchronization
- Failover handling for the client

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# Failure of a Cluster Node

- When a cluster node fails, the main concern is the queues it hosts
- Remember the defaults of a clustered queue:
  - All nodes share the metadata
  - One node contains the queue messages
  - Other nodes have a pointer to the owner of the queue
- Why don't we care about exchanges in case of failure?
  - The other nodes have the exchanges metadata
  - An exchange doesn't contain any messages, a queue does!

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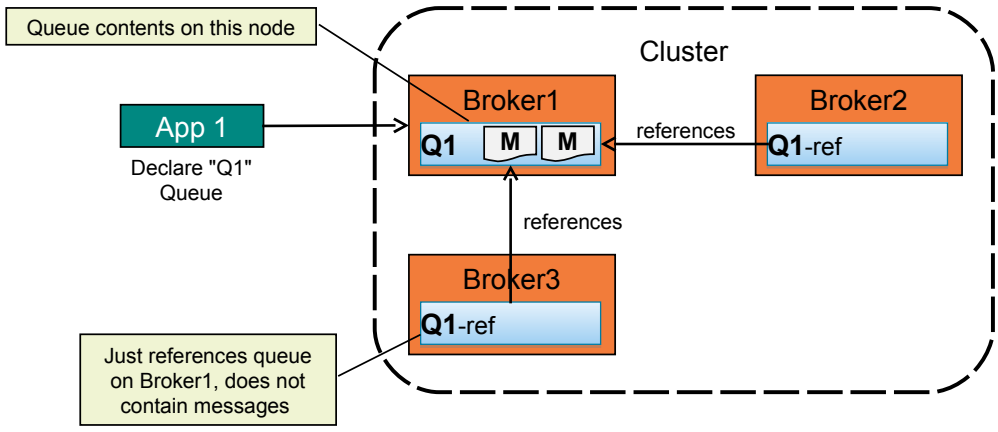
# Reminder: Queue in a Cluster

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# Failure of a Cluster Node

- What happens if the “owner” node dies?
  - Consumers lose their subscriptions
  - New messages matching the bindings are silently discarded
- If queue was durable, it cannot be re-created
  - The owner must be restored
- If queue wasn’t durable, it can be re-created
  - Even if the former owner isn’t running

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# Node Failure: Consequences for an Exchange

- An exchange is just a lookup table
- The channel handles the routing from exchanges to queues
- If a node fails, all the other nodes know the lookup table
  - This is a cluster, each node has the metadata of all exchanges
- The exchange is still visible to clients connected to other nodes

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# Node Failure: Consequences for an Exchange

- What happens if a node fails while the message is being routed?
  - If the producer used "fire and forget", the message can be lost
  - To avoid lost messages on the producer side:
    - Use transactions
    - Or use RabbitMQ's publisher confirms extension
    - In both cases, the producer can know if the message didn't make it to the queue
- At the end, the producer needs to reconnect to another node
  - Or wait for the node to be up again

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# Agenda

- Cluster node failures and consequences
- **Mirrored queues**
- Slaves synchronization
- Failover handling for the client

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# Mirrored Queues

- A mirrored queue replicates its content on multiple cluster nodes
- The content of a mirrored queue lives on one master node
- The content is replicated on other nodes of the cluster
- Mirrored queues provide high availability
- Mirrored queues also affect performance

**NOTE** Mirrored queues were introduced in RabbitMQ 2.6.0. There was no built-in HA solution before mirrored queues.

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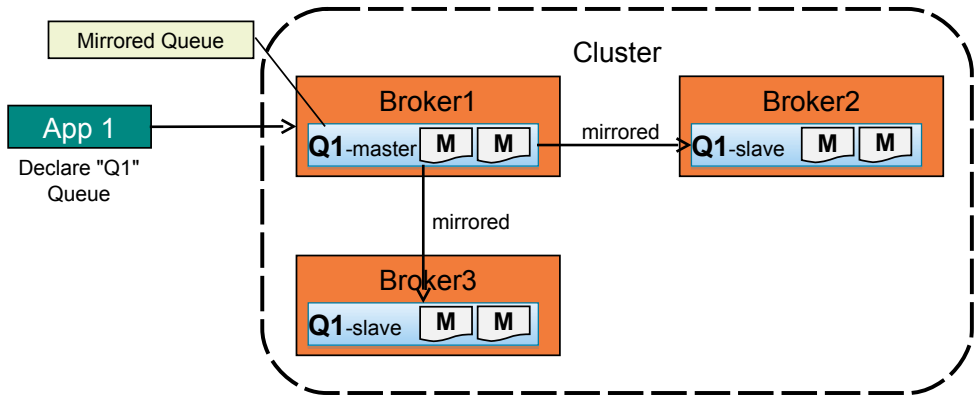
# Mirrored Queue

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# Mirrored Queue Creation

- Mirrored queues are designated through broker policies
- Regex's on queue names are used to determine whether policy applies
- Policies applied
  - At queue creation, if queue's name matches policy
  - At policy creation, on existing queues if they match
- Regular queues can be promoted to mirrored queues!

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# Mirrored Queue Policy Options

- Two HA parameters when creating the policy
  - ha-mode: mode of mirroring/replication
  - ha-params: parameters, depends on the mode

| ha-mode | ha-params | Description |
|---|---|---|
| all | (none) | Mirrored across all nodes (simpler but slower) |
| exactly | Count of mirrors | Total number of mirrors, nodes are selected randomly |
| nodes | Names of nodes | Mirrored to the specified list of nodes. Fine-grained but implies knowledge of the nodes in the cluster |

- A policy specifying exactly 2 mirrors will provide a good balance between redundancy and performance

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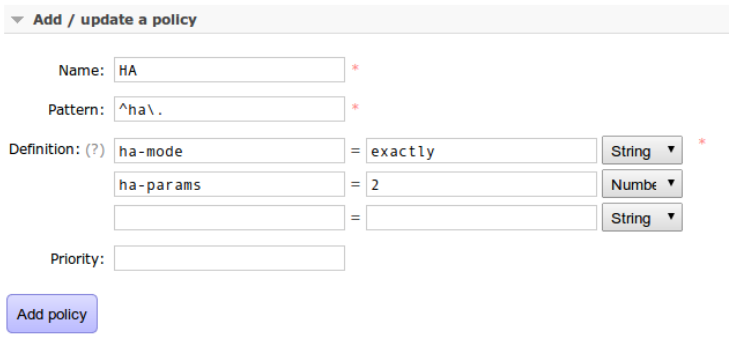
# Declaring the HA Policy

- The management plugin supports the creation of HA policies




- The matching queue(s) become mirrored

| Overview | | | | | | Messages | | | Message rates | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Node | Exclusive | Parameters | Policy | Status | Ready | Unacked | Total | incoming | deliver / get | ack |
| ha.quotations | server1@acogoluegnes-zenbook +1 | | D | HA | Idle | 0 | 0 | 0 | | | |

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# Queue Master Distribution Strategies

- How to distribute queue masters between nodes?
  - You don't want a node to be the master of too many queues
- 3 strategies:
  - Pick the node hosting the minimum numbers of masters
  - Pick the node the client that declares the queue is connected to
  - Pick a random node

***NOTE*** The default is to pick the node the client declaring the queue is connected to.

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## Queue Master Distribution Strategies

- 3 ways
  - Use the `x-queue-master-locator` queue declare argument
  - Use the `queue-master-locator` policy key
  - Use the `queue_master_locator` key in the configuration file
- 3 possible values:
  - `min-masters`
  - `client-local`
  - `random`

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## Failure of the Master of a Mirrored Queue

- The eldest slave becomes the new master
  - It has the best chance to be synchronized with the master
  - If it's not, messages held only on the master are lost!
- Messages that are pending acknowledgment are re-queued
- Consumers connected to the failing node must reconnect to another node
- Consumers of the remaining nodes don't have to do anything

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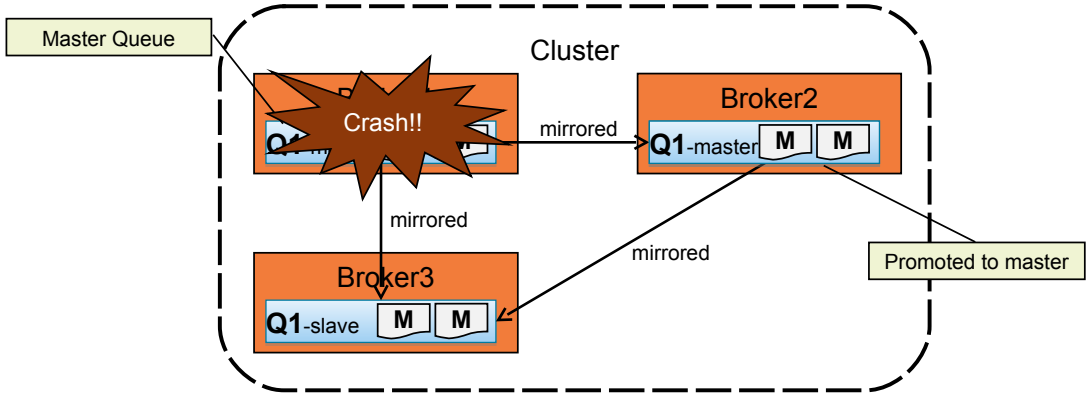
# Failure of the Master of a Mirrored Queue

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# Master Promotion Behavior

- Why does the newly promoted master re-queue unack'd messages?
- The new master can't know what truly happened to these messages
  - Perhaps the consumers sent the acknowledgment but…
  - … The master could have failed
    - When the ACK was between the consumer and the master
    - When the ACK was broadcast from master to slaves
    - While the consumer is still processing the message
  - Consumers must
    - Pick up the new master
    - Be able to deal with duplicate messages

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# Nodes Joining a Cluster with Mirrored Queues

- If the HA Policy dictates there are not enough mirrors for a given queue when a newcomer joins the cluster:
  - Queue mirrors are created as slave queues
  - The new slave queue on the newcomer starts queuing incoming messages
  - Existing messages from the master queue are not replicated to the slave on the newcomer
  - There is no “catch-up” of existing messages
  - The newcomer is considered unsynchronized
  - As messages are consumed, the slave queue on the newcomer gets synchronized naturally
  - This is the default behavior: no synchronization when joining the cluster

**NOTE** RabbitMQ provides a mechanism to automatically or manually synchronize new slave queues.

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# Nodes Joining a Cluster with Mirrored Queues

- If messages stay a long time in the queue, a newcomer doesn’t bring much redundancy!
- Best practices
  - Start up all nodes and then create a mirrored queue
  - Do not use the broker to hold messages for long periods of times
  - Consume messages as fast as possible

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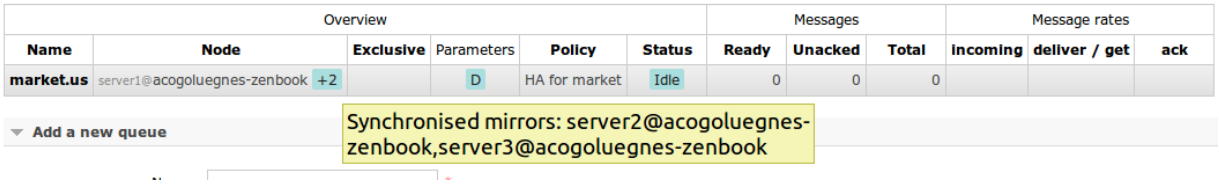
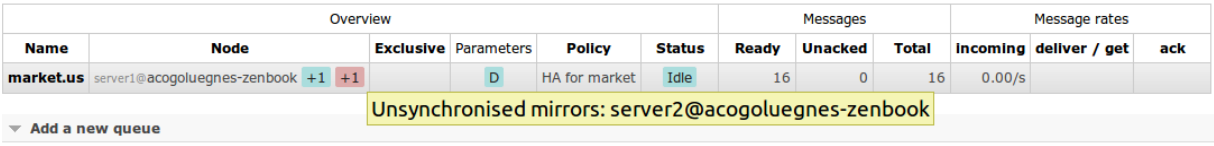
# Monitoring Mirrored Queues

- Slaves are synchronized:




- One slave is not synchronized:






# Monitoring Mirrored Queues

- Slaves are synchronized when the last 2 columns are identical

```
$ rabbitmqctl list_queues name pid slave_pids synchronised_slave_pids
Listing queues ...
quotations  <'s1@host'.1.12915.0> \
           [<'s2@host'.2.10752.0>, <'s3@host'.3.8343.0>] \
           [<'s2@host'.2.10752.0>, <'s3@host'.3.8343.0>]
...done.
```

- Slaves are unsynchronized when the last 2 columns are not identical

```
$ rabbitmqctl list_queues name pid slave_pids synchronised_slave_pids
Listing queues ...
quotations  <'s1@host'.1.12915.0> \
           [<'s2@host'.2.10752.0>, <'s3@host'.3.8343.0>] \
           [<'s2@host'.2.10752.0>]
...done.
```



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# Agenda

- Cluster node failures and consequences
- Mirrored queues
- **Slaves synchronization**
- Failover handling for the client

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# Synchronizing Unsynchronized Slaves

- Automatic synchronization when creating policy
  - Set ha-sync-mode key to automatic
  - Default is manual


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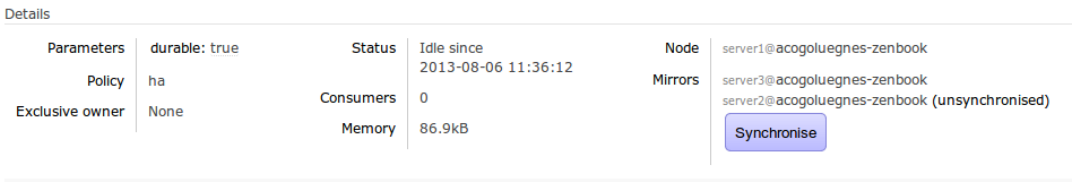
# Synchronizing Unsynchronized Slaves

- How to synchronize manually?
- Command line

```
$ rabbitmqctl sync_queue myqueue
```

- Management plugin (in queue details)

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# Mirrored Queues Synchronization

- Avoid explicit synchronization
  - Either automatic or manual
  - Queue is unresponsive during the sync
- Prefer the natural synchronization
  - Works well if consumers are working correctly

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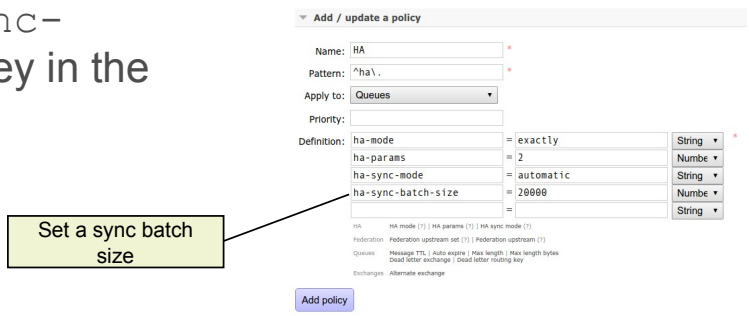
# Synchronization Optimization

- RabbitMQ can synchronize messages in batches
  - Can make the sync must faster
  - E.g. from 60 seconds to a few seconds for 1M messages
- Use the `ha-sync-batch-size` key in the policy

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# Agenda

- Cluster node failures and consequences
- Mirrored queues
- Slaves synchronization
- **Failover handling for the client**

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# Failover on Client Side

- Node failures aren't transparent to client
- Clients must deal with node failures
- Clients bindings provide callbacks in case of errors
- These callbacks make the recovery code easier to write
- There are many failure scenarios: always test yours!

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# Shutdown Hook

- The connection has a shutdown hook
- The developer can add a `ShutdownListener`

```
connection.addShutdownListener(new ShutdownListener() {
  @Override
  public void shutdownCompleted(ShutdownSignalException cause) {

  }
});
```

Called when connection is closed

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# Shutdown Hook in Case Of Server Failure

- Shutdown listeners are called when the connection closes
- The close method can be called in normal condition
- Check the cause of the closing to execute recovery code

```
connection.addShutdownListener(new ShutdownListener() {
  @Override
  public void shutdownCompleted(ShutdownSignalException cause) {
    if(cause.isHardError()) {
      // recovery code
    }
  }
});
```

True in case of connection failure

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# What To Do After Failure

- A client works against exchanges and queues
  - It can also define bindings
- Bindings and non-mirrored queues can disappear after a failure
- A client should re-declare everything it uses after it detected a failure
  - Especially non-mirrored queues and bindings
- Declarations are idempotent
  - They work even if the resource already exists…
  - … as long as the to-be-declared resource has the same options as the existing one
- Don't take for granted your resources are still valid after a failure!

