Red Hat AMQ Clients 2.11

Using the AMQ C++ Client

For Use with AMQ Clients 2.11

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Legal Notice

Abstract

This guide describes how to install and configure the client, run hands-on examples, and use your client with other AMQ components.

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MAKING OPEN SOURCE MORE INCLUSIVE

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright's message.

CHAPTER 1. OVERVIEW

AMQ C++ is a library for developing messaging applications. It enables you to write C++ applications that send and receive AMQP messages.

AMQ C++ is part of AMQ Clients, a suite of messaging libraries supporting multiple languages and platforms. For an overview of the clients, see AMQ Clients Overview. For information about this release, see AMQ Clients 2.11 Release Notes .

AMQ C++ is based on the Proton API from Apache Qpid. For detailed API documentation, see the AMQ C++ API reference.

1.1. KEY FEATURES

- An event-driven API that simplifies integration with existing applications
- SSL/TLS for secure communication
- Flexible SASL authentication
- Automatic reconnect and failover
- Seamless conversion between AMQP and language-native data types
- Access to all the features and capabilities of AMQP 1.0

1.2. SUPPORTED STANDARDS AND PROTOCOLS

AMQ C++ supports the following industry-recognized standards and network protocols:

- Version 1.0 of the Advanced Message Queueing Protocol (AMQP)
- Versions 1.0, 1.1, 1.2, and 1.3 of the Transport Layer Security (TLS) protocol, the successor to SSL
- Simple Authentication and Security Layer (SASL) mechanisms supported by Cyrus SASL, including ANONYMOUS, PLAIN, SCRAM, EXTERNAL, and GSSAPI (Kerberos)
- Modern TCP with IPv6

1.3. SUPPORTED CONFIGURATIONS

Refer to Red Hat AMQ Supported Configurations on the Red Hat Customer Portal for current information regarding AMQ C++ supported configurations.

1.4. TERMS AND CONCEPTS

This section introduces the core API entities and describes how they operate together.

Table 1.1. API terms

Entity	Description
Container	A top-level container of connections.

Entity	Description
Connection	A channel for communication between two peers on a network. It contains sessions.
Session	A context for sending and receiving messages. It contains senders and receivers.
Sender	A channel for sending messages to a target. It has a target.
Receiver	A channel for receiving messages from a source. It has a source.
Source	A named point of origin for messages.
Target	A named destination for messages.
Message	An application-specific piece of information.
Delivery	A message transfer.

AMQ C++ sends and receives *messages*. Messages are transferred between connected peers over *senders* and *receivers*. Senders and receivers are established over *sessions*. Sessions are established over *connections*. Connections are established between two uniquely identified *containers*. Though a connection can have multiple sessions, often this is not needed. The API allows you to ignore sessions unless you require them.

A sending peer creates a sender to send messages. The sender has a *target* that identifies a queue or topic at the remote peer. A receiving peer creates a receiver to receive messages. The receiver has a *source* that identifies a queue or topic at the remote peer.

The sending of a message is called a *delivery*. The message is the content sent, including all metadata such as headers and annotations. The delivery is the protocol exchange associated with the transfer of that content.

To indicate that a delivery is complete, either the sender or the receiver settles it. When the other side learns that it has been settled, it will no longer communicate about that delivery. The receiver can also indicate whether it accepts or rejects the message.

1.5. DOCUMENT CONVENTIONS

The sudo command

In this document, **sudo** is used for any command that requires root privileges. Exercise caution when using **sudo** because any changes can affect the entire system. For more information about **sudo**, see Using the sudo command.

File paths

In this document, all file paths are valid for Linux, UNIX, and similar operating systems (for example, **/home/andrea**). On Microsoft Windows, you must use the equivalent Windows paths (for example, **C:\Users\andrea**).

Variable text

This document contains code blocks with variables that you must replace with values specific to your environment. Variable text is enclosed in arrow braces and styled as italic monospace. For example, in the following command, replace ***<project-dir>*** with the value for your environment:

```
$ cd <project-dir>
```

CHAPTER 2. INSTALLATION

This chapter guides you through the steps to install AMQ C++ in your environment.

2.1. PREREQUISITES

- You must have a subscription to access AMQ release files and repositories.
- To install packages on Red Hat Enterprise Linux, you must register your system.
- To build programs using AMQ C++ on Red Hat Enterprise Linux, you must install the **gcc-c++**, **cmake**, and **make** packages.
- To build programs using AMQ C++ on Microsoft Windows, you must install Visual Studio.

2.2. INSTALLING ON RED HAT ENTERPRISE LINUX

Procedure

1. Use the **subscription-manager** command to subscribe to the required package repositories. Replace ***<version>*** with **2** for the main release stream or **2.11** for the long term support release stream. If necessary, replace ***<variant>*** with the value for your variant of Red Hat Enterprise Linux (for example, **server** or **workstation**).

   Red Hat Enterprise Linux 7

   ```
   $ sudo subscription-manager repos --enable=amq-clients-<version>-for-rhel-7-<variant>-rpms
   ```

   Red Hat Enterprise Linux 8

   ```
   $ sudo subscription-manager repos --enable=amq-clients-<version>-for-rhel-8-x86_64-rpms
   ```

2. Use the **yum** command to install the **qpid-proton-cpp-devel** and **qpid-proton-cpp-docs** packages.

   ```
   $ sudo yum install qpid-proton-cpp-devel qpid-proton-cpp-docs
   ```

For more information about using packages, see Appendix B, *Using Red Hat Enterprise Linux packages*.

2.3. INSTALLING ON MICROSOFT WINDOWS

Procedure

1. Open a browser and log in to the Red Hat Customer Portal **Product Downloads** page at access.redhat.com/downloads.
2. Locate the **Red Hat AMQ Clients** entry in the **INTEGRATION AND AUTOMATION** category.
3. Click **Red Hat AMQ Clients** The **Software Downloads** page opens.
4. Download the **AMQ Clients 2.11.0 C++** .zip file.

5. Extract the file contents into a directory of your choosing by right-clicking on the zip file and selecting **Extract All**.

