Mobile and Web Messaging

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by Jeff Mesnil

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Part II. MQTT

A Marion, la lumière qui éclaire mes pas.

Preface

What This Book is About

This is a book about messaging protocols and how software developers can use them to build more responsive, resilient applications running on mobile devices and Web browsers.

Messaging protocols are nothing new. They have been used with success in enterprise software for many years. They have been one of the building blocks that let different services and platforms communicate with each other. Their designs make them well suited to build applications for mobile devices and the Web.

Nowadays, HTTP has emerged as the mainstream transport protocol and is extensively used to communicate between any clients (from web browsers of course but also from desktop and mobile applications, backend services, etc.) and web servers. It has replaced almost all proprietary or non standard protocols and is likely to be the de facto choice if your application needs to communicate with any remote endpoint.

Messaging protocols complement HTTP and this book will show cases where a messaging protocol is better suited than HTTP (or any other request/reply transport protocol) to build mobile or web applications.

What This Book is Not About

Messaging is an overloaded term that can mean many different things in software development. In this book, we will only talk about *application messaging protocols*.

This book is not about *messaging applications* like Apple's `Messages` or `WhatsApp`. These applications can be built on top of messaging protocols and this book may be a good introduction if you intend to build one. However there are many other features expected in messaging applications that will not be covered in this book.

This book is also not about *programming language or framework messaging* (as used in Objective-C to invoke methods on a object or in Erlang to communicate between processes).

In the rest of this book, we will use the term *messaging* in the context of application messaging protocol.

Messaging is Simple

At its core, the concept of a messaging protocol is simple:

- An application *produces* a *message* to a *destination* on a *broker*.
- An application subscribes to this same destination to *consume* the message.

In these two sentences, I introduced the five concepts that are (almost) all there is to know about messaging.

A messaging protocol is a simple idea. Most of the complexity of using one is figuring out the best suited *model* for your applications (how the producers and consumers will exchanges messages). This book will show the two models that are most commonly used: *point-to-point* and *publish/subscribe*.

Enterprise Messaging Is Not So Simple

When companies are acquired or merged, they need a way to enable communication between their systems. Messaging is one approach to achieve this integration in a unobstrusive way (as much as it is possible). The systems must agree on the data representation (transmitted in the *message*) and the *destination* (or the topic of interest shared by the different systems).

With its use in enterprise software, messaging protocols became increasingly complex to meet enterprise requirements (high-availability, failover, load-balancing, etc.).

Besides, the integrated applications must often agree on a messaging system to use throughout the company. In the Java world, the specification that deals with messaging is called Java Message Service [jms]. It defines a set of interfaces that a Java application can use to send and receive messages. However, JMS does not define any protocol (how the bytes are sent over the wire) and leave this implementation detail to the JMS brokers that implement the API. This means that JMS implementations are not interoperable: one must use the broker's client implementation to send a message to the broker. If applications were using different JMS brokers, they had interoperability issues and must use *bridges* to transfer messages from one JMS broker to another. This lack of interoperability brings complexity as you need to add servers to host the bridges, make them redundant for high-availability, etc.

Over time, we have seen the appearances of enterprise messaging protocols such as the Advanced Message Queuing Protocol [amqp] that handles enterprise features and interoperability. This leads to complex protocols that are difficult to implement and whose interoperability is subjective (backwards compatibility is not guaranteed, different implementations may not implement the whole specification leading to interoperability issues).

Mobile Messaging Is Simple Again

The increasing complexity of messaging protocols used in enterprise software makes them difficult to implement and they are not best suited for constrained environments such as mobile devices.

Mobile devices requires messaging protocols with more constrained goals that turns out to be simpler and more efficient to use without draining battery or requiring always-on network connections.

While these simpler protocols do not provide all the features offered by enterprise-class messaging protocols, they are a good fit for mobile and Web platforms.

In this book, I will talk about two of them, STOMP and MQTT.

STOMP really shines for its simplicity if you need to send one text message from any system (operating system, virtual machines, web browsers) to another. It is simple enough that a network client such as `telnet` *is* a STOMP client.

MQTT was created to broadcast data from small devices with low power usage and constrained memory resources. It is well suited for mobile devices as it preserves battery life and memory.

These protocols are simple to understand and implement. Messaging brokers often provide both of them. For example, a desktop application can use STOMP to send a message and another mobile application can consume the same message using MQTT. The applications are free to use the most appropriate messaging protocol for their needs and rely on the broker implementations for interoperability.

With the advent of mobile devices, we can use these simple messaging protocols to build more reactive, efficient applications. Since these protocols are available both for mobile and web platformss, choosing between these two plaftorms is not constrained by using a messaging protocol.

At the same time, we can leverage these messaging protocols to integrate with legacy systems too. If the messaging broker also supports an enterprise-class messaging API (such as JMS) or protocols (such as AMQP), we can build mobile and Web applications that can consume messages sent from legacy systems.

What's in This Book

In this book, I will introduce messaging protocols for mobile devices and Web applications.

Chapter 1, Introduction
: In this chapter, I introduce the concepts of messaging protocols, their models and message representation. To illustrate the use of messaging protocols on mobile and Web platforms, we will build two applications, one using STOMP and the other MQTT. Both applications will come in two parts: one will run on mobile devices, the other inside a Web browser and they will communicate using messages. This chapter explains the overall design of these two example applications.

Chapter 2, Mobile Messaging With STOMP
: In this chapter, I present STOMP, a simple text-based messaging protocol. I use StompKit, an iOS library for STOMP, to build the `Locations` application that sends GPS data from the device and receives text messages.

Chapter 3, Web Messaging With STOMP
: In this chapter, I introduce stomp.js, a JavaScript library for STOMP, and write a Web application that receives messages with the GPS datat from the `Locations` application on iOS devices and display them on a map. This Web application will also send text messages to the iOS application.

Chapter 4, Advanced STOMP
: In this chapter, I present the advanced features of STOMP that we did not use in the previous chapters to build our applications. These advanced features are not always used by messaging applications but they may prove useful as the applications grow in complexity.

Chapter 5, Beyond STOMP
: In this chapter, I present features that are not part of STOMP but available from some STOMP brokers. These features often help solve common issues and reduce code complexity by leveraging the brokers.

Chapter 6, Mobile Messaging With MQTT
: In this chapter, I introduce MQTT, a binary messaging protocol well suited to broadcast data from mobile or embedded devices and write a mobile application, `Motions`, on iOS that uses MQTT to broadcast data about the device motion using the MQTTKit libary and listen for alerts to change the color of the application.

Chapter 7, Web Messaging With MQTT
: In this chapter, I use MQTT over Web Socket to write a Web application that receives the device motion data sent by the `Motions` application to display them and sends alerts to the devices to change their color.

Chapter 8, Advanced MQTT
: In this chapter, I present the advanced features of MQTT that were not used in the previous chapters.

Appendix A, ActiveMQ
: In this appendix, we explain how to install and configure the messaging broker, Apache ActiveMQ, that is used in the book to run the STOMP examples.

Appendix B, Mosquitto
: In this appendix, we explain how to install and configure the Mosquitto broker and its command-line tools that are used in the book to send and receive MQTT messages.

> **What Should I Read?**
>
> The book is organized to be read in order but some chapters can be skipped depending on your experience. The Chapter 1 introduces all the concepts discussed throughout the book.
>
> If you are interested in mobile applications, you can focus on Chapters 2 and 6 that present two different messaging protocols for mobile devices. If you are writing Web applications, Chapters 3 and 7 are the most relevant.
>
> If you are interested by the STOMP protocol, Chapters 2, 3, 4, and 5 and the most relevant. If you are interested by MQTT, you can read Chapters 6, 7, and 8 instead.

Target Audience

This book is an introduction to the STOMP and MQTT messaging protocols and assumes no prior experience with them. This book explains in detail the messaging protocols. Each platform's clients may provide a different API to deal with the protocols but the underlying concepts remain the same. For both protocols, we will see two different libraries: an Objective-C library for iOS and a JavaScript library for Web applications.

Basic programming skills are required. The examples in the book runs on different platforms and we used the programming language that made the most sense for each of them.

The mobile applications on iOS will be written in Objective-C. The graphical application requires minimal knowledge of Xcode and Interface Builder but all the changes are described step by step in the book.

The Web applications use the JavaScript language. We leverage jQuery to make the Web applications interactive and manipulate the page elements but the messaging code is independent of any JavaScript frameworks.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold`
: Shows commands or other text that should be typed literally by the user.

`Constant width italic`
: Shows text that should be replaced with user-supplied values or by values determined by context.

This icon signifies a tip, suggestion, or general note.

This icon indicates a warning or caution.

Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at *https://github.com/mobile-web-messaging/code/*.

The book contains all the code required to run the examples and the general instructions to setup the user interface of the iOS applications.

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Thanks to all developers that reported issues on this book and the code examples.

CHAPTER 1
Introduction

In this chapter, I present the main concepts of messaging protocols. To illustrate their use on mobile and Web platforms, we will write two applications (one for each messaging protocol that are described, STOMP and MQTT). This chapter will present the overal design of these two applications that will be written in the subsequent chapters.

Messaging Concepts

In the preface, I introduced messaging protocols in two sentences and five concepts:

- An application *produces* a *message* to a *destination* on a *broker*.
- An application subscribes to this same destination to *consume* the message.

Let's now define these five concepts:

1. A *message* is the data exchanged between applications
2. A *destination* is a type of address that is used to exchange messages
3. A *producer* is an application that sends *messages* **to** a *destination*
4. A *consumer* is an application that consumes *messages* **from** a *destination*
5. A *broker* is the server entity that will handle messages from producers and deliver them to the consumers according to their destinations.

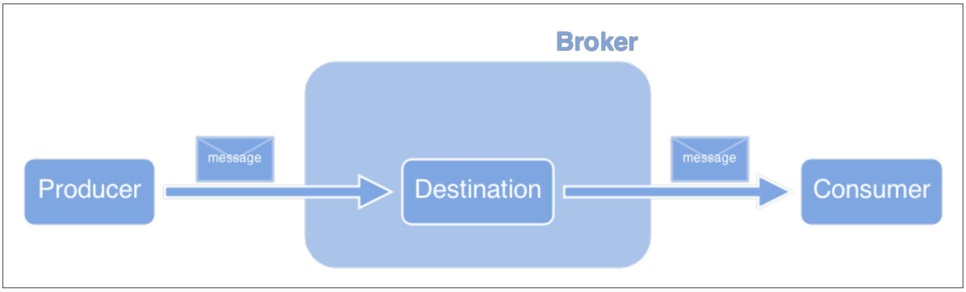
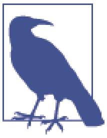


Figure 1-1. Messaging Concepts

The simplicity of messaging can be deceiving but it is this simplicity that allows to use it in powerful ways.



Messaging Terminology

Depending on the messaging protocol or model, the *producer* is sometimes called *sender* or *publisher*. Likewise, the *consumer* may be called *receiver* or *subscriber*.

In this book, I will always use the general terms of *producer* and *consumer*.

One key aspect of messaging is that it loosely couples its participants. The producer and consumer know nothing of each other. When one application produces a message, it has no knowledge on when or where the message will be consumed. There may be one or many consumers that will receive the message. It also possible that the message will not be consumed at all if nobody has registered any interest for it.

Likewise, when an application consumes a message, it does not know which application sent it as they never communicate directly. The consumed message could contain enough information to identify the application but that is not required (and more often than not, it is not necessary).

Producers and consumers do not even need to be online at the same time. The producers can send a message and exit. The message will be held by the broker until a consumer subscribes to the same destination. At that moment, the broker will deliver the message to the consumer.

Producers and consumers need to know about the broker to connect to it but they may even not connect to the same broker. A set of brokers can constitute a cluster and messages would flow from one to another before they are finally delivered to a consumer.

Messaging Models

A messaging model describes how the messages will be routed between the producer and consumers.

There are two main messaging models:

- Point-to-Point
- Publish/Subscribe

Point-to-Point

In a Point-to-Point messaging model, a message sent by a producer will be routed to a single consumer.

The producer sends a message to a destination identified as a *queue* in that messaging model. There can be zero, one or many consumers subscribed (or *bound*) to this queue and the messaging broker will route incoming messages to only one of these consumers to deliver the message. As illustrated in Figure 1-2, when the producer sends a message to the queue, only one of the consumers that are subscribed receives the message.

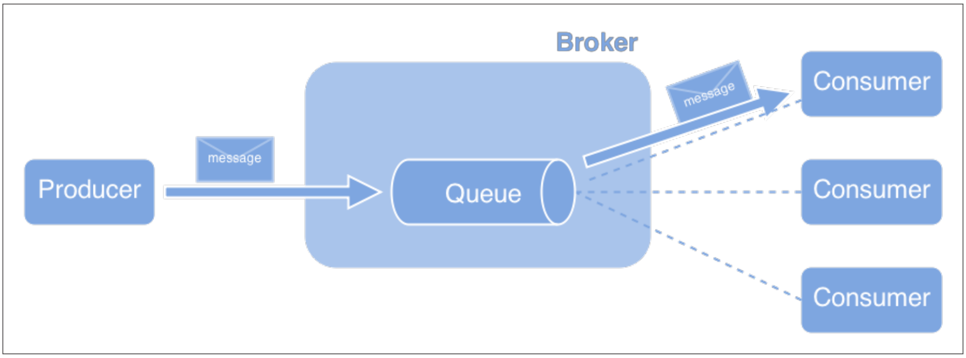


Figure 1-2. Diagram of the Point-to-Point Topology

This messaging model is also called *one-to-one*: for *one* message sent by a producer to the queue, there is only *one* consumer that will receive it.

If there are no consumers bound to the queue, the broker will retain the incoming messages until a consumer subscribes and then deliver the message to this consumer. Some messaging brokers allow to *expire* messages if they remain in the queue for a certain amount of time. This can be useful to avoid having consumers receive a message corresponding to stale data.

The Point-to-point model is best used when only one consumer must process a message. A queue can be used to load-balance the message processing across different clients and ensure that only one client will receive it.

Publish/Subscribe

In a Publish/Subscribe messaging model (often shortened as pub/sub), a message sent by a producer is routed to many consumers.

The producer sends a message to a destination identified as a *topic* in that messaging model. There can be zero or many consumers subscribed to this topic and the messaging broker will route incoming message to *all* these consumers to deliver the message. If there are no consumers bound to the topic, the broker may *not* retain the incoming messages. As illustrated in Figure 1-3, when the producer sends a message to the topic, all the consumers that are subscribed receive the message.

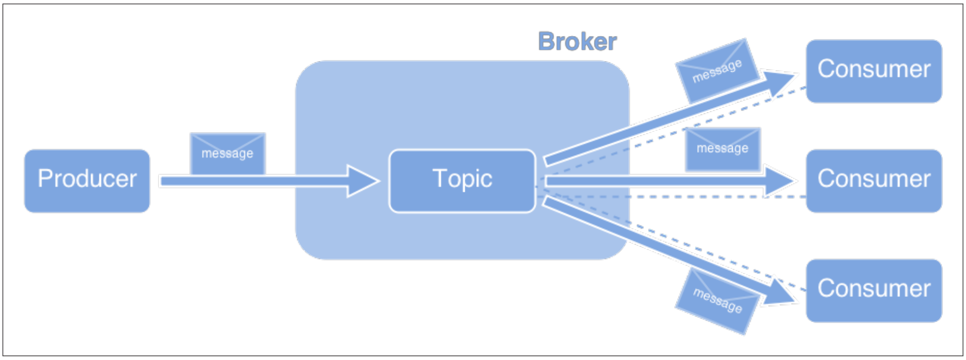


Figure 1-3. Diagram of the Publish/Subscribe Topology

This messaging model is also called *one-to-many*: for *one* message sent by a producer to a topic, there are *many* consumers that may receive it.

When a message is sent to a topic in this model, we often say that it is *broadcasted* to all consumers as they will all receive it.

Some protocols define the notion of *durable subscribers*. If a consumer subscribes to the topic as a durable subscriber, the broker will retain messages when the consumer is offline and deliver the messages sent to the topic during its downtime when the consumer comes online again.

The Publish/Subscribe model is particularly suited to send updates. A producer will send a message on the topic with its updated data and any consumer that is subscribed to the topic will be notified of the updates.

Message Representation

Producers and consumers exchange information using messages.

A message is composed of three separate data: destination, headers, and body

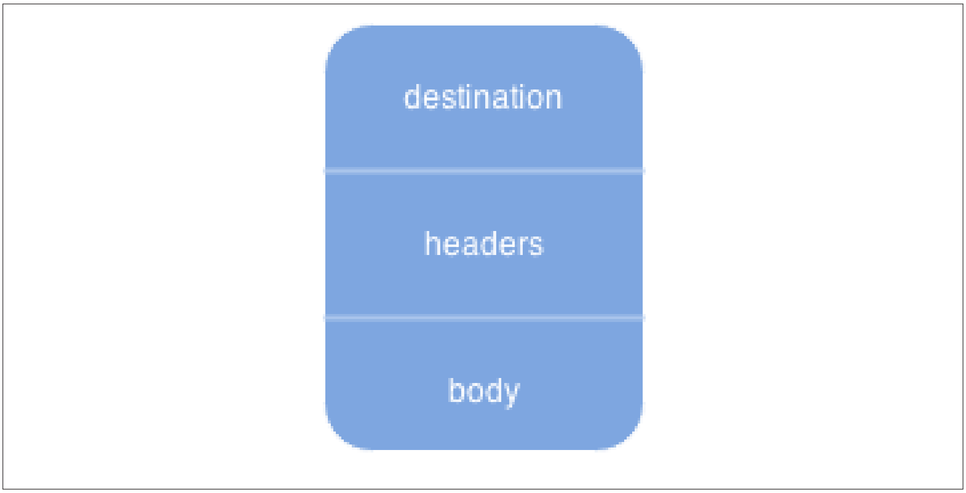


Figure 1-4. Diagram of a Message

When a producer sends a message to a *destination*, the name of the destination is put inside the message. When a consumer receives this message, it can use this information to know which destination held this message. This is especially useful when a consumer is subscribes to many destinations as it helps identify the exchanged data.

A message may also contain *headers*. Messaging protocols uses headers to add metadata information to the messages. These metadata can be read by the consumers and give addition contextual information to a message. Examples of such metadata are message identifiers (that uniquely identify a message for a broker), timestamp (the date and time it was sent by the producer), redelivered flag (if the message was delivered unsuccessfully a first time and is delivered again), etc. Headers are specific to messaging protocols. Some messaging protocols (such as STOMP) allows the producer to set application-specific headers in addition to the headers defined by the protocol. Other protocols (such as MQTT) does not allow to set application-specific headers. In that case, the producer has to put any application-specific information in the message payload.

Finally, a message can have an optional *body* (or payload) that contains the data exchanged between the producer and consumer. The type of body depends on the messaging protocols, some defining text payload (such as STOMP) or binary (MQTT). A payload is an *opaque blob of content*. The broker do not read or modify it when it routes a message.

In most cases, we will only use the message body to pass information using a variety of format (JSON string, simple plain string, array of float values, etc.). However if the protocol permits it, we will also set additional headers to the message to give metadata information about the body (its content type, its length, etc.) or activate some broker features.

Examples

To illustrate the use of messaging protocols on mobile and Web platforms, we will build two set of applications in this book. Each set will be be composed of an iOS application and a web one. The first application will use STOMP and the second one MQTT.

Locations Application Using STOMP

Suppose that we work for a delivery company that uses a fleet of trucks to deliver packages to its clients.

Each truck is responsible for the delivery of packages and they receive orders from their headquarters. To efficiently manage all the trucks, the company headquarter want to monitor the truck's positions and be able to send them orders on-the-go.

We will build a very simple application named `Locations` that looks similar to this example.

The "truck" will use an iOS application to broadcast the device's geolocation data using its GPS sensor and display text messages that it receives from the headquarters. The "headquarter" will use a Web application to display the locations of all the "trucks" on a map. It will also be used to send text messages to a given truck on their devices:

1. In Chapter 2, we will write the `Locations` iOS application using the STOMP protocol to send GPS data and receive text from an iOS device.
2. In Chapter 3, we will write the Web application using STOMP protocol over Web Sockets to receive GPS data in a Web browser and send text to the devices.

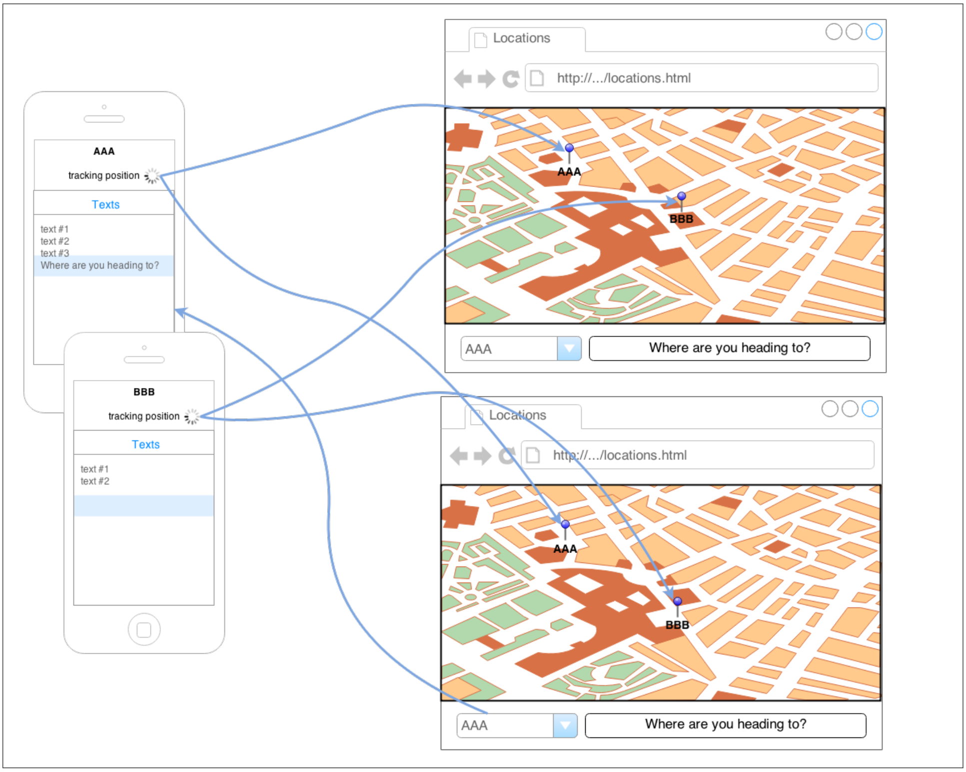


Figure 1-5. Diagram of the Locations application with two devices, AAA and BBB, and two web applications.

Before introducing STOMP, the messaging protocol that will be used by the application, we can already define the application's messaging models and how the different parts of the application will exchange messages.

Locations Messaging Models

In this application, we will use two destinations, one with a Publish/Subscribe model to broadcast the device GPS data and one with a Point-to-Point model for the text messages:

- `device.XXX.location` is the *topic* to broadcast its GPS geolocation data where `XXX` is the device identifier (Publish/Subscribe model)
- `device.XXX.text` is the *queue* to receive simple text message (Point-to-Point model)

A topic is used to send the GPS data as this allows potentially many consumers to receive the information. However a queue is used to handle the device's text as only one single device will consume messages from this destination.

Each device (identified by an unique identifier `XXX`) running the `Locations` application will be:

- a *producer* of messages to the topic `device.XXX.location`
- the only *consumer* of messages from the queue `device.XXX.text`

Conversely, the Web application will be:

- a *consumer* of messages from *all* the topics of the form `device.XXX.location`
- a *producer* of message to *all* the queues of the form `device.XXX.text`

Locations Message Representation

There will be two types of exchanged messages:

- one to represent GPS data (exhanged on the topics `device.XXX.location`)
- one to represent orders (exchanged on the queues `device.XXX.text`)

The `Locations` iOS application will send the GPS data using a JSON representation in the message payload:

Example 1-1. Geolocation Message Payload

```
{
  "deviceID": "BBB",❶
  "lat": 48.8581,❷
  "lng": 2.2946,❸
  "ts": "2013-09-23T08:43Z"❹
}
```

❶ `deviceID` is the identifier of the device that sends its position

❷ `lat` is a number representing the position's *latitude*

❸ `lng` is a number representing the position's *longitude*

❹ `ts` is a string representing the time when the position was taken (using the ISO 8601 format)

The text messages that will be consumed by the `Locations` iOS application will be represented as a simple plain text string.

Example 1-2. Text Message Payload

```
"Where are you heading to?"
```

A more realistic representation of this message would also contain additional information such the identifier of the headquarter sending the message, etc. We are using a plain text version as this format is enough to provide a first version.

With the messaging topology and data representation known, we can now refine the `Locations` application diagram.

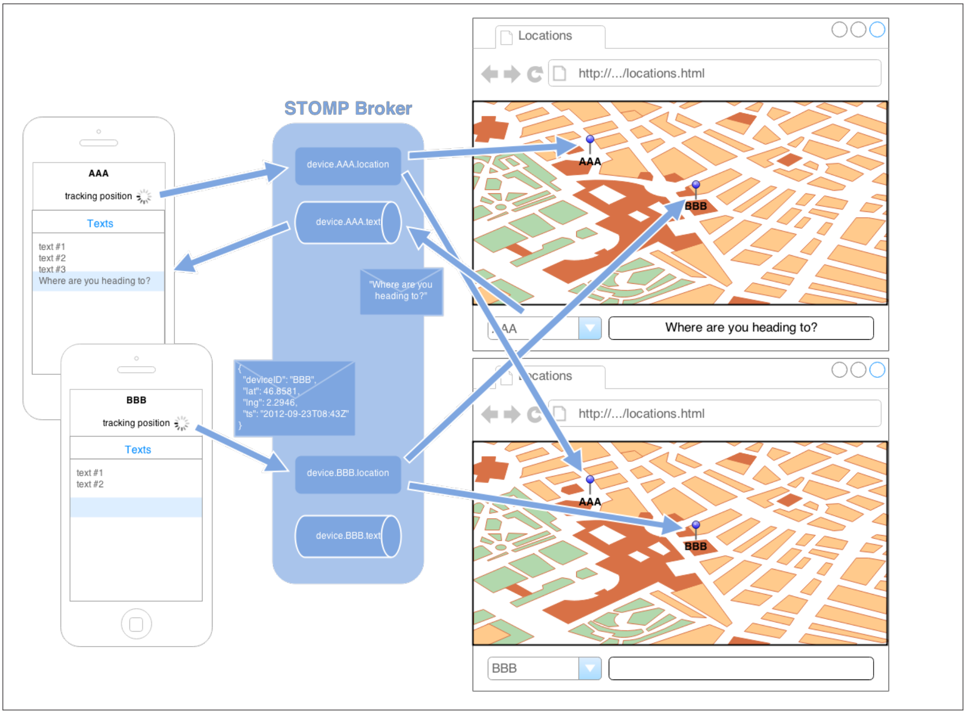


Figure 1-6. Diagram of the Locations application with its messaging models and representations

Motions Application Using MQTT

Most mobile devices contain sensor that allows to track the device motions (and to a certain extent the motion of its owner). Using additional sensors, we could even imagine having access to the owner's health data (heart rate, hydration, blood glucose level, etc.). This type of information could be sent to a centralized application that would be able to track the data and extract personal information about them to report to the owner.