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# Reconnection After A Failure

- The cause of failure can be a crash or a network glitch
- Client can try to reconnect to the same node
  - No problem if cause was network glitch
  - Problem if node is down
- This is where a load balancer helps
  - The entry point for the client is the load balancer
  - Load balancer detects node failure and dispatches on available nodes
  - Client isn't coupled to cluster nodes
- If there's no load balancer, client needs to know nodes in advance
  - Doesn't have to be hardcoded, can be part of configuration

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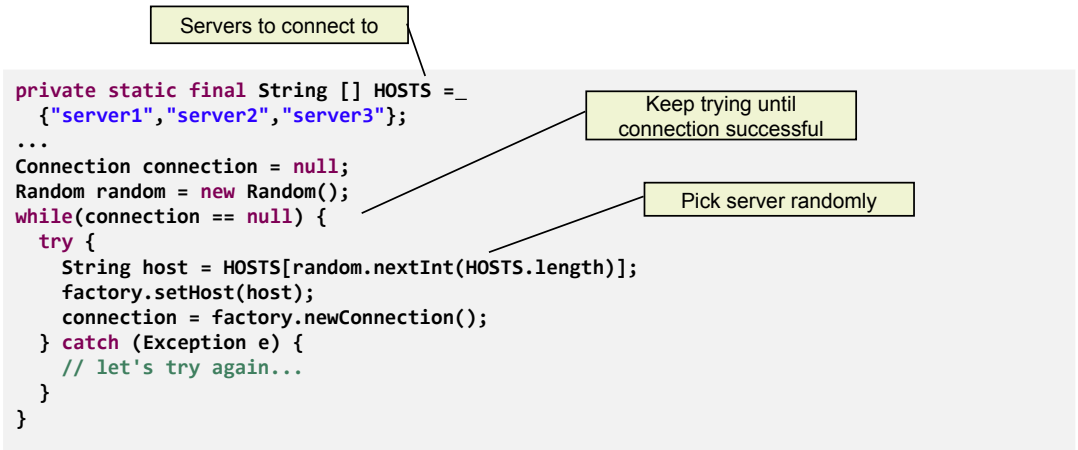
# Client Reconnection (manual)

- Reconnect randomly or with any other algorithm




```
private static final String [] HOSTS =_
  {"server1","server2","server3"};
...
Connection connection = null;
Random random = new Random();
while(connection == null) {
  try {
    String host = HOSTS[random.nextInt(HOSTS.length)];
    factory.setHost(host);
    connection = factory.newConnection();
  } catch (Exception e) {
    // let's try again...
  }
}
```

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# Client Reconnection (built-in support)

- Built-in, but no control over the choice algorithm

```
Address[] adresses = new Address[]{
  new Address("server1",5672),
  new Address("server2",5672),
  new Address("server3",5672),
};
Connection connection = factory.newConnection(adresses);
```

The servers to connect to

Pick the first that succeeds in the array

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# Failover For Producers

- Failover for producers is easy as they're active
  - Same thing for active consumers
- This is the typical workflow of a producer:
  - Gets a channel from the connection
  - Sends messages
  - Closes the channel
- What should the producer consider?
  - Getting a workable channel: if the connection is dead, opening a channel throws an exception. The producer needs to open a new connection and to retry.
  - Ensure the sent messages made it to the broker: this isn't always a requirement, but sometimes it matters.

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# Producers Ensure Broker Got Sent Messages

- Remember, sending uses "fire and forget" by default
  - When the method returns, the message is on its way to the broker
- "Fire and forget" is fast, but doesn't provide guaranteed delivery
- Use transactions to be sure the messages reached the broker

```
channel.txSelect();

byte[] msg = "NASDAQ".getBytes();
channel.basicPublish(stockExchange, stockCategory, null, msg);

channel.txCommit();
```

Create the transaction

Publish the message

Commit the transaction. When this method returns, it means the message reached the broker

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# Publisher Confirms

- Transactions provide strong guarantees, but they're slow
  - They're also part of AMQP
- RabbitMQ provides the publisher confirmations extension
- Publisher can be sure messages made it to the broker
  - This is faster than transactions

```
channel.confirmSelect();

byte[] msg = "NASDAQ".getBytes();
channel.basicPublish(stockExchange, stockCategory, null, msg);

channel.waitForConfirms();
```

Enable publisher confirmations on channel

Method blocks until broker responds it received all messages

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# Failover for Asynchronous Consumers

- Asynchronous consumer can die with its connection
- Register a shutdown listener to handle node failure
- Just after connection creation:

```
public void connectAndListen() {
  ...
  connection.addShutdownListener(new ShutdownListener() {
    @Override
    public void shutdownCompleted(ShutdownSignalException cause) {
      if(cause.isHardError()) {
        connectAndListen();
      }
    }
  });
  ...
}
```

Re-launch connection creation and listener registration after the connection dies.

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# Queues and Failure

- Remember, standard non-mirrored queues are only on one node at a time
  - Other nodes reference the owning node
- If the owning node dies, the queue disappears from the cluster!
- This can have profound impacts on consumers!

**NOTE** Mirrored queues do survive a node failure, though all the messages may not.

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# Failure of a Node for an Async Consumer

- Use case:
  - Asynchronous consumer is consuming from a queue
  - Queue is on server 1
  - Consumer is connected to server 2
- Failure scenario
  - server2 dies
  - Consumer detects failure and manages to connect on server1
- Everything is fine!
  - server2 could have come back again, consumer could have reconnected to it
- It is when the owning node fails that things go wrong…

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# Failure of the Owner of a Queue

- Use case:
  - Async consumer is consuming from a queue
  - Queue is on server 1
  - Consumer is connected to server 2
- Failure scenario
  - server1 dies, the queue disappears from the cluster
  - Consumer doesn't detect anything, it keeps on listening and see nothing
  - server1 comes back to life, queue comes back in the cluster
  - Consumer still doesn't see anything!
- RabbitMQ provides an extension to notify the consumer

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# Consumer Cancellation Extension

- Consumer listens on a queue but isn't connected to owning node
- Consumer can be notified when owning node dies
  - It can recreate the queue on the node it is listening on

```
channel.basicConsume("quotations", true,new DefaultConsumer(channel) {
  @Override
  public void handleDelivery(String consumerTag, Envelope envelope,
         AMQP.BasicProperties properties, byte[] body) throws IOException { }

  @Override
  public void handleCancel(String consumerTag) throws IOException {
    recreateQueueAndRestartListening();
  }
});
```

Called when the owning node dies

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# Failure of the Master of a Mirrored Queue

- The queue still exists, messages aren't lost
- A consumer cancellation notification is not sent to consumers connected to other nodes
  - No action is required those consumers, they will continue to receive messages

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# Automatic recovery with the Java client

- The Java client supports automatic recovery of
  - Connections
  - Topology (queues, exchanges, bindings, consumers)
- In practice, in case of failure of the node the client is connected to:
  - The client reconnects and restores connection and channel listeners
  - The client can redeclare resources (queues, exchanges, etc)

**NOTE** The Java client supports automatic recovery since version 3.3.0.

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# Automatic recovery activation

- Just activate the flag at the ConnectionFactory level

```
factory.setAutomaticRecoveryEnabled(true);
Connection connection = factory.newConnection();
```

Set up the flag

Connection that will recover automatically

- Even better to use an array of addresses

```
factory.setAutomaticRecoveryEnabled(true);
Address[] adresses = new Address[]{
  new Address("server1",5672),
  new Address("server2",5672),
  new Address("server3",5672),
};
Connection connection = factory.newConnection(adresses);
```

In case of failure, automically tries the different addresses

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# Automatic recovery semantics

- Kicks in only when the client gets disconnected
- Restores connection and channel listeners
- Restores QoS setting on channels
- Doesn't handle re-publication (use public confirms or transaction instead)
- Restore resources
  - Resource restoration is activated by default, but can be disabled

**NOTE** For full details about the automatic recovery:
http://www.rabbitmq.com/apit-guide.html#recovery

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# Automatic recovery conclusion

- A feature of the Java client
  - Not available on all clients
- Just a commodity, doesn't prevent from knowing about important details
  - Failure of nodes, consumer cancellation, etc.
- Don't blindly rely on it
  - Test your failure scenarios

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## Recovery With Spring AMQP

- Higher-level modules can offer support for recovery
- This makes the client code less tedious and error-prone
- E.g. Spring AMQP takes care of recovery:
  - Automatic re-connection to the broker in case of failure
  - Automatic declaration callback to initialize resources after re-connection
  - Transparent retry

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## Summary

- Cluster node failures can result in message loss
- Mirrored queues provide high-availability and reduce the chance of message loss in the event of a node failure
- Slave synchronization policies can be configured
- Be certain to test client failover handling

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# Lab

## Creating and Managing an HA Cluster

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# Plugins

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## Agenda

- **RabbitMQ plugins introduction**
- LDAP authentication
- Shovel
- Federation
- Shovel vs federation
- STOMP

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# RabbitMQ Plugins

- RabbitMQ capabilities can be extended with plugins
  - AMQP client
  - Management
  - STOMP
  - LDAP authentication
  - Shovel
  - Federation
  - etc.
- Can build custom plugins
  - http://www.rabbitmq.com/plugin-development.html

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# RabbitMQ Plugins

```
$ rabbitmq-plugins list
 Configured: E = explicitly enabled; e = implicitly enabled
 | Status:   * = running on rabbit@myhost
 |/
[e*] amqp_client                       3.6.1
[  ] cowboy                            1.0.3
[  ] cowlib                            1.0.1
[e*] mochiweb                          2.13.0
[  ] rabbitmq_amqp1_0                  3.6.1
[  ] rabbitmq_auth_backend_ldap        3.6.1
[  ] rabbitmq_auth_mechanism_ssl       3.6.1
[  ] rabbitmq_consistent_hash_exchange 3.6.1
[  ] rabbitmq_event_exchange           3.6.1
[  ] rabbitmq_federation               3.6.1
[  ] rabbitmq_federation_management    3.6.1
[E*] rabbitmq_management               3.6.1
[e*] rabbitmq_management_agent         3.6.1
[  ] rabbitmq_management_visualiser    3.6.1
[  ] rabbitmq_mqtt                     3.6.1
[  ] rabbitmq_recent_history_exchange  1.2.1
[  ] rabbitmq_sharding                 0.1.0
[  ] rabbitmq_shovel                   3.6.1
[  ] rabbitmq_shovel_management        3.6.1
[  ] rabbitmq_stomp                    3.6.1
[  ] rabbitmq_tracing                  3.6.1
[e*] rabbitmq_web_dispatch             3.6.1
[  ] rabbitmq_web_stomp                3.6.1
[  ] rabbitmq_web_stomp_examples       3.6.1
[  ] sockjs                            0.3.4
[e*] webmachine                        1.10.3
```

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# How to Install Plugins

- Plugins must be in the plugins directory
- Enabling or disabling plugins has no effect on a running RabbitMQ server ? restart is required to activate plugins
- Command to see the list of available / installed plugins

```
$ rabbitmq-plugins list
```

- Command to enable a plugin

```
$ rabbitmq-plugins enable <plugin-name>
```

- Command to disable a plugin

```
$ rabbitmq-plugins disable <plugin-name>
```

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# Agenda

- RabbitMQ plugins introduction
- **LDAP authentication**
- Shovel
- Federation
- Shovel vs federation
- STOMP

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# LDAP Authentication

- This plugin lets the RabbitMQ server use an LDAP server to perform
  - Authentication (who can log in)
  - Authorization (with which permissions)
- Plugin must be enabled before using it (requires server restart)

```
$ rabbitmq-plugins enable rabbitmq_auth_backend_ldap
```

- The LDAP authentication provider needs to be added to the providers list in the configuration

```
[{rabbit,
   [{auth_backends, [rabbit_auth_backend_ldap, rabbit_auth_backend_internal]}]
 }].
```

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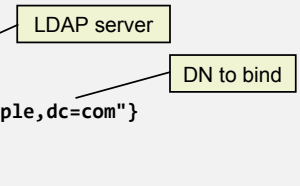
# LDAP Authentication Usage

- Minimal configuration file with some options might look like

```
[
  {rabbit, [{auth_backends, [rabbit_auth_backend_ldap]}]},
  {rabbitmq_auth_backend_ldap,
   [ {servers,               ["ldap.mycompany.com"]},
     {user_dn_pattern,       "cn=${username},ou=people,dc=example,dc=com"}
     {port,                  "389"} ] }
].
```




- Authorization can also be configured to control
  - vhost access
  - Resource (exchange, queue, binding)
  - Full access (i.e., administrator)

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# Agenda

- RabbitMQ plugins introduction
- LDAP authentication
- **Shovel**
- Federation
- Shovel vs federation
- STOMP

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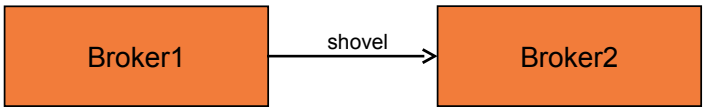
# Shovel Plugin

- This plugin transfers messages from a queue on one broker to an exchange on another broker




- Shovel can be on
  - The source broker (typical)
  - A third broker
- Shovel is just a well-written client application
  - Reads messages from source
  - Forwards messages to destination
  - Deals with connection failures
  - Has plenty of options

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# Shovel Plugin

- Shovel has 2 modules
  - Shovel engine
  - Shovel management console
- Enable both plugins

```
rabbitmq-plugins enable rabbitmq_shovel
rabbitmq-plugins enable rabbitmq_shovel_management
```

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# Static and dynamic shovels

- There are 2 kinds of shovels
- Static shovels
  - Defined in the broker configuration file
  - Require a restart of the hosting broker to change
  - Many options
- Dynamic shovels
  - Defined in the broker's parameters
  - Can be created and deleted at runtime
  - Fewer options than static shovels

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# Static Shovel Configuration

- One of the simplest shovel configurations

```
[
{rabbitmq_shovel,
    [ {shovels, [ {my_shovel,
                    [ {sources,
                        [ {brokers, [ "amqp://localhost:5672"
                                    ]}
                        ]}
                    , {destinations,
                        [ {broker, "amqp://localhost:5673"}
                        ]}
                    , {queue, <<"market">>}
                    , {publish_fields, [ {exchange, <<"from.market">>}
                                       , {routing_key, <<"from_shovel">>}
                                       ]}
                    ]}
                ]}
    ]}
].
```

The shovel's name

Source and destination broker URI's

- Source queue
- Destination exchange
- Published routing-key

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# Shovel Plugin Management

- This configuration is displayed in the management console
  - Only when the shovel-management plugin is enabled

Overview | Connections | Channels | Exchanges | Queues | Admin

## Shovel Status

| Name | State | Source | Destination | Last changed |
|---|---|---|---|---|
| my_first_shovel | running | type: network<br>virtual_host: /<br>host: localhost<br>username: guest<br>port: 5672<br>ssl: false | type: network<br>virtual_host: /<br>host: localhost<br>username: guest<br>port: 5673<br>ssl: false | 2013-08-06 17:11:30 |

Users
Virtual Hosts
Policies
Shovel Status

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# Static Shovel Configuration

- Shovel plugin can also declare and bind AMQP resources
  - Exchanges, bindings, queues

```
[...]
{sources, [{brokers, ["amqp://srv-one.domain.com“]},
           {declarations,
                    ['queue.declare',
                      {'queue.bind',
                           [{exchange, <<"my_exchange">>},
                           {queue,    <<my_queue>>}]}
 ]}]},

{destinations, [{brokers, ["amqp://srv-two.domain.com"}],
                       {declarations,
                          [{'exchange.declare',
                                  [{exchange, <<"my_exchange">>},
                                   {type, <<"direct">>},
                                   durable]}
                          ]}]}
[...]
```

Queue and binding declaration

Exchange declaration

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# Dynamic Shovel Declaration

- A dynamic shovel is defined as a named parameter
- Several ways to declare a dynamic shovel
  - `rabbitmqctl set_parameter` command
  - HTTP API
  - Management plugin (web UI)

Example of a JSON definition for `rabbitmqctl`

```
{
  "src-uri":"amqp://localhost:5672",
  "src-queue":"market",
  "dest-uri":"amqp://localhost:5673",
  "dest-exchange":"from.market",
  "dest-exchange-key":"from_shovel"
}
```