When you extract the contents of the .zip file, a directory named **amq-clients-2.11.0-cpp-win** is created. This is the top-level directory of the installation and is referred to as ***<install-dir>*** throughout this document.

CHAPTER 3. GETTING STARTED

This chapter guides you through the steps to set up your environment and run a simple messaging program.

3.1. PREREQUISITES

- You must complete the installation procedure for your environment.
- You must have an AMQP 1.0 message broker listening for connections on interface **localhost** and port **5672**. It must have anonymous access enabled. For more information, see Starting the broker.
- You must have a queue named **examples**. For more information, see Creating a queue.

3.2. RUNNING HELLO WORLD ON RED HAT ENTERPRISE LINUX

The Hello World example creates a connection to the broker, sends a message containing a greeting to the **examples** queue, and receives it back. On success, it prints the received message to the console.

Procedure

1. Copy the examples to a location of your choosing.

```
$ cp -r /usr/share/proton/examples/cpp cpp-examples
```

2. Create a build directory and change to that directory:

```
$ mkdir cpp-examples/bld
$ cd cpp-examples/bld
```

3. Use **cmake** to configure the build and use **make** to compile the examples.

```
$ cmake ..
$ make
```

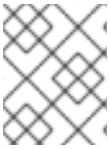
4. Run the **helloworld** program.

```
$ ./helloworld
Hello World!
```

CHAPTER 4. EXAMPLES

This chapter demonstrates the use of AMQ C++ through example programs.

For more examples, see the AMQ C++ example suite and the Qpid Proton C++ examples.



NOTE

The code presented in this guide uses C++11 features. AMQ C++ is also compatible with C++03, but the code requires minor modifications.

4.1. SENDING MESSAGES

This client program connects to a server using **<connection-url>**, creates a sender for target **<address>**, sends a message containing **<message-body>**, closes the connection, and exits.

Example: Sending messages

```
#include <proton/connection.hpp>
#include <proton/container.hpp>
#include <proton/message.hpp>
#include <proton/messaging_handler.hpp>
#include <proton/sender.hpp>
#include <proton/target.hpp>

#include <iostream>
#include <string>

struct send_handler : public proton::messaging_handler {
    std::string conn_url_ {};
    std::string address_ {};
    std::string message_body_ {};

    void on_container_start(proton::container& cont) override {
        cont.connect(conn_url_);

        // To connect with a user and password:
        //
        // proton::connection_options opts {};
        // opts.user("<user>");
        // opts.password("<password>");
        //
        // cont.connect(conn_url_, opts);
    }

    void on_connection_open(proton::connection& conn) override {
        conn.open_sender(address_);
    }

    void on_sender_open(proton::sender& snd) override {
        std::cout << "SEND: Opened sender for target address '"
                  << snd.target().address() << "'\n";
    }

    void on_sendable(proton::sender& snd) override {
```

```
        proton::message msg {message_body_};
        snd.send(msg);

        std::cout << "SEND: Sent message '" << msg.body() << "'\n";

        snd.close();
        snd.connection().close();
    }
};

int main(int argc, char** argv) {
    if (argc != 4) {
        std::cerr << "Usage: send <connection-url> <address> <message-body>\n";
        return 1;
    }

    send_handler handler {};
    handler.conn_url_ = argv[1];
    handler.address_ = argv[2];
    handler.message_body_ = argv[3];

    proton::container cont {handler};

    try {
        cont.run();
    } catch (const std::exception& e) {
        std::cerr << e.what() << "\n";
        return 1;
    }

    return 0;
}
```

Running the example

To run the example program, copy it to a local file, compile it, and execute it from the command line. For more information, see Chapter 3, *Getting started*.

```
$ g++ send.cpp -o send -std=c++11 -lstdc++ -lqpid-proton-cpp
$ ./send amqp://localhost queue1 hello
```

4.2. RECEIVING MESSAGES

This client program connects to a server using **<connection-url>**, creates a receiver for source **<address>**, and receives messages until it is terminated or it reaches **<count>** messages.

Example: Receiving messages

```
#include <proton/connection.hpp>
#include <proton/container.hpp>
#include <proton/delivery.hpp>
#include <proton/message.hpp>
#include <proton/messaging_handler.hpp>
#include <proton/receiver.hpp>
#include <proton/source.hpp>
```

```
#include <iostream>
#include <string>

struct receive_handler : public proton::messaging_handler {
    std::string conn_url_ {};
    std::string address_ {};
    int desired_ {0};
    int received_ {0};

    void on_container_start(proton::container& cont) override {
        cont.connect(conn_url_);

        // To connect with a user and password:
        //
        // proton::connection_options opts {};
        // opts.user("<user>");
        // opts.password("<password>");
        //
        // cont.connect(conn_url_, opts);
    }

    void on_connection_open(proton::connection& conn) override {
        conn.open_receiver(address_);
    }

    void on_receiver_open(proton::receiver& rcv) override {
        std::cout << "RECEIVE: Opened receiver for source address '"
                  << rcv.source().address() << "'\n";
    }

    void on_message(proton::delivery& dlv, proton::message& msg) override {
        std::cout << "RECEIVE: Received message '" << msg.body() << "'\n";

        received_++;

        if (received_ == desired_) {
            dlv.receiver().close();
            dlv.connection().close();
        }
    }
};

int main(int argc, char** argv) {
    if (argc != 3 && argc != 4) {
        std::cerr << "Usage: receive <connection-url> <address> [<message-count>]\n";
        return 1;
    }

    receive_handler handler {};
    handler.conn_url_ = argv[1];
    handler.address_ = argv[2];

    if (argc == 4) {
        handler.desired_ = std::stoi(argv[3]);
    }
```

```
    proton::container cont {handler};

    try {
        cont.run();
    } catch (const std::exception& e) {
        std::cerr << e.what() << "\n";
        return 1;
    }

    return 0;
}
```

Running the example

To run the example program, copy it to a local file, compile it, and execute it from the command line. For more information, see Chapter 3, *Getting started*.

```
$ g++ receive.cpp -o receive -std=c++11 -lstdc++ -lqpid-proton-cpp
$ ./receive amqp://localhost queue1
```

CHAPTER 5. USING THE API

For more information, see the AMQ C++ API reference and AMQ C++ example suite .