We will write a simple application, `Motions` that follows this model to illustrate the use of MQTT protocol. The iOS application will track the device motion and change its background color to "alert" its user when an alert message is received.

Device motion will be represented by three values corresponding to its pitch, roll and yaw values as shown in the illustration below.

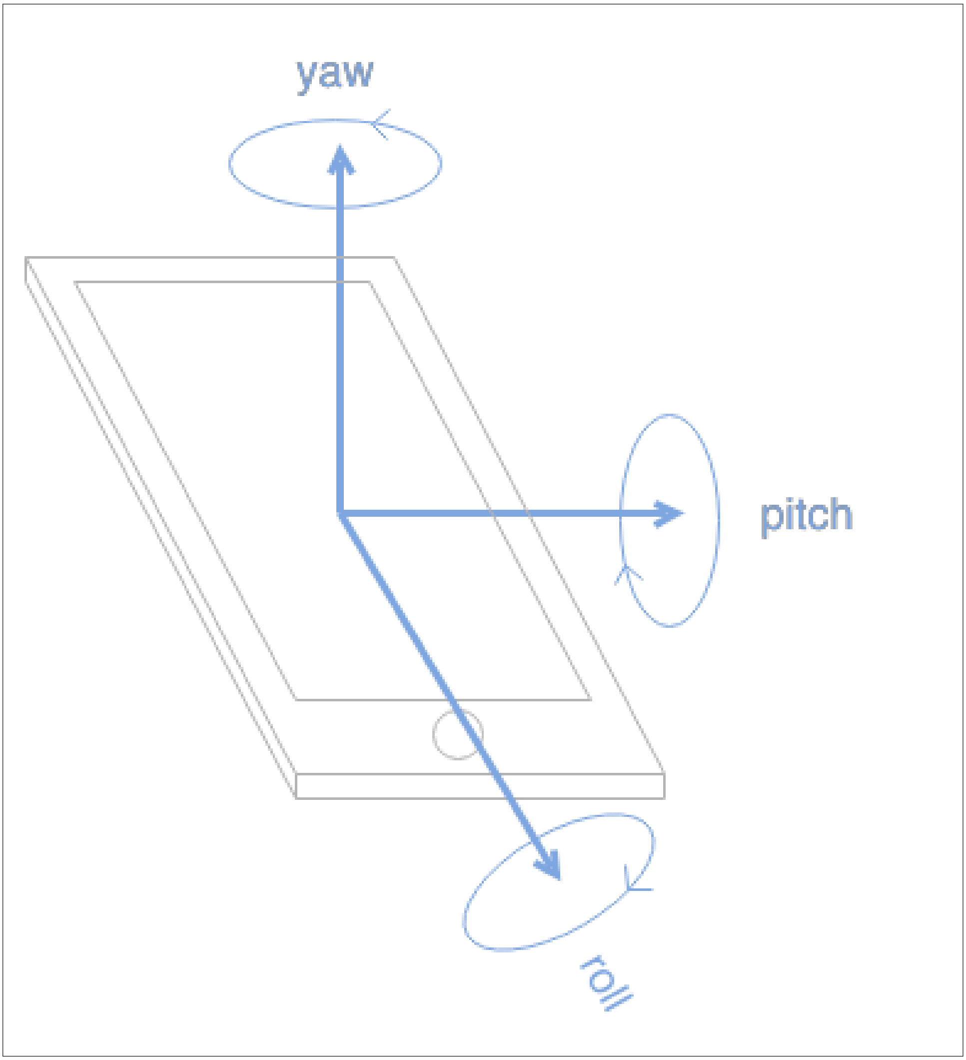


Figure 1-7. The pitch, roll and yaw values represents the device motion.

The pending Web application will display the motions of all devices that broadcast them and be able to send alert messages to them:

1. In Chapter 6, we will write the `Motions` iOS application using the MQTT protocol to send data about the device motions and receive alerts.
2. In Chapter 7, we will write a Web application using MQTT protocol over Web Sockets to receive all the device motions data and display them. The Web application will also be able to send alert messages to any devices sending its motions data.

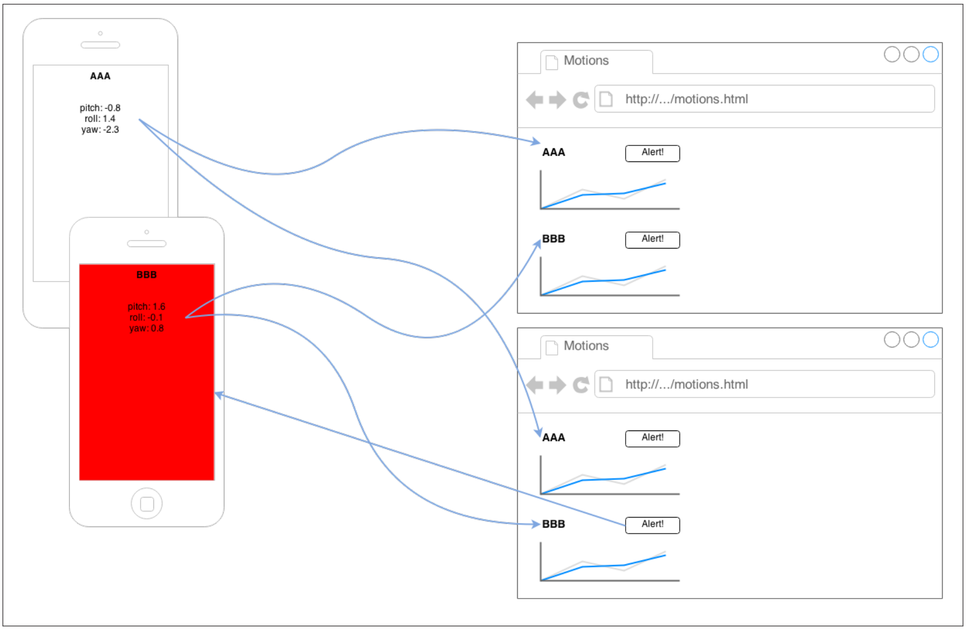


Figure 1-8. The Motions application with two clients, AAA and BBB and two Web applications monitoring them.

Motions Messaging Models

In this application we will use two destination with the Publish/Subscribe model:

- `/mwm/XXX/motion` (where `XXX` is the device identifier) is the topic to broadcast the device motion data (Publish/Subscribe model)
- `/mwm/XXX/alert` is the topic to exchange alert messages for a given device (Publish/Subscribe model)

Each device running the `Motions` application will be:

- a *producer* of messages to the topic `/mwm/XXX/motion`
- a *consumer* of messages from the topic `/mwm/XXX/alert`

Conversely, the Web application will be:

- a *consumer* of messages from all the topics of the form `/mwm/XXX/motion`
- a *producer* of message to all the topics of the form `/mwm/XXX/alert`

> MQTT only supports the *Publish/Subscribe* messaging model. Ideally, the alert destination would be better modeled as a queue (one per device). Since MQTT does not have support for queues, we will work around that by using one topic for each device and only have the corresponding device subscribes to it.

Motions Message Representation

There will be two types of exchanged messages:

- one to represent device motion data (exhanged on the topics `/mwm/XXX/motion`)
- one to represent alerts (exchanged on the topics `/mwm/XXX/alert`)

The `Motions` iOS application will send the device motions data in a binary message where its payload will be composed of three 64-bit floats representing the device's pitch, roll and yaw values.

Example 1-3. Device Motion Message Paylaod

```
<< 1.6 -0.1 0.8 >> ❶
```

❶ The message is composed of three 64-bit floats for the `pitch`, `roll`, and `yaw` values

The alert messages that will be consumed by the `Motions` iOS application will be represented as a simple plain text string corresponding to a color. The `Motions` application will use this payload to change temporarily its background color to *alert* the user.

Example 1-4. Alert Message Payload

```
"red" ❶
```

❶ The message is composed of a string containing the name of a simple color.

With the messaging topology and data representation known, we can now refine the `Motions` application diagram.

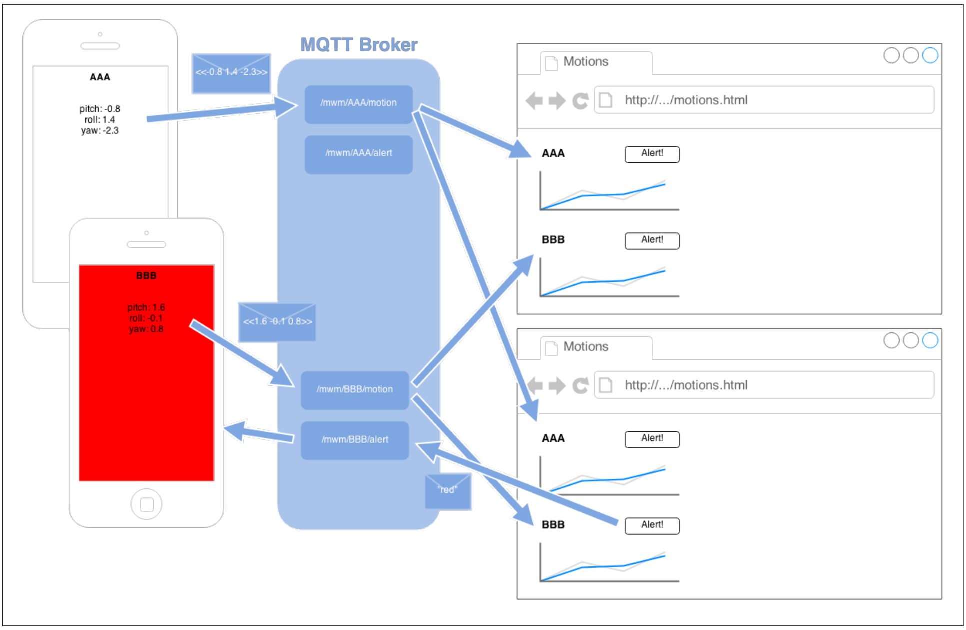


Figure 1-9. Diagram of the Motions application with its messaging models and representations.

Summary

In this chapter, we learnt about the messaging protocols and how they differ from request/reply protocols. We introduced two messaging models - *Point-to-Point* and *Publish/Subscribe* - and the parts that compose a message - *destination*, *headers*, and *payload*.

We have also described the two applications with their messaging models and representation that will be written in the subsequent chapters: the `Locations` application that uses STOMP and the `Motions` applications that uses MQTT.

In the next chapter, we will start writing the `Locations` application running on iOS devices. If you are more interested by learning about MQTT, you can go directly to Chapter 6 to start writing the `Motions` application.

PART I
STOMP

For the next four chapters, we will use the STOMP protocol to build our applications.

This book covers the latest released version of the protocol at the time of this writing: STOMP 1.2 [stomp1.2].

STOMP is a simple text-based messaging protocol that is well suited to develop lightweight messaging applications on any platforms. It provides an interoperable wire format so that any client can communicate with any message broker. The simplicity of the protocol ensures that it is straightforward to have interoperability between client and brokers.

STOMP does not define the semantic of the destination, they depend on the STOMP broker you are using.

There are some conventions shared by STOMP brokers (for example, prefixing a destination by `/queue/` to use a queue and by `/topic/` to use a topic) but you need to consult your broker documentation to check which messaging model are supported (including *Point-to-Point* and *Publish/Subscribe*) and how to use them.

STOMP is based on text and a few parsing rules which makes it simple to use from any platform able to read and write text and open a network connection. However, being text-based means that the protocol is not the most efficient to use as it requires more network bandwidth and memory than corresponding binary-based protocols. If your applications can work with these constraints, STOMP is a a good messaging protocol to use.

Install and Configure a STOMP Broker

Before using a STOMP client, a broker must be installed and configured to be able to exchange messages.

In this book, we use Apache ActiveMQ as the messaging broker. The Appendix A shows how to install and configure ActiveMQ.

Once ActiveMQ is started, it will accept STOMP connections on the `61613` port.

CHAPTER 2

Mobile Messaging with STOMP

In this chapter, we will write our first messaging client: an native application running on an iPhone. We will use STOMP to send and receive messages using the Objective-C library StompKit.

In "Locations Application Using STOMP" on page 6, we described the `Locations` application. In this chapter, we will write the iOS application that broadcasts the device's position and receive text messages.

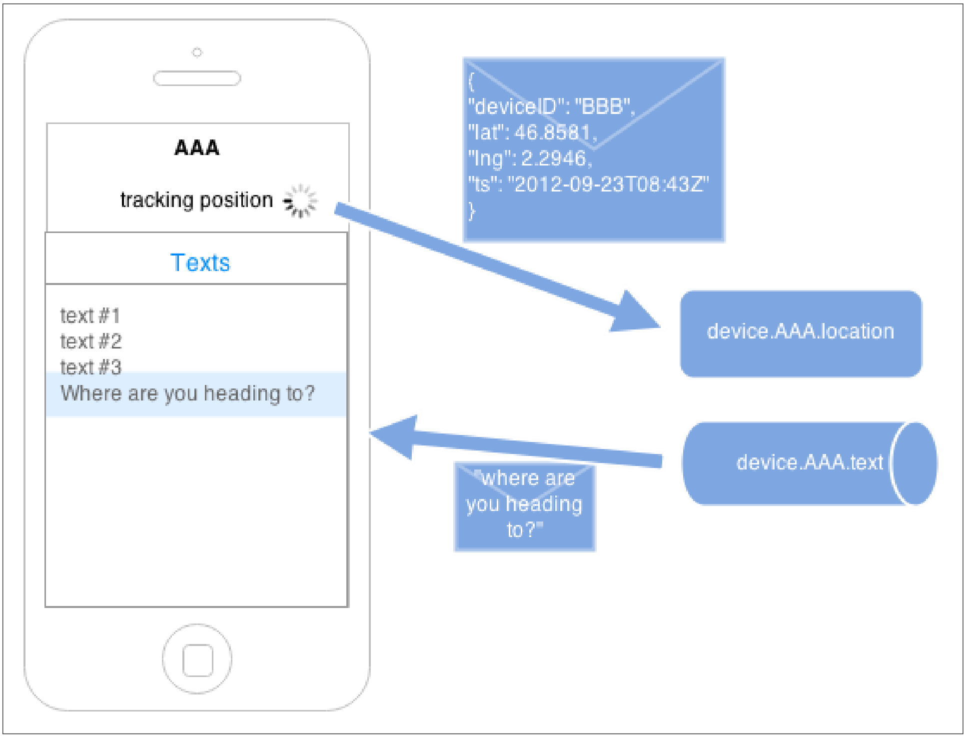
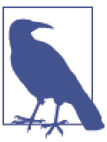


Figure 2-1. Diagram of the Locations iOS application



About the Code

All along the chapter, we will show all the code required to run the application.

The whole application code can be retrieved from the GitHub repository in the `stomp/ios/` directory.

StompKit

To use STOMP on iOS, we will use the `StompKit` Objective-C library that implements the STOMP protocol in a modern event-driven way using ARC, Grand Central Dispatch and blocks.

The source code of this library project is hosted on GitHub.

Create the Locations Project with Xcode

We will use Xcode to create the `Locations` iOS application.

Once Xcode is installed and started, we create a new project from its launch screen:

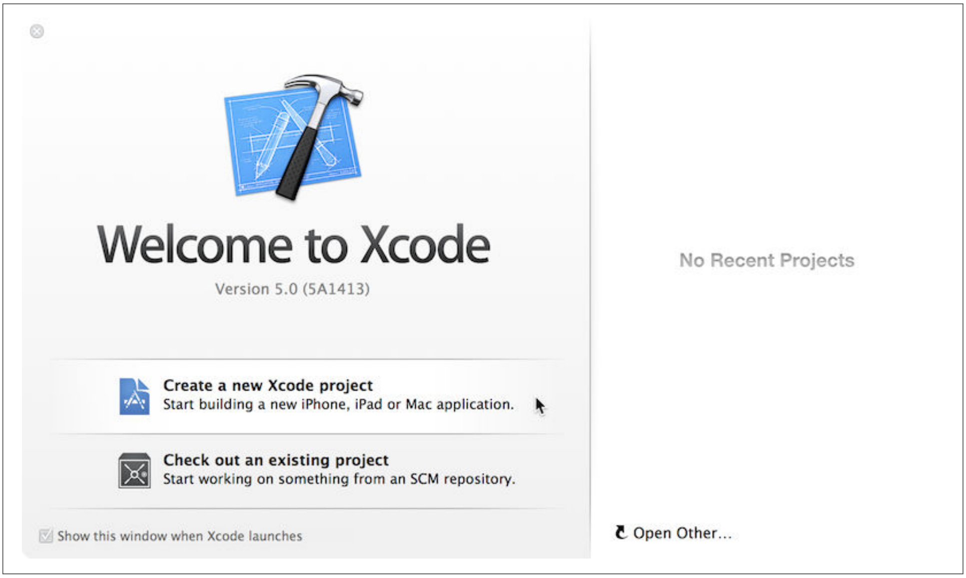


Figure 2-2. Select Create a new Xcode project from Xcode launch screen.

The application consists in a single view so we choose the `Single View Application` template in `iOs > Application` from the template screen.

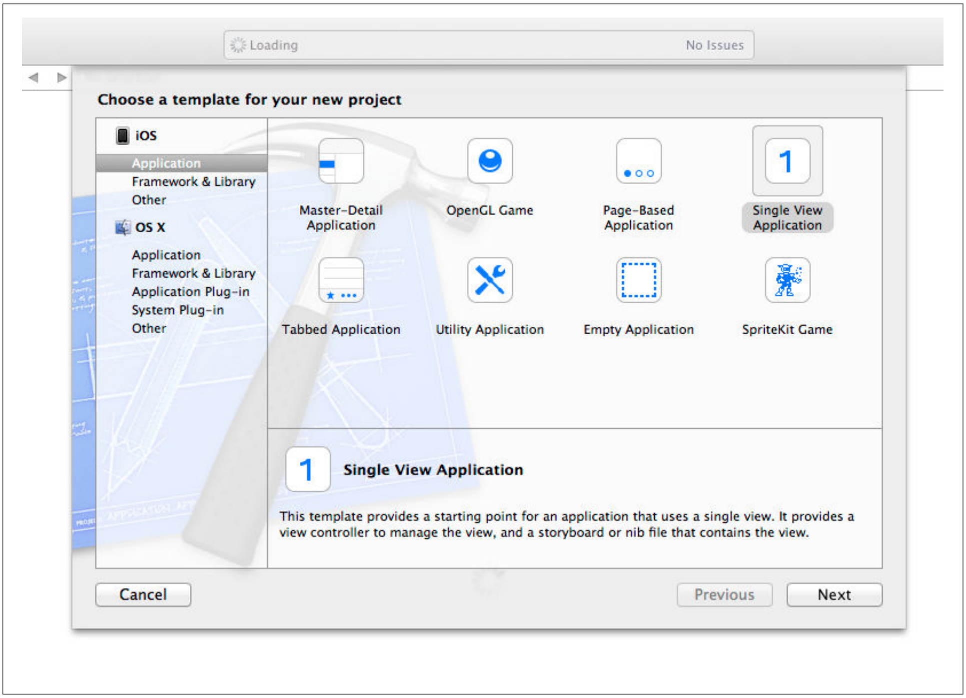


Figure 2-3. Select Single View Application from the template screen

We will call the project `Locations` and select to build it only for iPhone devices.

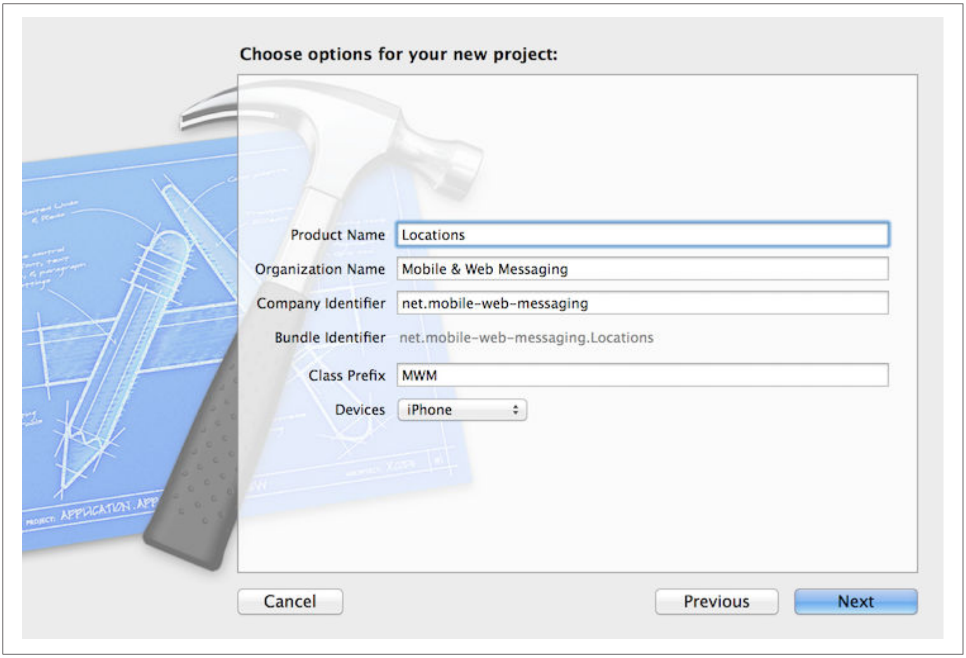


Figure 2-4. XCode project options screen

Finally we will save it in a folder on our machine.

Create the Podfile

To import the library that we will use to send and receive messages, we will setup the project to use CocoaPods, an Objective-C Library Manager.

First we need to close Xcode because we will modify the project structure to import our dependencies.

After installing CocoaPods by following the instructions on its web site, we create a file named **`Podfile`** at the root of the project (in the same directory than `Locations.xcodeproj`).

Example 2-1. Locations' Podfile

```
xcodeproj 'Locations.xcodeproj'

pod 'StompKit', '~> 0.1'

platform :ios, '5.0'
```

After saving this file, run the **`pod install`** command.

Example 2-2. Install Locations dependencies

```
$ pod install
Analyzing dependencies
Downloading dependencies
Installing CocoaAsyncSocket (7.3.2)
Installing StompKit (0.1.0)
Generating Pods project
Integrating client project

[!] From now on use `Locations.xcworkspace`.
```

We can now open again Xcode but we must do it using the *Workspace* file named `Locations.xcworkspace`, and not the *Project* file named `Locations.xcodeproj`.

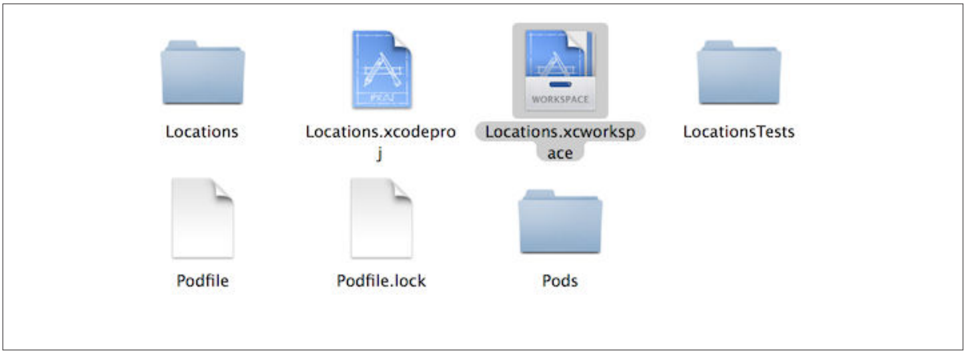


Figure 2-5. Open the Workspace file

First, we will verify that the project is setup correctly and that the application can run in the iOS simulator.

We will simulate the latest iPhone devices by selecting `Product > Destination > iPhone Retina (4-inch 64-bit)` from Xcode menu bar.

If we run the application by selecting **`Product`** > **`Run`** (or pressing ⌘+R), the iOS simulator starts and opens the application which is composed of a blank view.