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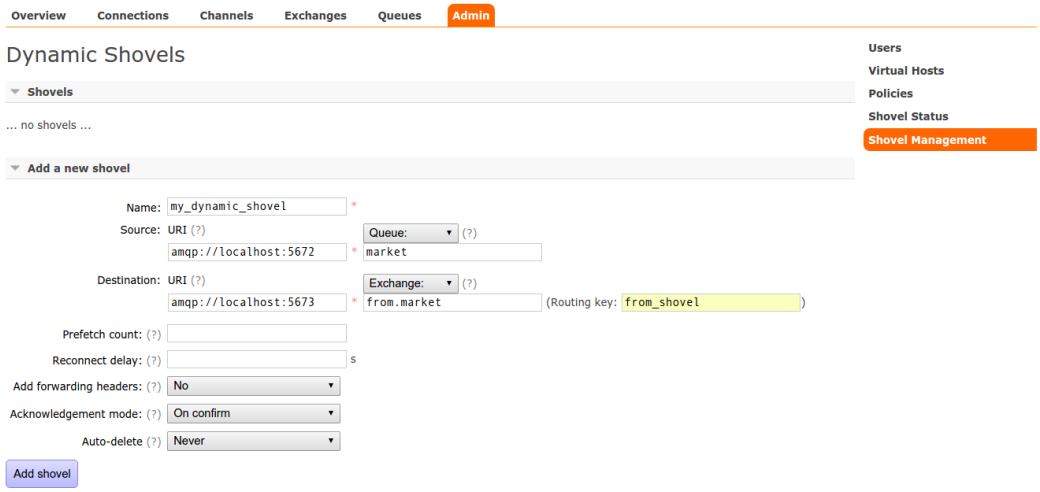
# Dynamic Shovel with the web UI

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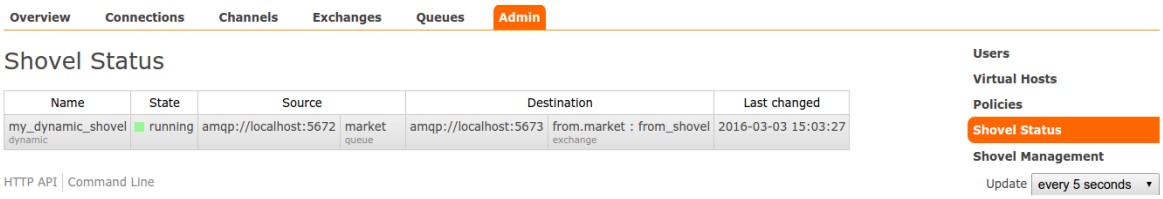
# Dynamic Shovel Status

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# Agenda

- RabbitMQ plugins introduction
- LDAP authentication
- Shovel
- **Federation**
- Shovel vs federation
- STOMP

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# Federation Plugin

- Goal: forwarding messages between brokers without requiring clustering
- This is useful because
  - Federated brokers may have different users and virtual hosts
  - Federated brokers don't need to run in the same version of RabbitMQ and Erlang (whereas clustering requires it)
- Federation is designed to scale out publish / subscribe messaging across WAN
- Plugins need to be enabled

```
rabbitmq-plugins enable rabbitmq_federation
rabbitmq-plugins enable rabbitmq_federation_management
```

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# Federation Plugin

- Federation works at the exchange level or the queue level
  - But it's one or the other
- One broker receives messages published on another broker
- Federation works seamlessly within a cluster
  - Federated exchanges/queues are just plain resources
- Exchange level
  - Messages published to an exhange are also published to another exchange
- Queue level
  - Messages of a queue get forwarded to another queue

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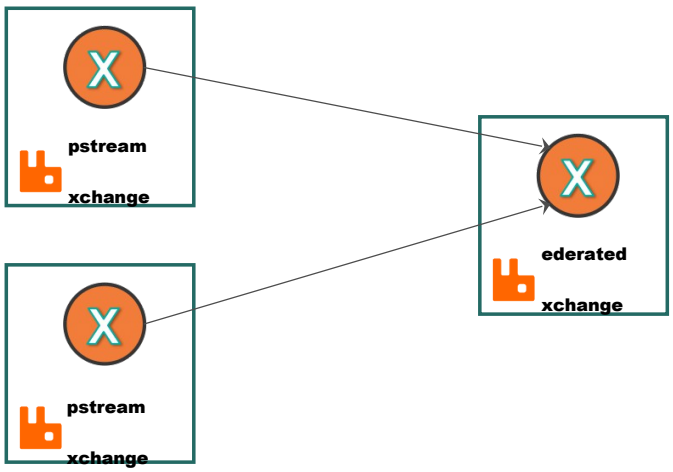
# A federated exchange

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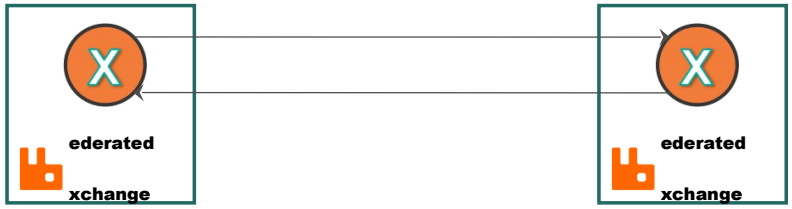
# Federated exchange example: pair

- Set max-hops to 1
  - Messages are copied only once
- A consumer on one broker receives messages published on the other one
  - And vice-versa

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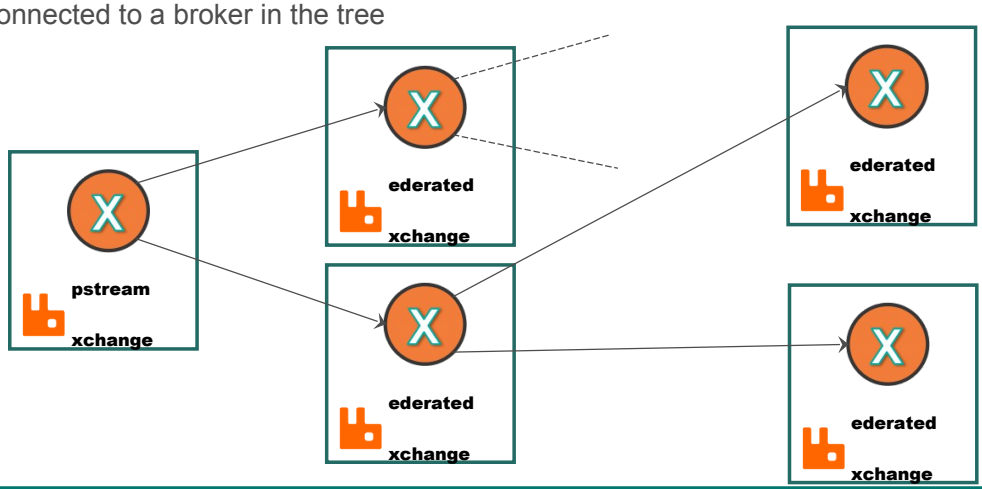
# Federated exchange example: fan-out

- Messages published to the upstream exchange can be received by any consumer connected to a broker in the tree

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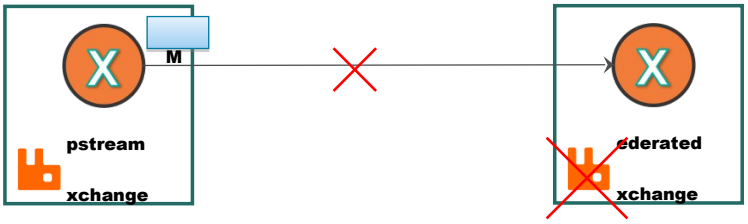
# Federated exchange configuration

- Configuration takes place on the federated exchange's broker
  - No configuration on upstream exchanges' brokers
- Messages sent to the upstream exchange are forwarded to the federated exchange
- Messages are queued if federated broker is down

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# Federated exchange configuration steps

- Declare the upstream
  - The upstream server to connect to
- Declare the policy to apply the upstream to federated exchanges

**NOTE** You can use rabbitmqctl, the HTTP API, or the web UI to configure the federation.

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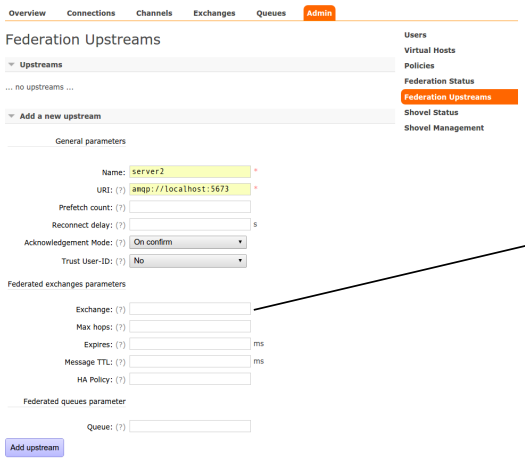
# Declaring the upstream

- The upstream broker to connect to

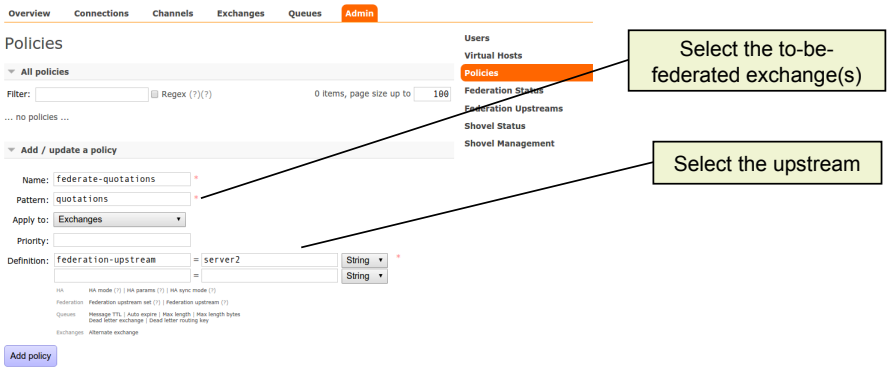



Name of the upstream exchange (default is to use the name of federated exchange)



# The policy

- Targeting exchange(s) of an upstream




Select the to-be-federated exchange(s)

Select the upstream

**NOTE** The policy can target an *upstream set*. This implies an extra configuration step with the `rabbitmqctl set_parameter` command to define the upstream set.



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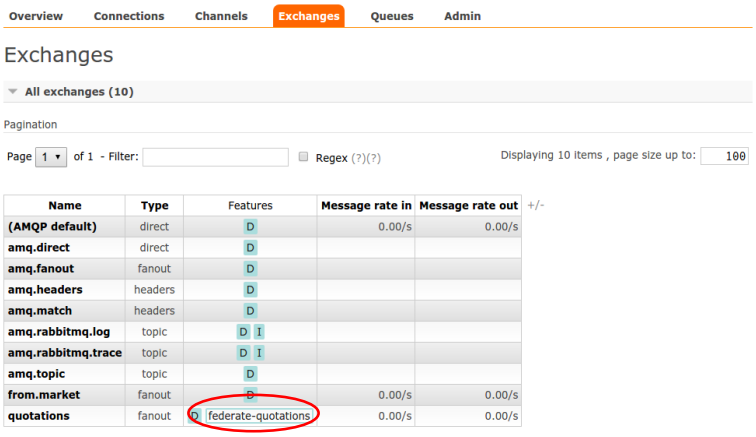
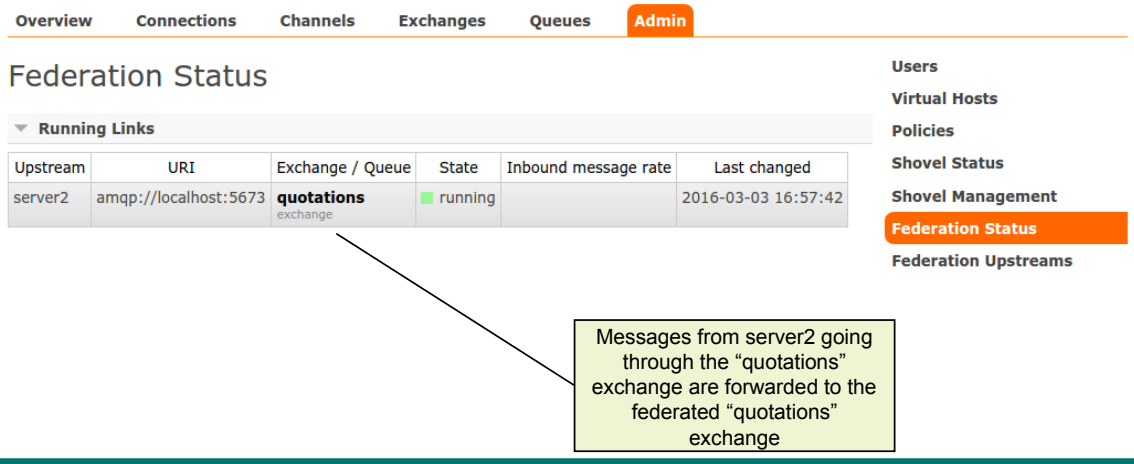
# Checking the federation

- The policy must apply to the exchange(s)






# Checking the federation status



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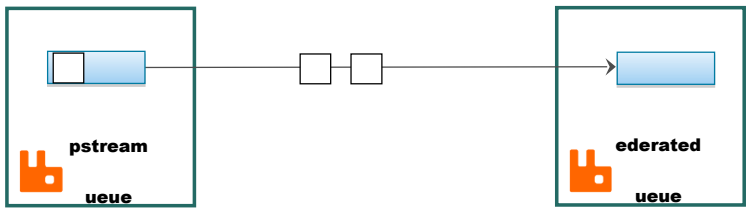
# A federated queue

- The federated queue is downstream
- The federated queue can get messages from the upstream queue

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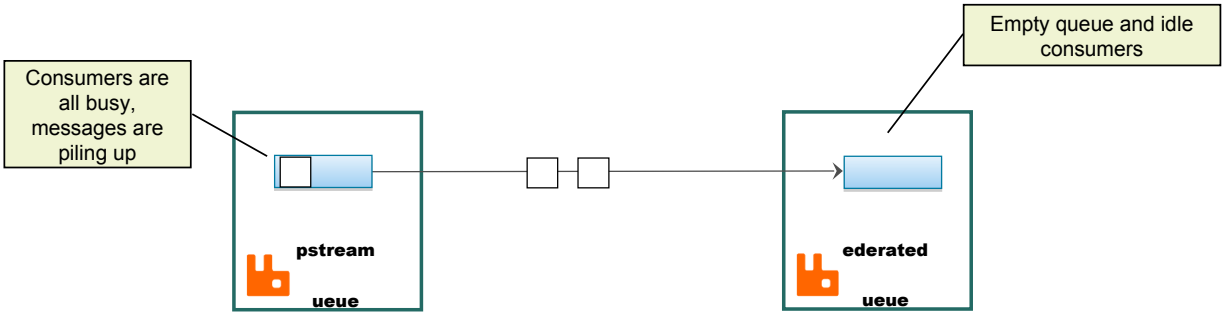
# Federated queue, why?

- A way to load balance the load of a queue across nodes/clusters
- The federated queue shares its spare consuming capacity
  - When messages in the upstream queue piles up
  - When the federated queue has no messages and idle consumers

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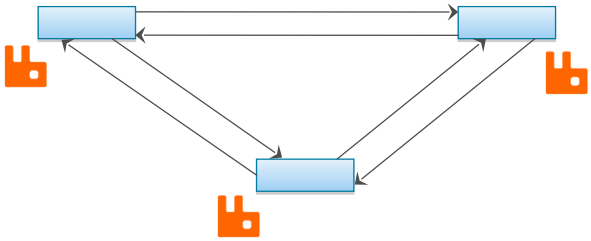
# Federated queue example

- Queues are federated between each other
- Each of them can share its spare consuming capacity with the others



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# Federated queue configuration steps

- Configuration takes place on the federated queue's broker
  - No configuration on upstream queues' brokers
- Declare the upstream
  - The upstream server to connect to
- Declare the policy to apply the upstream to federated queues

**NOTE** You can use rabbitmqctl, the HTTP API, or the web UI to configure the federation.

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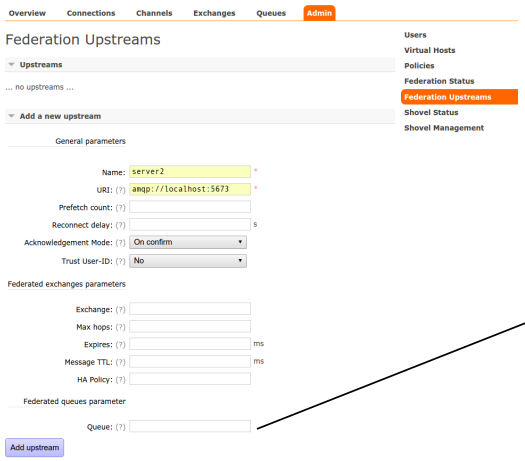
# Declaring the upstream

- The upstream broker to connect to

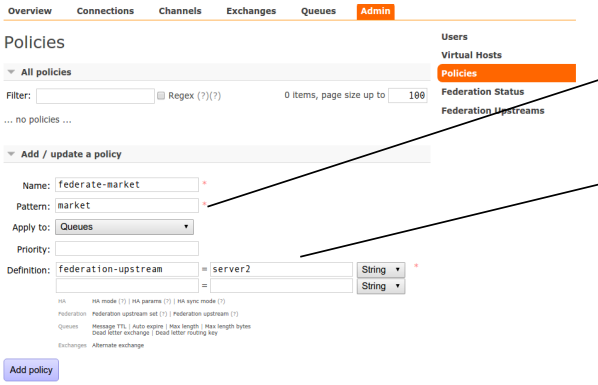



Name of the upstream queue (default is to use the name of federated queue)



# The policy

- Targeting queue(s) of an upstream




Select the to-be-federated queue(s)

Select the upstream

**NOTE** The policy can target an *upstream set*. This implies an extra configuration step with the `rabbitmqctl set_parameter` command to define the upstream set.