5.1. HANDLING MESSAGING EVENTS

AMQ C++ is an asynchronous event-driven API. To define how the application handles events, the user implements callback methods on the **messaging_handler** class. These methods are then called as network activity or timers trigger new events.

Example: Handling messaging events

```
struct example_handler : public proton::messaging_handler {
    void on_container_start(proton::container& cont) override {
        std::cout << "The container has started\n";
    }

    void on_sendable(proton::sender& snd) override {
        std::cout << "A message can be sent\n";
    }

    void on_message(proton::delivery& dlv, proton::message& msg) override {
        std::cout << "A message is received\n";
    }
};
```

These are only a few common-case events. The full set is documented in the API reference.

5.2. CREATING A CONTAINER

The container is the top-level API object. It is the entry point for creating connections, and it is responsible for running the main event loop. It is often constructed with a global event handler.

Example: Creating a container

```
int main() {
    example_handler handler {};
    proton::container cont {handler};
    cont.run();
}
```

5.3. SETTING THE CONTAINER IDENTITY

Each container instance has a unique identity called the container ID. When AMQ C++ makes a connection, it sends the container ID to the remote peer. To set the container ID, pass it to the **proton::container** constructor.

Example: Setting the container identity

```
proton::container cont {handler, "job-processor-3"};
```

If the user does not set the ID, the library will generate a UUID when the container is constucted.

CHAPTER 6. NETWORK CONNECTIONS

6.1. CONNECTION URLS

Connection URLs encode the information used to establish new connections.

Connection URL syntax

```
scheme://host[:port]
```

- *Scheme* - The connection transport, either **amqp** for unencrypted TCP or **amqps** for TCP with SSL/TLS encryption.
- *Host* - The remote network host. The value can be a hostname or a numeric IP address. IPv6 addresses must be enclosed in square brackets.
- *Port* - The remote network port. This value is optional. The default value is 5672 for the **amqp** scheme and 5671 for the **amqps** scheme.

Connection URL examples

```
amqps://example.com
amqps://example.net:56720
amqp://127.0.0.1
amqp://[::1]:2000
```

6.2. CREATING OUTGOING CONNECTIONS

To connect to a remote server, call the **container::connect()** method with a connection URL. This is typically done inside the **messaging_handler::on_container_start()** method.

Example: Creating outgoing connections

```
class example_handler : public proton::messaging_handler {
    void on_container_start(proton::container& cont) override {
        cont.connect("amqp://example.com");
    }

    void on_connection_open(proton::connection& conn) override {
        std::cout << "The connection is open\n";
    }
};
```

For information about creating secure connections, see Chapter 7, *Security*.

6.3. CONFIGURING RECONNECT

Reconnect allows a client to recover from lost connections. It is used to ensure that the components in a distributed system reestablish communication after temporary network or component failures.

AMQ C++ disables reconnect by default. To enable it, set the **reconnect** connection option to an instance of the **reconnect_options** class.

Example: Enabling reconnect

```
proton::connection_options opts {};
proton::reconnect_options ropts {};

opts.reconnect(ropts);

container.connect("amqp://example.com", opts);
```

With reconnect enabled, if a connection is lost or a connection attempt fails, the client will try again after a brief delay. The delay increases exponentially for each new attempt.

To control the delays between connection attempts, set the **delay**, **delay_multiplier**, and **max_delay** options. All durations are specified in milliseconds.

To limit the number of reconnect attempts, set the **max_attempts** option. Setting it to 0 removes any limit.

Example: Configuring reconnect

```
proton::connection_options opts {};
proton::reconnect_options ropts {};

ropts.delay(proton::duration(10));
ropts.delay_multiplier(2.0);
ropts.max_delay(proton::duration::FOREVER);
ropts.max_attempts(0);

opts.reconnect(ropts);

container.connect("amqp://example.com", opts);
```

6.4. CONFIGURING FAILOVER

AMQ C++ allows you to configure multiple connection endpoints. If connecting to one fails, the client attempts to connect to the next in the list. If the list is exhausted, the process starts over.

To specify alternate connection endpoints, set the **failover_urls** reconnect option to a list of connection URLs.

Example: Configuring failover

```
std::vector<std::string> failover_urls = {
    "amqp://backup1.example.com",
    "amqp://backup2.example.com"
};

proton::connection_options opts {};
proton::reconnect_options ropts {};

opts.reconnect(ropts);
ropts.failover_urls(failover_urls);

container.connect("amqp://primary.example.com", opts);
```

6.5. ACCEPTING INCOMING CONNECTIONS

AMQ C++ can accept inbound network connections, enabling you to build custom messaging servers.

To start listening for connections, use the **proton::container::listen()** method with a URL containing the local host address and port to listen on.

Example: Accepting incoming connections

```
class example_handler : public proton::messaging_handler {
    void on_container_start(proton::container& cont) override {
        cont.listen("0.0.0.0");
    }

    void on_connection_open(proton::connection& conn) override {
        std::cout << "New incoming connection\n";
    }
};
```

The special IP address **0.0.0.0** listens on all available IPv4 interfaces. To listen on all IPv6 interfaces, use **[::0]**.

For more information, see the server receive.cpp example.

CHAPTER 7. SECURITY

7.1. SECURING CONNECTIONS WITH SSL/TLS

AMQ C++ uses SSL/TLS to encrypt communication between clients and servers.

To connect to a remote server with SSL/TLS, set the **ssl_client_options** connection option and use a connection URL with the **amqps** scheme. The **ssl_client_options** constructor takes the filename, directory, or database ID of a CA certificate.

Example: Enabling SSL/TLS

```
proton::ssl_client_options sopts {"/etc/pki/ca-trust"};
proton::connection_options opts {};

opts.ssl_client_options(sopts);

container.connect("amqps://example.com", opts);
```

7.2. CONNECTING WITH A USER AND PASSWORD

AMQ C++ can authenticate connections with a user and password.