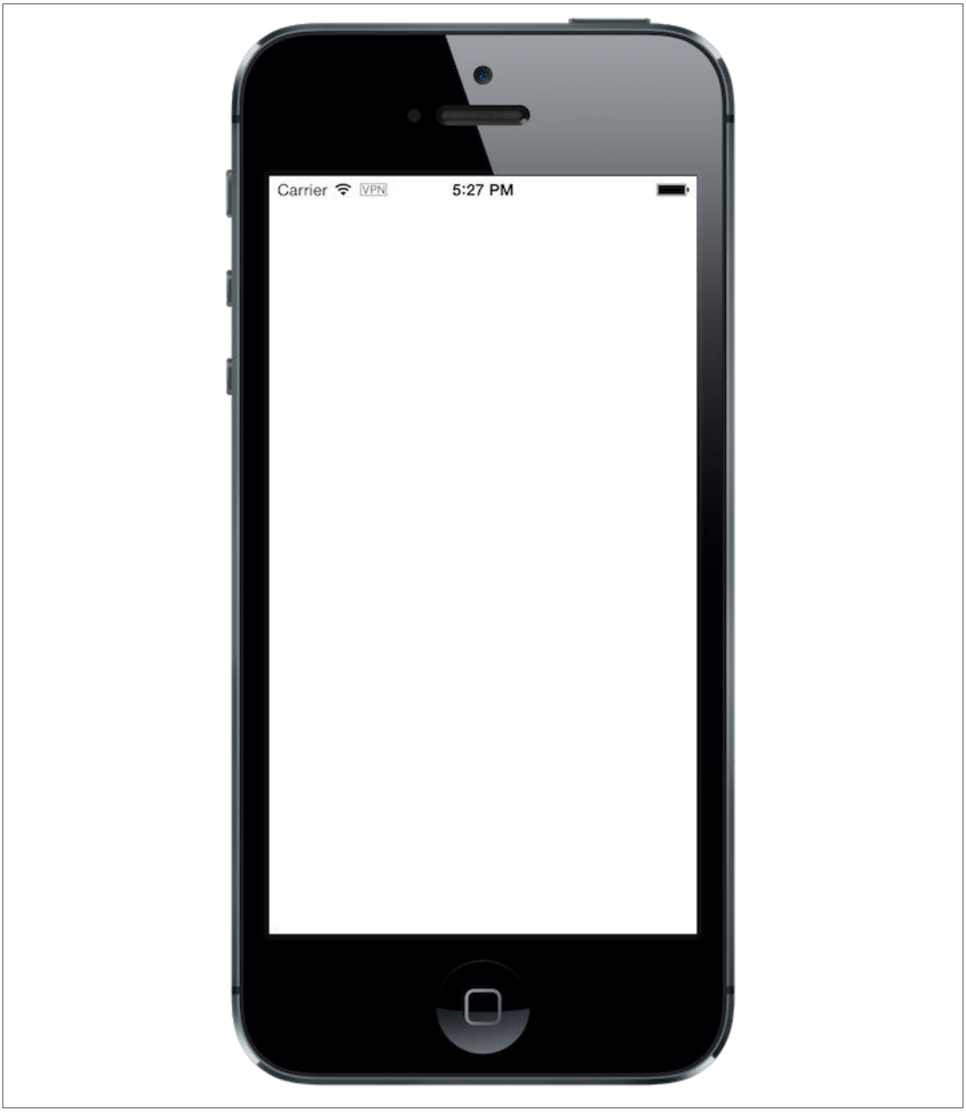


Figure 2-6. Locations Blank View

Nothing is displayed but it confirms that the project and its dependencies are successfully compiled and launched.

Identify the Device

The iPhone device is will broadcast its position. The first thing to do is identify the device. To keep the example simple, we will use a *universal unique identifier* (or UUID) as the device identifier and display it in the view.

Since the application will run only on iPhone devices, all the user interface will be set-up in the **`Main.storyboard`** file.

Click on **`Main.storyboard`** to open it. From the `Object` library, drag a `Label` on the `View`'s window. Place it at the top of the view and change the text to `Device ID`.

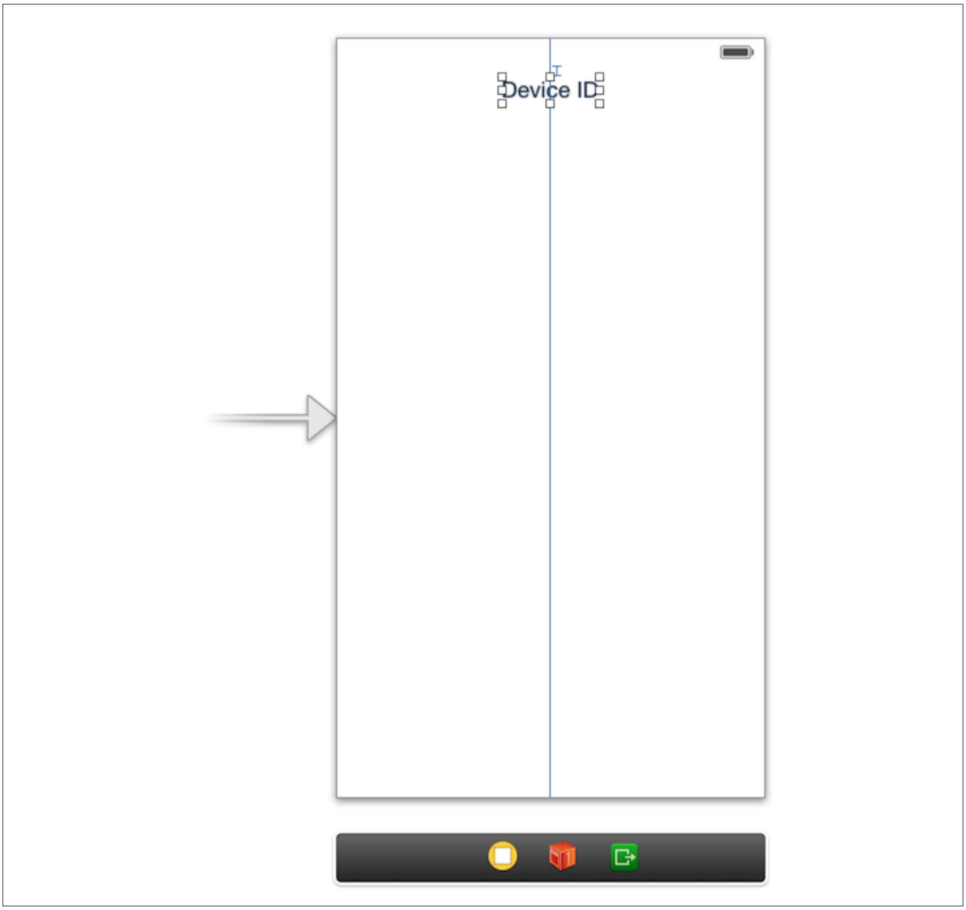


Figure 2-7. Add the Device ID label.

Interface Layout Constraints

I will not describe into details how to set up the layout constraints for the graphical objects so that they adapt correctly to the device's size and orientation.

However the example code in the GitHib repository is constrained correctly.

The UUID that we will generate is quite long so we will change its appearance by setting its `Font` to `System 13.0` and its `Alignment` to `centered` to fit the screen.

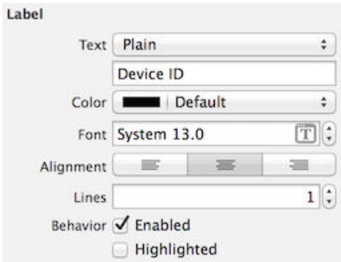


Figure 2-8. Change the appearance of the device ID label.

We will connect this label to the `MWMViewController` object.

Add the necessary outlet property in the `MWMViewController` private interface in MWMViewController.m+ and a `NSString` to hold the identifier.

```
@interface MWMViewController ()

@property (weak, nonatomic) IBOutlet UILabel *deviceIDLabel;

@property (copy, nonatomic) NSString *deviceID;

@end
```

Open the `Main.storyboard` and control-click on `View Controller` to see its connection panel. Drag from `deviceIDLabel` to the `UILabel` to connect it.

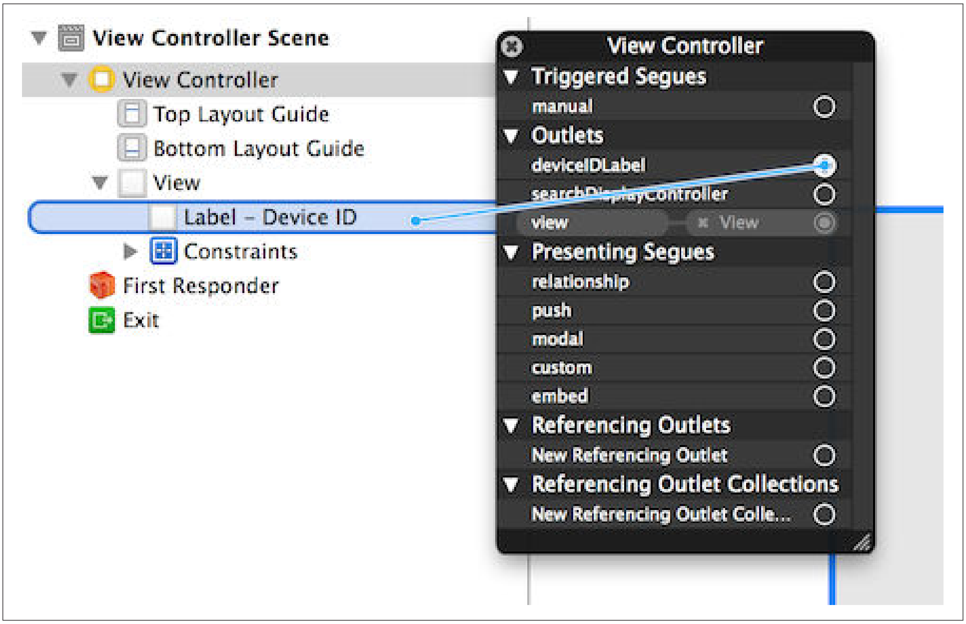


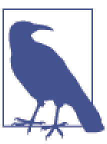
Figure 2-9. Connect the deviceIDLabel outlet property to the device ID UILabel.

Now that the outlet property is connected to the label, we need to generate a UUUID for the application and display it when the view appears.

Open the `MWMViewController.m` file to add code to the `MWMViewController` *implementation*. When the application starts and the view is loaded in `viewDidLoad`, we set the `deviceID` using a UUID.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);
}
```



About Unique Identifier

The `identifierForVendor` property will uniquely identify the device for the application's vendor (that we set to `net.mobile-web-messaging` when we created the project).

We also need to set the label to this ID when the view will appear.

```
- (void)viewWillAppear:(BOOL)animated
{
```

```
        self.deviceIDLabel.text = self.deviceID;
    }
```

If we run the application, we will see the device ID displayed instead of `Device ID` in the view.

Figure 2-10. Display the device ID.

Now that we have the identifier of the device, the next step is to retrieve its geolocation data using the `CoreLocation` framework before we can send them in a STOMP message.

> The next sections deal with setting up the framework and writing code to retrieve the GPS data from the device and display them. This is unrelated to messaging and you can skip them if you only want to read how to send and receive messages. Still, we thought the messaging code would be more meaningful if it was using real data instead of generating random dummy data. By using GPS data instead, we will be able to build a mobile application that display these data on a map in the next chapter.

Display the Device Position

We will retrieve the geolocation data from the device's GPS sensor to send them using STOMP messages. However, we also want to have some graphical feedback to show that the data changes over the time as we move with our device.

To display the geolocation data, we will add a `UILabel` to the view and change its text to `Current position: ???`

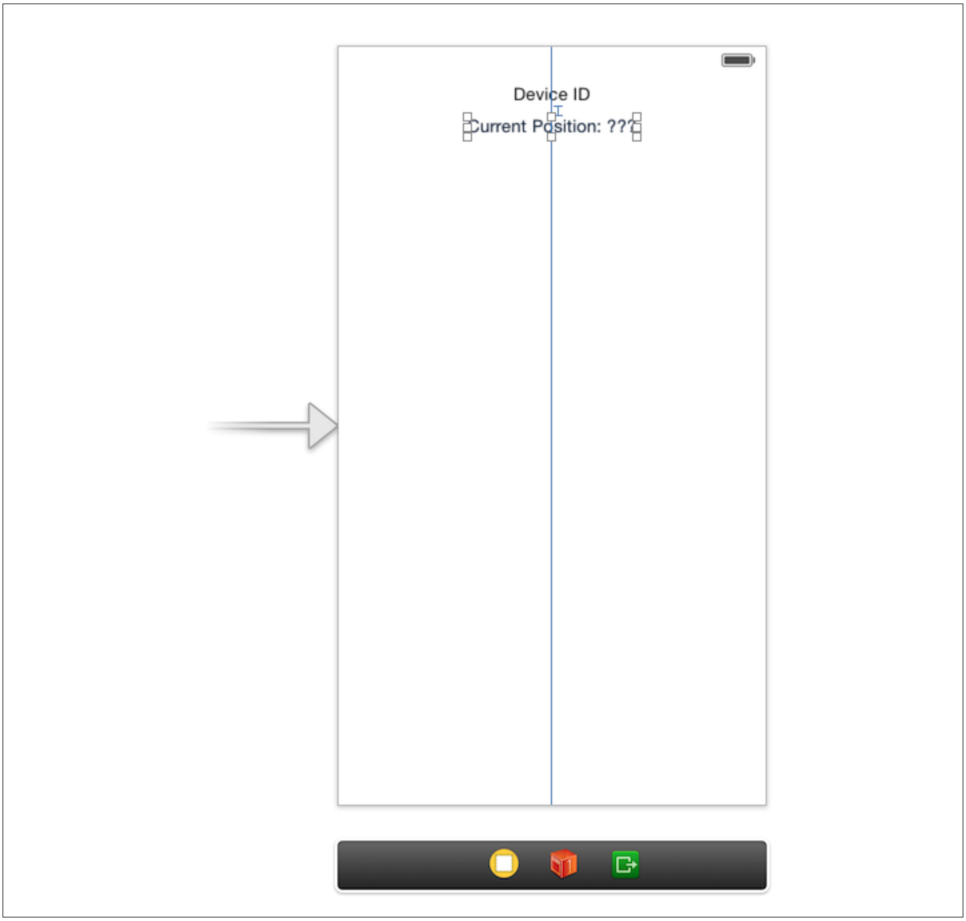


Figure 2-11. Add the current position label

We will change its appearance to match the `deviceID` label by setting its `Font` to `System 13.0` and its `Alignment` to centered.

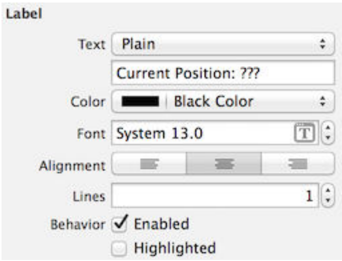


Figure 2-12. Change the appearance of the current position label.

Open the `MWMViewController.m` file and add a property to the `MWMViewController` private interface.

```
@property (weak, nonatomic) IBOutlet UILabel *currentPositionLabel;
```

We then bind this property to the label. Open the `Main.storyboard` and control-click on `View Controller` to see its connection panel. Drag from `currentPositionLabel` to the label to connect it.

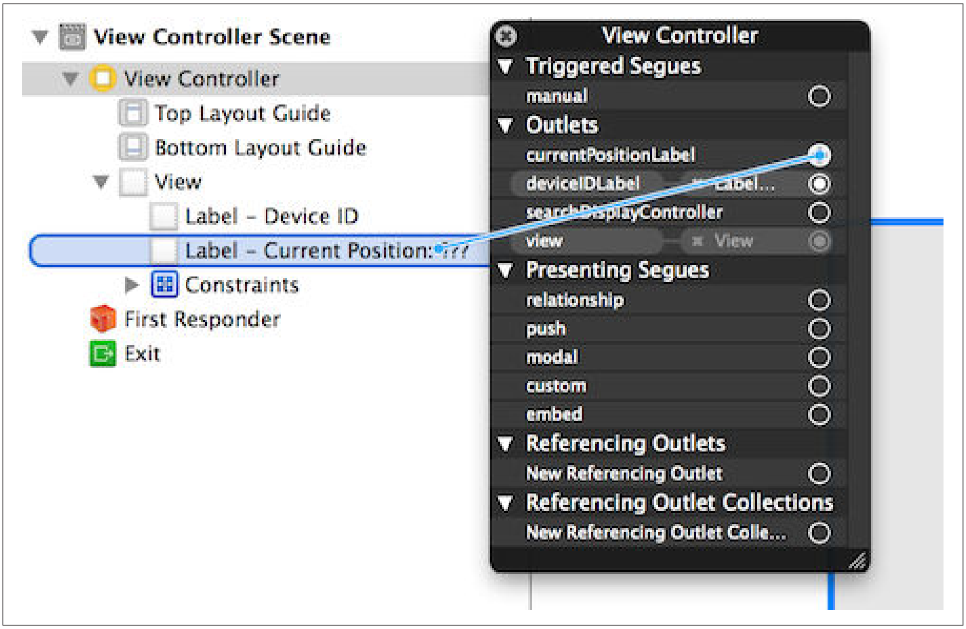


Figure 2-13. Connect the currentPositionLabel outlet property to the current position UILabel.

The label is now connected to the property. The next step is to retrieve the geolocation data from the device to update this property and send a STOMP message with them.

Access the Device Geolocation Data with CoreLocation Framework

iOS provides the `CoreLocation` framework to access the location data.

We need to add it to the libraries linked by the application. Click on the `Locations` project and then the `Locations` target. In the `General` tab, under the `Linked Frameworks and Libraries` section, click on the + button. In the selection window, type **`CoreLocation`**, select the `CoreLocation.framework` and click on the `Add` button.

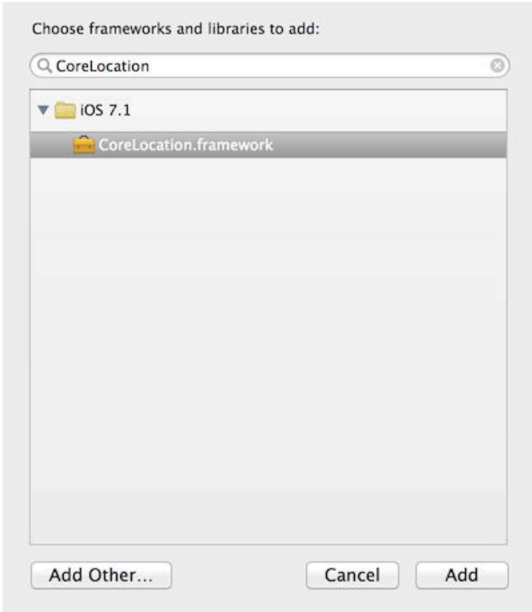


Figure 2-14. Add the CoreLocation framework.

We can now use the `CoreLocation` framework by importing `<CoreLocation/CoreLocation.h>` at the top of the `MWMViewController.m` file.

We will make the `MWMViewController` private interface conform to the `CLLocationManagerDelegate` protocol and declare a `CLLocationManager` property named `locationManager`.

```
#import <CoreLocation/CoreLocation.h>

interface MWMViewController () <CLLocationManagerDelegate>

@property (strong, nonatomic) CLLocationManager *locationManager;

@end
```

We will define two methods to start and stop updating the current location. When the apps starts updating the current location in `startUpdatingCurrentLocation`, it creates the `locationManager` if it is not already created and designates the controller as the locationManager's `delegate`. We will also Since the geolocation data will be used to follow the device as it moves, we set the locationManagere's `desiredAccuracy` to `kCLLocationAccuracyBestForNavigation`.

Finally, the application will start listening for the device location by calling locationManager's `startUpdatingLocation` method.

Example 2-3.

```
#pragma mark - CoreLocation actions

- (void)startUpdatingCurrentLocation
{
    NSLog(@"startUpdatingCurrentLocation");

    // if location services are restricted do nothing
    if ([CLLocationManager authorizationStatus] == kCLAuthorizationStatusDenied ||
           [CLLocationManager  authorizationStatus] == kCLAuthorizationStatusRestric
ted) {
        return;
    }

    // if locationManager does not currently exist, create it
    if (!self.locationManager) {
        self.locationManager = [[CLLocationManager alloc] init];
        // set its delegate to self
        self.locationManager.delegate = self;
        // use the accuracy best suite for navigation
        self.locationManager.desiredAccuracy = kCLLocationAccuracyBestForNavigation;
    }

    // start updating the location
    [self.locationManager startUpdatingLocation];
}
```

To stop receiving the device location in `stopUpdatingCurrentLocation`, we simply call locationManager's `stopUpdatingLocation` method.

Example 2-4.

```
- (void)stopUpdatingCurrentLocation
{
    [self.locationManager stopUpdatingLocation];
}
```

The location of the device will be received by the designated `CLLocationManager Delegate` (in our case, the `MWMViewController` implementation itself). We need to implement the `locationManager:didUpdateToLocation:fromLocation:` method and extract the coordinates from the `newLocation`'s `coordinate`.

Once we have them, we can update the `currentPositionLabel`'s `text` to display them.

Example 2-5.

```
#pragma mark - CLLocationManagerDelegate protocol
```

```
- (void)locationManager:(CLLocationManager *)manager
    didUpdateToLocation:(CLLocation *)newLocation
           fromLocation:(CLLocation *)oldLocation
{
    // ignore if the location is older than 30s
    if (fabs([newLocation.timestamp timeIntervalSinceDate:[NSDate date]]) > 30) {
        return;
    }

    CLLocationCoordinate2D coord = [newLocation coordinate];
     self.currentPositionLabel.text = [NSString stringWithFormat:@"φ:%.4F, λ:%.4F",
coord.latitude, coord.longitude];
}
```

If there is any problem with the `locationManager`, we want to warn the user about it and stop updating the location. To do so, we implement the `CLLocationManager Delegate`’s `locationManager:didFailWithError:` method to display a warning to the user:

Example 2-6.

```
- (void)locationManager:(CLLocationManager *)manager
       didFailWithError:(NSError *)error
{
    // reset the current position label
    self.currentPositionLabel.text = @"Current position: ???";

    // show the error alert
    UIAlertView *alert = [[UIAlertView alloc] init];
    alert.title = @"Error obtaining location";
    alert.message = [error localizedDescription];
    [alert addButtonWithTitle:@"OK"];
    [alert show];
}
```

Now that the code related to `CoreLocation` is in place, we just need to call the `star tUpdatingCurrentLocation` method when the view will appear.

Example 2-7.

```
- (void)viewWillAppear:(BOOL)animated
{
    self.truckIDLabel.text = self.truckID;

    [self startUpdatingCurrentLocation];
}
```

We also need to stop updating the location when the view disappears in `viewDidDi sappear:`.

Example 2-8.

```
- (void)viewDidDisappear:(BOOL)animated
{
    [self stopUpdatingCurrentLocation];
}
```

The first time the application asks the `locationManager` to start updating the device location, the user will see an alert view asking his or her permission to access the device location.

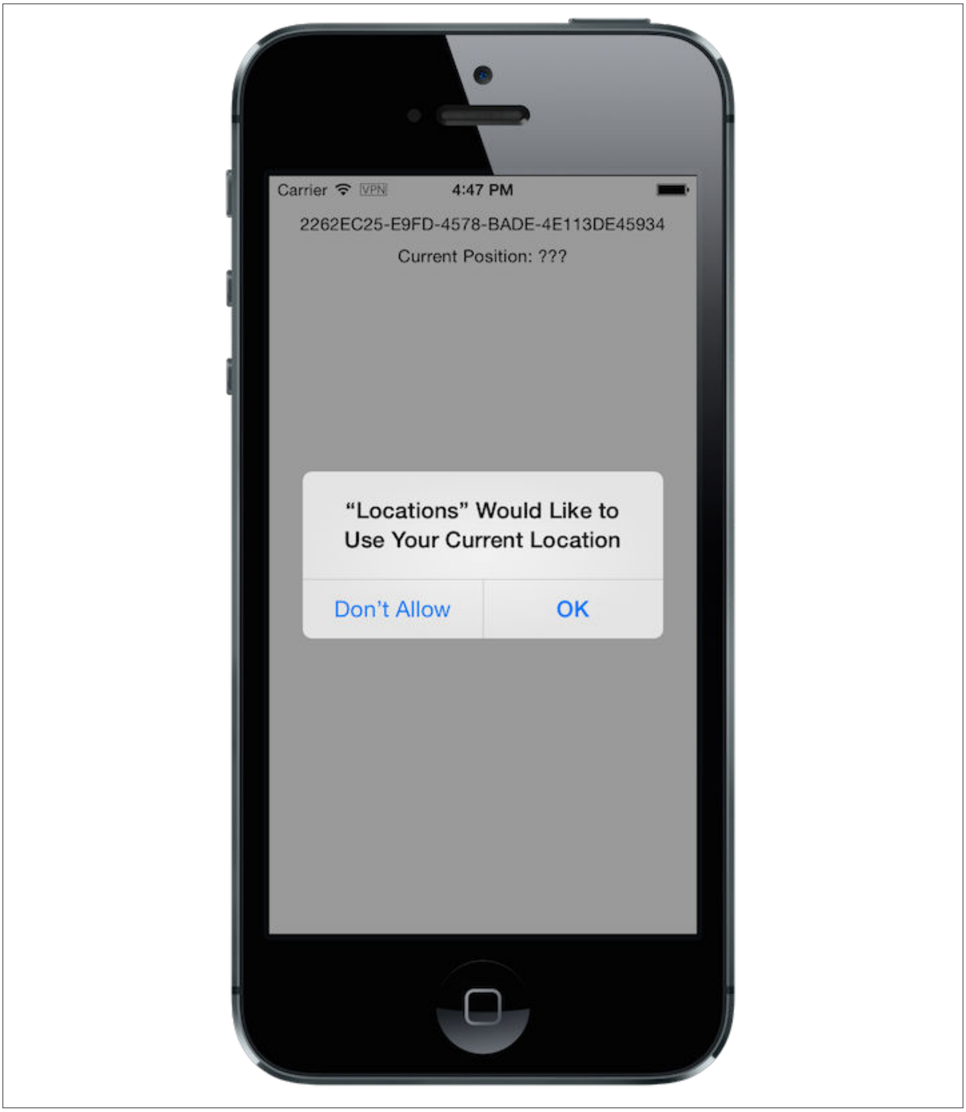


Figure 2-15. Permission to use the current location.

If the user taps `OK`, the `locationManager` will start update the device location and the label for its current position will be updated with the latitude and longitude.

Figure 2-16. Display the current position of the device.

Simulate a Location with iOS Simulator

If you are running the application on an iPhone device, the real geolocation data from the device will be used. If you run the application using the `iOS Simulator`, you can simulate different location in the `Debug > Location` menu. For example, the `Freeway Drive` will simulate a car driving on a freeway between Palo Alto and San Francisco.

Whether you are running the application on a device or in the simulator, you should see the `currentPositionLabel` be udpated. The latitude and longitude numbers are difficult to interpret as such but in the next chapter Chapter 3, we will be able to use them to draw the position on a map to locate the devices.

Now that the `Locations` application is handling the device geolocation data, the next step is to send them using STOMP.

Create a STOMP Client with StompKit

Before sending any messages, we must first import the `StompKit` library that we add to the `Podfile` file at the beginning of this chapter.

We must import its header file `StompKit.h` at the top of the `MWMViewController.m` file and add a `STOMPClient` property named `client` to the `MWMViewController` private interface.

Example 2-9.