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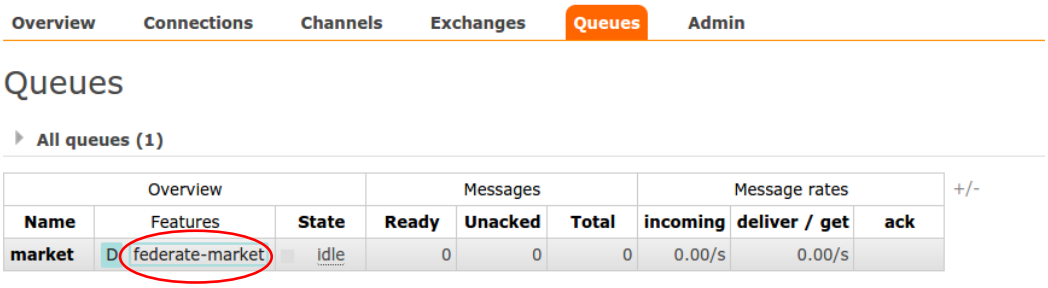
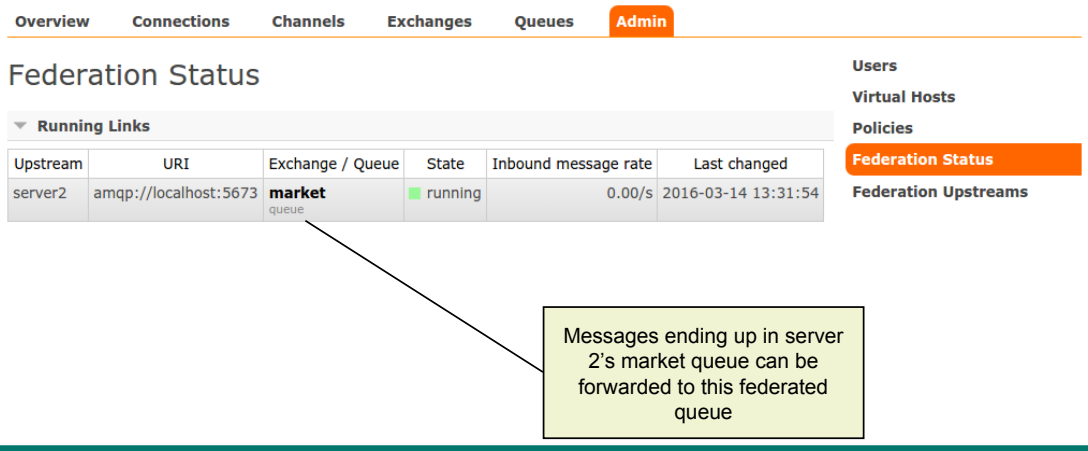
# Checking the federation

- The policy must apply to the queue(s)






# Checking the federation status



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# Agenda

- RabbitMQ plugins introduction
- LDAP authentication
- Shovel
- Federation
- **Shovel vs federation**
- STOMP

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# Shovel or Federation?

- Conceptually, the Shovel and Federation plugin are similar
- They do not work at the same level
  - Shovel works at a lower level than federation
    - It simply consumes messages from a queue
    - And forwards it to an exchange on another broker
  - Federation mirrors messages from an exchange/queue to another
    - This is achieved with some optimizations
    - Main idea is to communicate only when it's required
- Shovel provides more control than Federation
  - Federation is more opinionated, Shovel is a customizable AMQP client

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# Shovel and Federation vs. Clustering

| Shovel / Federation | Clustering |
|---|---|
| Brokers are logically separate and may have different owners. | A cluster forms a single logical broker. |
| Brokers can run different versions of RabbitMQ and Erlang. | Nodes must run the same version of RabbitMQ and frequently Erlang. |
| Brokers can be connected via unreliable WAN links. Communication is via AMQP (optionally secured by SSL), requiring appropriate users and permissions to be set up | Brokers must be connected via reliable LAN links. Communication is via Erlang internode messaging. |
| Brokers can be connected in whatever topology you arrange. Links can be one- or two-way. | All nodes connect to all other nodes in both directions. |

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# Shovel and Federation vs. Clustering

| Shovel / Federation | Clustering |
|---|---|
| Some exchanges in a broker may be federated while some may be local. | Clustering is all-or-nothing. |
| A client connecting to any broker can only see queues in that broker. | A client connecting to any node can see queues on all nodes in a virtual host |

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# Agenda

- RabbitMQ plugins introduction
- LDAP authentication
- Shovel
- Federation
- Shovel vs federation
- **STOMP**

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# STOMP Plugin

- This plugin provides a STOMP support in RabbitMQ
- It supports both STOMP 1.0, 1.1, and 1.2
- Plugin must be enabled

```
$ rabbitmq-plugins enable rabbitmq_stomp
```

- Adapter waits for connections on 61613

**NOTE** STOMP (Streaming Text Oriented Message Protocol) is a text-based messaging protocol.

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# STOMP Connection

- STOMP uses TCP, clients like telnet or nc (netcat) work

```
$ nc localhost 61613
CONNECT
login:guest
passcode:guest

^@
CONNECTED
session:session-gsKcEyvX3_9VC8mPu9UoxA
heart-beat:0,0
version:1.0
```

Request

Response

- ^@ inserts null byte, to send the request
  - Use Ctrl+@ to insert null byte
- Don't want to authenticate?

```
[
  {rabbitmq_stomp, [{default_user,[{login, "guest"},
                                   {passcode, "guest"}]},
                    {implicit_connect, true}]}
].
```

No authentication

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# STOMP Plugin Semantics

- STOMP specification is quite generic
- Values of destination header in SEND and MESSAGE frames are broker-specific
  - MESSAGE symbolizes a message when the client receives it
  - SEND is used to send a message
  - SUBSCRIBE is used to register to a source of messages
- RabbitMQ supports the below destination types (SEND and SUBSCRIBE frames)
  - /exchange
  - /queue
  - /amq/queue (queues outside STOMP gateway, i.e., : existing queues)
  - /topic (in a JMS / STOMP manner)
  - /temp-queue (reply-to template)

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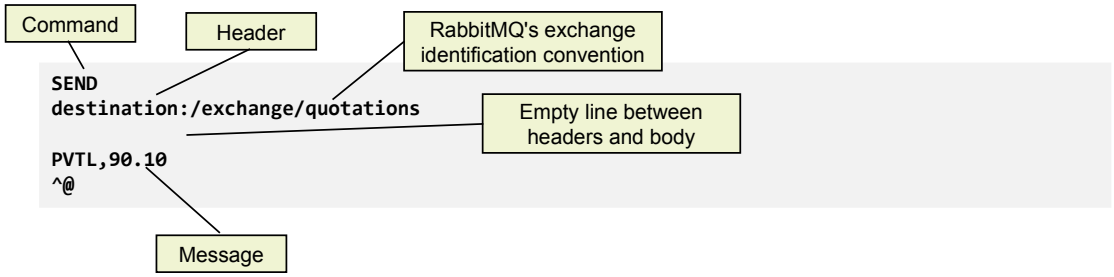
# Sending a STOMP Message to RabbitMQ

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# STOMP Plugin – Exchange Examples

- SUBSCRIBE
  - /exchange/my-exchange/my-routing-key

Will create an exclusive and auto-delete queue on the direct exchange named "my-exchange", bind it using the routing key, and register a receiver for the current STOMP session

- SEND
  - /exchange/my-exchange/my-routing-key

Will send to the exchange named "my-exchange" with the routing key "my-routing-key"

- /exchange destinations are not suitable for consuming messages from existing queues
  - A new queue is created for each subscriber.

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# STOMP Plugin – Queue Examples

- SEND and SUBSCRIBE
  - /queue/my-queue

Will create a shared queue named "my-queue"

  - /amq/queue/my-amqp-queue
    - Send to the default exchange
    - Subscribe for the current STOMP session

Will use an existing AMQP queue

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# For the Latest Plugin Information

- For the latest available configuration and features
  - Please consult http://www.rabbitmq.com/plugins.html

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# Summary

- There are numerous plugins available that extend the functionality of RabbitMQ

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# Performance

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## Agenda

- **Factors that impact performance**
- Flow control
- Best practices

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# What Factors Impact Performance?

- Business factors:
  - Message size
  - Topology
- Client code:
  - Durability / message persistence
  - Acknowledgments
  - Transactions
  - Publisher confirms
  - Channel configuration
- Broker:
  - Queue durability
  - Clustering
  - High Availability (mirrored) queues

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# Business Factors

- Message size has huge impact on performance
  - Message creation or parsing
  - Network overhead
  - Storing the message on the broker
  - etc…
- Topology of your networks and where brokers are physically installed also impacts performance
  - Mainly because of network latency

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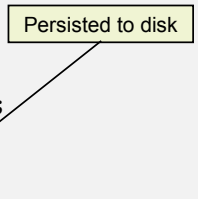
# Durability / Persistence

- Usage of the client API can have a big impact on performance
  - In good and bad
  - Really important to understand what you are doing
- With durability and persistence, all messages are written to disk
  - If durable flag is set on queue
  - If message is marked as persistent

```
// declare the durable queue
channel.queueDeclare("my-queue", true, false, false, null);

// set the message as persistent (deliveryMode = 2)
AMQP.BasicProperties.Builder builder = new AMQP.BasicProperties.Builder();
AMQP.BasicProperties props = builder.deliveryMode(2).build();

String message = "Hello World!";
channel.basicPublish("my-exchange", "key", props, message.getBytes());
```

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# Delivery Mode

- Non-persistent (1)
  - Messages are kept in memory (volatile)
  - *Even if the queue is marked as durable!!*
  - Default setting
- Persistent (2)
  - All messages are written to disk

```
AMQP.BasicProperties.Builder builder = new AMQP.BasicProperties.Builder();

// set the message as non-persistent (default)
AMQP.BasicProperties props = builder.build();

// set the message as persistent (deliveryMode = 2)
AMQP.BasicProperties props = builder.deliveryMode(2).build();
```

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# Acknowledgements

- Using acknowledgments impact performance
- Client has to send explicit ACK to the broker
- Broker has to manage several cases:
  - Read but unacknowledged messages
  - Acknowledgments coming later
  - Rejections
- Acknowledgment
  - Can be set to automatic mode (auto-ack)
  - Explicitly acknowledged when clients ask for it
  - Behavior specified on
    - Channel.basicGet()
    - Channel.basicConsumer()

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# Acknowledgements

- Automatic acknowledgement

```
boolean autoAck = true;
GetResponse response = channel.basicGet("queueName", autoAck);

if (response != null) {
  // do business logic here
}
```

Auto-acknowledgement flag

- Manual (client) acknowledgement

```
boolean autoAck = false;
GetResponse response = channel.basicGet("queueName", autoAck);

if (response != null) {
  long deliveryTag = response.getEnvelope().getDeliveryTag();
  // do business logic here
  boolean multiple = false;
  channel.basicAck(deliveryTag, multiple);
}
```

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# Transactions

- Transactions require extra communication to
  - Commit
  - Rollback
- When grouping multiple messages per transaction, the broker has to manage multiple uncommitted messages until the commit comes
- Transaction for consumers
  - Ability to group multiple consumed messages with a single commit
- Transaction for publishers
  - Message is not readable for others until it's committed
  - Add extra-delay for consumers to process the message

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# Transactions

- Using transactions to send messages atomically

```
channel.txSelect();

byte[] msgNasdaq = "NASDAQ".getBytes();
byte[] msgDJ = "DOWJONES".getBytes();
byte[] msgSP500 = "SP500".getBytes();

channel.basicPublish(stockExchange, stockCategory, null, msgNasdaq);
channel.basicPublish(stockExchange, stockCategory, null, msgDJ);
channel.basicPublish(stockExchange, stockCategory, null, msgSP500);

/*
 * 1) until this next instruction, broker has to manage uncommited messages
 * in case a rollback is needed. This is costly.
 *
 * 2) until this next instruction, messages are also not available for consumers
 */
channel.txCommit();
```

Will commit the batch of messages

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# Publisher Confirms

- For the publisher, transactions are often unnecessarily weighted and decrease throughput up to a factor of 250
  - Especially when you commit messages one-by-one
- RabbitMQ has the concept of "publisher confirms"
  - Analogous to consumer acknowledgments, but on the publisher side
  - A confirmation is sent by the broker after it has accepted the message
- For both sending and receiving, use publisher confirms and consumer acknowledgments
  - Transactions are heavier
  - Confirms and acknowledgements are usually sufficient for most use cases

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# Publisher Confirms

- Client needs to put channel in confirm mode
  - `Channel.confirmSelect()`

```
ConnectionFactory factory = new ConnectionFactory();
Connection connection = factory.newConnection();
Channel channel = connection.createChannel();

channel.confirmSelect();
```

- Client can explicitly wait to have all published messages confirmed by the broker before doing more actions
  - `Channel.waitForConfirms()`
  - `Channel.waitForConfirmsOrDie()`

```
channel.basicPublish("exchangeName", "routingKey", null, "message".getBytes());

channel.waitForConfirms();
```

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# Delivery configuration on the client side

- The broker can limit what it delivers to consumers
- The consumer configures delivery at the channel level
- The broker continues deliveries, depending on consumer's ACK
- `Channel.basicQos()` to specify the "quality of service"
- Parameters:
  - prefetchCount: the number of unacknowledged messages the server will deliver to a channel (0 means there is no limit) in a single batch

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# "Quality of service" configuration

- `basicQos()` allows consumer-driven flow control
  - Consumer doesn't get overwhelmed
  - Method call is blocking when value is reached
- Useless if auto-ack is enabled, because messages are acknowledged as soon as they are delivered

```
ConnectionFactory factory = new ConnectionFactory();
Connection connection = factory.newConnection();
Channel channel = connection.createChannel();

int prefetchCount = 100;
channel.basicQos(prefetchCount);

boolean autoAck = false;

while(true){
  GetResponse response = channel.basicGet("queueName", autoAck);
}
```

100 messages will be delivered before they are ack'd

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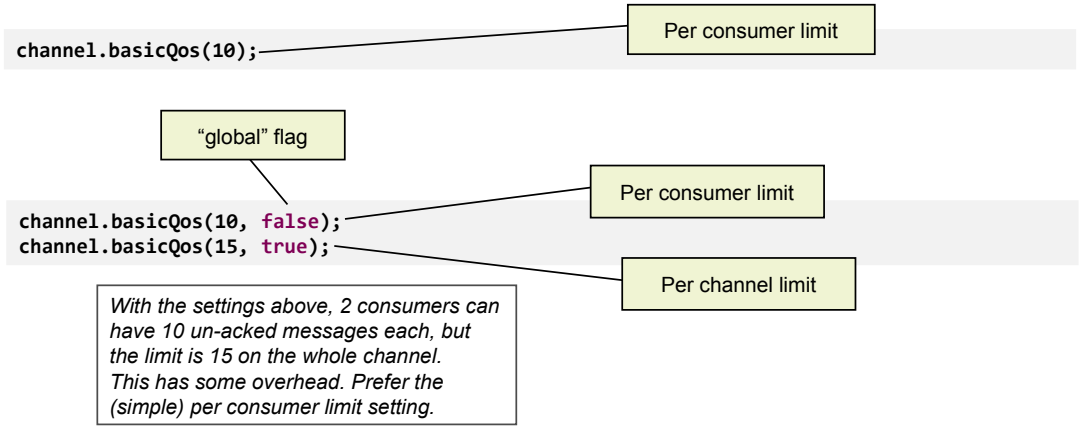
# “Quality of service” scope, the global flag




**NOTE** The meaning of the global flag in RabbitMQ is different than in the AMQP specification.

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# Consumer Priorities

- Consumers can declare a priority level when they start consuming
- RabbitMQ would then
  - first deliver messages to high-priority consumers
  - fall back to low-priority consumers when high-priority consumers are *blocked*
- When to use consumer priorities?
  - To prioritize consumers with some specific hardware, e.g. prefer consumers with SSD drives
  - To prioritize consumers connected to the master of a mirrored queue
- When does a consumer get blocked?
  - When it reaches its « quality of service » limit
  - When it experiments network congestion