To specify the credentials used for authentication, set the **user** and **password** options on the **connect** method.

Example: Connecting with a user and password

```
proton::connection_options opts {};

opts.user("alice");
opts.password("secret");

container.connect("amqps://example.com", opts);
```

7.3. CONFIGURING SASL AUTHENTICATION

AMQ C++ uses the SASL protocol to perform authentication. SASL can use a number of different authentication *mechanisms*. When two network peers connect, they exchange their allowed mechanisms, and the strongest mechanism allowed by both is selected.

NOTE

The client uses Cyrus SASL to perform authentication. Cyrus SASL uses plug-ins to support specific SASL mechanisms. Before you can use a particular SASL mechanism, the relevant plug-in must be installed. For example, you need the **cyrus-sasl-plain** plug-in in order to use SASL PLAIN authentication.

To see a list of Cyrus SASL plug-ins in Red Hat Enterprise Linux, use the **yum search cyrus-sasl** command. To install a Cyrus SASL plug-in, use the **yum install PLUG-IN** command.

By default, AMQ C++ allows all of the mechanisms supported by the local SASL library configuration. To restrict the allowed mechanisms and thereby control what mechanisms can be negotiated, use the **sasl_allowed_mechs** connection option. This option accepts a string containing a space-separated list of mechanism names.

Example: Configuring SASL authentication

```
proton::connection_options opts {};

opts.sasl_allowed_mechs("ANONYMOUS");

container.connect("amqps://example.com", opts);
```

This example forces the connection to authenticate using the **ANONYMOUS** mechanism even if the server we connect to offers other options. Valid mechanisms include **ANONYMOUS**, **PLAIN**, **SCRAM-SHA-256**, **SCRAM-SHA-1**, **GSSAPI**, and **EXTERNAL**.

AMQ C++ enables SASL by default. To disable it, set the **sasl_enabled** connection option to false.

Example: Disabling SASL

```
proton::connection_options opts {};

opts.sasl_enabled(false);

container.connect("amqps://example.com", opts);
```

7.4. AUTHENTICATING USING KERBEROS

Kerberos is a network protocol for centrally managed authentication based on the exchange of encrypted tickets. See Using Kerberos for more information.

1. Configure Kerberos in your operating system. See Configuring Kerberos to set up Kerberos on Red Hat Enterprise Linux.
2. Enable the **GSSAPI** SASL mechanism in your client application.

   ```
   proton::connection_options opts {};

   opts.sasl_allowed_mechs("GSSAPI");

   container.connect("amqps://example.com", opts);
   ```

3. Use the **kinit** command to authenticate your user credentials and store the resulting Kerberos ticket.

   ```
   $ kinit USER@REALM
   ```

4. Run the client program.

CHAPTER 8. SENDERS AND RECEIVERS

The client uses sender and receiver links to represent channels for delivering messages. Senders and receivers are unidirectional, with a source end for the message origin, and a target end for the message destination.

Sources and targets often point to queues or topics on a message broker. Sources are also used to represent subscriptions.

8.1. CREATING QUEUES AND TOPICS ON DEMAND

Some message servers support on-demand creation of queues and topics. When a sender or receiver is attached, the server uses the sender target address or the receiver source address to create a queue or topic with a name matching the address.

The message server typically defaults to creating either a queue (for one-to-one message delivery) or a topic (for one-to-many message delivery). The client can indicate which it prefers by setting the **queue** or **topic** capability on the source or target.

To select queue or topic semantics, follow these steps:

1. Configure your message server for automatic creation of queues and topics. This is often the default configuration.

2. Set either the **queue** or **topic** capability on your sender target or receiver source, as in the examples below.

Example: Sending to a queue created on demand

```
void on_container_start(proton::container& cont) override {
    proton::connection conn = cont.connect("amqp://example.com");
    proton::sender_options opts {};
    proton::target_options topts {};

    topts.capabilities(std::vector<proton::symbol> { "queue" });
    opts.target(topts);

    conn.open_sender("jobs", opts);
}
```

Example: Receiving from a topic created on demand

```
void on_container_start(proton::container& cont) override {
    proton::connection conn = cont.connect("amqp://example.com");
    proton::receiver_options opts {};
    proton::source_options sopts {};

    sopts.capabilities(std::vector<proton::symbol> { "topic" });
    opts.source(sopts);

    conn.open_receiver("notifications", opts);
}
```

For more details, see the following examples:

- queue-send.cpp
- queue-receive.cpp
- topic-send.cpp
- topic-receive.cpp

8.2. CREATING DURABLE SUBSCRIPTIONS

A durable subscription is a piece of state on the remote server representing a message receiver. Ordinarily, message receivers are discarded when a client closes. However, because durable subscriptions are persistent, clients can detach from them and then re-attach later. Any messages received while detached are available when the client re-attaches.

Durable subscriptions are uniquely identified by combining the client container ID and receiver name to form a subscription ID. These must have stable values so that the subscription can be recovered.

To create a durable subscription, follow these steps:

1. Set the connection container ID to a stable value, such as **client-1**:

```
proton::container cont {handler, "client-1"};
```

2. Create a receiver with a stable name, such as **sub-1**, and configure the receiver source for durability by setting the **durability_mode** and **expiry_policy** options:

```
void on_container_start(proton::container& cont) override {
    proton::connection conn = cont.connect("amqp://example.com");
    proton::receiver_options opts {};
    proton::source_options sopts {};

    opts.name("sub-1");
    sopts.durability_mode(proton::source::UNSETTLED_STATE);
    sopts.expiry_policy(proton::source::NEVER);

    opts.source(sopts);

    conn.open_receiver("notifications", opts);
}
```

To detach from a subscription, use the **proton::receiver::detach()** method. To terminate the subscription, use the **proton::receiver::close()** method.

For more information, see the durable-subscribe.cpp example.

8.3. CREATING SHARED SUBSCRIPTIONS

A shared subscription is a piece of state on the remote server representing one or more message receivers. Because it is shared, multiple clients can consume from the same stream of messages.