```
#import <StompKit.h>

@interface MWMViewController () <CLLocationManagerDelegate>

@property (nonatomic, strong) STOMPClient *client;

@end
```

The `client` property will be used to communicate with the STOMP broker after it is created and connected.

We do not need to conform to any protocol to use `StompKit` as its API is based on *blocks* instead of protocol delegates.

The `client` variable is created when the controller's view is loaded in `MWMViewController`'s `viewDidLoad` method implementation. To create it, we need to pass the host and port of the STOMP broker to connect to. These information depends on the broker you are using. If you have configured ActiveMQ on your machine as described in the appendix Appendix A, you will be able to connect on its `61613` port.

The host will depend on your network configuration. On my local network, my server has the IP address `192.168.1.25`. I will use this value for the example but you will have to replace this by your own server address to run the applications.

Example 2-10.

```
#define kHost     @"192.168.1.25"
#define kPort     61613
```

```
...

@implementation MWMViewController

- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);

    self.client = [[STOMPClient alloc] initWithHost:kHost port:kPort];
}
```

Connect to a STOMP Broker

When the `client` object is created, it is not connected to the STOMP broker yet. To connect, we must call its `connectWithHeaders:completionHandler:` method.

StompKit uses Grand Central Dispatch and blocks to provide an event-driven API. This means that the client is *not* connected when the call to its `connectWithHeaders:completionHandler:` method returns but when the completionHandler block is called.

We can pass a dictionary to `connectWithHeaders:completionHandler:` to add additional headers during the connection to the STOMP broker. In our application, we will send a `client-id` header set to the `deviceID` to uniquely identify the client against the STOMP broker.

This ensures that no two devices will be able to connect using the same identifier. Once a client is connected with a given `client-id`, any subsequent clients that uses the same value will fail to connect to the broker.

We will encapsulate this code in a `connect` method in `MWMViewController` implementation.

Example 2-11.

```
@implementation MWMViewController

#pragma mark - Messaging

- (void)connect
{
    NSLog(@"Connecting...");
    [self.client connectWithHeaders:@{ @"client-id": self.deviceID}
                  completionHandler:^(STOMPFrame *connectedFrame, NSError *error) {
                      if (error) {
```

```
                        // We have not been able to connect to the broker.
                        // Let's log the error
                        NSLog(@"Error during connection: %@", error);
                    } else {
                        // we are connected to the STOMP broker without an error
                        NSLog(@"Connected");
                    }
                }];
    // when the method returns, we can not assume that the client is connected
}

@end
```

We will call this `connect` method when the view appears in `viewWillAppear:`.

Example 2-12.

```
- (void)viewWillAppear:(BOOL)animated
{
    self.truckIDLabel.text = self.truckID;

    [self startUpdatingCurrentLocation];
    [self connect];
}
```

Disconnect from a STOMP Broker

The `STOMPClient` disconnects from the broker using its `disconnect:` method. This method takes a block that will be called when the client is disconnected from the server. The block takes a `NSError` parameter that is set if there is an error during the disconnection operation.

Example 2-13.

```
#pragma mark - Messaging

- (void)disconnect
{
    NSLog(@"Disconnecting...");
    [self.client disconnect:^(NSError *error) {
        if (error) {
            NSLog(@"Error during disconnection: %@", error);
        } else {
            // the client is disconnected from the broker without any problem
            NSLog(@"Disconnected");
        }
    }];
    // when the method returns, we can not assume that the client is disconnected
}
```

We will disconnect from the broker once the view has disappeared in `viewDidDisappear:`.

Example 2-14.

```
- (void)viewDidDisappear:(BOOL)animated
{
    [self stopUpdatingCurrentLocation];
    [self disconnect];
}
```

At this stage, we have an application that connect to the STOMP broker when its view is displayed and disconnect when its view disappears.

If we run the application, we see logs in Xcode that shows the connection process:

```
2014-03-13 17:07:21.667 Locations[79069:60b] Connecting...
2014-03-13 17:07:21.723 Locations[79069:3903] Connected
```

Send STOMP Messages

We now have a connection to the STOMP broker and we receive the device's geolocation data from the `CoreLocation` framework. The last step to do is to send these data to the topic associated to the device ID.

As we described in "Locations Messaging Models" on page 7, each device will send its location on a topic named after its identifier.

```
NSString *destination = [NSString stringWithFormat:@"/topic/device.%@.loca
tion", self.deviceID];
```

ActiveMQ STOMP Destinations Naming Conventions

ActiveMQ convention is to prefix a STOMP destination by `/topic/` to use a Publish/Subscribe messaging model and by `/queue/` to use a Point-to-Point model.

Since we designed our application to use a topic for the `device.XXX.location`, we must preprend it with `/topic/`

As we described in "Locations Message Representation" on page 8, the message representation is a JSON string that contains the location coordinates, the timestamp and the device ID. We build a `NSDictionary` from these data and serialize it as a JSON string:

```
NSDictionary *dict = @{
    @"deviceID": self.deviceID,
    @"lat": [NSNumber numberWithDouble:location.coordinate.latitude],
    @"lng": [NSNumber numberWithDouble:location.coordinate.longitude],
```

```
        @"ts": [dateFormatter stringFromDate:location.timestamp]
    };
    NSData  *data  =  [NSJSONSerialization  dataWithJSONObject:dict  options:0  er
    ror:nil];
    NSString *body =[[NSString alloc] initWithData:data encoding:NSUTF8StringEncod
    ing];
```

This body follows the JSON format. We will add a `content-type` header in the STOMP message and set it to `application/json; charset=utf-8` to let the STOMP brokers and the eventual consumers know that this message's payload can be read as JSON string encoded with UTF-8. Without such a `content-type`, the consumers would not necessarily know how to *read* the data in the body and interpret them.

```
    NSDictionary *headers = @{
        @"content-type": @"application/json;charset=utf-8"
    };
```

We now have the `destination`, `headers`, and `body` to send in the message. Last step is to use the `client`'s `sendTo:headers:body` method to send it.

```
    // send the message
    [self.client sendTo:destination
                headers:headers
                   body:body];
```

We will encapsulate all these steps in a `sendLocation:` method that takes a `CLLocation` parameter.

Example 2-15.

```
- (void)sendLocation:(CLLocation *)location
{
    // build a static NSDateFormatter to display the current date in ISO-8601
    static NSDateFormatter *dateFormatter = nil;
    static dispatch_once_t onceToken;
    dispatch_once(&onceToken, ^{
        dateFormatter = [[NSDateFormatter alloc] init];
        dateFormatter.dateFormat = @"yyyy-MM-d'T'HH:mm:ssZZZZZ";
    });

    // send the message to the truck's topic
       NSString  *destination  =  [NSString  stringWithFormat:@"/topic/device.%@.loca
tion", self.deviceID];

    // build a dictionary containing all the information to send
    NSDictionary *dict = @{
        @"deviceID": self.deviceID,
        @"lat": [NSNumber numberWithDouble:location.coordinate.latitude],
        @"lng": [NSNumber numberWithDouble:location.coordinate.longitude],
        @"ts": [dateFormatter stringFromDate:location.timestamp]
    };
```

```
    // create a JSON string from this dictionary
      NSData *data = [NSJSONSerialization dataWithJSONObject:dict options:0 er
ror:nil];
     NSString *body =[[NSString alloc] initWithData:data encoding:NSUTF8StringEncod
ing];

    NSDictionary *headers = @{
        @"content-type": @"application/json;charset=utf-8"
    };

    // send the message
    [self.client sendTo:destination
                headers:headers
                   body:body];
}
```

Next step is to call this method every time we receive an updated location in the `loca tionManager:didUpdateToLocation:fromLocation:` method.

Example 2-16.

```
- (void)locationManager:(CLLocationManager *)manager
    didUpdateToLocation:(CLLocation *)newLocation
           fromLocation:(CLLocation *)oldLocation
{
    // ignore if the location is older than 30s
    if (fabs([newLocation.timestamp timeIntervalSinceDate:[NSDate date]]) > 30) {
        return;
    }

    CLLocationCoordinate2D coord = [newLocation coordinate];
     self.currentPositionLabel.text = [NSString stringWithFormat:@"φ:%.4F, λ:%.4F",
coord.latitude, coord.longitude];

    // send a message with the location data
    [self sendLocation:newLocation];
}
```

Messages will be sent every time the device location changes. This is a bit unconvenient when developing this application as I do not want to move around my home whenever I need to update my location and send a message.

To simplify development, we will add code to send the last known location when the user shakes the device.

We will need add a `lastKnownLocation` property to the `MWMViewController` private interface and use it to store the location returned by the `CLLocationManager` delegate method.

Example 2-17.

```
@interface MWMViewController () <CLLocationManagerDelegate>

...
@property (strong, nonatomic) CLLocation *lastKnownLocation;

@end

@implementation MWMViewController

...

#pragma mark - CLLocationManagerDelegate protocol

- (void)locationManager:(CLLocationManager *)manager
    didUpdateToLocation:(CLLocation *)newLocation
           fromLocation:(CLLocation *)oldLocation
{

    ...

    // send a message with the location data
    [self sendLocation:newLocation];
    // store the location to send it again when user shakes the device
    self.lastKnownLocation = newLocation;
}
```

To send a message with this `lastKnownLocation` when the user shakes the device, we must implement the `motionEnded:withEvent:` method in the `MWMViewController` implementation and check if the event is a motion shake (identified by `UIEventSubtypeMotionShake`).

Example 2-18.

```
#pragma mark - User Events

- (void)motionEnded:(UIEventSubtype)motion withEvent:(UIEvent *)event
{
    if (motion == UIEventSubtypeMotionShake) {
        NSLog(@"device is shaked");
        if (self.lastKnownLocation) {
            [self sendLocation:self.lastKnownLocation];
        }
    }
}
```

When we run the application, a STOMP message will be sent every time the location manager updates the device's location or when the user shakes the device.

How can we check that messages are effectively sent?

We will confirm it at three different stages:

1. Display debug log on the device to check that messages are sent
2. Use ActiveMQ administration console to check that it effectively handled the sent messages
3. Write the simplest STOMP consumer that can receive these messages

Display StompKit Debug Log

Every time the StompKit library sends a message to a STOMP broker, it logs the STOMP frame that is sent.

To display them in the console, edit the file named `StompKit.m` in Xcode that is under the `Pods` project (its full path is `Pods` > `Pods` > `StompKit` > `StompKit.m` in the Project Navigator view) and change the macro to activate logs by replacing the `0` by `1`.

```
#pragma mark Logging macros

#if 1 // set to 1 to enable logs

...
```

If we restart the application, we now see debug statements in Xcode's Debug console:

```
2014-03-13 17:19:05.711 Locations[79549:60b] >>> SEND
destination:/topic/device.2262EC25-E9FD-4578-BADE-4E113DE45934.location
content-type:application/json;charset=utf-8
content-length:122

{"lng":-122.03254905,"deviceID":"2262EC25-E9FD-4578-BADE-4E113DE45934","lat":
37.33521504,"ts":"2014-03-13T17:19:05+01:00"}
...
```

This confirms that STOMP messages are effectively sent by the `Locations` application.

ActiveMQ Admin Console

In "Administration Web Console" on page 158, we have used the ActiveMQ admin console to check the broker configuration. We can also use this console to check the destinations and their associated metrics.

Go to the ActiveMQ admin console in your Web browser at *http://localhost:8161/hawtio* and navigate the ActiveMQ tree down to the postion topic in `mybroker > Topic > device.2262EC25-E9FD-4578-BADE-4E113DE45934.location`.

In the right side panel, select `Attributes` in the top menu to display all the attributes associated to this topic.

To check whether the broker is receiving the messages on this destination, the attribute to check is `Enqueue count`. It corresponds to the messages that has been *enqueued* (or in other word, *sent*) to the destination. We see that this value is growing over time (it was at `113` when the screenshot below was captured). This confirms that the broker is actually receiving the messages sent by the mobule application.

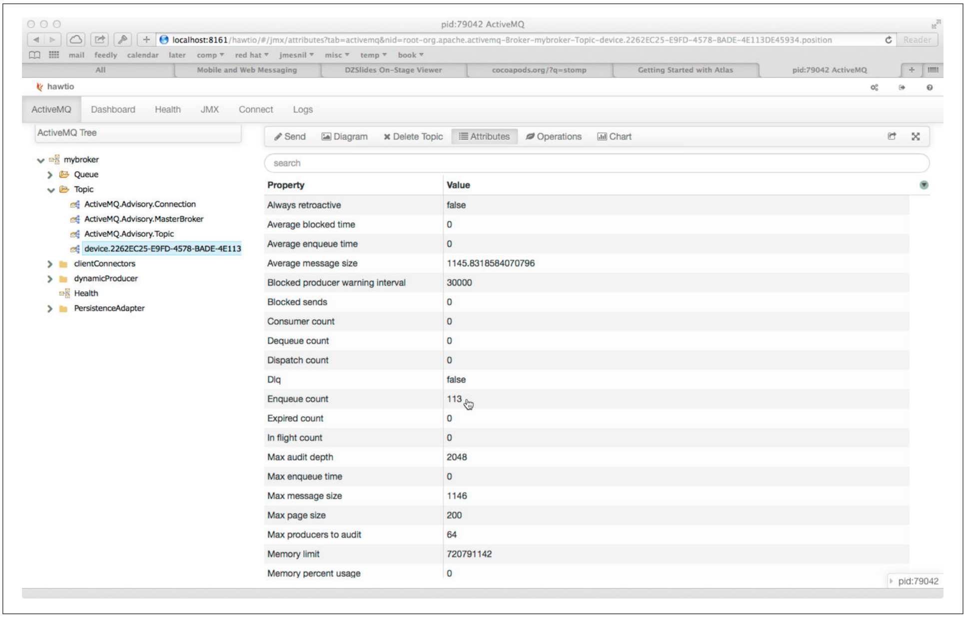


Figure 2-17. Check the number of messages sent to a destination in ActiveMQ admin console

Another interesting attribute is `Dequeue count`. It corresponds to the messages removed from the topic and sent to consumers. In our case, it stays at `0` because there is no consumer that are subscribed to this destination.

a Simple STOMP Consumer

When I presented STOMP, I wrote that the protocol is so simple that a `telnet` client *is* a STOMP client.

Let's prove that by writing the simplest STOMP client that will consume the messages sent by the application to the destination.

We need to open a `telnet` client to connect to the broker host on the `61613` port. Since I am on the same machine than the broker, I will simply connect to `localhost`:

Example 2-19. Connection with a telnet Client

```
$ telnet localhost 61613
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
```

Once the client is connected, we must connect to the broker to open a STOMP connection (as we did in the application using `STOMPClient`'s `connectWithHeaders:completionHandler:` method).

Example 2-20. Connect to a STOMP Broker

```
CONNECT

^@
```

A STOMP frame must be ended by a NULL octet.

The `^@` is the ASCII character for NULL octet. Type `ctrl + @` to enter it.

Note also that there is a blank line between the `CONNECT` line and the NULL octet. This blank line is mandatory to separate the command name and the headers from the beginning of the optional payload (that is not present in the `CONNECT` frame).

Once you type `ctrl + @`, the messaging broker will process the `CONNECT` frame and reply with a `CONNECTED` frame:

Example 2-21. Receive a Connection Confirmation

```
CONNECTED
heart-beat:0,0
session:ID:jeff.local-63055-1391518653216-2:23
server:ActiveMQ/5.9.0
version:1.2
```

The STOMP connection is now established and the telnet client can now exchange messages with the broker. We are only interested to consume messages sent by the application on the device's location topic. The device ID is displayed on the application screen. You will have to adapt the command to use your own device ID to receive its message.

```
SUBSCRIBE
destination:/topic/device.2262EC25-E9FD-4578-BADE-4E113DE45934.location

^@
```

As soon as we sent this command to the STOMP broker, we will receive `MESSAGE` frames that corresponds to the messages sent by the application:

```
MESSAGE
content-type:application/json;charset=utf-8
message-id:ID:jeff.local-50971-1394726830317-2:5:-1:1:323
destination:/topic/device.2262EC25-E9FD-4578-BADE-4E113DE45934.location
timestamp:1394727930755
expires:0
content-length:122
priority:4

{"lng":-122.12966111,"deviceID":"2262EC25-E9FD-4578-BADE-4E113DE45934","lat":
37.36492641,"ts":"2014-03-13T17:25:30+01:00"}
```

> We can see that there are more headers in the consumed messages that in the messages we sent (which only had `content-type` and `content-length`). These headers are added by the STOMP broker and provides additional metadata about the messages. We will explore some of them later in Chapter 4 and Chapter 5.

At this stage, we have a mobile application that is a STOMP *producer*. It broadcasts its position by sending messages to a STOMP destination.

Display the Text Messages

We will now write the second part of the `Locations` application that will *consume* STOMP messages containing some text and display them in a table.

We will write the graphical part first by adding a `UITable` to the user interface.

Click on `Main.storyboard` to open it. From the `Object` library, drag a `Table View` on the View's window. Place it below the current position `UILabel`.

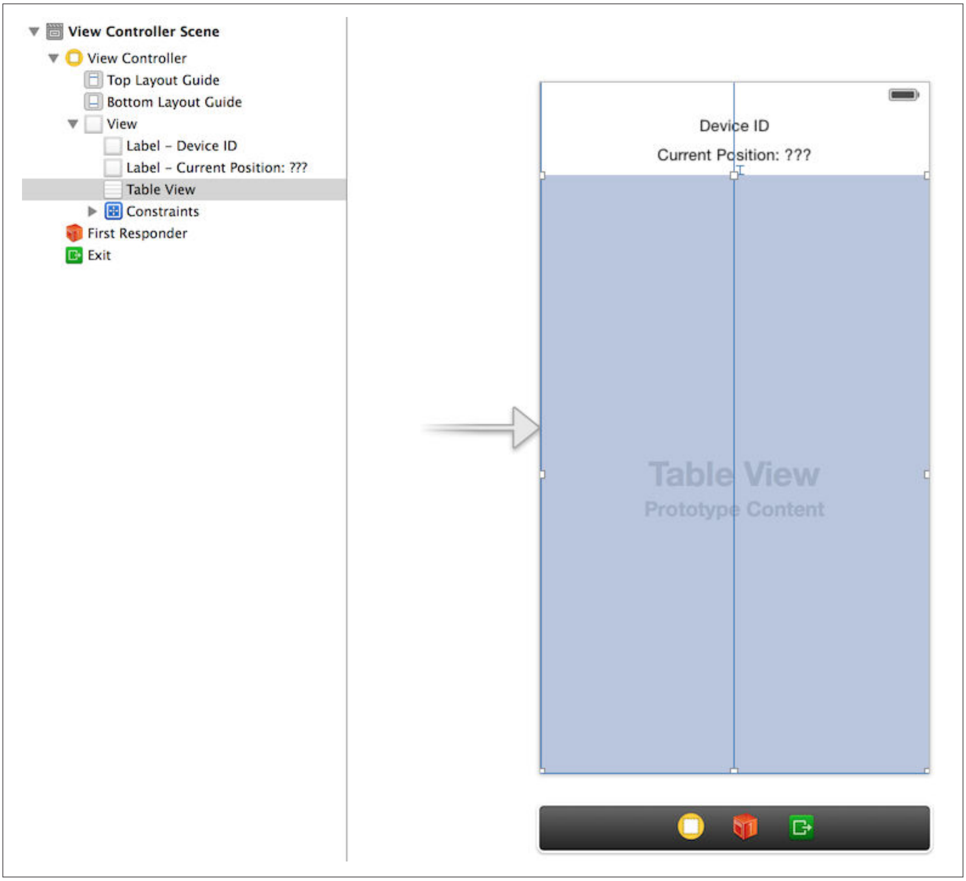


Figure 2-18. Add a Table View

From the `Object` library, drag a `Table View Cell` inside the `Table View`.

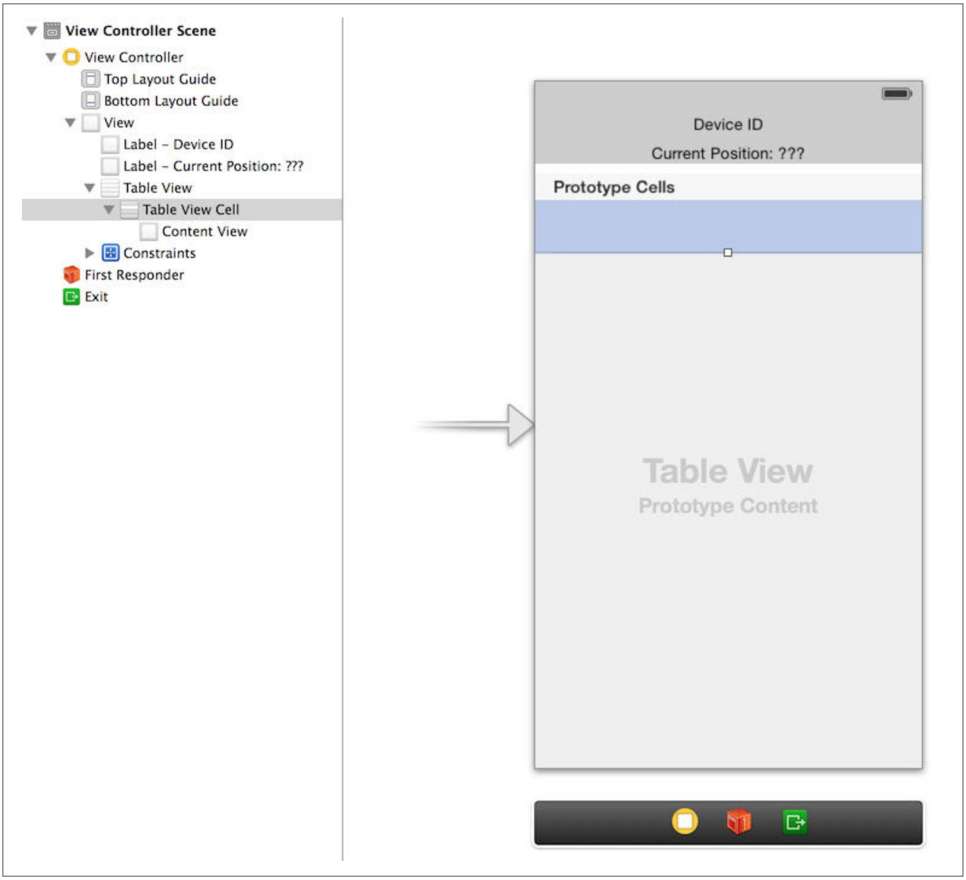


Figure 2-19. Add a Table View Cell

We will change the `Table View Cell` properties by setting its `Style` to `Basic` and its `Identifier` to `TextCell`.

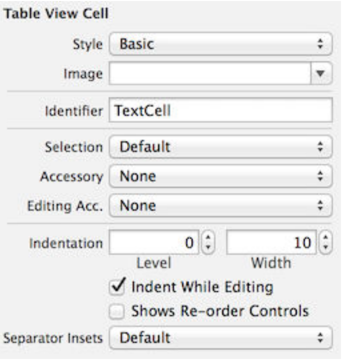


Figure 2-20. Edit the Table View Cell Properties

The `MWMViewController` interface will be declared as both the data source and delegate of the table. Open the `MWMViewController.m` file, make the `MWMViewController` interface conform to the `UITableViewDataSource` and `UITableViewDelegate` protocols and add an outlet property for the table.

Example 2-22.