**NOTE** By default, RabbitMQ distributes messages to consumers in a round-robin fashion.

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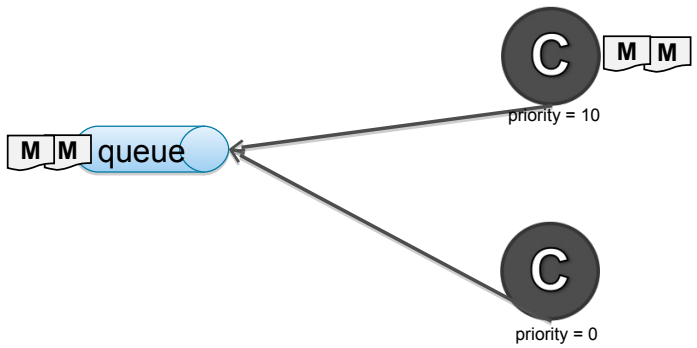
# Consumer Priorities




Consumer cannot hold more than 3 un-acked messages

Broker falls back to low-priority consumer when high-priority consumer is blocked

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# Consumer priority declaration

```
int prefetchCount = 100;
channel.basicQos(prefetchCount);

Map<String,Object> arguments = new HashMap<>();
arguments.put("x-priority", 10);
channel.basicConsume("queue", false, arguments, consumer);
```

Use an appropriate quality of service, to control when the consumer gets blocked

Use the x-priority argument when starting consuming

Set auto-ack flag to false, otherwise the consumer will consume all the messages the broker can send

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# Message Persistence

- Be aware of performance implications when specifying persistent messages
  - Every message will be written to disk
  - If publisher confirms are used and/or consumer acknowledgements, this can have significant impact on performance
  - Performance impact is due to additional disk I/O

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# Clustering and Mirrored Queues

- Certain types of clusters have mirrored-queues that replicate metadata and data on other queues in the cluster
  - Overhead to replicate all the data across the nodes
  - Commit and acknowledgment are also replicated across the nodes
  - If persistent messages, and/or publisher confirms, and/or consumer acknowledgements are used, performance impact will be higher with mirrored queues, as overhead is also "mirrored"

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## Agenda

- Factors that impact performance
- **Flow control**
- Best practices

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## Memory-based Flow Control

- RabbitMQ comes with a nice feature
  - Memory-based flow control
- Used to prevent the broker from accepting too much traffic from producers
  - So that memory is not filled in case of verbose producers
- Why is it needed?
  - By default on RabbitMQ, messages are accepted from clients even if they are not written to disk yet
  - Accepting messages is much faster than writing messages to disk
  - In a heavy load scenario, without any flow control available memory could be completely consumed

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# Memory-based Flow Control

- How does it work?
  - Producers are throttled to reduce throughput
  - Consumers aren't affected
  - Alarm is raised in the log
- The default memory threshold is 40% of the server RAM
  - This does not prevent RabbitMQ from using more than 40% RAM
  - It is just the point where flow control is turned on
- Usage
  - Memory threshold value can be modified in rabbitmq.config file
  - Value of 0 disables the flow control

```
[{rabbit, [{vm_memory_high_watermark, 0.4}]}]
```

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# Per-connection Flow Control

- What if a connection publishes too quickly?
- RabbitMQ blocks the connection automatically
- Happens when publishing is faster than routing
- Connection appears then as "blocked"
- Hard to monitor, as blocking can happen several times per second
  - Check last_blocked_by and last_blocked_age fields with rabbitmqctl/web ui

**NOTE** RabbitMQ blocks only connections that publish messages.

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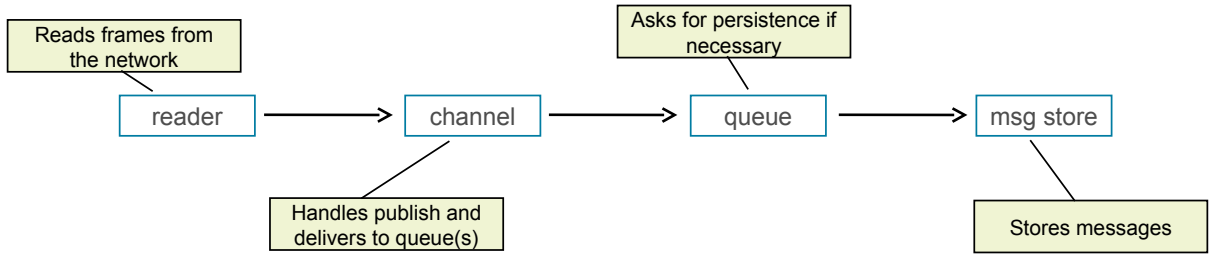
# Flow control internals

- The flow control is credit-based
- To understand it, let's look inside the rabbit
- Messages go through these RabbitMQ's internal components:




**NOTE** At runtime, each component is an Erlang process.

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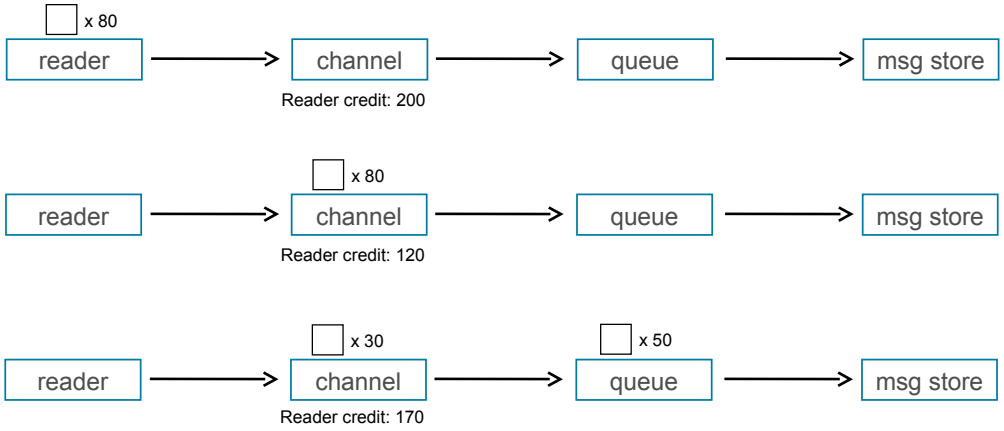
# Credit flow

- Each process grants credits to upstream processes

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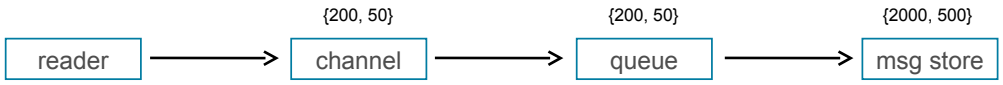
# Credit flow

- Process grants credits back when it has managed to handle messages
- If a process has no credit left, it's blocked by the downstream process
  - This is how the per-connection flow control is implemented, by blocking the reader
- The credit flow can be configured with 2 values
  - InitialCredit: the initial credit the process grants to upstream processes
  - MoreCreditAfter: the number of messages the process must handle before granting credit back
- Defaults:

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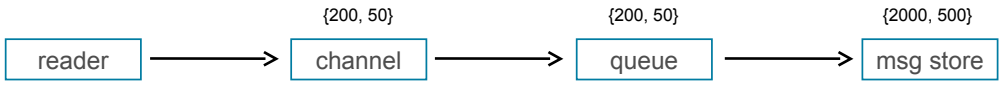
# Credit flow considerations

- The credit is *per* process
  - Many channels can send to the same queue
  - That's why a queue has an initial credit of 2000 from the message store
- Raising up the values
  - More messages going through the broker
  - More RAM usage
- Be careful with these settings, experiment with your workload

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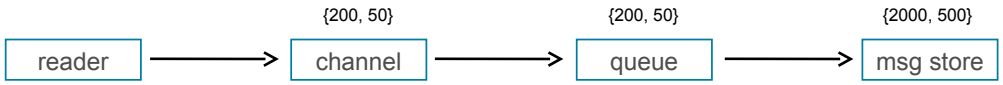
# Credit flow configuration

- In RabbitMQ configuration file:

```
[
{rabbit, [
  {credit_flow_default_credit, {200, 50}},
  {msg_store_credit_disc_bound, {2000, 500}}
]}
].
```




**NOTE** These settings have been introduced in RabbitMQ 3.5.5.

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# Blocked connection notifications

- RabbitMQ can notify clients when it blocks their connections
- Clients can then take some actions:
  - Throttle or stop their publishing
  - Add more consumers
- The point is to give some air to drain the queues

**NOTE** Blocked connection notifications is an extension introduced in RabbitMQ 3.2. The official RabbitMQ clients support this feature.

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## Add a blocked connection listener

- Add the listener at the connection level:

```
ConnectionFactory factory = new ConnectionFactory();
Connection connection = factory.newConnection();
connection.addBlockedListener(new BlockedListener() {

  public void handleBlocked(String reason) { }

  public void handleUnblocked() { }

});
```

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## Blocked connection listener semantics

- Blocked event:
  - Called for RAM and disk flow control
  - Can be called several times before unblocked event!
- Unblocked event:
  - Called when all resource alarms have cleared and the connection is fully unblocked

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## Message paging

- Queues keep an in-memory cache of messages
  - To deliver messages to consumers as fast as possible
- If RabbitMQ needs memory, it pages out the messages to disk
- Paging « blocks » the queue
  - It can't receive new messages
- Strive to consume faster than you publish!

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## Message paging internals

- RabbitMQ's backing store is made of 2 parts
  - message store: stores content of messages
  - queue index: store per message per queue data
- Small messages are paged out in the queue index
  - This is an optimization
  - Default limit size is 4096
  - Set with `queue_index_embed_msgs_below` in config file

**NOTE** A node has 2 backing stores, one for persistent messages and one for paging. They work the same way.

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## Message paging internals

- Broker pages first in the message store, then in the queue index
- Queue index paging doesn't always happen
  - Broker calculates how much memory to free
  - There a threshold to trigger the paging
  - Default is more than 2048 messages to page to trigger paging
- This is configurable, test with your own workload

**NOTE** Queue index paging performance has been greatly improved in RabbitMQ 3.5.5.

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## Queue index paging configuration

- In RabbitMQ configuration file:

```
[
{rabbit, [
  {msg_store_io_batch_size, 2048}
]}
].
```

- Raising the value
  - Less paging (paging to disk is costly)
  - More RAM usage

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## Lazy queues

- Sometimes, queues fill up
  - Consumers can't keep up, or are shut down for maintenance
  - Consumers can be unstable
- If your queues fill up regularly, use *lazy queues*
- Lazy queues are good when you need very long queues
  - Millions of messages

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## Lazy queues semantics

- Lazy queues
  - Send messages to the disk if there's no consumer
  - Load messages in memory when requested by consumers
- Consequences
  - Lazy queues consume much less RAM that default queues
  - Lazy queues increase I/O, but not more than when using persistent messages

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## Lazy queues declaration

- 2 ways to declare a lazy queue
- Use an argument when declaring the queue
  - `x-queue-mode = lazy`
- Use a policy
  - `queue-mode = lazy`

**NOTE** By using a policy, you can change the mode at runtime. Switching from default to lazy will page out the messages to disk, and thus block the queue.

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## Agenda

- Factors that impact performance
- Flow control
- **Best practices**

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## Best Practices on Client Side

- Prefer confirms and acknowledgments over transactions
  - These are lighter and generally satisfy most requirements
- Use durability and persistence only when required
  - This also has a big impact on performance
  - Efficient design avoids having to use persistence
    - Idempotency
    - Retry logic
- When dealing with multiple resources (e.g. queue + database)
  - Use best effort pattern

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## Best Practices on Server Side

- Do not deactivate the flow control mechanism
  - Server won't crash because it gets overwhelmed by publishers
- Monitor the health of your broker
  - By checking the log
  - By having an external health-check mechanism

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## Summary

- Numerous factors can impact performance
- RabbitMQ has built-in flow control to protect the server
- Use client and server best practices to maximize performance

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## Lab

Comparing and Benchmarking Classic Configurations

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# Security

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## Agenda

- **Virtual hosts, users, and access control**
- Authentication
- Secured communication

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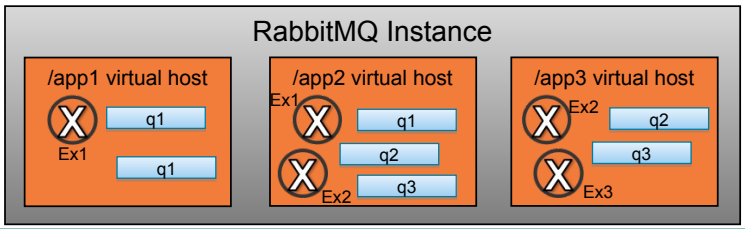
# Virtual Hosts

- Virtual hosts are a way to logically partition a broker
- Inside a virtual host, exchanges and queues are commonly referred to as “resources”
- Resources are named entities in a given virtual host
- Two resources with the same name but in different virtual hosts are different
  - i.e. Analogous to different namespaces
- You cannot bind resources between different virtual hosts (eg. /app1 Ex1 cannot be bound to /app2 q3)

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# What are Virtual Hosts Good For?

- Logical organization
  - one virtual host for each application/system, to avoid name collision
- Security
  - a first level of access control is enforced when a client connects to the broker
- Access control
  - a user has permissions on resources inside a given virtual host

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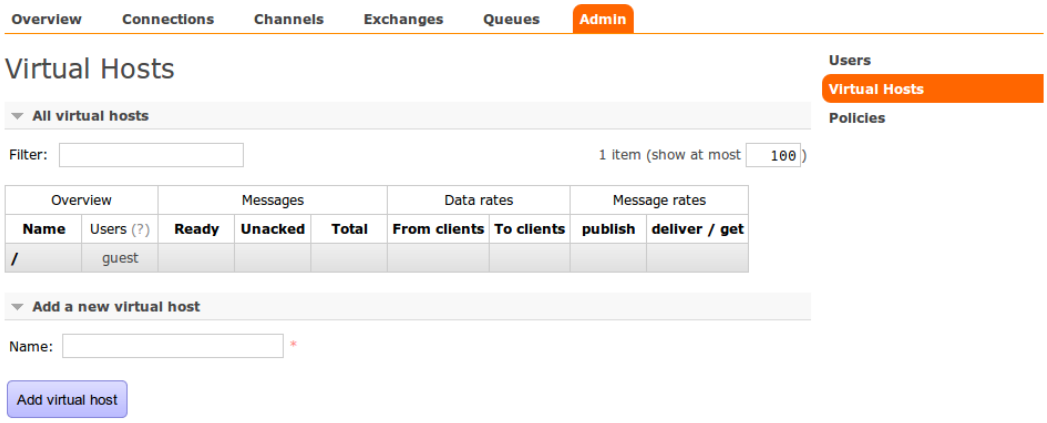
# Virtual Host Management from the UI

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# Command Line Virtual Host Management

- `rabbitmqctl` has commands to manage virtual hosts
  - `add_vhost, delete_vhost, list_vhosts`

```
$ rabbitmqctl add_vhost quotations
Creating vhost "quotations" ...
...done.
$ rabbitmqctl list_vhosts
Listing vhosts ...
/
quotations
...done.
```

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# Virtual Hosts, Users, and Access Control

- RabbitMQ allows for fine-grained access control
  - E.g., what a client can do with exchanges and queues in a virtual host
- Access control implies several notions:
  - Virtual hosts
  - Users
  - Permissions
- Let's cover users now before moving on to permissions!