The client configures a shared subscription by setting the **shared** capability on the receiver source.

Shared subscriptions are uniquely identified by combining the client container ID and receiver name to form a subscription ID. These must have stable values so that multiple client processes can locate the

same subscription. If the **global** capability is set in addition to **shared**, the receiver name alone is used to identify the subscription.

To create a durable subscription, follow these steps:

1. Set the connection container ID to a stable value, such as **client-1**:

```
proton::container cont {handler, "client-1"};
```

2. Create a receiver with a stable name, such as **sub-1**, and configure the receiver source for sharing by setting the **shared** capability:

```
void on_container_start(proton::container& cont) override {
    proton::connection conn = cont.connect("amqp://example.com");
    proton::receiver_options opts {};
    proton::source_options sopts {};

    opts.name("sub-1");
    sopts.capabilities(std::vector<proton::symbol> { "shared" });

    opts.source(sopts);

    conn.open_receiver("notifications", opts);
}
```

To detach from a subscription, use the **proton::receiver::detach()** method. To terminate the subscription, use the **proton::receiver::close()** method.

For more information, see the shared-subscribe.cpp example.

CHAPTER 9. MESSAGE DELIVERY

9.1. SENDING MESSAGES

To send a message, override the **on_sendable** event handler and call the **sender::send()** method. The **sendable** event fires when the **proton::sender** has enough credit to send at least one message.

Example: Sending messages

```
struct example_handler : public proton::messaging_handler {
    void on_container_start(proton::container& cont) override {
        proton::connection conn = cont.connect("amqp://example.com");
        conn.open_sender("jobs");
    }

    void on_sendable(proton::sender& snd) override {
        proton::message msg {"job-1"};
        snd.send(msg);
    }
};
```

9.2. TRACKING SENT MESSAGES

When a message is sent, the sender can keep a reference to the **tracker** object representing the transfer. The receiver accepts or rejects each message that is delivered. The sender is notified of the outcome for each tracked delivery.

To monitor the outcome of a sent message, override the **on_tracker_accept** and **on_tracker_reject** event handlers and map the delivery state update to the tracker returned from **send()**.

Example: Tracking sent messages

```
void on_sendable(proton::sender& snd) override {
    proton::message msg {"job-1"};
    proton::tracker trk = snd.send(msg);
}

void on_tracker_accept(proton::tracker& trk) override {
    std::cout << "Delivery for " << trk << " is accepted\n";
}

void on_tracker_reject(proton::tracker& trk) override {
    std::cout << "Delivery for " << trk << " is rejected\n";
}
```

The **tracker** object has a **tag()** method for accessing the unique identifier for each delivery. The delivery tag can be used to store in-flight messages for resending after a connection failure.

9.3. RECEIVING MESSAGES

To receive messages, create a receiver and override the **on_message** event handler.

Example: Receiving messages

```
struct example_handler : public proton::messaging_handler {
    void on_container_start(proton::container& cont) override {
        proton::connection conn = cont.connect("amqp://example.com");
        conn.open_receiver("jobs");
    }

    void on_message(proton::delivery& dlv, proton::message& msg) override {
        std::cout << "Received message '" << msg.body() << "'\n";
    }
};
```

The **delivery** object has a **tag()** method for accessing the unique identifier for each delivery.

9.4. ACKNOWLEDGING RECEIVED MESSAGES

To explicitly accept or reject a delivery, use the **delivery::accept()** or **delivery::reject()** methods in the **on_message** event handler.

Example: Acknowledging received messages

```
void on_message(proton::delivery& dlv, proton::message& msg) override {
    try {
        process_message(msg);
        dlv.accept();
    } catch (std::exception& e) {
        dlv.reject();
    }
}
```

By default, if you do not explicitly acknowledge a delivery, then the library accepts it after **on_message** returns. To disable this behavior, set the **auto_accept** receiver option to false.

CHAPTER 10. ERROR HANDLING

Errors in AMQ C++ can be handled in two different ways:

- Catching exceptions
- Overriding event-handling functions to intercept AMQP protocol or connection errors

Catching exceptions is the most basic, but least granular, way to handle errors. If an error is not handled using an override in a handler function, an exception is thrown.

10.1. CATCHING EXCEPTIONS

If an error is not handled using an override in an event-handling function, an exception is thrown by the container's **run** method.

All of the exceptions that AMQ C++ throws inherit from the **proton::error** class, which in turn inherits from the **std::runtime_error** and **std::exception** classes.

The following example illustrates how to catch any exception thrown from AMQ C++:

Example: API-specific exception handling

```
try {
    // Something that might throw an exception
} catch (proton::error& e) {
    // Handle Proton-specific problems here
} catch (std::exception& e) {
    // Handle more general problems here
}
```

If you do not require API-specific exception handling, you only need to catch **std::exception**, since **proton::error** inherits from it.

10.2. HANDLING CONNECTION AND PROTOCOL ERRORS

You can handle protocol-level errors by overriding the following **messaging_handler** methods:

- **on_transport_error(proton::transport&)**
- **on_connection_error(proton::connection&)**
- **on_session_error(proton::session&)**
- **on_receiver_error(proton::receiver&)**
- **on_sender_error(proton::sender&)**

These event handling routines are called whenever there is an error condition with the specific object that is in the event. After calling the error handler, the appropriate close handler is also called.

If one of the more specific error handlers is not overridden, the default error handler is called:

- **on_error(proton::error_condition&)**

NOTE

Because the close handlers are called in the event of any error, only the error itself needs to be handled within the error handler. Resource cleanup can be managed by close handlers. If there is no error handling that is specific to a particular object, it is typical to use the general **on_error** handler and not have a more specific handler.

NOTE

When reconnect is enabled and the remote server closes a connection with the **amqp:connection:forced** condition, the client does not treat it as an error and thus does not fire the **on_connection_error** handler. The client instead begins the reconnection process.

CHAPTER 11. LOGGING

11.1. ENABLING PROTOCOL LOGGING

The client can log AMQP protocol frames to the console. This data is often critical when diagnosing problems.