```
@interface MWMViewController () <CLLocationManagerDelegate, UITableViewDataSource,
UITableViewDelegate>

@property (weak, nonatomic) IBOutlet UITableView *tableView;

@end
```

We need to bind this outlet property to the table view. Open the `Main.storyboard` and control-click on `View Controller` to see its connection panel. Drag from `table View` to the table to connect it.

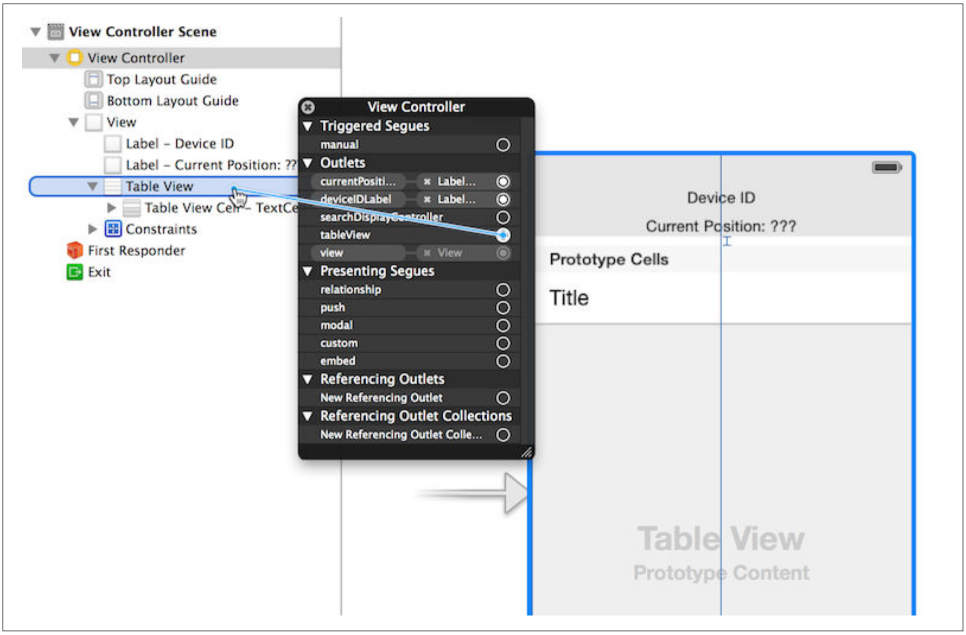


Figure 2-21. Connect the tableView outlet property to the Table View.

We also need to connect the `View Controller` to the `Table View` and declare it as it `dataSource` and `delegate`.

Open the `Main.storyboard` and control-click on `Table View` to see its connection panel. Drag from `dataSource` to the `View Controller` to connect it.

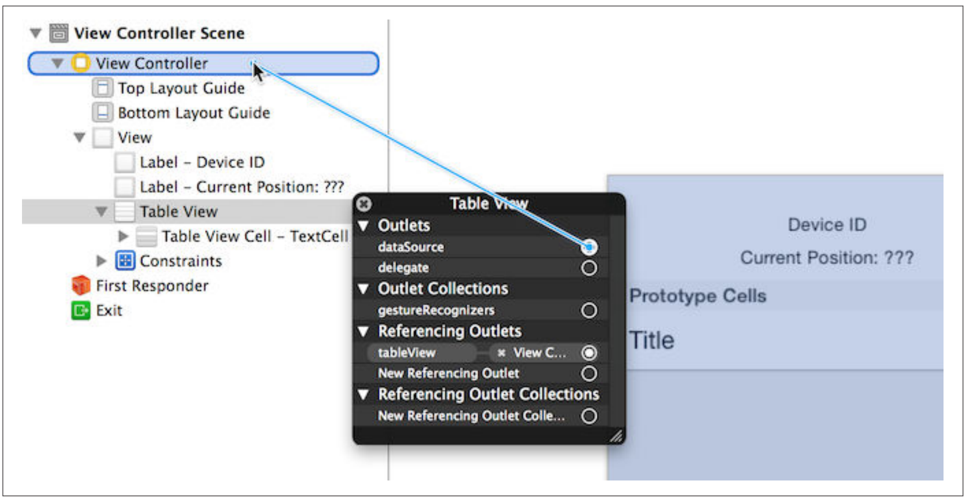


Figure 2-22. Connect the Table View's dataSource to the View Controller.

We do the same operation to connect the `Table View`'s `delegate` property to the `View Controller`.

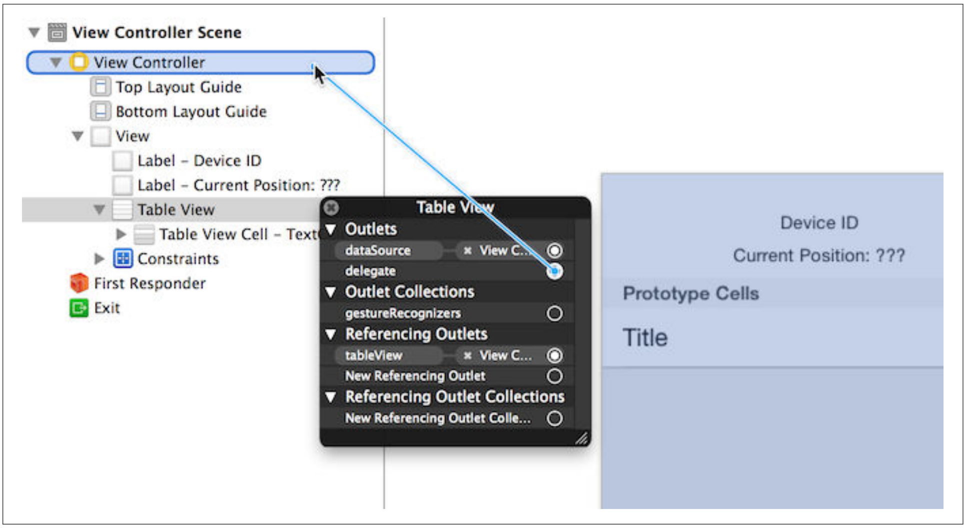


Figure 2-23. Connect the Table View's delegate to the View Controller.

The graphical objects are now properly connected to the properties. Next step is to make the `MWMViewController` implementation comply to the `UITableViewDataSource` and `UITableViewDelegate` protocols.

The table will only display the received text messages. As there is no interaction with the table, we do not need to add any methods from the `UITableViewDelegate` protocol. Let's just add a comment to the `MWMViewController` implementation to remember that.

```
#pragma mark - UITableViewDelegate

// no delegate actions
```

The controller is also the `dataSource` of the table. We will keep a list of the texts in memory in an array. Let's add a `texts` array to the `MWMViewController` implementation and instatiate it in its `viewDidLoad` method.

```
@implementation MWMViewController

// the texts are stored in an array of NSString.
NSMutableArray *texts;

- (void)viewDidLoad
{
    [super viewDidLoad];
```

```
    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);

    self.client = [[STOMPClient alloc] initWithHost:kHost port:kPort];

    texts = [[NSMutableArray alloc] init];
}
```

This texts array will be used as the source of data for the table. Let's implement the required UITableViewDataSource methods.

```
#pragma mark - UITableViewDataSource protocol

-  (NSInteger)tableView:(UITableView  *)tableView  numberOfRowsInSection:(NSInteg
er)section
{
    return [texts count];
}

- (UITableViewCell *)tableView:(UITableView *)tableView
         cellForRowAtIndexPath:(NSIndexPath *)indexPath
{
    // this identifier must be the same that was set in the
    // Table View Cell properties in the story board.
    static NSString *CellIdentifier = @"TextCell";

     UITableViewCell  *cell  =  [tableView  dequeueReusableCellWithIdentifier:CellI
dentifier];

    cell.textLabel.text = [texts objectAtIndex:indexPath.row];
    return cell;
}
```

With these methods implemented, the table will displayed all the texts that are stored in the texts array.

Receive STOMP Messages

Now that we are ready to display the table, next step is to subscribe to the device's text destination to consume STOMP messages and store their text payload in the texts array.

To consume messages, a STOMP client must:

1. connect to the broker
2. subscribe to the destination it wants to consume messages from.

Subscribe to a STOMP Destination

We already took care of step (1) by calling STOMPClient's connectWithHeaders:completionHandler: in MWMViewController's connect method.

Step (2) is handled in STOMPKit by calling STOMPClient's subscribeTo:headers:messageHandler: method.

This method takes 3 parameters:

- the destination that the client wants to consume from. In our case it is the destination /queue/device.XXX.text (we prepended the destination with the /queue/ prefix according to ActiveMQ naming convention).
- a dictionary of headers to pass additional metadata to the connection process. Since we do not have any such header for the time being, we will pass a empty dictionary
- a STOMPMessageHandler block with a STOMPMessage parameter that will be called every time the broker sends a messages to the client to consume it. In our case, we just have to get the NSString text from the message body property and add it to the texts array.

We will add a method named subscribe to the MWMViewController implementation:

```
#pragma mark - Messaging

- (void)subscribe
{
    // susbscribes to the device text queue:
         NSString  *destination  =  [NSString  stringWithFormat:@"/queue/device.
%@.text", self.deviceID];

    NSLog(@"subscribing to %@", destination);
    subscription = [self.client subscribeTo:destination
                                    headers:@{}
                             messageHandler:^(STOMPMessage *message) {
        // called every time a message is consumed from the destination
        NSLog(@"received message %@", message);
        // the text is send in a plain String, we use it as is.
        NSString *text = message.body;
        NSLog(@"adding text = %@", text);
        [texts addObject:text];
        // TODO reload the table
    }];
}
```

subscription is a object returned by the subscribe method that identifies the STOMP subscription and can be used to *unsubscribe*.

We declare this object in the `MWMViewController`'s implementation.

```
@implementation MWMViewController

STOMPSubscription *subscription;
```

We need to call this `subscribe` method as soon as the client is connected to the STOMP broker. The correct location is inside the `completionHandler` block of the `connect` method that will be called when the client is *successfully* connected to the STOMP broker:

```
#pragma mark - Messaging

- (void)connect
{
    NSLog(@"Connecting...");
    [self.client connectWithHeaders:@{ @"client-id": self.deviceID}
                  completionHandler:^(STOMPFrame *connectedFrame, NSError *er
ror) {
                      if (error) {
                          // We have not been able to connect to the broker.
                          // Let's log the error
                          NSLog(@"Error during connection: %@", error);
                      } else {
                             // we are connected to the STOMP broker without an
error
                          NSLog(@"Connected");
                          [self subscribe];
                      }
                  }];
    // when the method returns, we can not assume that the client is connected
}
```

Unsubscribe from the Destination

The application will consume messages from the destination as long as it remains connected to the STOMP broker.

We do not need to explicitly unsubscribe from the destination when we disconnect from the broker but it is a good practice to do so. To unsubscribe, we just need to call the `unsubscribe` method on the `subscription` object that was created when we subscribed to the text destination. We will unsubscribe just prior to disconnecting from the broker in the `viewDidDisappear:` method.

```
- (void)viewDidDisappear:(BOOL)animated
{
    [self stopUpdatingCurrentLocation];
    [subscription unsubscribe];
    [self disconnect];
}
```

Finish the Application

The application is now ready to consume messages. Let's start it and check that it is working.

Run the application in the iOS simulator or on your device.

Go to the ActiveMQ admin console and browse to the device text destination (in my case, its name is `device.2262EC25-E9FD-4578-BADE-4E113DE45934.text`) and click on the `Send` tab.

Fill the text area with a plain text string and set the `body format` to `Plain Text`

```
Hello, where are you?
```

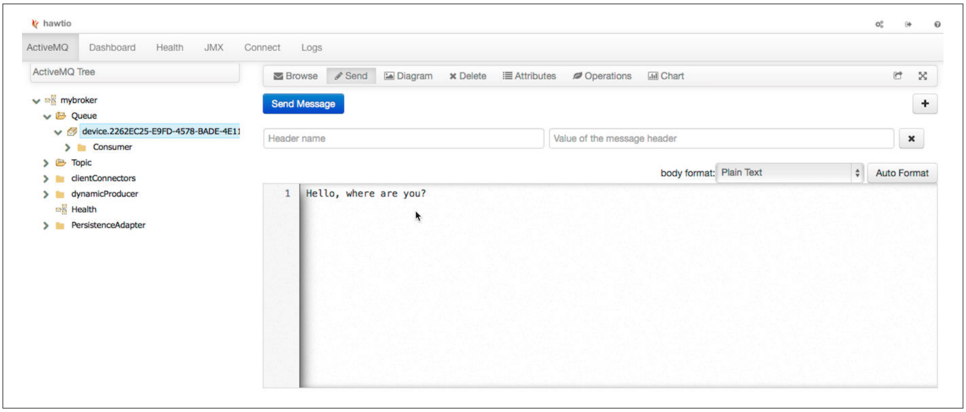


Figure 2-24. Send a Message using ActiveMQ Admin Console.

Click on the `Send Message` button to send the message on the destination.

We see in the application log that a STOMP message has been received and that the `text` was extracted from the message's body.

```
2014-03-14 14:24:19.807 Locations[86050:3903] received message MESSAGE
priority:0
destination:/queue/device.2262EC25-E9FD-4578-BADE-4E113DE45934.text
timestamp:1394803459806
message-id:ID\cjeff.local-53346-1394795959634-37\c1\c1\c1\c1
expires:0
subscription:sub-0

Hello, where are you?
2014-03-14 14:24:19.808 Locations[86050:3903] adding text = Hello, where are
you?
```

However, nothing is displayed in the application. We forgot to reload the table to display the received orders.

Let's fix that by calling `reloadData` on the `tableView` property from the `STOMPMessageHandler` block.

```
- (void)subscribe
{
    // susbscribes to the device text queue:
        NSString  *destination  =  [NSString  stringWithFormat:@"/queue/device.
%@.text", self.deviceID];

    NSLog(@"subscribing to %@", destination);
    subscription = [self.client subscribeTo:destination
                                    headers:@{}
                             messageHandler:^(STOMPMessage *message) {
        // called every time a message is consumed from the destination
        NSLog(@"received message %@", message);
        // the text is send in a plain String, we use it as is.
        NSString *text = message.body;
        NSLog(@"adding text = %@", text);
        [texts addObject:text];
        dispatch_async(dispatch_get_main_queue(), ^{
            [self.tableView reloadData];
        });
    }];
}
```

Note that we did not call directly `[self.tableView reloadData];` from the `STOMPMessageHandler` block.

STOMPKit uses Grand-Central Dispatch's global queue to handle the communication between the client and the STOMP brokers. The `STOMPMessageHandler` block is called on that queue. However any code that deals with `UIKit` (such as reloading the `tableView`) **must** be executed on the queue bound to the main thread. This is why we must wrap the `reloadData` call into a block executed on the main queue.

If we restart the application and send another message on the destination with ActiveMQ admin console, the table will display the text as soon as it is received.

Figure 2-25. The Received Text is Displayed in the Table.

Summary

In this chapter, we learn to use `StompKit` to send and receive STOMP messages from an iOS application.

To send a message, the application must:

1. connect to the STOMP broker

2. send the message to the destination

To consume a message, the application must

1. connect to the STOMP broker
2. subscribe to the destination and pass a block that is called every time a message is received. This block is executed on GCD global queue. If there are any code that changes the user interface, it must be wrapped in a block executed on the main queue.

We use two different types of message payloads:

- a JSON payload by using its string representation for the message body and specifying `application/json; charset=utf-8` in its `content-type` header
- a simple plain text payload without any `content-type` header

Sending and consuming messages are only possible once the client is *successfully* connected to the STOMP broker. Due to the event-driven design of StompKit, this is the case when the completionHandler block is executed without an error in `connectWithHeaders:completionHandler:`.

Web Messaging with STOMP

In this chapter, we will write a Web application that sends and receives messages using the STOMP protocol over HTML5 Web Sockets.

In "Locations Application Using STOMP" on page 6, we described the `Locations` application. In this chapter, we will write the Web application that consumes the device's GPS position to display them on a map and sends text messages to the devices.

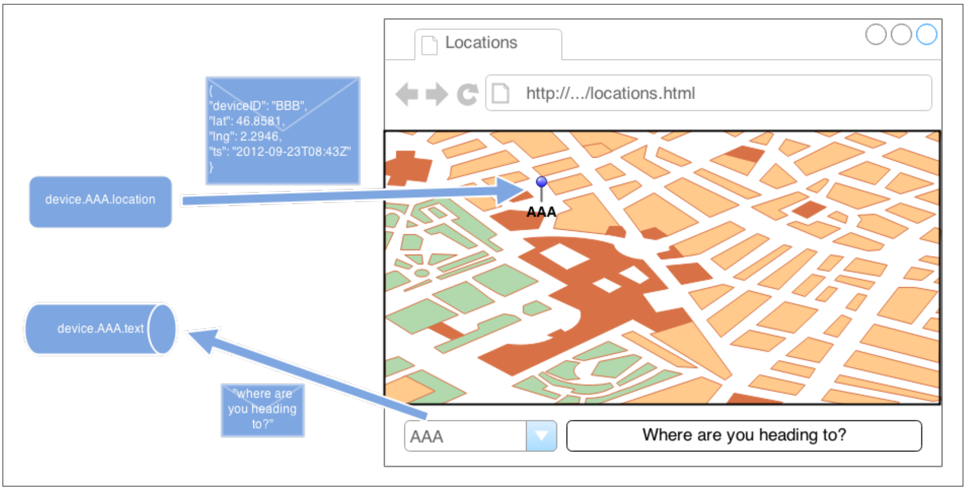


Figure 3-1. Diagram of the Locations Web application

About the Code

All along the chapter, we will show all the code required to run the application.

The whole application code can be retrieved from the GitHub repository in the `stomp/web/` directory.

HTML5 Web Sockets

Web Sockets is a recent features of Web browser that provides a bi-directional and full-duplex communication channel over a single TCP connection between the Web browser and the Web server. Before Web Sockets, communication was only one-way: the browser initiates the communication by sending a HTTP request to the Web server which replies with a HTTP response. The server could not send data to the browser without the browser having first sent a request. There exists some techniques to provide a bi-directional HTTP (such as HTTP long polling and HTTP streaming) but they have significant issues as described in [rfc6202].

Thanks to HTML5 Web Sockets, it is now possible to have two-way communication between the browser and the server. The server can send data to the browser without waiting for a request first. This enables to deliver messages from the Web server to the browser.

We are no longer limited to pull-based messages where the browser need to regularly contact the server to know whether there are any available messages to consume. This preserves bandwidth (the browser no longer need to send periodic query requests) and battery on mobile devices.

> Web Sockets have many use cases in addition to messaging. In some simple cases, sending data on Web Sockets without using a messaging protocol could be enough.
>
> For further information, the [highperfbrowser] book contains a thorough introduction to Web Sockets.

stomp.js, STOMP Over Web Sockets

If your Web browser supports Web Sockets (and all modern browsers do), we can then use a STOMP client that leverages them to send and receive STOMP messages directly from the Web browser.

stomp.is is a small JavaScript library (8KiB for its minified version) that provides a full-featured STOMP 1.2 client.

It can run in multiple JavaScript platforms. Its main target is the Web browser (using Web Sockets as its transport protocol) but it can also be used on other JavaScript platforms such as node.js (using TCP sockets).

A STOMP client running in a Web browser is similar to another STOMP client running on other platform with one exception: STOMP messages are transported by Web Sockets and not regular TCP sockets. The significant difference between them is that a Web Socket is created by sending a HTTP request with a `Upgrade: websocket` header. The STOMP broker must be able to handle such a HTTP request and upgrade the connection from HTTP to the STOMP protocol.

Web Sockets support is not part of the STOMP protocol. The most used STOMP brokers such as ActiveMQ (that is used in this book), HornetQ, or RabbitMQ support it but you will have to consult your broker documentation to check if it does.

Bootstrap the locations.html Web Application

As we explained in the first chapter, this Web application will be use to display the locations of the devices and send them text messages.

It will be a very simple one-page Web application that can be run from a Web server serving static pages. It does not require any server-side runtime as all the code will be executed inside the Web browser using JavaScript.

Let's bootstrap the Web application by creating a `locations.html` page.

Example 3-1. Template for the locations.html Web Application

```
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta content="width=device-width" name="viewport">
    <meta charset="utf-8">
    <title>Locations - STOMP Example</title>
  </head>
  <body>
    <h1>Locations - STOMP Example</h1>
      <form id='connect_form'>
        <fieldset>
          <label>WebSocket URL</label>
          <input name=url id='connect_url' value='ws://localhost:61614' type="text">
          <button id='connect_button' type="submit">Connect</button>
          <button type="button" id='disconnect_button' disabled>Disconnect</button>
        </fieldset>
      </form>
      <form id="text_form" style="display: none;">
        <fieldset>
          <legend>Send Text</legend>
          Device: <select id="deviceID"></select>
          <br>
```

```
          Text: <input id='text' size=64 placeholder="type the text to sent to the
device" type="text">
          <br>
          <button id='text_submit' type="submit">Send</button>
        </fieldset>
      </form>
      <hr>

      <div id="map-canvas" style="height:512px; width:100%; padding:0; margin:0">
      </div>

        <footer>&copy; 2014 <a href="http://mobile-web-messaging.net">Mobile &amp;
Web Messaging</a></footer>

      <!-- Scripts placed at the end of the document so the pages load faster -->
                    <script  src="http://ajax.googleapis.com/ajax/libs/jquery/1.9.0/
jquery.min.js"></script>
        <script src="https://maps.googleapis.com/maps/api/js?v=3.exp&sensor=false"></
script>
                  <script  src="https://cdnjs.cloudflare.com/ajax/libs/stomp.js/2.3.1/
stomp.min.js"></script>
      <script>
$(document).ready(function() {

// We will put all the JavaScript code in this block that is called
// when the document is ready

};
    </script>
  </body>
</html>
```

Create a Stomp Client with stomp.js

The STOMP client will be used for both consuming messages (from the device' location destination) and producing them (to the device's text destination).

We will declare the `client` variable to use it throughout our script.

```
$(document).ready(function() {

  var client; // keep a reference on the Stomp client that we will create

}
```

When the user click on the `Connect` button, the URL is retrieved from the `connect_url` input element and passed to the `connect` method. In this method, we will create the `client` and connect to the STOMP broker.

```
// handles the connect_form
$('#connect_form').submit(function() {
  var url = $("#connect_url").val();
```

```
    connect(url);
    return false;
  });
```

Connect to a STOMP Broker

In the `connect` method, we create the STOMP client by calling `Stomp.client(url)`. Once we have the `client` object, we call its `connect` method to connect to the STOMP broker. This method takes at least two arguments:

1. a set of headers containing additional metadata that the STOMP broker can use during the connection process. In our case, we have no such header so we will pass an empty JavaScript literal object `{}`.
2. a `connectedCallback` function that is called back when the client is successfully connected to the STOMP broker.

Example 3-2.

```
// Connection to the STOMP broker
// and subscription to the device's position destinations.
//
// the url paramater is the Web Socket URL of the STOMP broker
function connect(url) {

  // creates the callback that is called when the client
  // is successfully connected to the STOMP broker
  var connectedCallback =  function(frame) {
      ...
  };

  // create the STOMP client
  client = Stomp.client(url);
  // and connects to the STOMP broker
  client.connect({}, connectedCallback);
}
```

The `connectedCallback` is called when the client is successfully connected to the STOMP broker. At this stage, we can clean up the user interface by hiding the `Connect` button, showing the `Disconnect` button and the form to send text messages to the devices.

```
    var connectedCallback =  function(frame) {
      client.debug("connected to Stomp");
      // disable the connect button
      $("#connect_button").prop("disabled",true);
      // enable the disconnect button
```

```
    $("#disconnect_button").prop("disabled",false);
    // show the form to send text to the devices
    $("#text_form").show();

    // ...

  };
```

If we want to be notified when the connection is **unsuccesful**, we can pass an additional argument to the `connect` method which is a function that is called back if the connection is *not* successful.

Example 3-3.

```
client.connect({}, connectedCallback,
  function(frame) {
    // this function is executed if the connection to the STOMP broker failed.
});
```

Receive STOMP Messages

Once the client is connected successfully to the STOMP broker, it can subscribe to a destination using the `subscribe` method which takes two parameters:

1. the name of the destination
2. a function that is called back every time the broker delivers a message to the client.

Example 3-4.

```
client.subscribe(destination, function(message) {
  // this function is executed every time a message is consumed
});
```

The `message` parameter that is passed to the subscription callback corresponds to a STOMP message and has 3 properties:

- `command` - the command of the STOMP frame (when a message is receives, it will always be `MESSAGE`)
- `headers` - a JavaScript object containing all the frame headers. It can be empty if the message has no headers
- `body` - a string representing the message's payload. It can be `null` if the message has no payload.

Subscribe to a Wildcard Destination

This Web application is interested to receive the location of *any* devices that broadcasts it. This means that we must subscribe to the `/topic/device.XXX.location` for every device where XXX is the device identifier.

There are two different ways to achieve this. The first way is to know beforehands all the device IDs and subscribe to their topics one after the other. We can use the same subscription callback for all of them. However, that implies that the Web application must now have a way to know this list. For example, it could be a Web service that returns such a list.

The pseudo code for it would look like:

```
var listURL = "...";
var deviceIDs = fetch(listURL);
var callback = function(message) {
  // we use the same callback for every subscription
}
for (deviceID in deviceIDs) {
  var destination = "/topic/truck." + deviceID + ".location";
  client.subscribe(destination, callback);
}
```

But what happens if another device starts broadcasting its location *after* the Web application fetched the list of device IDs? The Web application will not subscribe to its topic and will never display it on the map. We would have to periodically fetch the list of device IDs and check whether there are new ones or if some devices have been removed.

Fortunately, the flexibility of STOMP protocol comes handy to manage this in a simpler fashion. STOMP defines very loosely the notion of destination:

> *A STOMP server is modelled as a set of destinations to which messages can be sent. The STOMP protocol treats destinations as opaque string and their syntax is server implementation specific. Additionally STOMP does not define what the delivery semantics of destinations should be. The delivery, or "message exchange", semantics of destinations can vary from server to server and even from destination to destination. This allows servers to be creative with the semantics that they can support with STOMP.*
>
> *—— STOMP 1.2 Protocol*

Until now, we have used *simple* destinations such as `/topic/device.2262EC25-E9FD-4578-BADE-4E113DE45934.location` or `/queue/device.2262EC25-E9FD-4578-BADE-4E113DE45934.text` that are straightforward to understand.

We will now use a feature from our STOMP broker, ActiveMQ, that allows to use *wildcard* destinations.

- `.` is used to separate names in a path

- * is used to match any name in a path
- > is used to recursively match any destination starting from this name

With our example using ActiveMQ, we can use this notation to subscribe to any device location topic by using the `/topic/device.*.location` wildcard destination (where * stands for *any device identifier*).

The subscription code becomes simpler:

```
// we use a wildcard destination to register to any
// destination that matches this pattern.
var destination = "/topic/device.*.location";
client.subscribe(destination, function(message) {
  // this function is called every time a message is received
});
```

> Since the semantic of STOMP destinations are specific to the STOMP broker, you have to check its documentation to know if they support wildcard destinations or similar concepts. If it does not, you have to revert to the first idea to fetch the list of devices and subscribe to each of the destination… or use another STOMP broker that supports this feature.

Since we no longer know *a priori* which device location we are receiving, we need a new way to determine which device has broadcast it. There are two pieces of information we can use. When a consumer receives a STOMP message, the message always have a `destination` header that corresponds to the *actual* destination that the client consumed consume from.

Since we are subscribing to the wildcard address `/topic/device.*.location`, the actual destination we consume from will be stored in the received message's headers in `message.headers["destination"]`. In my case, the value of this header would `/topic/device.2262EC25-E9FD-4578-BADE-4E113DE45934.location`. However, we would then have to parse this `destination` to extract the device ID from it and write brittle code for that.

If we look back at "Locations Message Representation" on page 8, the message representation for the location also contains the device ID in the `deviceID` property:

```
{
  "deviceID": "BBB",
  "lat": 48.8581,
  "lng": 2.2946,
  "ts": "2013-09-23T08:43Z"
}
```

The message is *self-contained* and defines all the interesting information that a consumer may need. When we receive such a location message, we know which device is sending it by simply looking at the `deviceID` property from the JSON object created from the message body.

```
var destination = "/topic/device.*.location";
client.subscribe(destination, function(message) {
  // this function is called every time a message is received
  // create an object from the JSON string contained in the message body
  var payload = JSON.parse(message.body);

  var deviceID = payload.deviceID;

  //...
});
```

When we receive the position of a device, the last step we need to make is to display its position on a map. We will wrap this code in a `show` method that is called from the subscription callback with the device identifier, its latitute and longitude.

The whole code to connect to the STOMP broker and subscribe to the wildcard destination is shown below.

```
// Connection to the STOMP broker
// and subscription to the device's position destinations.
//
// the url paramater is the Web Socket URL of the STOMP broker
function connect(url) {

  // creates the callback that is called when the client
  // is successfully connected to the STOMP broker
  var connectedCallback =  function(frame) {
    client.debug("connected to Stomp");
    // disable the connect button
    $("#connect_button").prop("disabled",true);
    // enable the disconnect button
    $("#disconnect_button").prop("disabled",false);
    // show the form to send text to the devices
    $("#text_form").show();

     // once the client is connected, subscribe to the device's location destina
tions.