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# User Management

- By default, RabbitMQ stores users in its internal database
- Users are managed through the management plugin and `rabbitmqctl`
- With plugins, users can be stored elsewhere
  - E.g., in an LDAP directory with the LDAP plugins
- Management plugin and rabbitmqctl can only see users in the internal database
- We're going to focus on internal database users

**NOTE** Remember that users are also used for authentication!

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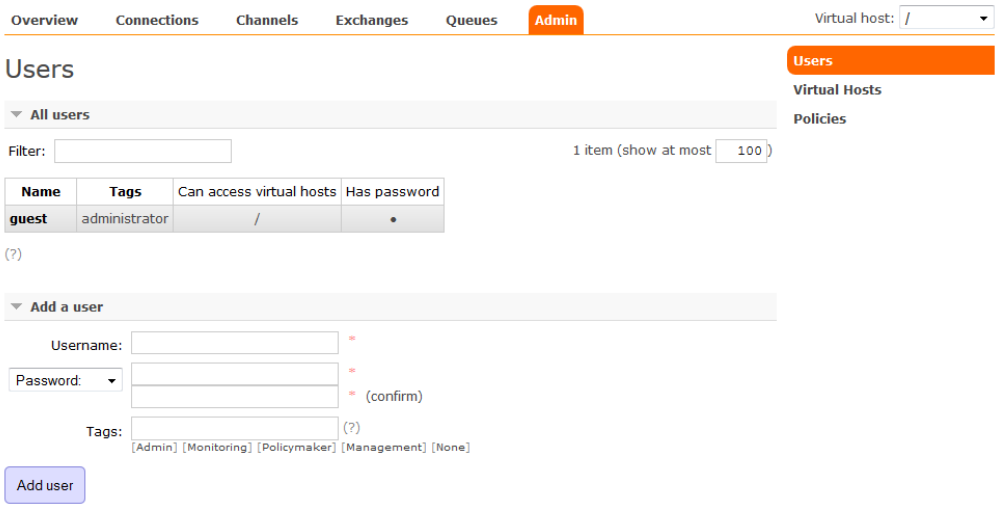
# User Management from the UI

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# Command Line User Management

- `rabbitmqctl` has commands to manage users
  - `add_user, delete_user, change_password, list_users`

```
$ rabbitmqctl add_user quotation_app secret
Creating user "quotation_app" ...
...done.
$ rabbitmqctl change_password quotation_app newpassword
Changing password for user "quotation_app" ...
...done.
$ rabbitmqctl list_users
Listing users ...
guest      [administrator]
quotation_app         []
...done.
```

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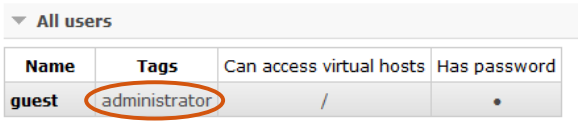
# User Tags

- Users can have tags

```
$ rabbitmqctl list_users
Listing users ...
guest     [administrator]
quotation_app         []
...done.
```




- Extend existing permissions model
- Don't affect authentication

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# User Tags

- "management": Access restricted to user's virtual host(s)
- "policymaker": "management" plus ability to manage policies in user's virtual host(s)
- "monitoring": "policymaker", can also view other users and resources on all virtual hosts
- "administrator": "monitoring" plus ability to manage virtual hosts, users, and permissions
- See https://www.rabbitmq.com/management.html#permissions
- Use management console or rabbitmqctl set_user_tags to manage tags

```
$ rabbitmqctl set_user_tags quotation_app administrator
Setting tags for user "quotation_app" to [administrator] ...
...done.
```

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# Default Access

- On first start or after database deletion, broker creates a new database
- The new database has the following resources:
  - Virtual host named `/`
  - `guest` user with `guest` password
- The default user has full access to `/` virtual host
- Best practice: delete default user or change password
  - Especially on production or publicly-accessible broker
- To change default user credentials:

```
[
    {rabbit, [
        {default_user,<<"admin">>},
        {default_pass,<<"changeit">>}
    ]}
].
```

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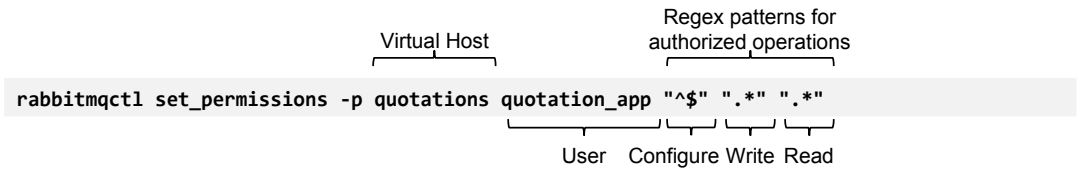
# Access Control

- RabbitMQ can enforce access rules
- Access rule = an operation on a resource
- Resource = exchange or queue in a virtual host
- Operation = configure, write, or read

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# Operations

- Configure
  - Create or destroy resources, or alter their behavior
  - E.g., declaring an exchange
  - E.g., deleting a queue
- Write
  - Inject messages into a resource
  - E.g., publishing to an exchange
  - E.g., binding a queue to an exchange
- Read
  - Retrieve messages from a resource
  - E.g., consuming messages from a queue
  - E.g., purging a queue
- For a comprehensive reference: http://www.rabbitmq.com/access-control.html

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# Permissions

- Permissions are expressed with regular expressions
- The regular expression is checked against a resource name
- One regular expression for each type of operation
- Common regular expressions
  - `^$` : matches nothing, prevents the operation on all resources
  - `.*` : matches everything, allows the operation on all resources
  - `^market\..*|eu\..*$` : matches "market.us" and "eu.paris"

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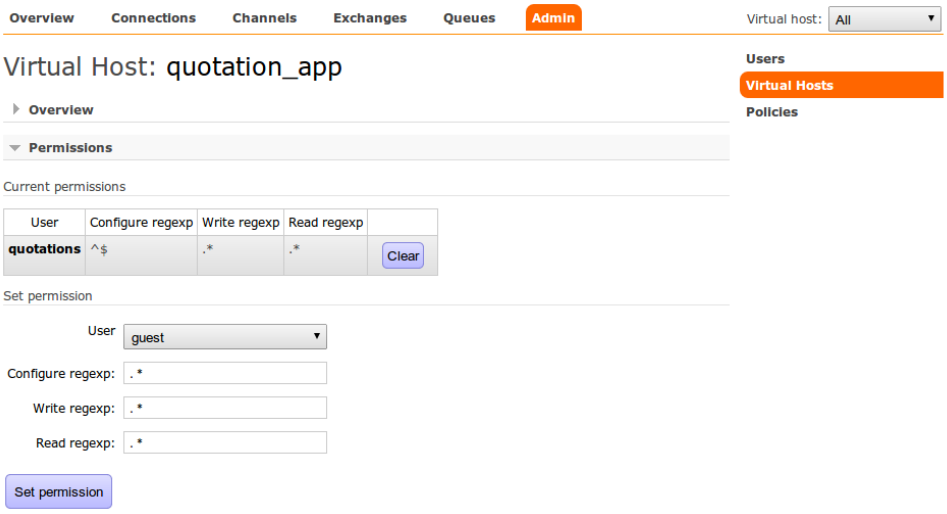
# Access Control from the UI






# Access Control from the Command Line

- `rabbitmqctl` has commands to manage access control
  - `set_permissions, clear_permissions, list_permissions`

```
$ rabbitmqctl set_permissions -p quotations quotation_app "^$" ".*" ".*"
Setting permissions for user "quotation_app" in vhost "quotations" ...
...done.
$ rabbitmqctl list_permissions -p quotations
Listing permissions in vhost "quotations" ...
quotation_app        ^$         .*         .*
...done.
```

- Remember:
  - Permissions aren't global
  - Permissions are specific to a virtual host



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# Agenda

- Virtual hosts, users, and access control
- **Authentication**
- Secured communication

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# Authentication

- RabbitMQ uses a pluggable authentication mechanism
- Server and client negotiate how they exchange credentials
- RabbitMQ supports the most common mechanisms
  - Username / password (plain text or over SSL)
  - Client certificate
- Custom plugins can extend authentication mechanisms
  - E.g., challenge / response

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# SASL

- The pluggable authentication mechanism is SASL
  - Simple Authentication and Security Layer
- SASL is embedded in AMQP and various protocols
- Thanks to SASL, AMQP doesn't need to worry about authentication
  - The onus is on the client and the broker

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# Supported Authentication Mechanisms

- PLAIN
  - Simple username / password
  - Password sent in plain text (can be protected with SSL)
- EXTERNAL
  - User's identity taken from outside the protocol
  - A plugin is usually in charge of determining the user's identity
  - E.g., rabbitmq-auth-mechanism-ssl can take the client's certificate and check if the server trusts it

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# Where to Configure Authentication?

- Server side: rabbitmq.config
  - PLAIN is the default

```
[
    {rabbit, [
        {auth_mechanisms,['PLAIN']},
        {auth_backends,[rabbit_auth_backend_internal]}
    ]}
].
```

- Client (Java binding)
  - again, default is PLAIN

```
connectionFactory.setSaslConfig(DefaultSaslConfig.PLAIN);
```

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# Agenda

- Virtual hosts, users, and access control
- Authentication
- **Secured communication**

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# Secured Communication With SSL/TLS

- RabbitMQ has built-in support for SSL/TLS
- TLS can be used to:
  - Encrypt communication between the broker and its clients (when they exchange sensitive data on public networks)
  - Authenticate the clients AND the broker
- Don't use SSL any more
  - SSL was officially deprecated in 2015
- Try to use the latest versions of TLS
  - At least TLS 1.1, or even TLS 1.2
  - Be careful not to break clients that don't support those versions though

**NOTE** SSL stands for Secure Socket Layer. TLS stands for Transport Layer Security. TLS is the new name/version of SSL.

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# RabbitMQ TLS Support and Erlang

- Prefer TLS over SSL
- RabbitMQ TLS builds on top of Erlang applications
  - `new_ssl` and `crypto`
- crypto needs OpenSSL
- There can be issues depending on the Erlang version and platform used
  - E.g. use Erlang 17.5 or later
- Check http://www.rabbitmq.com/ssl.html

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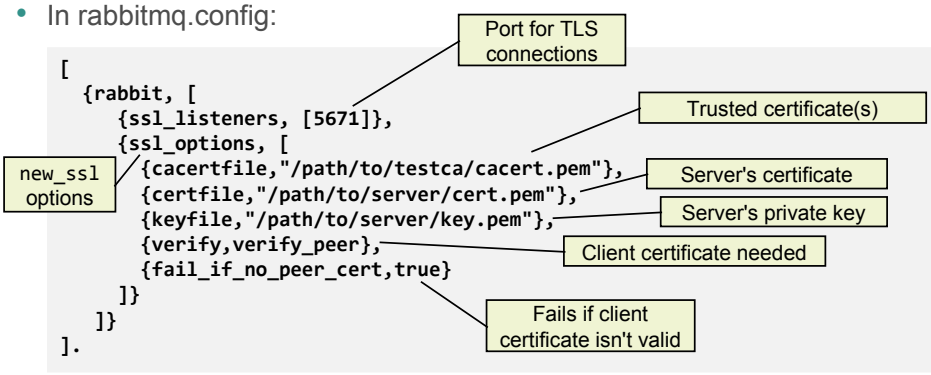
# TLS Configuration

- In rabbitmq.config:




**NOTE** Don't try to configure SSL/TLS without a bit of background on private/public keys, certificates, or without knowledge of OpenSSL!

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# TLS Configuration, no client authentication

- In rabbitmq.config:

```
[
  {rabbit, [
     {ssl_listeners, [5671]},
     {ssl_options, [
       {cacertfile,"/path/to/testca/cacert.pem"},
       {certfile,"/path/to/server/cert.pem"},
       {keyfile,"/path/to/server/key.pem"},
       {verify,verify_none}
     ]}
   ]}
].
```

No client authentication needed

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# TLS Options

- `new_ssl` Erlang application provides options
  - Through the `ssl_options` key
- E.g.,
  - Don't ask for a client certificate (when you need only encryption). User can authenticate with username / password.
  - Ask client certificate and validate it against internal DB or LDAP.
- Check `new_ssl` configuration

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# TLS on the Client Side

- Depends on the client platform
- E.g., Java
  - Certificates are usually manipulated through `keytool`
  - One can either:
    - Add server's certificate in JVM global keystore
    - add server's certificate on the connection factory (`ConnectionFactory.useSslProtocol(SSLContext)`)

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# TLS with a Java client

- No server authentication

```
ConnectionFactory factory = new ConnectionFactory();
factory.setUsername("guest");
factory.setPassword("guest");
factory.setVirtualHost("/");
factory.setHost("localhost");
factory.setPort(5671);

factory.setUseSslProtocol();

Connection connection = factory.newConnection();
```

Configure as usual

Use appropriate port

Trust any server

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# TLS with a Java client

- With server authentication

```
char [] trustPassphrase = "rabbitstore".toCharArray();
KeyStore tks = KeyStore.getInstance("JKS");
tks.load(new FileInputStream("/path/to/truststore"), trustPassphrase);
TrustManagerFactory tmf = TrustManagerFactory.getInstance("SunX509");
tmf.init(tks);

SSLContext c = SSLContext.getInstance("TLSv1.1");
c.init(null, tmf.getTrustManagers(), null);

ConnectionFactory factory = new ConnectionFactory();
(...)
factory.setUseSslProtocol(c);

Connection connection = factory.newConnection();
```

Creates trust store (contains server certificate)

Adds trust store to SSL context

Uses SSL context in connection factory

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## Summary

- Virtual hosts allow for multi-tenancy and fine-grained access control
- Authentication mechanism is pluggable
- TLS is recommended for secured communication between clients and the broker

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## Lab

Securing RabbitMQ

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# Operations and Monitoring

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## Agenda

- **Operations**
  - Disk, firewall, heartbeat, tuning
- Monitoring
- How to monitor with the HTTP API
- Support for third-party monitoring tools

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## Disk

- RabbitMQ files end up in `/var/lib`
  - Mnesia, message store
- Transient messages can be paged to disk!
  - If memory alert kicks in
- Pay attention to `/var/lib` partition!
  - At least 2 Gb

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## Firewall configuration

- The most common ports in RabbitMQ:
  - 4369, 25672 (Erlang)
  - 5672, 5671 (AMQP)
  - 15672 (management plugin)
  - 61613, 61614 (STOMP)
  - 1883, 8883 (MQTT)

***NOTE*** These ports can be changed by using RabbitMQ configuration.

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## Heartbeats

- Heartbeat timeout negotiated between server and client
  - To figure out when a connection is considered dead
  - Default is 60 seconds
- Heartbeat frames sent every (timeout / 2) seconds
  - After 2 missed heartbeats, the peer is considered unreachable
- Good value: between 6 and 12 seconds
  - Configurable at the client level

**NOTE** Heartbeat mechanisms can be different between protocols (AMQP, STOMP.) These settings are for the AMQP protocol.

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## Miscellaneous

- Change default credentials
- Don't use default vhost, use specific vhosts
  - Unless you're really in a single-tenant environment
- Don't use 32-bit Erlang
- Use odd number of nodes in your cluster
  - 3, 5, 7, etc

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# Tuning

- Usually, 2 types of workloads
- Throughput
  - common goal, you want a fast rabbit
- “Internet of Things” (IoT)
  - Many connections (100s K or 1s M)
  - Deals with sensors or very large web applications
- Impossible to tune for both at the same time!

**NOTE** Don’t apply the following settings blindy, benchmark and test in your own environment, with your target workload.

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# Throughput: TCP buffers size

- Increase TCP connection buffers
- In RabbitMQ configuration:

```
[
  {rabbit, [
  {tcp_listen_options, [
    {backlog,   128},
    {nodelay,   true}
    {sndbuf,    196608},
    {recbuf,    196608}
    ]}
  ]}
].
```

Set buffers size to 192 KB (default is usually 80-120 KB) Always use the same value for both buffers

**NOTE** Increasing TCP buffer size also increases the amount of RAM each connection uses.

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# Throughput: Erlang VM I/O thread pool

- Pool of threads used for I/O operations
- Use environment variable for Erlang arguments:

```
RABBITMQ_SERVER_ADDITIONAL_ERL_ARGS="+A 128"
```

Set pool size to 128

- Details:
  - Default size is 30
  - With 8+ cores, use pool size of 96+ (12 threads / core)
  - Don't increase too much, threads end up waiting on I/O anyway

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# Throughput: disable Nagle's algorithm

- Nagle's algorithm deals with the "small packet problem"
- Undesirable in highly interactive environments

```
[
  {kernel, [
    {inet_default_connect_options, [{nodelay, true}]},
    {inet_default_listen_options,  [{nodelay, true}]}
  ]},
  {rabbit, [
    {tcp_listen_options, [
                          {backlog,   4096},
                          {nodelay,   true}
                         ]}
  ]}
].
```

Disable Nagle for inter-node connections

Disable Nagle to serve client connections

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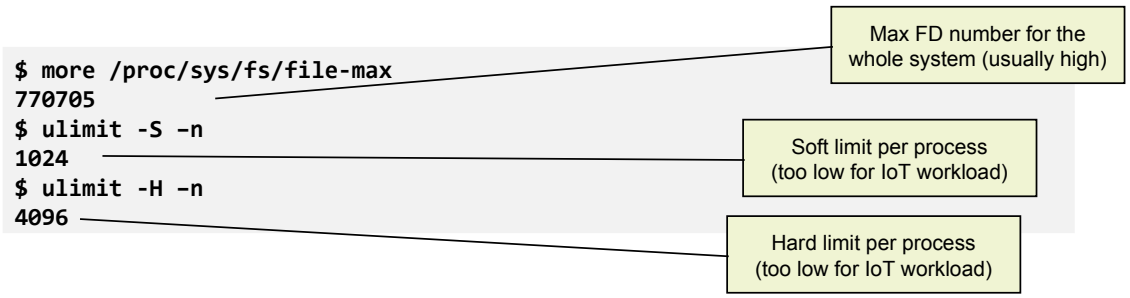
# IoT: Open File Descriptors (FD) Limit

- OS uses file descriptors to handle files and connections
- Defaults are usually way too low for IoT workloads:

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# IoT: Open FD limit settings

- Per user and per process
- In `/etc/security/limits.conf`

```
rabbitmq          soft    nofile          4096
rabbitmq          hard    nofile          8192
```

**NOTE** Configuration can change between distributions, check your own distribution documentation.

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# IoT: Open FD limit recommendation

- Take both connections and files number into account
- Multiply the number of connections per node by 1.5
  - E.g: expected connections = 100 K => limit = 150 K