To enable protocol logging, set the **PN_TRACE_FRM** environment variable to **1**:

Example: Enabling protocol logging

```
$ export PN_TRACE_FRM=1
$ <your-client-program>
```

To disable protocol logging, unset the **PN_TRACE_FRM** environment variable.

CHAPTER 12. THREADING AND SCHEDULING

AMQ C++ supports full multithreading with C++11 and later. Limited multithreading is possible with older versions of C++. See Section 12.6, “Using older versions of C++”.

12.1. THE THREADING MODEL

The **container** object can handle multiple connections concurrently. When AMQP events occur on connections, the container calls **messaging_handler** callback functions. Callbacks for any one connection are serialized (not called concurrently), but callbacks for different connections can be safely executed in parallel.

You can assign a handler to a connection in **container::connect()** or **listen_handler::on_accept()** using the **handler** connection option. It is recommended to create a separate handler for each connection so that the handler does not need locks or other synchronization to protect it against concurrent use by library threads. If any non-library threads use the handler concurrently, then you need synchronization.

12.2. THREAD-SAFETY RULES

The **connection**, **session**, **sender**, **receiver**, **tracker**, and **delivery** objects are not thread-safe and are subject to the following rules.

1. You must use them only from a **messaging_handler** callback or a **work_queue** function.
2. You must not use objects belonging to one connection from a callback for another connection.
3. You can store AMQ C++ objects in member variables for use in a later callback, provided you respect rule two.

The **message** object is a value type with the same threading constraints as a standard C++ built-in type. It cannot be concurrently modified.

12.3. WORK QUEUES

The **work_queue** interface provides a safe way to communicate between different connection handlers or between non-library threads and connection handlers.

- Each connection has an associated **work_queue**.
- The work queue is thread-safe (C++11 or greater). Any thread can add work.
- A **work** item is a **std::function**, and bound arguments are called like an event callback.

When the library calls the work function, it is serialized safely so that you can treat the work function like an event callback and safely access the handler and AMQ C++ objects stored on it.

12.4. THE WAKE PRIMITIVE

The **connection::wake()** method allows any thread to prompt activity on a connection by triggering an **on_connection_wake()** callback. This is the only thread-safe method on **connection**.

wake() is a lightweight, low-level primitive for signaling between threads.

- It does not carry any code or data, unlike **work_queue**.

- Multiple calls to **wake()** might be coalesced into a single **on_connection_wake()**.
- Calls to **on_connection_wake()** can occur without any application call to **wake()** since the library uses **wake()** internally.

The semantics of **wake()** are similar to **std::condition_variable::notify_one()**. There will be a wakeup, but there must be some shared application state to determine why the wakeup occurred and what, if anything, to do about it.

Work queues are easier to use in many instances, but **wake()** may be useful if you already have your own external thread-safe queues and need an efficient way to wake a connection to check them for data.

12.5. SCHEDULING DEFERRED WORK

AMQ C++ has the ability to execute code after a delay. You can use this to implement time-based behaviors in your application, such as periodically scheduled work or timeouts.

To defer work for a fixed amount of time, use the **schedule** method to set the delay and register a function defining the work.

Example: Sending a message after a delay

```
void on_sender_open(proton::sender& snd) override {
    proton::duration interval {5 * proton::duration::SECOND};
    snd.work_queue().schedule(interval, [=] { send(snd); });
}

void send(proton::sender snd) {
    if (snd.credit() > 0) {
        proton::message msg {"hello"};
        snd.send(msg);
    }
}
```

This example uses the **schedule** method on the work queue of the sender in order to establish it as the execution context for the work.

12.6. USING OLDER VERSIONS OF C++

Before C++11 there was no standard support for threading in C++. You can use AMQ C++ with threads but with the following limitations.

- The container does not create threads. It only uses the single thread that calls **container::run()**.
- None of the AMQ C++ library classes are thread-safe, including **container** and **work_queue**. You need an external lock to use **container** in multiple threads. The only exception is **connection::wake()**. It is thread-safe even in older C++.

The **container::schedule()** and **work_queue** APIs accept C++11 lambda functions to define units of work. If you are using a version of C++ that does not support lambdas, you must use the **make_work()** function instead.

CHAPTER 13. FILE-BASED CONFIGURATION

AMQ C++ can read the configuration options used to establish connections from a local file named **connect.json**. This enables you to configure connections in your application at the time of deployment.

The library attempts to read the file when the application calls the container **connect** method without supplying any connection options.

13.1. FILE LOCATIONS

If set, AMQ C++ uses the value of the **MESSAGING_CONNECT_FILE** environment variable to locate the configuration file.

If **MESSAGING_CONNECT_FILE** is not set, AMQ C++ searches for a file named **connect.json** at the following locations and in the order shown. It stops at the first match it encounters.

On Linux:

1. **$PWD/connect.json**, where **$PWD** is the current working directory of the client process
2. **$HOME/.config/messaging/connect.json**, where **$HOME** is the current user home directory
3. **/etc/messaging/connect.json**

On Windows:

1. **%cd%/connect.json**, where **%cd%** is the current working directory of the client process

If no **connect.json** file is found, the library uses default values for all options.

13.2. THE FILE FORMAT

The **connect.json** file contains JSON data, with additional support for JavaScript comments.

All of the configuration attributes are optional or have default values, so a simple example need only provide a few details:

Example: A simple connect.json file

```
{
    "host": "example.com",
    "user": "alice",
    "password": "secret"
}
```

SASL and SSL/TLS options are nested under **"sasl"** and **"tls"** namespaces:

Example: A connect.json file with SASL and SSL/TLS options

```
{
    "host": "example.com",
    "user": "ortega",
    "password": "secret",
    "sasl": {
```

```
        "mechanisms": ["SCRAM-SHA-1", "SCRAM-SHA-256"]
    },
    "tls": {
        "cert": "/home/ortega/cert.pem",
        "key": "/home/ortega/key.pem"
    }
}
```

13.3. CONFIGURATION OPTIONS

The option keys containing a dot (.) represent attributes nested inside a namespace.