    // we use a wildcard destination to register to any
    // destination that matches this pattern.
    var destination = "/topic/device.*.location";
    client.subscribe(destination, function(message) {
      // this function is called every time a message is received
      // create an object from the JSON string contained in the message body
      var payload = JSON.parse(message.body);

      var deviceID = payload.deviceID;
```

```
      if (!$("#deviceID option[value='" + deviceID + "']").length) {
        // if the device ID is not already in the list of devices we can send
orders to, we add it.
        $('#deviceID').append($('<option>', {value:deviceID}).text(deviceID));
      }
      // show the device location on the map
      show(deviceID, payload.lat, payload.lng);
    });
  };

  // create the STOMP client
  client = Stomp.client(url);
  // and connects to the STOMP broker
  client.connect({}, connectedCallback);
}
```

Draw the Device Locations on a Map

The Web application is now receiving the GPS coordinates of any devices that send them. We could just display them as text like we did for the iOS application in "Display the Device Position" on page 28 but we can make it prettier by drawing them on a map instead by using Google Maps API.

In Example 3-1 template, we already added the scripts to use Google Maps API. We now need to create the map and initialize it.

```
$(document).ready(function() {

  // Google map and the trackers to follow the trucks
  var map, trackers = {};

  function initialize() {
    var mapOptions = {
      zoom: 2,
      center: new google.maps.LatLng(30,0),
      mapTypeId: google.maps.MapTypeId.ROADMAP
    };
    map = new google.maps.Map($("#map-canvas").get(0), mapOptions);
  }

  // initialize the Google map.
  google.maps.event.addDomListener(window, 'load', initialize);
```

With this initialization code, the map will be drawn in the `map_canvas div` element and we can reference it using the `map` variable.

The `trackers` variable is a map whose key are the device identifiers and the values is a tracker with the latest location of the device on the map.

We have called a `show()` method in the subscription handler. We can now implement it now to display the device on the map using its coordinates.

```
// show the device at the given latitude and longitude
function show(deviceID, lat, lng) {
  var position = new google.maps.LatLng(lat, lng);
  // lazy instantiation of the map
  if (!map) {
    create_map(position);
  }
  if (trackers[deviceID]) {
    // the tracker is known, we just need to update its position
    trackers[deviceID].marker.setPosition(position);
  } else {
    // there is no tracker for this device yet, let's create it
    var marker = new google.maps.Marker({
      position: position,
      map: map,
      title: deviceID + " is here"});
    var infowindow = new google.maps.InfoWindow({
      content: "Device " + deviceID
    });
    var tracker = {
      marker: marker
    };
    // add it to the trackers
    trackers[deviceID] = tracker;
    google.maps.event.addListener(marker, 'click', function() {
      infowindow.open(map, marker);
    });
  }
}
```

If we open now this `locations.html` file in a Web browser, we will see a map of the whole world displayed.

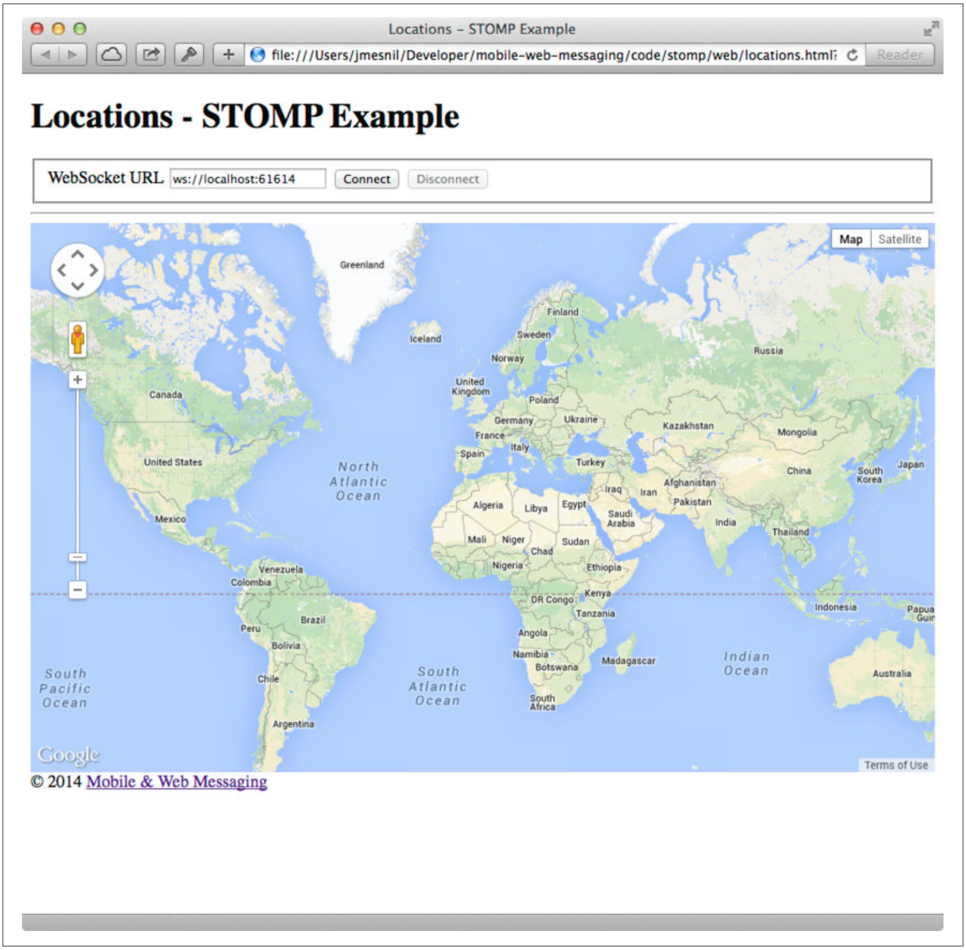


Figure 3-2. The Locations Web application.

If we click on the `Connect` button, markers will appear on the map for each device that broadcasts its coordinates.

In my case, I am using the `iOS simulator` to run the mobile application developed in the previous chapter and use its `Location` tool to simulate a freeway drive (as explained in "Simulate a Location with iOS Simulator" on page 36).

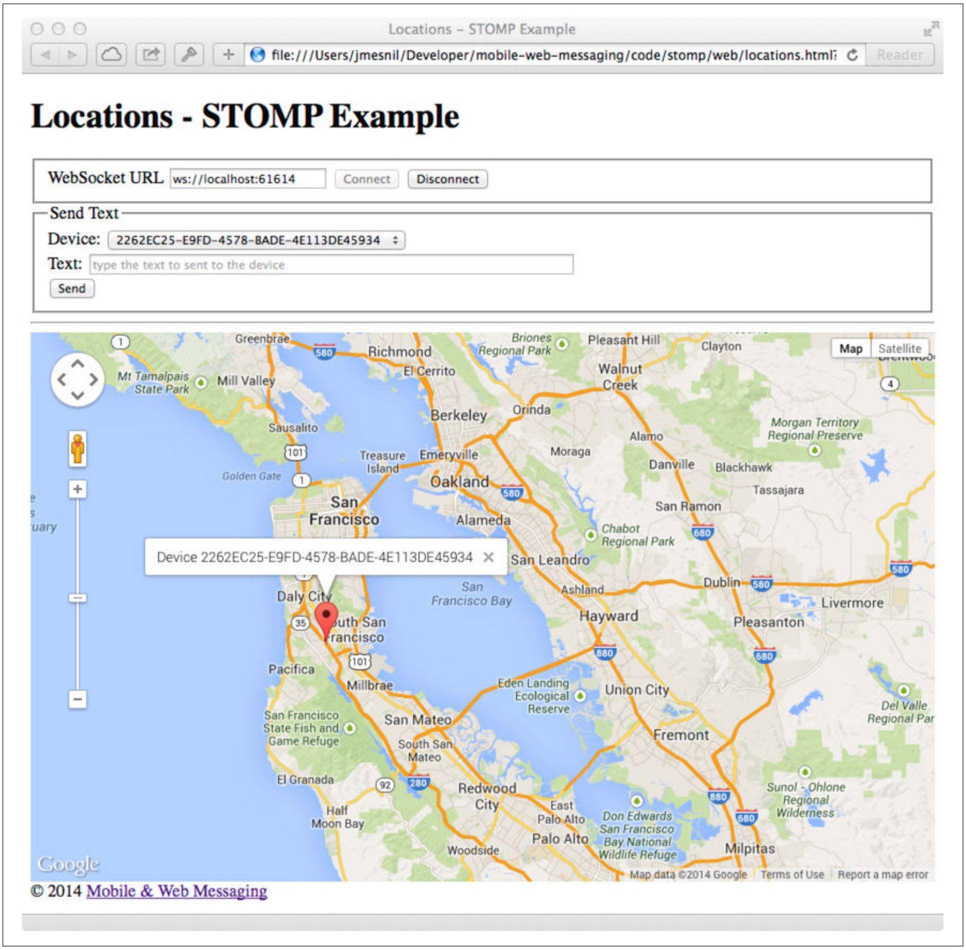


Figure 3-3. Simulate a freeway drive.

The position of the device is updated every time the Web application receives a STOMP message from the device's position destination and we see it move on the map.

At this stage, the Web application receives STOMP messages to display the position of the devices. We now need to write the code to send texts to the devices.

Send STOMP Messages

The STOMP client can send messages to the broker using its `send` method which takes three parameters:

- `destination` - the name of the destination

- `headers` - a JavaScript object containing any additional headers
- `body` - a string corresponding to the message payload.

Both `headers` and `body` are optional and can be omitted. However if you want to set the message body, you must also specify the headers (using an empty JavaScript literal if you have no header to set).

```
client.send(destination, {}, body);
```

As we described in "Locations Messaging Models" on page 7, we use a queue to send orders to a given device and the destination for this is named `/queue/device.XXX.text`

The text is sent in the STOMP message body as a plain text string.

```
Hello, Where are you?
```

We must respect this message format as it is the format expected by the iOS application to handle the texts and display them (we wrote this code in "Subscribe to a STOMP Destination" on page 54).

We added a HTML `<form>` element with the id `text_form` to send a text message. The device identifier is taken from the selected option in the `<select>` element identified by `deviceID`. The text itself is taken from the `<input>` element identified by `text`.

Once we know the `deviceID` and the `order`, we have all we need to send an order to this device. The destination for the order will be built using the `device`.

Piecing everything together, the code to send a STOMP message looks like:

```
// Send a text to a device
$('#text_form').submit(function() {
  var deviceID = $("#deviceID").val();
  var text = $("#text").val();

  // use the device's queue orders as the destination
  var destination = "/queue/device." + deviceID + ".text";
  // text is sent as a plain text string
  client.send(destination, {}, text);
  // reset the text input field
  $("#text").val("");
  return false;
});
```

If we reload the `locations.html` file after adding this code, we can now send any text message to a device by selecting it in the list in the `Send Text` form.

Let's type a text such as `Hello, Where are you?` and click on the `Send` button.

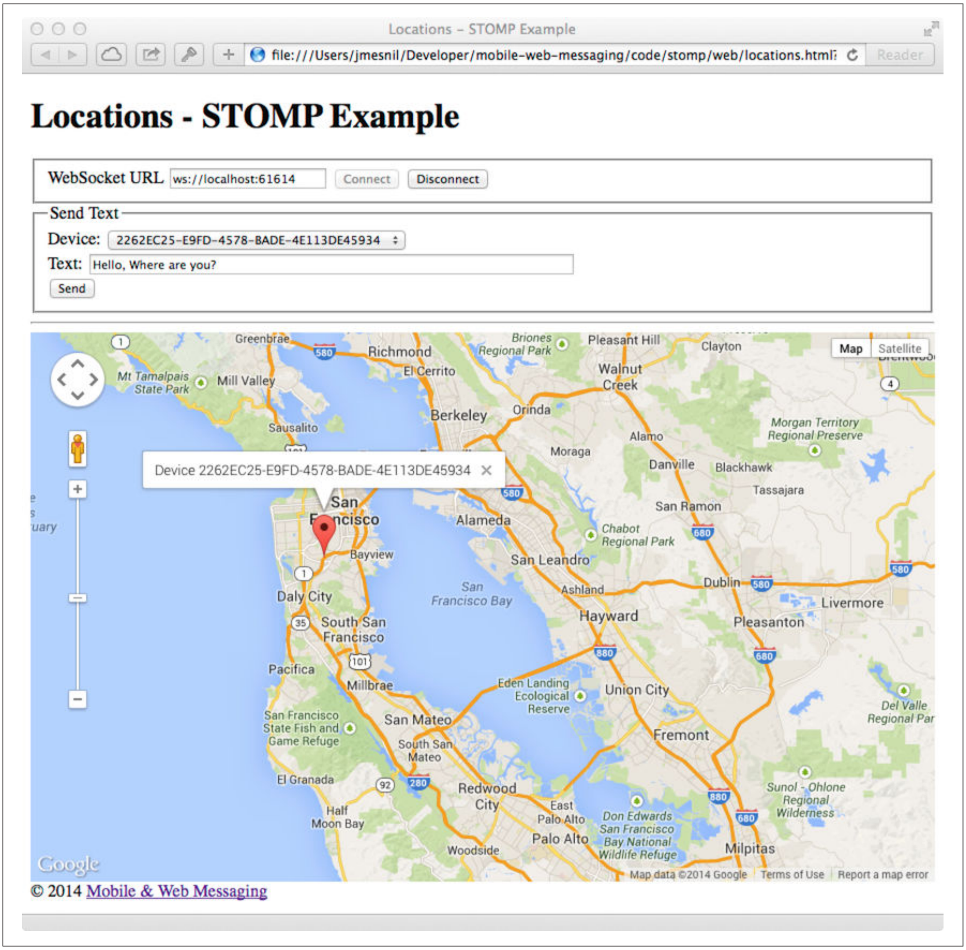


Figure 3-4. Send a text message to a device.

The message is sent when you click on the `Send` button. Since the `Locations` iOS application is subscribed to this destination, it will receive the message and display it in its table.

Figure 3-5. The Locations iOS application received the text.

Disconnect from the STOMP Broker

The `locations.html` connects to the STOMP broker when the user clicks on the `Connect` button. The user can then disconnect from the broker by clicking on the `Disconnect` button.

To disconnect from the STOMP broker, we call the `disconnect` method on the `client` and pass a callback that is called after the disconnection is successful.

In this callback, we clean up the trackers that are displayed on the map so that nothing is shown after the user is disconnected. We also revert the user interface by hiding the `Disconnect` button and the text form and showing the `Connect` button.

```
function disconnect() {
  // disconnect from the broker
  client.disconnect(function() {
     // once we are successfully disconnected, clear out all the trackers from
the map
    for (var tracker in trackers) {
      trackers[tracker].marker.setMap(null);
    }
    trackers = {};
  });
  $("#deviceID").empty();
  $("#connect_button").prop("disabled",false);
  $("#disconnect_button").prop("disabled",true);
  $("#text_form").hide();
}
```

Finally, we need to call this `disconnect` method when the `Disconnect` button is clicked.

```
$('#disconnect_button').click(function() {
  disconnect();
  return false;
});
```

Summary

In this chapter, we learn to use `stomp.js` to send and receive STOMP messages from a Web application.

Whether you are using `StompKit` in an iOS application or `stomp.js` in a Web application, the steps are always the same.

To send a message, the application must:

1. connect to the STOMP broker
2. send the message to the destination

To consume a message, the application must

1. connect to the STOMP broker

2. subscribe to the destination and pass a callback that is called every time a message is received.

At the end of this chapter, we have a very simple application that works. If you have access to several iPhone devices, you can see that the Web application will display the location of all the devices running the iOS application.

In the next chapter, we will learn about more advanced features of STOMP. We did not present them as they were not required to write this simple application. However, it is likely that you may need some of these features if your applications are more complex than this simple example.

CHAPTER 4

Advanced STOMP

In the two previous chapters, we have used STOMP to send and receive messages from a native iOS application and a Web application. STOMP provides additional features that we did not use to write these applications. In this chapter, we will make a tour of all the features provided by STOMP.

This chapter covers the latest version of the protocol when this book was written: STOMP 1.2 that was released on 2012, October 22nd.

As we present these features, we will show how to use them from either `StompKit` or `stomp.js`. The API may vary depending on the platform and language but the concept remains the same. If you have ever to use STOMP from another language or platform, you will have to adapt to the library API but the underlying concept will still apply.

Clients and brokers can use these features by sending additional frames (defined in the protocol) or by using message headers. The STOMP protocol defines frames to provide transactions, a combination of frames and headers for message acknowledgement and headers for hearbeat negotiation.

In this chapter, we will describe the features provided by the STOMP protocol that client and broker must support to be compliant.

STOMP is also extensible and clients and brokers can support additional features by using headers not defined in the protocol. We will describe such additional features in the next chapter.

In any case, the features (defined in the protocol or supported only by some brokers) rely on the structure of STOMP frames.

Frame Representation

All data exchanged between a client and a broker is done using STOMP frames. STOMP is modelled on HTTP and its frames follows a similar structure. Each frame is composed of 3 elements:

- a *command*
- an (optional) set of *headers*
- an (optional) *payload*

Example 4-1. STOMP Frame Structure

```
COMMAND❶
header1:value1❷
header2:value2
❸
payload^@❹
```

❶ A frame starts with a command string followed by an end-of-line (EOL)

❷ Header entries followed the format `<key>:<value>` and is ended by EOL

❸ A blank line separates the set of headers from the payload

❹ A frame is ended by a NULL octet (represented by `^@` in ASCII)

STOMP is based on text (using UTF-8 for its default encoding) but it can also transmit binary data in its payload by specifying an alternative encoding.

In the two previous chapters, we were sending JSON data in the messages. We were setting the string representation of the JSON structure in the message body and setting the `content-type` header to `application/json; charset=utf-8`.

STOMP uses frames not only to send messages (with the `SEND` command) and receive them (with the `MESSAGE` command) but also for all its operation comands (such as `CONNECT`, `DISCONNECT`, `SUBSCRIBE`, etc.).

Headers

STOMP defines only a handful of headers for its different frames.

It is also possible to add other headers when sending a frame as long as it does not collide with the headers already specified in the STOMP protocol.

An application may use headers instead of the message's payload to transmit data. The fundamental difference between headers and payload is that headers can be read (and modified) by the STOMP brokers. Payload is treated a a black box and the broker never reads or modifies it.

In practice, headers are most often used to specify additional features or constraints to the message processing.

Authentication

In the two previous chapters, the STOMP clients are connected to the broker *anonymously*. We do not pass any user credentials that the broker could use to authenticate the user and check whether he or she could send and/or receive messages.

If the STOMP broker is configured to accept secured connections, the client needs to pass `login` and `passcode` parameters when it connects to the STOMP broker.

> **ActiveMQ Authentication**
>
> By default, ActiveMQ accepts anonymous connections. To change its security settings to authenticate users and grant them restricted priviledges (so that they can only receive messages from example), consult its security documentation page.

StompKit Example

To use an authenticated connection with `StompKit`, you need to pass the login and passcode parameters to the headers dictionary when calling the `connectWithHeaders:completionHandler` method on the `STOMPClient`. `StompKit` defines the `kHeaderLogin` and `kHeaderPasscode` constants to represent the headers keys.

```
- (void)connect
{
    NSLog(@"Connecting...");

    NSString *login = @"...";
    NSString *passcode = @"...";
    [self.client connectWithHeaders:@{ @"client-id": self.deviceID,
                                       kHeaderLogin: login,
                                       kHeaderPasscode: passcode}
                          completionHandler:^(STOMPFrame *connectedFrame, NSError *error) {
                          ...
}
```

stomp.js Example

A `stomp.js` client can be authenticated by adding the `login` and `passcode` headers to the first parameter of its `connect` method.

```
function connect(url) {
  // create the STOMP client
  client = Stomp.client(url);

  ...

  var connectedCallback =  function(frame) {
    ...
  };

  var login = ...;
  var passcode = ...;

  client.connect({
      login: login,
      passcode: passcode,
    }, connectedCallback);
}
```

Message Acknowledgement

Message acknowledgement is a feature available to STOMP *consumers*.

When the broker delivers a message to a consumer, there is a transfer of responsibility between the broker and the consumer to determine which is the *owner* of the message. The consumer becomes responsible of the message by *acknowledging* the message.

By default, the STOMP broker will consider that the consumer automatically acknowledge the message when it is delivered to the consumer.

However there are cases where the consumer may prefer to acknowledge explicity the message. It leaves a window of opportunity to determine whether it can handle the message or not. For example, the client needs to write the message payload in a data store. There may be issues with opening a connection to the data store and the client could chose to acknowledge the message only after having successfully written its body to the data store. In case of failure, it will instead *nack* the message (explicitly refuse to take ownership of it). When the STOMP broker is informed of this negatively acknowledgement, it may then decide to deliver the message to another consumer subscribed to the destination or try again some time later depending on its configuration.

The consumer specifies its type of acknowledgement when it subscribes to a destination. STOMP supports 3 types of acknowledgements:

- `auto` (by default)
- `client`
- `client-individual`

If the client does not specify any type of acknowledgement or use `default`, it does not need to send any acknowledgement, the STOMP broker will consider the message acknowledged as soon as it is delivered to the client.

If `client` or `client-individual` is used, the consumer must send acknowledgements to the server with the `message-id` of the message that is acknowledged. The difference between `client` and `client-individual` is that `client` will acknowledged the message *and all other messages delivered to the consumer before*. Using `client-individual` will only acknowledge the message and no other messages. The consumer acknowledge a message by sending a `ACK` frame to the STOMP broker.

If `client` and `client-individual` is used, the consumer may explicitly refuse to handle the message by sending a `NACK` frame, a negative acknowledgement.

StompKit Example

The message acknowledgement is specified when the `STOMPClient` subscribes to a destination by calling its `subscribeTo:headers:messageHandler:` method. To specify a `client` or `client-individual` acknowledgement, you must set a `ack` header. `StompKit.h` defines constants to represent the header name, `kHeaderAck` and its accepted values, `kAckAuto`, `kAckClient`, and `kAckClientIndividual`.

The `STOMPMessage` parameter of the `messageHandler` has two methods `ack` and `nack` to respectively acknowledge or nack the message.

If the `ack` header is not set or if it set to `auto`, message acknowledgement is performed by the broker and calling the `STOMPMessage`'s `ack` and `nack` methods will do nothing.

```
// use client acknowledgement
[self.client subscribeTo:destination
                 headers:@{kHeaderAck: kAckClient}
          messageHandler:^(STOMPMessage *message) {
              // process the message
              // ...

              // acknowledge it
              [message ack];
              // or nack it with
              // [message nack]
          }];
```

stomp.js Example

The client can specify the type of acknowledgement by passing a dictionary with the ack header as the last parameter of its subscribe message.

The message parameter of the subscribe callback has two methods, ack and nack to respectively acknowledge or nack the message. If the acknowledgement type is auto (or if it is not specified at all), these ack and nack methods will do nothing.

```
client.subscribe(destination,
  function(message) {
    // process the message
    ...

    // acknowledge it
    message.ack();
    // or you can nack it by calling message.nack() instead.
  },
  {"ack": "client"}
);
```

There are many use cases where it is not necessary to use explicit acknowledgement.

For example, in the locations.html Web application, we do not need to acknowledge every message that we receive from the devices with their GPS position. At worst, there may be a problem to display the position but we know there are other messages that will come later to update the device's position.

Besides, acknowledging every message would have a performance cost. Sending the acknowledgement back to the broker would involve an additional network trip for every message.

The Locations iOS application is also consuming messages from the device's text queue. These messages may be more important to acknowledge explicitly. We could enhance the application by letting the user confirm that it has read the message's text and the message would be acknowledged after this confirmation only.

We could also let the user reject it by negatively acknowledged the message. In that case, these *nacked* messages would be handled back by the STOMP broker. Depending on the broker you use, it may provide additional features to handle these messages. A common feature is to use a "dead letter queue" where messages that are nacked multiple times from a destination are sent to a dead letter queue. An administrator can then inspect this dead letter queue to determine what to do with these messages. For example, it can send them to another device, send alerts about the device that rejected them, etc.

Transactions

STOMP has basic support for transactions.

Sending a message or acknowledging the consumption of messages can be performed inside a transaction. This means that the messages and acknowledgements are not processed by the broker when it receives the corresponding frames but when the transaction completes. If the client does not complete the transaction or aborts it, the broker will not process the frames that it received inside the transaction and will just discard them. Transactions ensure that messages and acknowledgement processing is *atomic*. *All* transacted messages and acknowledgements will be processed by the broker when the transaction is committed or *none* will be if the transaction is aborted.

A transaction is started by the client by sending a `BEGIN` frame to the broker. This frame must have a `transaction` header whose value is a transaction identifier that must be unique within a STOMP connection.

Sending a message can then be part of this transaction by adding a `transaction` header to its `SEND` frames set to the same transaction identifier. If a consumer is subscribed to a STOMP destination with `client` or `client-individual` acknowledgement modes, it can also make the message acknowledgement (or nack) inside a transaction by setting the `transaction` header on the `ACK` (or `NACK`) frame.

> By default, STOMP consumers use `auto` acknowledgement. In that case, the message acknowledgement is performed automatically by the STOMP broker when the message is delivered to the client and the acknowledgement can **not** be put inside a transaction.

To complete this active transaction and allows the broker to process it, the client must send a `COMMIT` frame with the same `transaction` header than in the corresponding `BEGIN` frame that started the transaction. To abort (or roll back) a transaction and discard any messages or acknowledgements sent inside it, the client must send instead an `ABORT` frame with this `transaction` header.

> Beginning a transaction is not sufficient to send subsequent messages inside it. If a transaction is begun, the message to send must have its `transaction` header set to the transaction identifier. Otherwise, the STOMP broker will not consider that the message is part of the transaction and will process it when it receives it instead of waiting for the transaction completion. If the client decides to abort the transaction, the message will have already been processed by the broker and will not be discarded.

STOMP does not provide a transaction timeout that would abort the transaction if it is not completed in a timely fashion. The transaction lifecycle (controlled by `BEGIN` and `COMMIT`/`ABORT` frames) is the responsibility of the client. However the broker will automatically abort any active transaction if the client send a `DISCONNECT` frame or if the underlying TCP connection fails.

StompKit Example

The `STOMPClient` can begin a transaction by calling its `begin:` method and passing a `NSString` that will be used to identify the transaction. Alternatively, you can call its `begin` method (without any parameter) and a transaction identifier will be automatically generated. Both `begin:` and `begin` methods returns a `STOMPTransaction` object. This object as a `identifier` property that contains the transaction identifier.

Sending a message, acknowledging, or nacking it can then be part of a transaction by adding a `transaction` header set to the transaction identifier (`StompKit.h` defines a `kHeaderTransaction` to represent this `transaction` header).

Finally the `STOMPTransaction` object has two methods `commit` and `abort` to respectively commit or rollback the transaction.