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# IoT: TCP buffers size

- Decrease TCP connection buffers to limit RAM usage
- Favor number of connections over throughput

```
[
  {rabbit, [
  {tcp_listen_options, [
    {backlog,   128},
    {nodelay,   true},
    {sndbuf,    32768},
    {recbuf,    32768}
    ]}
  ]}
].
```

Set buffers size to 32 KB (default is usually 80-120 KB) Always use the same value for both buffers

**NOTE** You'll need to find a trade-off between throughput and RAM usage, depending on your workload.

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# IoT: Connection backlog

- Increase the length of the queue of unaccepted connections
- Helps to handle a massive reconnection scenario

```
[
  {rabbit, [
  {tcp_listen_options, [
    {backlog,   4096},
    {nodelay,   true
    ]}
  ]}
].
```

Increase the length of queue of unaccepted connections (default is 128)

**NOTE** The length must also be changed at the OS level, with the `net.core.somaxconn` option (default is 128.)

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# IoT: miscellaneous

- Also:
  - Tune the Erlang VM I/O thread pool
  - Disable also Nagle's algorithm

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## Some additional resources…

- Very good resources in the official documentation
- Production checklist
  - https://www.rabbitmq.com/production-checklist.html
- Networking
  - https://www.rabbitmq.com/networking.html

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## Agenda

- Operations
  - Disk, firewall, heartbeat, tuning
- **Monitoring**
- How to monitor with the HTTP API
- Support for third-party monitoring tools

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# What to monitor

- System metrics (memory, file system, CPU usage)
- Global state of the cluster
  - Each node is responding
  - Network partitions
  - Message rates in the cluster
  - Message rates in exchanges and queues
  - Size of queues
  - Clients connections
- RabbitMQ log files
  - Erlang "System Application Support Libraries" (SASL) log file: `"=CRASH REPORT="`
  - Node log file: `"=ERROR REPORT="`

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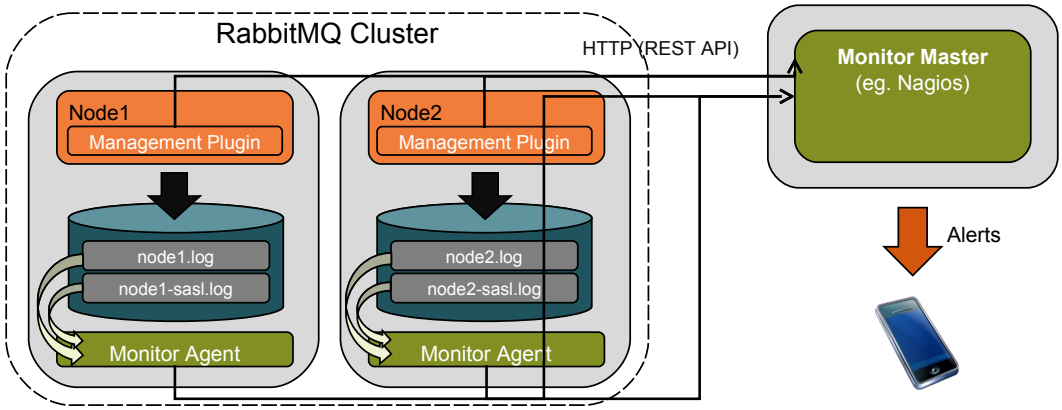
# Typical monitoring configuration




OS Level and RabbitMQ Log File Monitor Data

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# Queue size monitoring

- Queues are meant to be always empty
- Strive to keep them empty!
- Nevertheless, messages will be queued
  - Peak of traffic, consumers failure
- Set up an alert when queue size exceeds a limit
  - Limit depends on the application
- Ensure you can catch up with the backlog
  - It shouldn't take hours or days to unqueue the messages
- Ensure you can absorb messages at much higher rate than the usual, nominal rate
  - E.g. 10 times as much

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# Agenda

- Operations
  - Disk, firewall, heartbeat, tuning
- Monitoring
- **How to monitor with the HTTP API**
- Support for third-party monitoring tools

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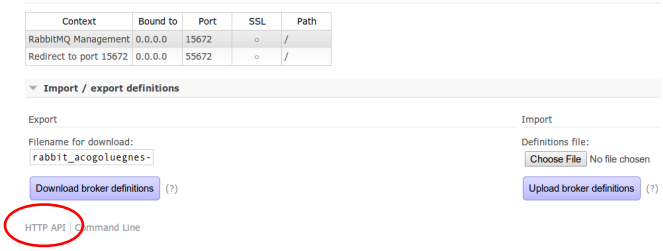
# RabbitMQ HTTP REST API

- The best way to monitor a cluster
  - Cluster aware
  - Provides messaging metrics, as well as some system metrics
  - Allows managing resources
- Plug your favorite third-party monitoring tool on it
- Access to help page from all web console pages






# HTTP API help page

**RabbitMQ Management HTTP API**

**Introduction**

Apart from this help page, all URIs will serve only resources of type `application/json`, and will require HTTP basic authentication (using the standard RabbitMQ user database). The default user is guest/guest.

Many URIs require the name of a virtual host as part of the path, since names only uniquely identify objects within a virtual host. As the default virtual host is called "`/`", this will need to be encoded as "`%2f`".

PUTing a resource creates it. The JSON object you upload must have certain mandatory keys (documented below) and may have optional keys. Other keys are ignored. Missing mandatory keys constitute an error.

Since bindings do not have names or IDs in AMQP we synthesise one based on all its properties. Since predicting this name is hard in the general case, you can also create bindings by POSTing to a factory URI. See the example below.

Many URIs return lists. Such URIs can have the query string parameters `sort` and `sort_reverse` added. `sort` allows you to select a primary field to sort by, and `sort_reverse` will reverse the sort order if set to `true`. The `sort` parameter can contain subfields separated by dots. This allows you to sort by a nested component of the listed items; it does not allow you to sort by more than one field. See the example below.

You can also restrict what information is returned per item with the `columns` parameter. This is a comma-separated list of subfields separated by dots. See the example below.

URIs which return some forms of numerical data (such as message rates and queue lengths) can return historical samples. To return samples you need to set an age and an increment for the samples you want. The end of the range returned will always correspond to the present. Use `msg_rates_age` and `msg_rates_incr` to return samples for messages sent and received, `data_rates_age` and `data_rates_incr` to return samples for bytes sent and received, and `lengths_age` and `lengths_incr` to return samples for queue lengths. For example, appending `?lengths_age=3600&lengths_incr=60` will return the last hour's data on queue lengths, with a sample for every minute.

**Examples**

A few quick examples for Windows and Unix, using the command line tool `curl`:

- Get a list of vhosts:

```
:: Windows
C:\> curl -i -u guest:guest http://localhost:15672/api/vhosts

# Unix
$ curl -i -u guest:guest http://localhost:15672/api/vhosts

HTTP/1.1 200 OK
Server: MochiWeb/1.1 WebMachine/1.10.0 (never breaks eye contact)
Date: Mon, 16 Sep 2013 12:00:02 GMT
Content-Type: application/json
Content-Length: 30

[{"name":"/","tracing":false}]
```



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# HTTP API reference

**Reference**

| GET | PUT | DELETE | POST | Path | Description |
|---|---|---|---|---|---|
| X | | | | /api/overview | Various random bits of information that describe the whole system. |
| X | | | | /api/nodes | A list of nodes in the RabbitMQ cluster. |
| X | | | | /api/nodes/*name* | An individual node in the RabbitMQ cluster. Add "?memory=true" to get memory statistics. |
| X | | | | /api/extensions | A list of extensions to the management plugin. |
| X | | | X | /api/definitions<br>/api/all-configuration *(deprecated)* | The server definitions - exchanges, queues, bindings, users, virtual hosts, permissions and parameters. Everything apart from messages. POST to upload an existing set of definitions. Note that:<br>• The definitions are merged. Anything already existing is untouched.<br>• Conflicts will cause an error.<br>• In the event of an error you will be left with a part-applied set of definitions.<br>For convenience you may upload a file from a browser to this URI (i.e. you can use `multipart/form-data` as well as `application/json`) in which case the definitions should be uploaded as a form field named "file". |
| X | | | | /api/connections | A list of all open connections. |
| X | | X | | /api/connections/*name* | An individual connection. DELETEing it will close the connection. Optionally set the "X-Reason" header when DELETEing to provide a reason. |
| X | | | | /api/channels | A list of all open channels. |
| X | | | | /api/channels/*channel* | Details about an individual channel. |
| X | | | | /api/exchanges | A list of all exchanges. |
| X | | | | /api/exchanges/*vhost* | A list of all exchanges in a given virtual host. |
| X | X | X | | /api/exchanges/*vhost*/*name* | An individual exchange. To PUT an exchange, you will need a body looking something like this:<br>`{"type":"direct","auto_delete":false,"durable":true,"internal":false,"arguments":[]}`<br>The `type` key is mandatory; other keys are optional. |
| X | | | | /api/exchanges/*vhost*/*name*/bindings/source | A list of all bindings in which a given exchange is the source. |
| X | | | | /api/exchanges/*vhost*/*name*/bindings/destination | A list of all bindings in which a given exchange is the destination. |
| | | | X | /api/exchanges/*vhost*/*name*/publish | Publish a message to a given exchange. You will need a body looking something like:<br>`{"properties":{},"routing_key":"my key","payload":"my body","payload_encoding":"string"}`<br>All keys are mandatory. The `payload_encoding` key should be either "string" (in which case the payload will be taken to be the UTF-8 encoding of the payload field) or "base64" (in which case the payload field is taken to be base64 encoded).<br>If the message is published successfully, the response will look like:<br>`{"routed": true}` |

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# HTTP API reference

HTTP method to use (only GET for monitoring)

URL to call (can have path variables)

**Reference**

| GET | PUT | DELETE | POST | Path | |
|---|---|---|---|---|---|
| X | | | | /api/overview | Various r |
| X | | | | /api/nodes | A list of |
| X | | | | /api/nodes/*name* | An indivi |
| X | | | | /api/extensions | A list of |
| X | | | X | /api/definitions<br>/api/all-configuration *(deprecated)* | The serv<br>message<br>• Th<br>• Cc<br>• In<br>For conv<br>applica |
| X | | | | /api/connections | A list of |
| X | | X | | /api/connections/*name* | An indivi<br>a reason |
| X | | | | /api/channels | A list of |
| X | | | | /api/channels/*channel* | Details a |
| X | | | | /api/exchanges | A list of |

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# RabbitMQ HTTP API

- Use any HTTP client

```
$ curl -i -u guest:guest http://localhost:15672/api/aliveness-test/%2f
Server: MochiWeb/1.1 WebMachine/1.10.0 (never breaks eye contact)
Date: Thu, 28 Nov 2013 15:21:03 GMT
Content-Type: application/json
Content-Length: 15
Cache-Control: no-cache

{"status":"ok"}
```

Encoded default virtual host
(/ => %2f)

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# Aliveness test

- /api/aliveness-test/{vhost}
- Creates a queue, publishes and consumes a message
- Returns OK if successful
- Queue isn't deleted to prevent churn

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## Cluster messaging metrics

- /api/overview
- Returns message rates, queue totals
- Useful for a coarse-grained view

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## Nodes information

- /api/nodes
- An array of all the nodes
  - Are they all there?
  - "running" = true?
- System metrics and nodes settings
  - Used file descriptors, RAM or disc node, etc.

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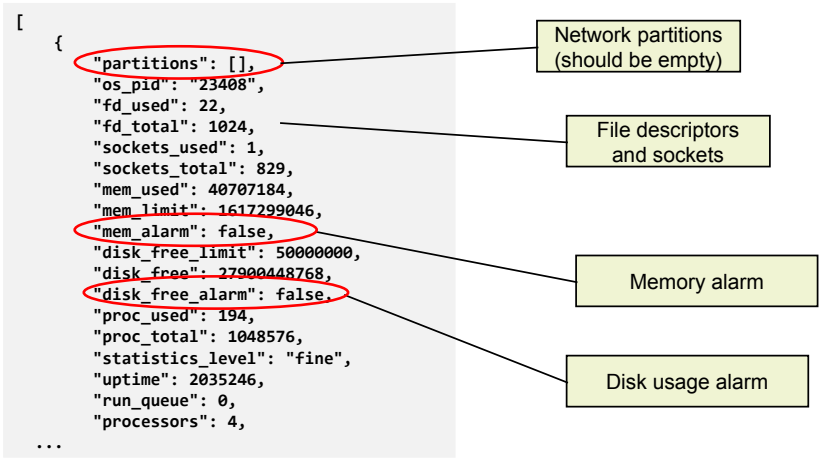
# Nodes information

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# Connections

- /api/connections
- All the connections, with host, port, client properties, received/sent octets, etc.
- Helps to detect clients that generate too much traffic
- Don't poll too often if you have lots of connections
  - Thousands or more

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## Channels

- /api/channels
- Message rates (ack, deliver), channel settings (transactional or not, prefetch count), etc.
- Useful to detect unusual behavior

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## Exchanges

- /api/exchanges, /api/exchanges/{vhost}, /api/exchanges/{vhost}/{name}
- Settings, rates
- Useful to check appropriate rate of messages (not too many, but enough)

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## Queues

- /api/queues, /api/queues/{vhost}, /api/queues/{vhost}/{name}
  - memory
  - size
  - consumer count
  - idle since
- Thresholds may differ by application and queue
- The kind of resource to monitor!

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## Account permissions for monitoring

- Separate account recommended
  - "monitoring" tag
- Read-only access to all resources in all vhosts
- For aliveness test, require:
  - write to amq.default
  - configure for "aliveness-test"

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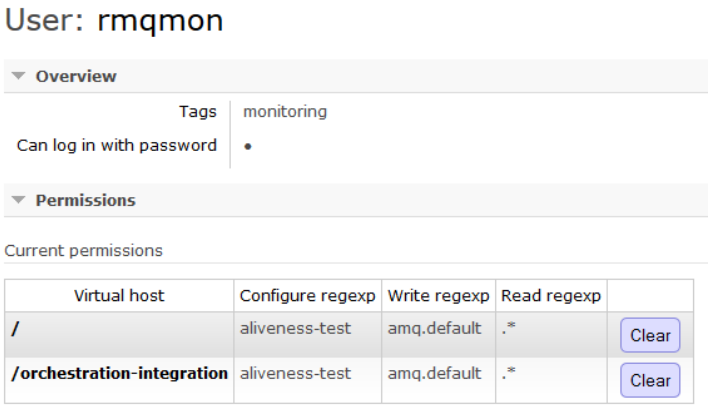
# Account permissions for monitoring

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# Agenda

- Operations
  - Disk, firewall, heartbeat, tuning
- Monitoring
- How to monitor with the HTTP API
- **Support for third-party monitoring tools**

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## Third-party monitoring tools

- Third-party monitoring tools may provide RabbitMQ plugins
- New Relic, Nagios, Splunk, etc.
- Simple to write your own with the HTTP API
  - Can use scripting language such as Perl or Python

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## Nagios support

- A set of Nagios checks
  - https://github.com/jamesc/nagios-plugins-rabbitmq
- PERL scripts, easy to customize

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## Nagios checks

- check_rabbitmq_aliveness
  - Issues a liveness test
- check_rabbitmq_server
  - Checks memory, processes, file descriptors, and sockets
- check_rabbitmq_objects
  - Checks number of virtual hosts, exchanges, bindings, queues, and channels

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## Nagios checks

- check_rabbitmq_overview
  - Checks number of messages (total, ready, and unacknowledged)
- check_rabbitmq_queue
  - Checks number of messages (total, ready, and unacknowledged) and of consumers for a queue
- check_rabbitmq_watermark
  - Checks if memory alarm or disk alarm has been triggered

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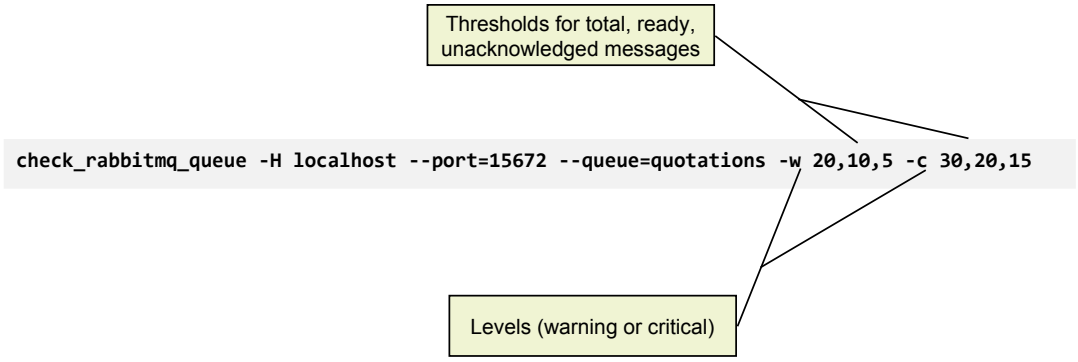
# Nagios checks, typical usage