Table 13.1. Configuration options in connect.json

Key	Value type	Default value	Description
scheme	string	**"amqps"**	**"amqp"** for cleartext or **"amqps"** for SSL/TLS
host	string	**"localhost"**	The hostname or IP address of the remote host
port	string or number	**"amqps"**	A port number or port literal
user	string	*None*	The user name for authentication
password	string	*None*	The password for authentication
sasl.mechanisms	list or string	*None (system defaults)*	A JSON list of enabled SASL mechanisms. A bare string represents one mechanism. If none are specified, the client uses the default mechanisms provided by the system.
sasl.allow_insecure	boolean	**false**	Enable mechanisms that send cleartext passwords
tls.cert	string	*None*	The filename or database ID of the client certificate
tls.key	string	*None*	The filename or database ID of the private key for the client certificate
tls.ca	string	*None*	The filename, directory, or database ID of the CA certificate
tls.verify	boolean	**true**	Require a valid server certificate with a matching hostname

CHAPTER 14. INTEROPERABILITY

This chapter discusses how to use AMQ C++ in combination with other AMQ components. For an overview of the compatibility of AMQ components, see the product introduction.

14.1. INTEROPERATING WITH OTHER AMQP CLIENTS

AMQP messages are composed using the AMQP type system. This common format is one of the reasons AMQP clients in different languages are able to interoperate with each other.

When sending messages, AMQ C++ automatically converts language-native types to AMQP-encoded data. When receiving messages, the reverse conversion takes place.

NOTE

More information about AMQP types is available at the interactive type reference maintained by the Apache Qpid project.

Table 14.1. AMQP types

AMQP type	Description
null	An empty value
boolean	A true or false value
char	A single Unicode character
string	A sequence of Unicode characters
binary	A sequence of bytes
byte	A signed 8-bit integer
short	A signed 16-bit integer
int	A signed 32-bit integer
long	A signed 64-bit integer
ubyte	An unsigned 8-bit integer
ushort	An unsigned 16-bit integer
uint	An unsigned 32-bit integer
ulong	An unsigned 64-bit integer
float	A 32-bit floating point number

AMQP type	Description
double	A 64-bit floating point number
array	A sequence of values of a single type
list	A sequence of values of variable type
map	A mapping from distinct keys to values
uuid	A universally unique identifier
symbol	A 7-bit ASCII string from a constrained domain
timestamp	An absolute point in time

Table 14.2. AMQ C++ types before encoding and after decoding

AMQP type	AMQ C++ type before encoding	AMQ C++ type after decoding
null	**nullptr**	**nullptr**
boolean	**bool**	**bool**
char	**wchar_t**	**wchar_t**
string	**std::string**	**std::string**
binary	**proton::binary**	**proton::binary**
byte	**int8_t**	**int8_t**
short	**int16_t**	**int16_t**
int	**int32_t**	**int32_t**
long	**int64_t**	**int64_t**
ubyte	**uint8_t**	**uint8_t**
ushort	**uint16_t**	**uint16_t**
uint	**uint32_t**	**uint32_t**
ulong	**uint64_t**	**uint64_t**

AMQP type	AMQ C++ type before encoding	AMQ C++ type after decoding
float	float	float
double	double	double
list	std::vector	std::vector
map	std::map	std::map
uuid	proton::uuid	proton::uuid
symbol	proton::symbol	proton::symbol
timestamp	proton::timestamp	proton::timestamp

Table 14.3. AMQ C++ and other AMQ client types (1 of 2)

AMQ C++ type before encoding	AMQ JavaScript type	AMQ .NET type
nullptr	null	null
bool	boolean	System.Boolean
wchar_t	number	System.Char
std::string	string	System.String
proton::binary	string	System.Byte[]
int8_t	number	System.SByte
int16_t	number	System.Int16
int32_t	number	System.Int32
int64_t	number	System.Int64
uint8_t	number	System.Byte
uint16_t	number	System.UInt16
uint32_t	number	System.UInt32
uint64_t	number	System.UInt64

AMQ C++ type before encoding	AMQ JavaScript type	AMQ .NET type
float	**number**	**System.Single**
double	**number**	**System.Double**
std::vector	**Array**	**Amqp.List**
std::map	**object**	**Amqp.Map**
proton::uuid	**number**	**System.Guid**
proton::symbol	**string**	**Amqp.Symbol**
proton::timestamp	**number**	**System.DateTime**

Table 14.4. AMQ C++ and other AMQ client types (2 of 2)

AMQ C++ type before encoding	AMQ Python type	AMQ Ruby type
nullptr	**None**	**nil**
bool	**bool**	**true, false**
wchar_t	**unicode**	**String**
std::string	**unicode**	**String**
proton::binary	**bytes**	**String**
int8_t	**int**	**Integer**
int16_t	**int**	**Integer**
int32_t	**long**	**Integer**
int64_t	**long**	**Integer**
uint8_t	**long**	**Integer**
uint16_t	**long**	**Integer**
uint32_t	**long**	**Integer**
uint64_t	**long**	**Integer**

AMQ C++ type before encoding	AMQ Python type	AMQ Ruby type
float	**float**	**Float**
double	**float**	**Float**
std::vector	**list**	**Array**
std::map	**dict**	**Hash**
proton::uuid	-	-
proton::symbol	**str**	**Symbol**
proton::timestamp	**long**	**Time**

14.2. INTEROPERATING WITH AMQ JMS

AMQP defines a standard mapping to the JMS messaging model. This section discusses the various aspects of that mapping. For more information, see the AMQ JMS Interoperability chapter.

JMS message types

AMQ C++ provides a single message type whose body type can vary. By contrast, the JMS API uses different message types to represent different kinds of data. The table below indicates how particular body types map to JMS message types.

For more explicit control of the resulting JMS message type, you can set the **x-opt-jms-msg-type** message annotation. See the AMQ JMS Interoperability chapter for more information.