```
// begin a transaction
STOMPTransaction *transaction = [self.client begin];
// or STOMPTransaction *transaction = [self.client begin:mytxid];
NSLog(@"started transaction %@", transaction.identifier);

// send message inside a transaction
[self.client sendTo:destination
            headers:@{kHeaderTransaction: transaction.identifier}
               body:body];

// acknowledge a message inside a transaction
[message ack:@{kHeaderTransaction: transaction.identifier}];
// or nack a message inside a transaction with
// [message nack:@{kHeaderTransaction: transaction.identifier}];

// commit the transaction
[transaction commit];
// or abort it
[transaction abort];
```

stomp.js Example

The API is very similar to `StompKit`. The `client` object has a `begin` method that can takes a parameter corresponding to the transaction identifier. If there is no parameter, an identifier is automatically generated. The `begin` method returns a `transaction` object that has an `id` property corresponding to the transaction identifier.

Sending a message, acknowledging, or nacking it can be part of a transaction by passing a `transaction` header set to the transaction identifier to these methods.

Finally, committing or aborting a transaction is performed by calling respectively the `commit` and `abort` method on the `transaction` object.

```
// begin a transaction
var tx = client.begin();
// or var tx = client.begin(mytxid);
console.log("started transaction " + tx.id);

// send a message inside a transaction
client.send(destination, {transaction: tx.id}, body);

// acknowledge a message inside a transaction
var subscription = client.subscribe(destination,
    function(message) {
      // do something with the message
      ...
      // and acknowledge it inside the transaction
      message.ack({ transaction: tx.id});
      // or nack it inside the transaction
      // message.nack({ transaction: tx.id});
    },
    {ack: 'client'}
  );

// commit the transaction
tx.commit();
// or abort it
tx.abort();
```

Error Handling

Until now, we have used STOMP in a perfect world where no unexpected problems happened. Realistically, problems will occur. On mobile devices, network will be lost and the connection to the STOMP broker will be broken.

STOMP provides basic support to handle errors. The STOMP broker can inform the client that an error occurs by sending a `ERROR` frame to the client. This frame may contain a `message` header that contains a short description of the error. Most STOMP brokers deliver `ERROR` frames with a message payload containing more detailed information on the error.

STOMP specifies that after delivering an `ERROR` frame to the client, the broker must close the connection. This means that STOMP is not resilient to error. If a single error occurs on the server, the broker will close the connection to the client. In addition, there is no guarantee that the client will be able to receive the `ERROR` frame before the connection is closed.

In practice, this implies that to be able to handle any errors in the client, we should:

1. Handle `ERRORS` frames coming from the broker
2. Handle unexpected connection closed events

StompKit Example

We will modify the `Locations` iOS to handle errors and automatically reconnect to the STOMP broker after a delay.

The `STOMPClient` has a `errorHandler` property that is called if the client encounters any error. Error can come from the STOMP protocol (when the broker deliver an `ERROR` frame) or from the underlying network connection (e.g. if the network is lost or if the broker closes the connection before any `ERROR` frame is delivered).

The `errorHandler` property is a block with a standard `NSError` parameter. If the error is coming from the STOMP broker, the corresponding `STOMPFrame` is stored in the error's `userInfo` dictionary with the key `frame`.

There are two places where we must handle reconnection:

1. during the initial connection (for example if the broker is not up during the initial reconnect, we will continue to attempt to connect to it until it is up again).
2. when we receive an error from the `STOMPClient`'s `errorHandler` property.

In both case, we will attempt to reconnect by disconnecting first (in the eventual case where the client is already connected), waiting for 10 seconds and connecting again. This code can be encapsulated in a `reconnect:` method of the `MWMViewController` implementation.

```
#pragma mark - Messaging

- (void)reconnect:(NSError *)error {
    NSLog(@"got error %@", error);
    STOMPFrame *frame = error.userInfo[@"frame"];
    if (frame) {
        NSString *message = frame.headers[@"message"];
        NSLog(@"error from the STOMP protocol: %@", message);
    }
    [self disconnect];
    sleep(10);
    NSLog(@"Reconnecting...");
    [self connect];
}
```

We then must call this `reconnect:` method from the client's `errorHandler` property and the `completionHandler` block of its `connectWithHeaders:completionHandler:` method (both called from the `MWMViewController` `connect` method).

```
- (void)connect
{
    NSLog(@"Connecting...");
    __weak typeof(self) weakSelf = self;
    self.client.errorHandler = ^(NSError* error) {
        [weakSelf reconnect:error];
    };
    [self.client connectWithHeaders:@{ @"client-id": self.deviceID }
                  completionHandler:^(STOMPFrame *connectedFrame, NSError *er
ror) {
                      if (error) {
                          NSLog(@"Error during connection: %@", error);
                          [weakSelf reconnect:error];
                      } else {
                            // we are connected to the STOMP broker without an
error
                          NSLog(@"Connected");
                          [self subscribe];
                      }
                  }];
    // when the method returns, we can not assume that the client is connected
}
```

To avoid a retain/release cycle between `self` and the blocks, we need to create a *weak* reference of `self` and uses it from the blocks.

stomp.js Example

A `stomp.js client` can specify an `errorCallback` handler as the last parameter of its `connect` method. This handler will be called whenever the client encounters an error (whether coming from the STOMP protocol or the underlying network connection).

We can modify the `locations.html` Web application to automatically reconnect when an error occurs.

We will create a `reconnect` method which disconnects the `stomp.js` client if it is connected and calls `connect` again with the Web socket URL.

```
function reconnect(url) {
  if (client.connected) {
    console.log("disconnecting...");
    disconnect()
  }
  console.log("reconnecting");
  connect(url);
}
```

We then need to create an `errorCallback` handler that calls this `reconnect` method and pass it as the last parameter of the `client`'s `connect` method.

```
function connect(url) {
  var connectedCallback =  function(frame) {
    ...
  };
  var errorCallback = function(error) {
    client.debug("received error: " + error);
    reconnect(url);
  };

  // create the STOMP client
  client = Stomp.client(url);
  // and connects to the STOMP broker
  client.connect({}, connectedCallback, errorCallback);
}
```

> A Web socket can be opened only once. If a problem occurs and the socket is closed, it can no longer be used. This implies that we can not just call the `client`'s `connect` method again as its Web socket is no longer usable. Instead we must create a *new* `client` which will open a new Web socket.

Whenever an error occurs (for example if the network connection is broken or the STOMP broker becomes temporarily unavailable), the `errorCallback` will be called and the client will try to reconnect.

Depending on your application, you may instead decide to report the error to the user and let him know that the client is no longer able to exchange messages with the broker.

Receipts

STOMP provides a basic mechanism to let a client know when the broker has received and processed its frames. This can be used with any STOMP frames. For example a client can be notified when the broker receives a message that a producer send (using a `SEND` frame) or when a consumer subscribes to a destination (with a `SUBSCRIBE` frame).

To use this mechanism, the frame that is sent to the broker must include a `receipt` header with any arbitrary value. After the broker has processed the frame, it will deliver a `RECEIPT` frame to the client with a `receipt-id` header corresponding to the `receipt` header in the frame that has been processed.

As an example, we can use receipt to confirm that a consumer has been subscribed successfully to a destination. If the broker can not successfully create the subscription, it will send back an ERROR frame to the client and close the connection. In practice, this means that a successful subscription is *silent*, the client is not informed of its success. We can use receipts to have an explicit confirmation of the subscription by adding a receipt header when the client subscribes to a destination. The broker must then deliver a RECEIPT frame that will inform the client that the broker has processed its subscription successfully. If the subscription is not successful, the broker will deliver a ERROR frame that has a receipt-id header corresponding to the RECEIPT's receipt header to be able to correlate the error.

Another use case for receipts is to make sending a message *synchronous*. The client would send a message with a receipt header and blocks until it receives the corresponding RECEIPT frame. This would add reliability (the client is sure that the broker has processed its message) at the cost of performance (the client can do nothing until the RECEIPT frame is received).

StompKit Example

A STOMPClient has a receiptHandler property that can be set to handle receipts. The receiptHandler is a block that take a STOMPFrame corresponding to a RECEIPT frame.

Let's add a receipt for the device text queue's subscription to the Locations iOS application.

In its subscribe method, we will build a receipt identifier for the subscription receipt and set the client's receiptHandler. In this block, we just check if the headers of the frame parameter contains a kHeaderReceiptID key whose value match the receipt identifier.

To receive such a receipt from the subscription, we need to add a kHeaderReceipt header to the subscribeTo:headers:messageHandler: and set it to the receipt identifier.

```
- (void)subscribe
{
    // susbscribes to the device text queue:
         NSString  *destination  =  [NSString  stringWithFormat:@"/queue/device.
%@.text", self.deviceID];

    // build a receipt identifier
     NSString *receipt = [NSString stringWithFormat:@"%@-%@", self.deviceID, des
tination];
     // set the client's receiptHandler to handle any receipt delivered by the
broker
    self.client.receiptHandler = ^(STOMPFrame *frame) {
        NSString *receiptID = [frame.headers objectForKey:kHeaderReceiptID];
        if ([receiptID isEqualToString:receipt]) {
            NSLog(@"Susbscribed to %@", destination);
        }
```

```
    };
    NSLog(@"Subscribing to %@", destination);
    // pass a receipt header to be informed of the subscription processing
    subscription = [self.client subscribeTo:destination
                                    headers:@{kHeaderReceipt: receipt}
                             messageHandler:^(STOMPMessage *message) {
        ...
    }];
}
```

If the Locations iOS application is run with this code, we see the log that confirms the client is successfully subscribed to the destination.

```
2014-04-21 17:30:39.205 Locations[2384:3903] Subscribing to /queue/device.
2262EC25-E9FD-4578-BADE-4E113DE45934.text
2014-04-21 17:30:39.208 Locations[2384:3903] Subscribed to /queue/device.
2262EC25-E9FD-4578-BADE-4E113DE45934.text
```

Note that the client's `receiptHandler` will receive any receipt delivered to the client. If you expect receipts from different STOMP frames, the client will have to handle all of them from a single `receiptHandler` block.

stomp.js Example

The `stomp.js` client has a `onreceipt` handler that can be set to receive receipts. It takes a function with a single `frame` parameter corresponding to a `RECEIPT` frame.

To receive a receipt for a subscription, we just need to add a `receipt` header to the headers passed as the last parameter of the `subscribe` method.

```
var destination = "/topic/device.*.location";

var receipt = "receipt_" + destination;
client.onreceipt = function(frame) {
  var receiptID = frame.headers['receipt-id'];
  if (receipt === receiptID) {
    console.log("subscribed to " + destination);
  }
}
client.subscribe(destination, function(message) {
  ...
}, {receipt: receipt});
```

If we reload the `locations.html` web application, the browser console will display a log when the receipt confirming the subscription is handled by the client.

All `stomp.js` method that corresponds to STOMP frames accept a `headers` parameter that can be used to receive `RECEIPT` frames from the broker.

Heart-beating

STOMP offers a mechanism to test the healthiness of a network connection between a STOMP client and a broker using heart-beating. In the absence of messages exchanged between the STOMP client and the broker, both can send *heartbeat* periodically to inform the other that is alive but has no activity.

If heart-beating is enabled, this allows the client and the broker to be informed in case of network failures and act accordingly (the client could try to reconnect to the broker, the broker could clean up the resources created on behalf of the client, etc.).

Heart-beating is negotiated between the client and the broker when the client connects to the broker (by sending a `CONNECT` frame) and the broker accepts the connection (by sending a `CONNECTED` frame to the client). Both frames accepts a `heart-beat` header whose value contains two integers separated by a comma.

```
CONNECT
heart-beat:<cx>,<cy>

CONNECTED:
heart-beat:<sx>,<sy>
```

- `<cx>` is the smallest number of milliseconds between heartbeats that the client guarantees. If it is set to `0`, the client will not send any heartbeat at all.
- `<cy>` is the desired number of milliseconds between heartbeats coming from the broker. If it is set to `0`, the client is does not want to receive any heartbeat.
- `<sx>` is the smallest number of milliseconds between heartbeats that the broker guarantees. If it is set to `0`, the broker will not send any heartbeat at all.
- `<sy>` is the desired number of milliseconds between heartbeats coming from the client. If it is set to `0`, the broker does not want to receive any heartbeat.

When the client is successfully connected to the STOMP broker (it has received the `CONNECTED` frame), it must determine the frequency of the heartbeats to send to the broker and the frequency of heartbeats coming from the broker.

The values that are used to determine the frequency of heartbeats sent to broker are `<cx>` and `<sy>`. If `<cx>` is `0` (the client will send no heartbeat) or if `<sy>` is `0` (the broker does not expect any client heartbeats), there will be no client heartbeating at all. This means that the broker will not be able to test the healthiness of the client connection. Otherwise, both server and broker expect to exchange client heartbeats. The frequency is then determined by the maximum value between the value guaranted by the client, `<cx>`, and the value desired by the broker, `<sy>`. In other words, the client must send heartbeats at least `MAX(cx,sy)` milliseconds.

For the heartbeats sent by the broker to the client, the algorithm is the same but using the <cy> and <sx> values.

Let's take a simple example to illustrate the algorithm. A STOMP client connect to the broker with the heart-beat header set to 0,60000 (the client will not send any heartbeats but desires to receive the broker's ones every minute).

```
CONNECT
heart-beat:0,60000
....
```

The broker accepts the connection and replies with a CONNECTED frame that contains a heart-beat header set to 20000,30000 (the broker guarantees to send heartbeat every 20 seconds and desires to receive the client's ones every 30 seconds).

```
CONNECTED
heart-beat:20000,30000
....
```

Since the client specified that it will send no heartbeat (0 as the first value of the CONNECT's heart-beat header), client heartbeating is disabled and the broker should not expect any (although it *desired* to receive them every 20 seconds).

The client desired to receive the broker heartbeat every minute (60000 as the second value of the CONNECT's heart-beat header). The broker replied that it can guarantee to send them at least every 30 seconds (second value of the CONNECTED's heart-beat header). In that case, the broker and the client agrees that the broker must send heartbeats every minute (the maximum between 1 minute and 30 seoncds). In other words, the broker *could* send heartbeats every 30 seconds (as it guaranteed in the CONNECTED frame) but the client will only check them every minute.

ActiveMQ Heart-beating

ActiveMQ supports heart-beating and mirrors the heartbeat values sent by the STOMP client. This lets the STOMP client be the sole decider of the heartbeating values.

This means that if a client connects with a heart-beat header set to <cx>,<sy>, the broker will accept the connection with a heart-beat header set to <sy>,<cx>.

The client guaranted to send hearbeat every <cx> milliseconds, so the broker replied that it desires to receive them at this rate. The client desired to receive heartbeat every <sy> milliseconds, so the broker replied that it guarantees to send its heartbeat at this rate.

The client should set its heart-beat header according to its usage. For example if an application is sending messages at a regular rate (such as the Locations iOS application), there is no need to send heartbeats to the broker at a similar (or faster) rate.

The messages sent are proof enough of the client activity. Likewise if a client expects to receive messages at a regular rate (such as the `Locations` web application), there is no need to require the broker to send frequent heartbeats.

However if the application does not send messages often (the `Locations` web application will seldom sent text messages to the device' text topics), it probably should send heartbeats more frequently to inform the broker of its healthiness. Likewise, if the application does not receive messages often (such as the `Locations` iOS application), it should desire more frequent heartbeats from the broker.

StompKit Example

A `STOMPClient` supports heart-beating by passing the `heart-beat` header when it connects to the broker using its `connectWithHeaders:completionHandler` method.

By default, `StompKit` defines a heartbeat of `5000,10000` (send heartbeat every 5 seconds and receive them every 10 seconds).

Let's add heart-beating to the `Locations` iOS application. The application often sends messages (every time the device GPS position is updated) but receive them less frequently (when an user sends a message from the web application). We will guarantee to send heartbeat every minute (60000ms) and desires to receive them from the broker every 20 seconds (20000ms).

```
- (void)connect
{
    NSLog(@"Connecting...");
    self.client.errorHandler = ^(NSError* error) {
        NSLog(@"got error from STOMP: %@", error);
    };
    // will send a heartbeat at most every minute.
    // expect broker's heartbeat at least every 20 seconds.
    NSString *heartbeat = @"60000,20000";
    [self.client connectWithHeaders:@{ @"client-id": self.deviceID,
                                        kHeaderHeartBeat: heartbeat }
                      completionHandler:^(STOMPFrame *connectedFrame, NSError *er
ror) {
                          ...
                     }];
}
```

stomp.js Example

The `STOMP` client has a `heartbeat` property composed of two properties:

- `heartbeat.outgoing` is the guaranteed frequency of heartbeat it can send to the broker (i.e. <cx>)

- `heartbeat.incoming` is the desired frequency of heartbeat coming from the broker (i.e. <cy>).

By default, `stomp.js` defines a heartbeat of `10000,10000` (to send and receive heartbeats every 10 seconds).

These properties must be modified **before** the `connect` method is called to take them into account.

```
// create the STOMP client
client = Stomp.client(url);

// will send a heartbeat at most every 20 seconds
client.heartbeat.outgoing = 20000;
// expects broker's heartbeat at least every minute
client.heartbeat.incoming = 60000;
client.connect({}, function(frame) {
  ...
});
```

Summary

In an ideal world, only the basic features of STOMP would be required to use messaging in mobile and web applications. However to handle errors that will eventually happen under normal use, we need to leverage advanced STOMP features.

In this chapter, we learn to use:

- *authentication* to ensure that only authenticated clients can communicate with the STOMP broker
- *acknowledgement* to let the client accepts explicitly the delivery of a message
- *transaction* to send messages as a single atomic unit-of-work
- *error handling* to face unexpected issues and eventually reconnect to the broker
- *receipt* to receive confirmation that a frame has been succesfully processed by the broker
- *heart-beating* to ensure that the network connection between the client and broker is healthy and kill the connection if that is not the case

CHAPTER 5
Beyond STOMP

STOMP provides a simple yet flexible messaging protocol. It also offers an extensible way for brokers to provide additional features beyond the ones specified in the protocol.

In this chapter, we will show how to leverage broker features with STOMP headers. Until this chapter, all STOMP brokers could be used to send and receive messages from our applications but in this chapter, you will have to check your broker documentation to see if it provides these features (or others not covered by this chapter).

Message Persistence

Some STOMP brokers support **persistent** messages to ensure that if a message is held by the broker when it crashes, the message will be persisted (that means stored on a durable support) so that the broker can fetch it when it restarts and handle it again. This prevents any data loss (at the cost of performance since the broker must ensure that the message is effectively written on the storage support). To use persistent messages, most STOMP brokers (including ActiveMQ) require that the message must be sent with a `persistent` header set to `true`.

In the `Locations` application we send two types of messages: one for with the device location and one for text messages.

The location messages do not need to be persisted and survive a broker crash. It has minimal consequences if these messages are lost if the broker was crashed. Once the broker is up again, the device will send updated position.

However for the text messages sent to the devices, we want to make sure that they are not lost before the device had a chance to receive it. We could declare these messages as persistent in the `locations.html` Web application to ensure that they survive a broker crash.

```
var order = "XXX";
client.send("/topic/mytopic", { persistent: true}, order);
```

When the broker receives the message, it will check the `persistent` header and persist the message if it is true.

Persisting messages adds a significant cost: the broker must write the message to a durable support (on a file system or in a database) and wait for the operating system to effectively write it (some operating system will buffer data before writtent them to disk). The broker must also have sufficient space on the durable support to write the persistent messages (once a persistent message has been delivered to all its consumers, the broker can safely discard it from the durable support).

To add further reliability, the client could use receipts (as described in "Receipts" on page 90) to wait until the broker has processed its message (and persisted it). Once the receipt is received, the client is guaranteed that the message would survive a server crash. Without a receipt, there is a small window for failure if the server crash *after* receiving the message but *before* storing it on its durable support.

Filtered Consumer

There are cases where a consumer may be interested only by a subset of all messages delivered from a destination.

Every time a consumer is delivered a message, it can filter it out (using the message's headers or its payload) to take into account only the interesting ones. However, this is inefficient since the consumer is still receiving all messages from the destination but may potentially discard many of them.

Some STOMP brokers allows to specify a filter (or selector) when a consumer subscribes to a destination. Before delivering the message to the destination's consumers, the STOMP broker will check whether the message matches the consumer's filter. The message is delivered to the consumer only if it matches the filter.

A filter is similar to a SQL 92 conditional query using the message headers. The message payload is opaque for the STOMP broker and can not be used by filters.

It turns out that this can be quite powerful since STOMP allows to add any user-specified header. If we want to filter out messages, we can put interesting information in the headers (either by removing them from the payload or duplicating them).

For example, we could add a `country` header when a location message is sent by the `Location` iOS application. The value of this header would correspond to the country where the device is located (for example `FR` for France, `DE` for Germany, `IT` for Italy, etc.).

```
- (void)sendLocation:(CLLocation *)location
{
    // ...

    NSString *country = [self findCountryFrom:location];
    NSDictionary *headers = @{
        @"content-type": @"application/json;charset=utf-8",
        @"country": country
    };

    // send the message
    [self.client sendTo:destination
                headers:headers
                   body:body];
}
```

With this new header in the message representation, the consumers can now filter out messages to receive only the ones for some countries.

If we want to receive only messages from France, Germany and Italy, we just need to add a `selector` header when the consumer subscribes to the destination.

```
client.subscribe(destination, function(message) {
  // Only messages with the country header with the value FR, DE, or IT will
  // be delivered to the client.
  // ...
}, {selector: "country IN ('FR', 'DE', 'IT')"});
```

If the STOMP broker support filtered consumers and your application can leverage them, this can significantely reduce the amount of messages sent on the network, saving bandwidth, CPU and battery usage on the client (filtered out messages will not be sent over the network and will not be processed at all by the client).

ActiveMQ Selector

ActiveMQ has specific rules related to use filtered consumer with STOMP that are described in its Selectors documentation page.

Priority

Messages sent to a destinations are usually delivered to a consumer in the order of their arrival. That means that if a producer sent messages A, B, and C in that order, a single consumer will receive the messages in the same order: A, B, and C.

However, there are cases where a producer wants to send a more *urgent* message that should take precedence over messages that it already sent.

Some STOMP brokers provides a way to achieve this using message *priority*. When a producer sends a message, it can sets a `priority` header to change the message priority. The usual semantics for the priority value is copied from JMS API which defines ten levels of priority value, with `0` as the lowest priority and `9` as the highest (and `4` as the default priority).

A broker will often try to deliver expedited messages before messages of lower priority but this is not a strong requirement. To ensure a *fair* delivery of messages, it may deliver lower priority messages so that a single producer sending only messages with the highest priority does not prevent the delivery of messages of lower priority from other producers.

In the `Locations` application, we do not have an use case where changing the priority of a message would make sense since we use different channels for tracking device location and sending text messages to the device. If we were using a single channel for both kind of messages, we could give the text messages a higher priority (for example `7`) so that they may be deliver ahead of messages with normal priority.

```
client.send(destination, { priority: 7 }, text);
```

Expiration

Messages can be valid for only a given duration after which they are not relevant anymore. For example, the locations messages sent by the `Locations` iOS application are valid for a short period of time after which the device has likely moved to another location.

Some STOMP brokers allow to expire messages after a period of time. The broker will periodically check that if messages held by its destinations have expired. If that is the case, it will discard them from the destinations and consumers will not receive them.

ActiveMQ accepts a `expires` header when a message is sent by a STOMP producer to specify until which time the message is valid. The value is the number of milliseconds between the UNIX time (00:00:00, Thursday, 1st January 1970 UTC) and the expiration date.

For example, if we want to expire messages ten minutes after they are sent by the `Locations` applications, we need to add an `expires` header whose value is the number of milliseconds since the Unix time and ten minutes after now.

```
- (void)sendLocation:(CLLocation *)location
{
    // ...