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# New Relic RabbitMQ Plugin

- Cloud based monitoring
- Custom RabbitMQ plugin
  - Uses Ruby
  - https://github.com/gopivotal/newrelic_pivotal_agent

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# Plugin configuration

```
…
# Configuration for RabbitMQ  rabbitmq:
# Must enable rabbit management plugin
# Note: When monitoring multiple nodes you should use the real hostnames instead of localhost

# Uncomment the appropriate line for your version
# RabbitMQ Default URL version 3.0
management_api_url: http://guest:guest@localhost:15672
# RabbitMQ Default URL versions prior to 3.0
#management_api_url: http://guest:guest@localhost:55672
#
# Set "debug: true" to see additional debug output
#debug: false
…
```

Set host URL

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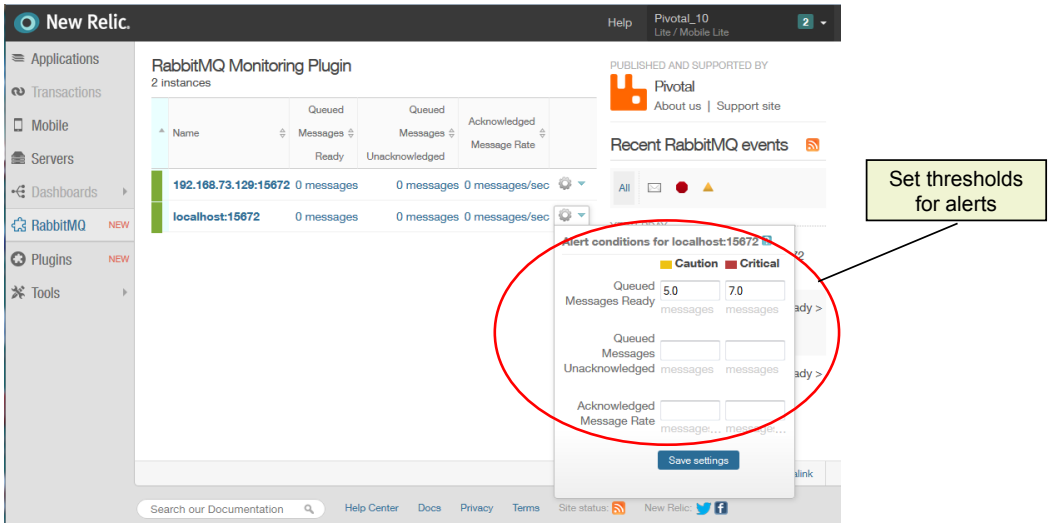
# New Relic dashboard home

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# Summary

- Important to tune RabbitMQ for the type of load expected
- Monitoring is supported through the HTTP REST API
- Support for third-party monitoring tools such as Nagios and New Relic is available

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# Finishing Up

## Course Completed

What's Next?

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## What's Next

- Congratulations, we've finished the course
- What to do next?
  - Certification
  - Other courses
  - Resources
  - Evaluation

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## Certification

- Computer-based exam
- Check https://academy.pivotal.io/ for details

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## Other Courses

- Many courses available
  - Pivotal Cloud Foundry
  - Spring
  - Gemfire
  - Data Science
  - Greenplum
  - Pivotal HDB
- See http://pivotal.io/academy for the most up-to-date list

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## Pivotal Support Offerings

- Support Portal: https://support.pivotal.io
- Global organization provides 24x7 support
- Premium and Developer support offerings:
  - http://www.pivotal.io/support/offerings
  - http://www.pivotal.io/support/oss
- Both Pivotal and Open Source products
- Community forums, Knowledge Base, Product documents

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## Pivotal Consulting

- Custom consulting engagement?
  - Contact us at https://pivotal.io/contact/spring-consulting
  - Even if you don't have a support contract!
- Pivotal Labs
  - Agile development experts
  - https://pivotal.io/labs


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## Resources

- RabbitMQ product website
  - http://www.rabbitmq.com/
- Mailing list
  - https://groups.google.com/forum/#!forum/rabbitmq-users
- Want to contribute?
  - http://www.rabbitmq.com/github.html

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## Thank You!

- We hope you enjoyed the course
- Please fill out the course evaluation

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# Spring AMQP

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## Agenda

- **Introduction to Spring**
- Spring AMQP Overview
- Spring's AmqpTemplate
- Configuring AMQP Resources with Spring
- Sending Messages
- Receiving Messages

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# What is Spring?

- At it's core, a widely used Java framework
- Supports dependency injection: decouples application from implementation code
  - Facilitates multiple implementations
  - Separates service definition from configuration
- Speeds application development
  - Relieves developer from tedious boilerplate code for things such as connection retries, transactions, etc.
- Plethora of projects

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# Spring Projects

| | | |
|---|---|---|
| Spring AMQP | Spring for Android | Spring Batch |
| Spring Data JPA | Spring Data Commons | Spring Data JDBC Extensions |
| Spring Data MongoDB | Spring Data Neo4J | Spring Data Redis |
| Spring Data REST | Spring Data Solr | Spring Flex |
| Spring Framework | Spring Data GemFire | Spring for Apache Hadoop |
| Spring HATEOAS | Spring Integration | Spring LDAP |
| Spring Mobile | Spring Roo | Spring Security |
| Spring Security OAuth | Spring Shell | Spring Social |
| Spring Social Facebook | Spring Social Twitter | Spring Web Flow |
| Spring Web Services | | |

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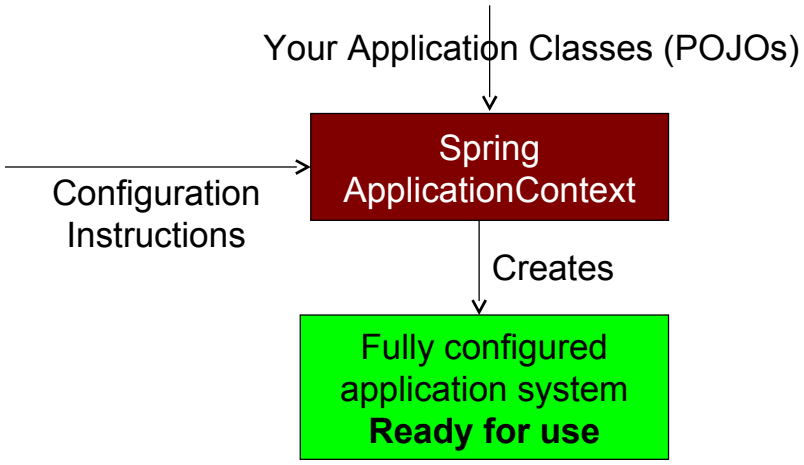
## How Spring Works

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## Steps

1. Define classes
2. Define configuration
   - Using Java, annotations, or XML
3. Create application code to load dependencies defined in configuration

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# Your Application Classes

```
public class TransferServiceImpl implements TransferService {
    public TransferServiceImpl(AccountRepository ar) {
        this.accountRepository = ar;
    }
    …
}
```

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# Configuration

```
@Configuration
public class ApplicationConfiguration {

  @Bean TransferService transferService() {
    return new TransferServiceImpl(accountRepository());
  }

  @Bean AccountRepository accountRepository() {
    return new JdbcAccountRepository(dataSource());
  }

  @Bean DataSource dataSource() {
    org.apache.tomcat.jdbc.pool.DataSource ds = new org.apache.tomcat.jdbc.pool.DataSource();
    ds.setDriverClassName("org.postgresql.Driver");
    ds.setUrl("jdbc:postgresql://localhost/transfer");
    ds.setUsername("transfer-app");
    ds.setPassword("secret45");
    return new ds;
  }
}
```

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# Creating and Using the Application

```
// Create the application from the configuration
ApplicationContext context =
    new AnnotationConfigApplicationContext(ApplicationConfiguration.class);

// Look up the application service interface
TransferService service = context.getBean(TransferService.class);

// Use the application
service.transfer(new MonetaryAmount("300.00"), "1", "2");
```

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# Agenda

- Introduction to Spring
- **Spring AMQP Overview**
- Spring's AmqpTemplate
- Configuring AMQP Resources with Spring
- Sending Messages
- Receiving Messages

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## Spring AMQP features

- RabbitTemplate for sending and receiving messages
- Sophisticated listener container for async consumption
- Auto-declaration of configured resources with RabbitAdmin
- Java/XML configuration and programatic use as well
- Auto-recovery after node failure
- Queue affinity handling for the best performance
- And more…

| NOTE | This module does not cover all these features! |
|---|---|

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## Agenda

- Introduction to Spring
- Spring AMQP Overview
- **Spring's AmqpTemplate**
- Configuring AMQP Resources with Spring
- Sending Messages
- Receiving Messages

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# Spring's AmqpTemplate

- Interface that defines main operations, such as sending/receiving messages
- RabbitTemplate is currently the only implementation
  - Specifically depends on RabbitMQ Java-client
- Simplifies usage of the API
  - Reduces boilerplate code
  - Manages resources transparently
  - Converts checked exceptions to runtime equivalents
  - Provides convenience methods and callbacks

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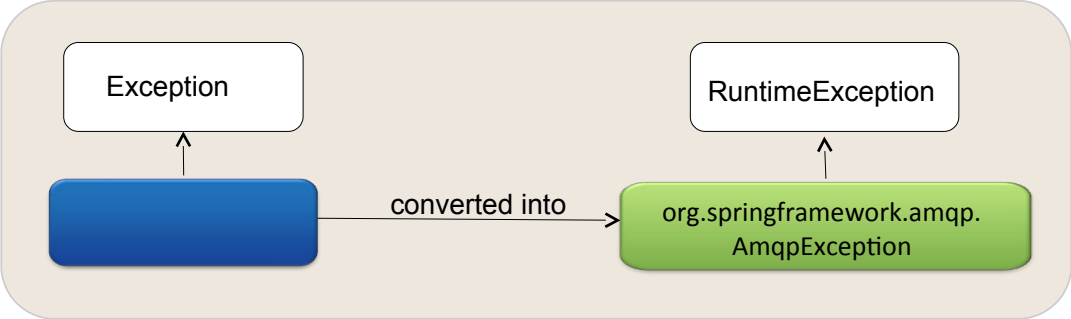
# Exception Handling

- Exceptions in AMQP checked by default
- AmqpTemplate converts checked exceptions to runtime equivalents

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## Agenda

- Introduction to Spring
- Spring AMQP Overview
- Spring's AmqpTemplate
- **Configuring AMQP Resources with Spring**
- Sending Messages
- Receiving Messages

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## ConnectionFactory Configuration

- Typically use the CachingConnectionFactory

```
@Bean ConnectionFactory connectionFactory() {
  CachingConnectionFactory connectionFactory =
    new CachingConnectionFactory("localhost");
  connectionFactory.setUsername("guest");
  connectionFactory.setPassword("guest");
  return connectionFactory;
}
```

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# RabbitTemplate Configuration

- *Must* provide reference to ConnectionFactory
  - via either constructor or setter injection
- Optionally provide delegates to handle some of the work
  - Message Converter

```
@Bean RabbitTemplate rabbitTemplate() {
  RabbitTemplate tpl = new RabbitTemplate(
    connectionFactory()
  );
  tpl.setMessageConverter(new JsonMessageConverter());
  return tpl;
}
```

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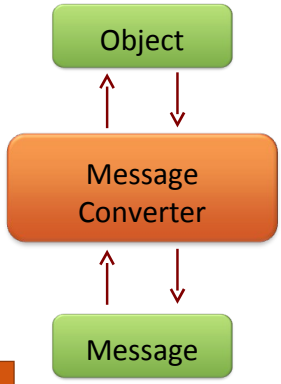
# MessageConverter

- RabbitTemplate uses MessageConverter to convert between objects and messages
  - You only send and receive objects
  - Decouples application from AMQP transport
- Default SimpleMessageConverter handles basic types
  - text-based content
  - serialized Java objects
  - simple byte arrays




**NOTE** It is possible to implement custom converters by implementing the MessageConverter interface

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# JSON MessageConverter

- Avoid Java serialization
  - Otherwise could only support Java clients
- JSON:  common language-independent message payload
- JsonMessageConverter: one implementation available

```
@Bean RabbitTemplate rabbitTemplate() {
  RabbitTemplate tpl = new RabbitTemplate(
    connectionFactory()
  );
  tpl.setMessageConverter(new JsonMessageConverter());
  return tpl;
}
```

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# CachingConnectionFactory settings

- CachingConnectionFactory has many settings
  - E.g. channel cache size, default is 1
- Override defaults during bean creation

```
@Bean ConnectionFactory connectionFactory() {
  CachingConnectionFactory connectionFactory =
    new CachingConnectionFactory("localhost");
  connectionFactory.setChannelCacheSize(10);
  return connectionFactory;
}
```

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## Agenda

- Introduction to Spring
- Spring AMQP Overview
- Spring's AmqpTemplate
- Configuring AMQP Resources with Spring
- **Sending Messages**
- Receiving Messages

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## Sending Messages

- Template provides several options
  - One line methods leveraging template's MessageConverter
  - Callback-accepting methods that reveal more of the AMQP Java-client API
- Use simplest option for the task at hand

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# Sending a POJO

- Message can be sent in one single line

```
public class OrderManagerImpl implements OrderManager {

     @Autowired RabbitTemplate rabbitTemplate;
     private final String ORDERS_EXCHANGE = "Orders";

     public void placeOrder(Order order) {

          String routingKey = order.getSourceRegion();
          // Use message converter
          rabbitTemplate.convertAndSend(ORDERS_EXCHANGE,
                    routingKey, order);

     }
}
```

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## Synchronous Message Reception

- AmqpTemplate can also receive messages, but methods are blocking (with optional timeout)
  - receive()
  - receive(String queueName)
- MessageConverter can be leveraged for message reception as well

```
Object someSerializable =
                template.receiveAndConvert();

Object someSerializable =
                template.receiveAndConvert(someQueue);
```

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## Synchronous Request-Reply

- RPC pattern using messaging
- Convenience convertSendAndReceive() method deserializes reply message payload into object

```
…
String orderId = "12345";
OrderDetailsRequest req = new OrderDetailsRequest(orderId);

String exchange = "order-services";
String routingKey = "get-order-details-req.1_0";
Order order = (Order)template.convertSendAndReceive(
                                    exchange, routingKey, req);
…
```

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## AMQP Asynchronous Listener Interfaces

- MessageListener
- ChannelAwareMessageListener (if access to channel required)

```
import org.springframework.amqp.core.Message;
import org.springframework.amqp.rabbit.core.ChannelAwareMessageListener;
import com.rabbitmq.client.Channel;

public class GetOrderDetails implements ChannelAwareMessageListener {

  public void onMessage(Message msg, Channel channel) {
    // Process message…
  }
}
```

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## Spring's MessageListener Container

- Required for asynchronous listeners
- Default implementation: SimpleMessageListenerContainer
- Uses AMQP Java client
- Configurable
  - concurrency
  - acknowledgements
  - transactional channel
  - etc.

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# Defining a Simple AMQP Message Listener

- Use SimpleMessageListenerContainer

```
@Bean SimpleMessageListenerContainer messageListenerContainer() {
  SimpleMessageListenerContainer container =
    new SimpleMessageListenerContainer();
  container.setConnectionFactory(connectionFactory());
  container.setQueueNames("quotes");
  container.setMessageListener(quoteRequestAmqpEndpoint());
  return container;
}
```

- Listener must implement MessageListener or ChannelAwareMessageListener

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# Spring vs AMQP Acknowledgement Modes

- Caution: Spring-AMQP's acknowledgement mode terminology differs from AMQP!

| Spring-AMQP Ack Mode | AMQP Auto-Ack | Description |
|---|---|---|
| None | true | No acknowledgements in either case. |
| Auto | false | Spring container is responsible for acknowledging the message. |
| Manual | false | Developer must explicitly acknowledge the message. |

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# Spring's Message-Driven POJO

- Spring also allows you to specify a plain Java object that can serve as a listener
  - MessageConverter provides parameter
  - Any return value sent to response-exchange after conversion

```
public class OrderService {
        public OrderConfirmation order(Order o) {}
}
```

(1) (2) (3)

```
SimpleMessageListenerContainer container = (...);
container.setQueueNames("queue.orders");
MessageListenerAdapter adapter = new MessageListenerAdapter(orderService);
adapter.setDefaultListenerMethod("order");
adapter.setResponseExchange("exchange.confirmations");
container.setMessageListener(adapter);
```

(1) (2) (3)

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# Summary

- Spring AMQP simplifies and reduces boilerplate code
- AmqpTemplate defines main operations, such as sending/receiving messages
- MessageConverter's simplify serialization/deserialization of Java objects
- Both synchronous and asynchronous message consumers are supported

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# Lab

## Using the Spring AMQP Template

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