Table 14.5. AMQ C++ and JMS message types

AMQ C++ body type	JMS message type
std::string	**TextMessage**
nullptr	**TextMessage**
proton::binary	**BytesMessage**
Any other type	**ObjectMessage**

14.3. CONNECTING TO AMQ BROKER

AMQ Broker is designed to interoperate with AMQP 1.0 clients. Check the following to ensure the broker is configured for AMQP messaging:

- Port 5672 in the network firewall is open.
- The AMQ Broker AMQP acceptor is enabled. See Default acceptor settings.

- The necessary addresses are configured on the broker. See Addresses, Queues, and Topics.
- The broker is configured to permit access from your client, and the client is configured to send the required credentials. See Broker Security.

14.4. CONNECTING TO AMQ INTERCONNECT

AMQ Interconnect works with any AMQP 1.0 client. Check the following to ensure the components are configured correctly:

- Port 5672 in the network firewall is open.
- The router is configured to permit access from your client, and the client is configured to send the required credentials. See Securing network connections.

APPENDIX A. USING YOUR SUBSCRIPTION

AMQ is provided through a software subscription. To manage your subscriptions, access your account at the Red Hat Customer Portal.

A.1. ACCESSING YOUR ACCOUNT

Procedure

1. Go to access.redhat.com.
2. If you do not already have an account, create one.
3. Log in to your account.

A.2. ACTIVATING A SUBSCRIPTION

Procedure

1. Go to access.redhat.com.
2. Navigate to **My Subscriptions**.
3. Navigate to **Activate a subscription** and enter your 16-digit activation number.

A.3. DOWNLOADING RELEASE FILES

To access .zip, .tar.gz, and other release files, use the customer portal to find the relevant files for download. If you are using RPM packages or the Red Hat Maven repository, this step is not required.

Procedure

1. Open a browser and log in to the Red Hat Customer Portal **Product Downloads** page at access.redhat.com/downloads.
2. Locate the **Red Hat AMQ** entries in the **INTEGRATION AND AUTOMATION** category.
3. Select the desired AMQ product. The **Software Downloads** page opens.
4. Click the **Download** link for your component.

A.4. REGISTERING YOUR SYSTEM FOR PACKAGES

To install RPM packages for this product on Red Hat Enterprise Linux, your system must be registered. If you are using downloaded release files, this step is not required.

Procedure

1. Go to access.redhat.com.
2. Navigate to **Registration Assistant**.
3. Select your OS version and continue to the next page.

4. Use the listed command in your system terminal to complete the registration.

For more information about registering your system, see one of the following resources:

- Red Hat Enterprise Linux 7 - Registering the system and managing subscriptions
- Red Hat Enterprise Linux 8 - Registering the system and managing subscriptions

APPENDIX B. USING RED HAT ENTERPRISE LINUX PACKAGES

This section describes how to use software delivered as RPM packages for Red Hat Enterprise Linux.

To ensure the RPM packages for this product are available, you must first register your system.

B.1. OVERVIEW

A component such as a library or server often has multiple packages associated with it. You do not have to install them all. You can install only the ones you need.

The primary package typically has the simplest name, without additional qualifiers. This package provides all the required interfaces for using the component at program run time.

Packages with names ending in **-devel** contain headers for C and C++ libraries. These are required at compile time to build programs that depend on this package.

Packages with names ending in **-docs** contain documentation and example programs for the component.

For more information about using RPM packages, see one of the following resources:

- Red Hat Enterprise Linux 7 - Installing and managing software
- Red Hat Enterprise Linux 8 - Managing software packages

B.2. SEARCHING FOR PACKAGES

To search for packages, use the **yum search** command. The search results include package names, which you can use as the value for ***<package>*** in the other commands listed in this section.

```
$ yum search <keyword>...
```

B.3. INSTALLING PACKAGES

To install packages, use the **yum install** command.

```
$ sudo yum install <package>...
```

B.4. QUERYING PACKAGE INFORMATION

To list the packages installed in your system, use the **rpm -qa** command.

```
$ rpm -qa
```

To get information about a particular package, use the **rpm -qi** command.

```
$ rpm -qi <package>
```

To list all the files associated with a package, use the **rpm -ql** command.

```
$ rpm -ql <package>
```

-

APPENDIX C. USING AMQ BROKER WITH THE EXAMPLES

The AMQ C++ examples require a running message broker with a queue named **examples**. Use the procedures below to install and start the broker and define the queue.

C.1. INSTALLING THE BROKER

Follow the instructions in *Getting Started with AMQ Broker* to install the broker and create a broker instance. Enable anonymous access.

The following procedures refer to the location of the broker instance as ***<broker-instance-dir>***.

C.2. STARTING THE BROKER

Procedure

1. Use the **artemis run** command to start the broker.

```
$ <broker-instance-dir>/bin/artemis run
```

2. Check the console output for any critical errors logged during startup. The broker logs **Server is now live** when it is ready.

```
$ example-broker/bin/artemis run

        __  __  ____    ____          _
      /\   |  \/  |/ __ \  |  _ \        | |
     /  \  | \  / | |  | | | |_) |_ __ ___ | | _____ _ __
    / /\ \ | |\/| | |  | | |  _ <| '__/ _ \| |/ / _ \ '__|
   / ____ \| |  | | |__| | | |_) | | | (_) |   <  __/ |
  /_/    \_\_|  |_|\____\_\ |____/|_|  \___/|_|\_\___|_|

  Red Hat AMQ <version>

2020-06-03 12:12:11,807 INFO  [org.apache.activemq.artemis.integration.bootstrap]
AMQ101000: Starting ActiveMQ Artemis Server
...
2020-06-03 12:12:12,336 INFO  [org.apache.activemq.artemis.core.server] AMQ221007:
Server is now live
...
```

C.3. CREATING A QUEUE

In a new terminal, use the **artemis queue** command to create a queue named **examples**.

```
$ <broker-instance-dir>/bin/artemis queue create --name examples --address examples --auto-
create-address --anycast
```

You are prompted to answer a series of yes or no questions. Answer **N** for no to all of them.

Once the queue is created, the broker is ready for use with the example programs.

C.4. STOPPING THE BROKER

When you are done running the examples, use the **artemis stop** command to stop the broker.

```
$ <broker-instance-dir>/bin/artemis stop
```

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