    // 10 minutes from now
    NSTimeInterval expiration = [[NSDate date] timeIntervalSince1970] + 600000;
```

```
    NSDictionary *headers = @{
        @"content-type": @"application/json;charset=utf-8",
        @"expires": [NSNumber numberWithLong:(long)expiration]
    };

    // send the message
    [self.client sendTo:destination
            headers:headers
               body:body];
}
```

Expiring messages can improve the healthiness of your applications. Producers have no knowledge on when their messages will be consumed and by whom. However if they know that the data sent in their messages has a limited lifetime, they can expire them after a given time instead of letting the broker deliver them to consumers after they stop being valid.

Summary

In this chapter, we learn that STOMP is a simple and flexible protocol that can be extended by brokers and clients using additional headers.

Based on the ActiveMQ broker, we see that STOMP can be extended:

- to support persistent messages by passing a `persistent` header set to `true` when messages are sent.
- to have consumer uses a `selector` filter to receive only messages whose headers match the filter.
- to send messages with a higher or lower priority using the `priority` header.
- to expire messages after a expiration date so that broker will not deliver messages after this date.

Depending on the STOMP broker you use, you may be able to use these features or others to improve the design of your architecture and reduce the network bandwidth, the CPU and battery usage so that producers and consumers only deal with relevant messages and ignore the others.

PART II
MQTT

This book covers the latest released version of the protocol at the time of this writing: MQTT 3.1 [mqttv3.1].

MQTT is a simple and lightweight messaging protocol that only supports the *Publish/Subscribe* messaging model.

MQTT is a binary protocol and its wireformat (the bits that are sent over the wire) is very compact reducing bandwidth and memory usage. It defines a small set of features and there are clients for it on many platforms ranging from traditional operating systems to embedded devices. In the next two chapters, we will write a mobile application for iOS and a Web application but the description of the MQTT protocol applies to any client (although their API may differ).

Eclipse Public MQTT Server

For the MQTT `Motions` application, we will not run a MQTT broker on our local network but use instead a public MQTT broker hosted by iot.eclipse.org, the portal for Internet of Things development of the Eclipse foundation. This public broker is running using the Mosquitto project (the same codebase underneath MQTTKit) and any MQTT client can connect to it. While it is not appropriate to use it for production (there is no uptime guarantee for it), it shows that it is possible to use MQTT on Internet.

MQTT clients can connect to it using the `iot.eclipse.org` hostname on the port `1883` (that is reserved for MQTT).

CHAPTER 6

Mobile Messaging with MQTT

In this chapter, we will write an iOS application using the `MQTTKit` library to send and receive messages using the MQTT protocol.

In "Motions Application Using MQTT" on page 9, we described the `Motions` application. In this chapter, we will write the iOS application that broadcasts the device motion data and receives alert messages.

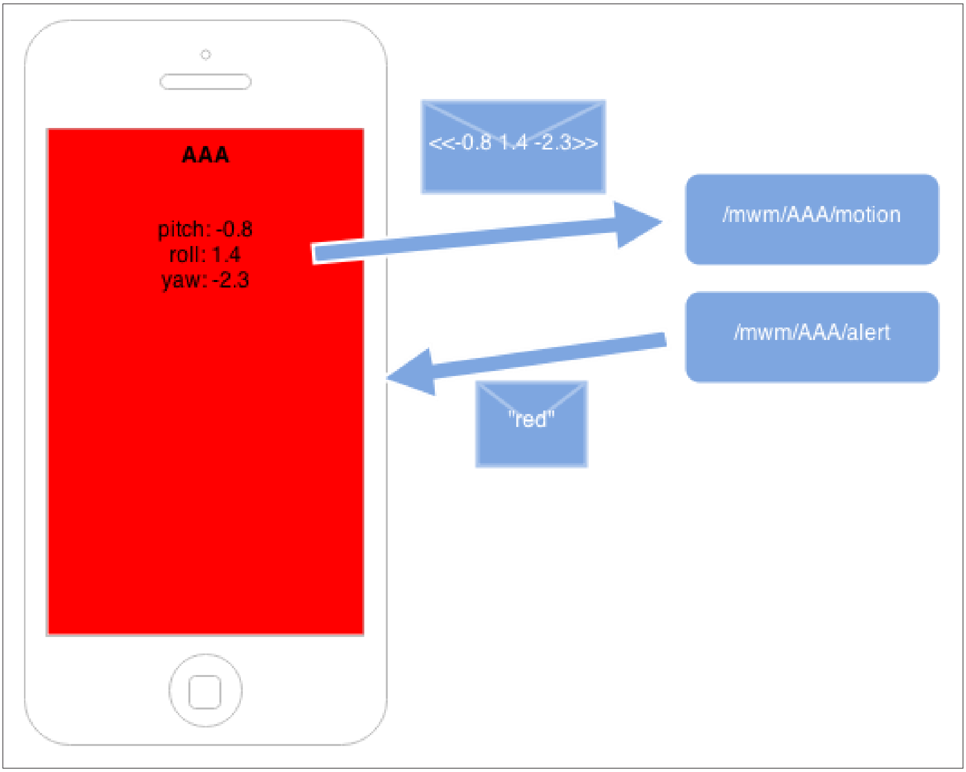
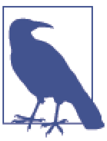


Figure 6-1. Diagram of the Motions iOS application



About the Code

All along the chapter, we will show all the code required to run the application.

The whole application code can be retrieved from the GitHub repository in the `mqtt/ios/` directory.

MQTTKit

This book uses the MQTTKit library for iOS (and Mac OS X) applications. It is a modern Objective-C library that uses ARC and blocks to write messaging clients in a simple fashion. It is based on the Mosquitto project that provides a lower-level C implementation of MQTT.

The source code of this library project is hosted on GitHub.

Create the Motions Project with Xcode

We will use Xcode to create the `Locations` iOS application.

Once Xcode is installed and started, we select `Create a new Xcode project` from its launch screen. The application will be composed of a single view so we select the `Single View Application` template in `iOS > Application` from the template screen.

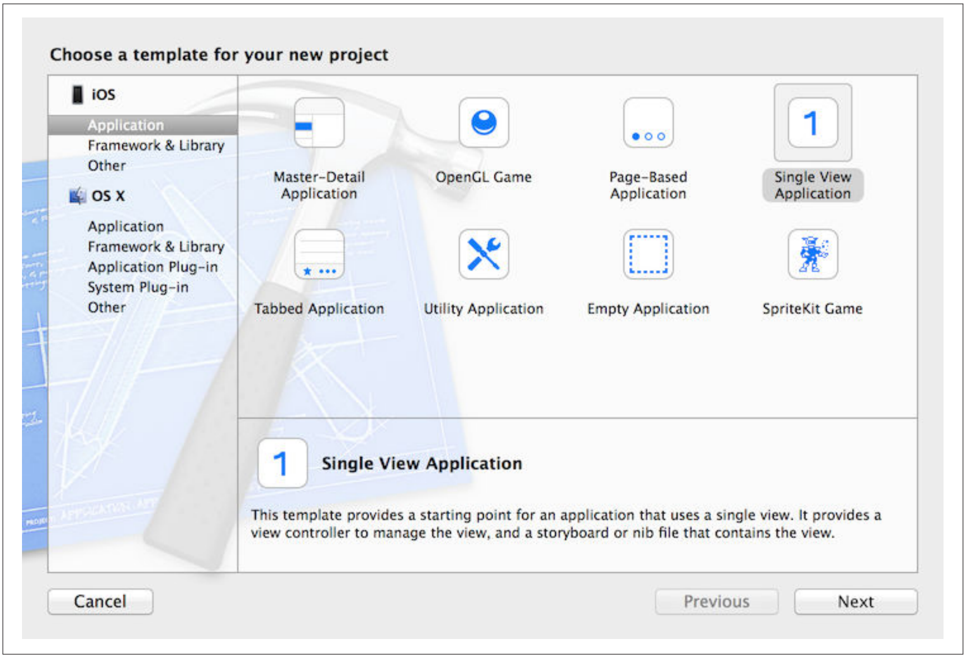


Figure 6-2. Select Single View Application from the template screen.

We will call the project `Motions` and select to build it only for iPhone devices.

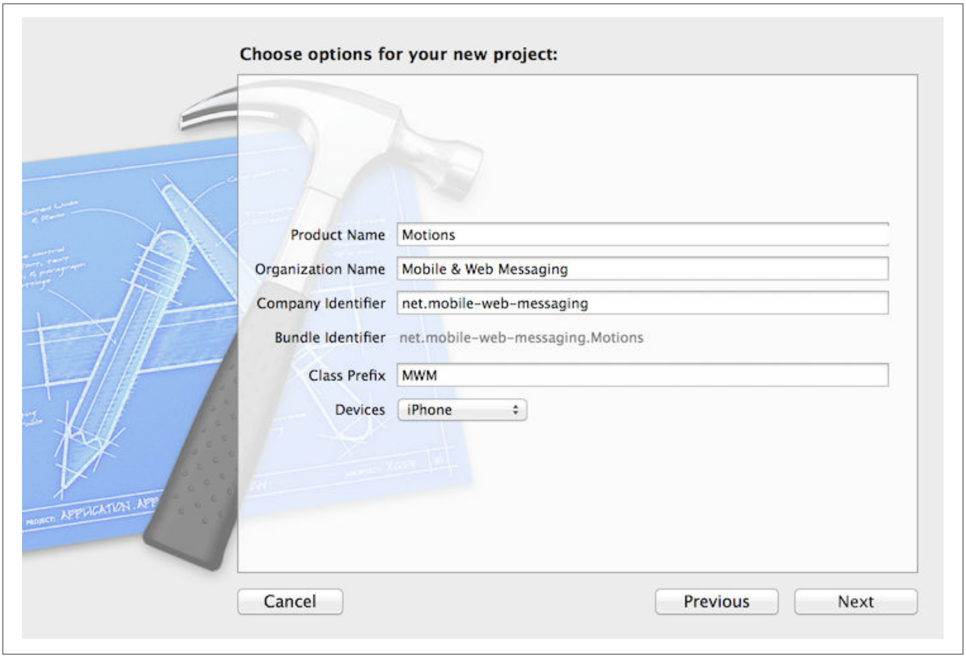


Figure 6-3. XCode project options screen

Finally we will save it in a folder on our machine.

Create the Podfile

We will again use CocoaPods to manage the project dependencies (as explained in "Create the Podfile" on page 21 for the STOMP example).

We close Xcode because CocoaPods will modify the project settings to import the dependencies.

We create a file named **`Podfile`** at the root of the project (in the same directory as `Motions.xcodeproj`).

Example 6-1. Motions's Podfile

```
xcodeproj 'Motions.xcodeproj'

pod 'MQTTKit', :git => 'https://github.com/mobile-web-messaging/MQTTKit.git'

platform :ios, '5.0'
```

After saving this file, run the **`pod install`** command.

Example 6-2. Install Motions Dependencies

```
$ pod install
Analyzing dependencies
Pre-downloading:     `MQTTKit`     from     `https://github.com/mobile-web-messaging/
MQTTKit.git`
Downloading dependencies
Installing MQTTKit (0.1.1)
Generating Pods project
Integrating client project

[!] From now on use `Motions.xcworkspace`.
```

We can now open again Xcode but we must do it using the *Workspace* file named `Motions.xcworkspace`, and not the *Project* file named `Motions.xcodeproj`.

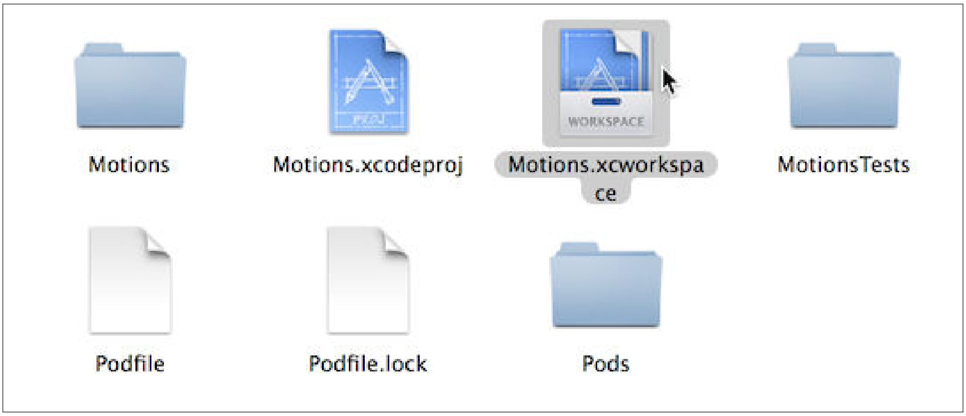


Figure 6-4. Open the workspace file

First, we will verify that the project is setup correctly and that the application can run in the iOS simulator.

We will simulate the latest iPhone devices by selecting `Product > Destination > iPhone Retina (4-inch 64-bit)` from Xcode menubar.

If we run the application by selecting **`Product`** > **`Run`** (or pressing ⌘+R), the iOS simulator starts and opens the application which is composed of a blank view. This confirms that the project and its dependencies are successfully compiled and launched.

Identify the Device

This step is similar to the `Locations` iOS application that is described in "Identify the Device" on page 24.

We will generate an unique identifier for the iOS device and display it in the view.

Click on **`Main.storyboard`** to open it. From the `Object` library, drag a `Label` on the `View`'s window. Place it at the top of the view and change the text to `Device ID`.

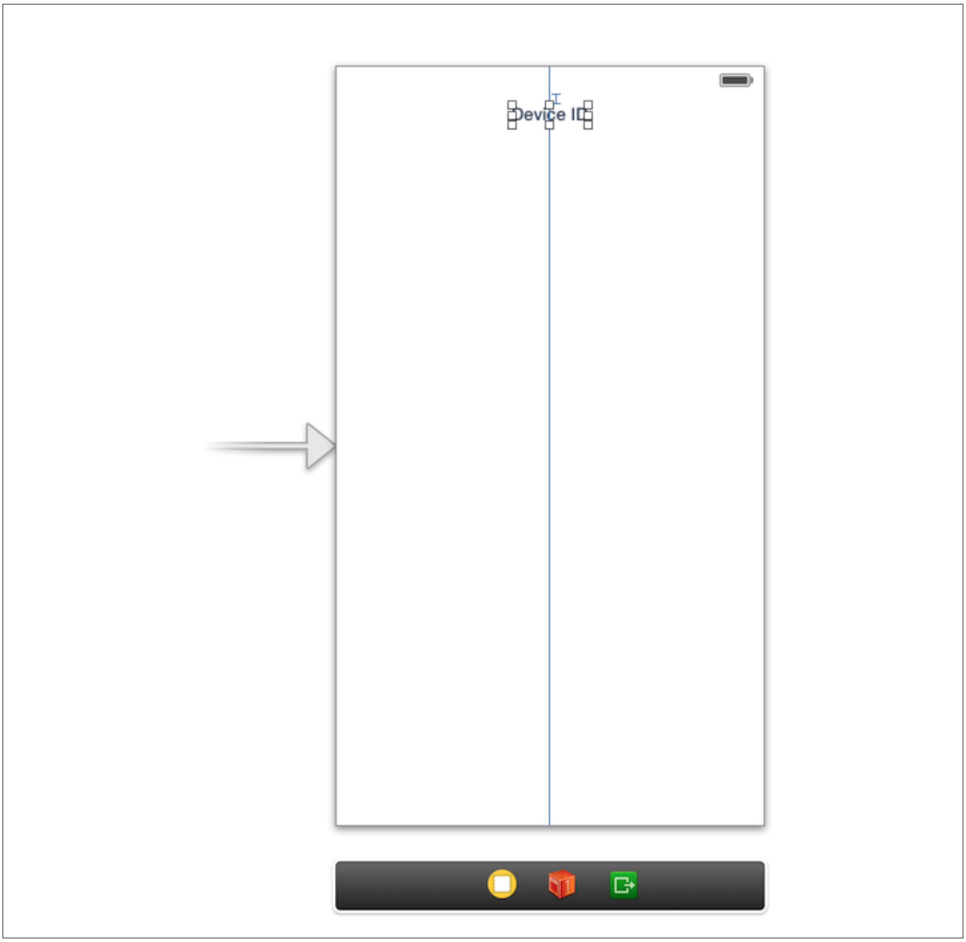


Figure 6-5. Add the Device ID label.

We will again change its `Font` to `System 13.0` and its `Alignment` to `centered` to fit the screen.

This label will be connected to a `deviceIDLabel` outlet property defined in the `MWMViewController` private interface in `MWMViewController.m` file. We also add a `deviceID` string to store the device identifier.

```
@interface MWMViewController ()

@property (weak, nonatomic) IBOutlet UILabel *deviceIDLabel;
```

```
@property (strong, nonatomic) NSString *deviceID;

@end
```

Open the Main.storyboard and control-click on View Controller to see its connection panel. Drag from deviceIDLabel to the UILabel to connect it.

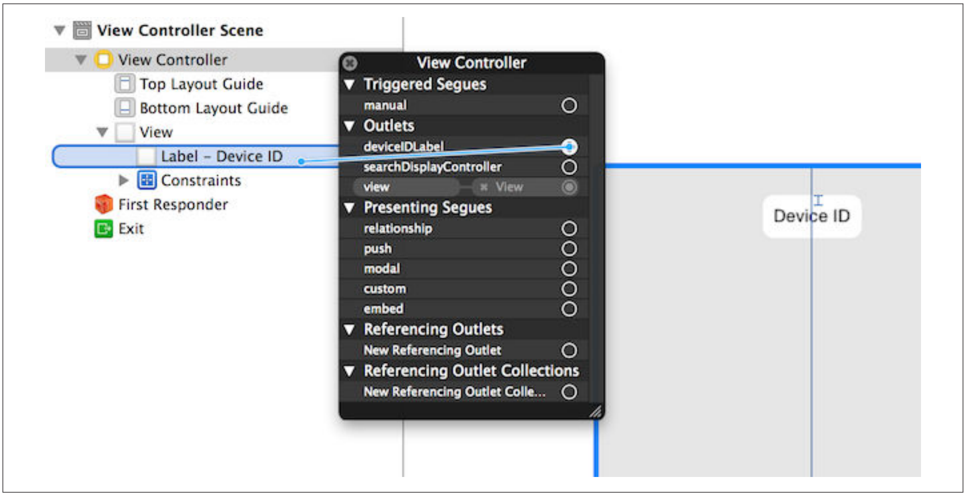


Figure 6-6. Connect the deviceIDLabel outlet property to the device ID UILabel.

The device identifier is generated in the MWMViewController implementation when the view is loaded and stored in the deviceID property. We also set the deviceIDLabel's text to this identifier.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);
    self.deviceIDLabel.text = self.deviceID;
}
```

Display the Device Motions Values

The device motion will be identified using the *pitch*, *roll* and *yaw* values. To have some graphical feedback as we move the device, we will add three UILabel that shows these three values.

Click on **Main.storyboard** to open it. From the Object library, drag three Labels on the View's window below the Device ID label. Change their respective text to pitch, roll, and yaw.

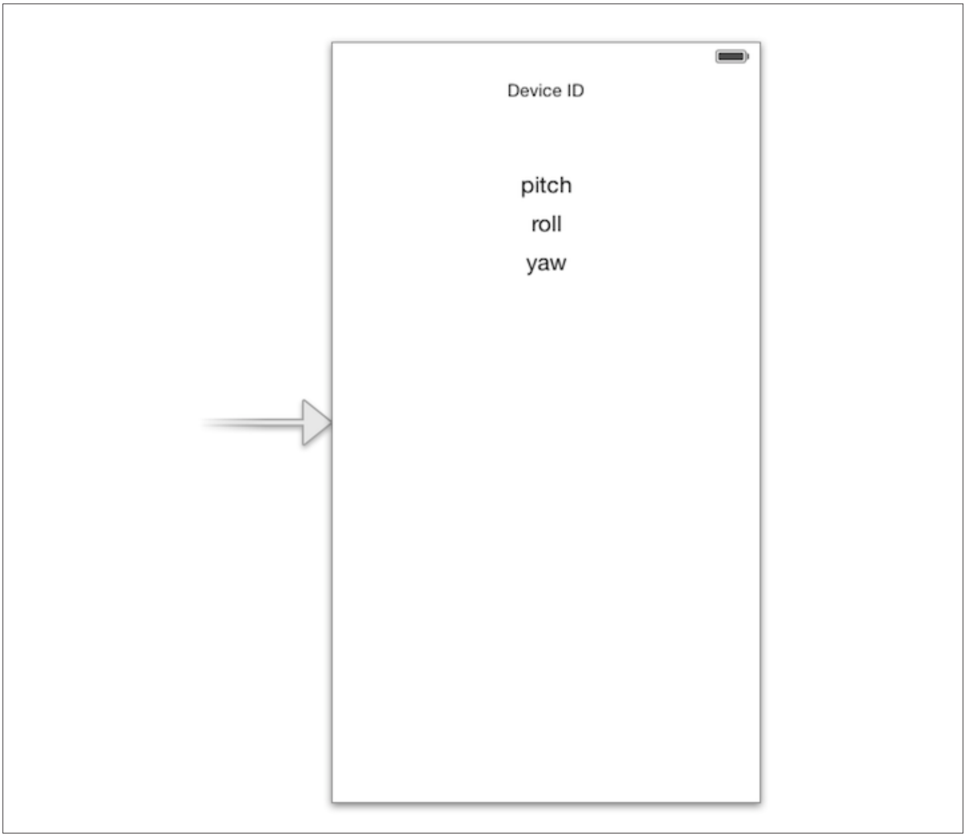


Figure 6-7. Add three labels to display the device's pitch, roll and yaw values.

We create three outlet properties in the `MWMViewController` private interface for these labels.

```
@interface MWMViewController ()

@property (weak, nonatomic) IBOutlet UILabel *deviceIDLabel;
@property (weak, nonatomic) IBOutlet UILabel *pitchLabel;
@property (weak, nonatomic) IBOutlet UILabel *rollLabel;
@property (weak, nonatomic) IBOutlet UILabel *yawLabel;

@property (strong, nonatomic) NSString *deviceID;

@end
```

Next step is to the connect the three labels in the `Main.storyboard` to these three outlet properties.

Open the `Main.storyboard` and control-click on `View Controller` to see its connection panel. Drag from its `pitchLabel` property to the corresponding pitch `UILabel` to connect it.

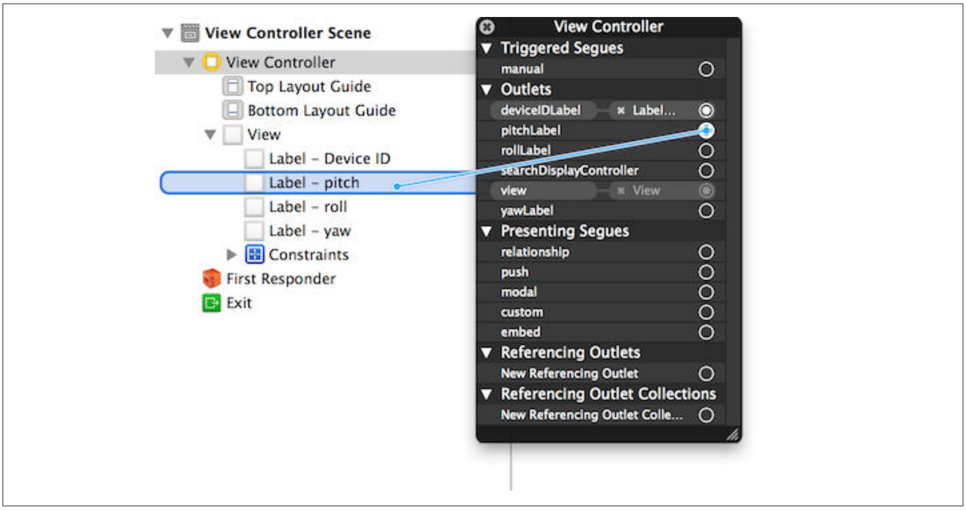


Figure 6-8. Connect the pitchLabel outlet property to the pitch UILabel.

Repeat this operation for the `rollLabel` and `yawLabel` to connect them.

At this stage, the graphical objects are connected and we can capture the device motion to update these labels and then broadcast the motion data using MQTT.

Capture the Device Motions with CoreMotion Framework

iOS provides the `CoreMotion` framework to capture the motion of the devices.

We need to add it to the libraries linked by the application. Click on the `Motions` project and then the `Motions` target. In the `General` tab, under the `Linked Frameworks and Libraries` section, click on the + button. In the selection window, type **`CoreMotion`**, select the `CoreMotion.framework` and click on the `Add` button.

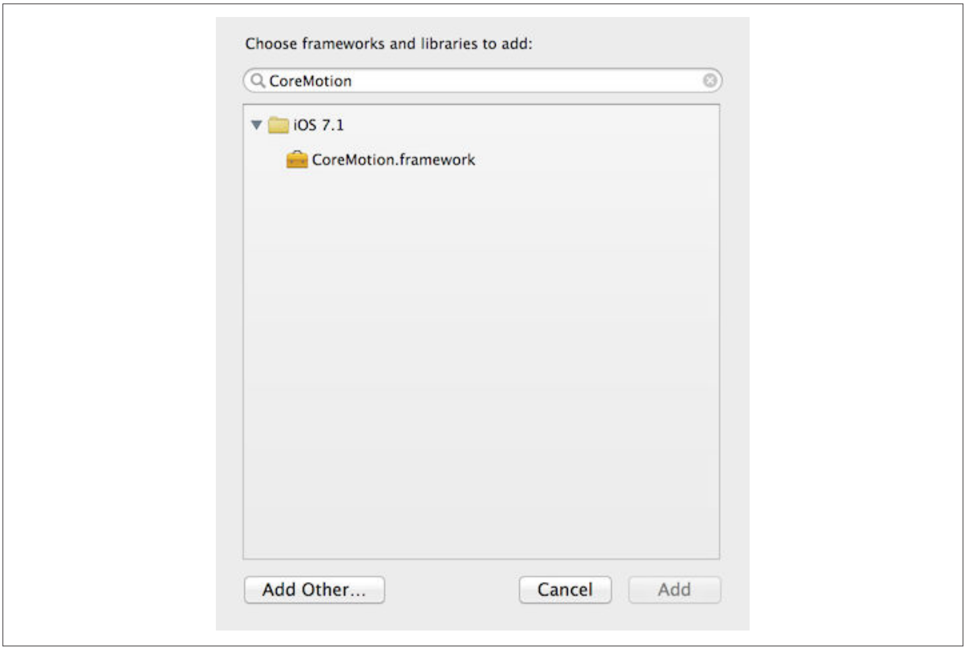


Figure 6-9. Add the CoreMotion framework.

We can now use the CoreMotion framework by importing <CoreMotion/CoreMotion.h> at the top of the MWMViewController.m file.

We will also define a motionManager property in MWMViewController private interface to use CoreMotion.

```
#import <CoreMotion/CoreMotion.h>

@interface MWMViewController ()

@property (strong, nonatomic) CMMotionManager *motionManager;

@end
```

This motionManager is used to capture the device motions. We must create a new CMMotionManager, specify the interval of update and call its startDeviceMotionUpdatesToQueue:withHandler: method to get the device motion periodically in a block. We create a new NSOperationQueue to receive these updates on this queue.

The device motion is represented by a CMDeviceMotion object. In our example, we are interested only by its attitude property that contains the pitch, roll and yaw value we want to broadcast. Their values are expressed in radians, so we will convert them in degrees to display them.

Since the block to receive motion update is executed on the NSOperationQueue we have created, we can not update the UILabel from it. We must instead create another block and call dispatch_async to execute the graphical changes on the UI main queue (that is retrieved by calling dispatch_get_main_queue()).

All this logic can be written in viewDidLoad so that the motion manager will start receiving updates when the view is loaded.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);
    self.deviceIDLabel.text = self.deviceID;

    self.motionManager = [[CMMotionManager alloc] init];
    // get the device motion updates every second.
    self.motionManager.deviceMotionUpdateInterval = 1;
    NSOperationQueue *queue = [[NSOperationQueue alloc] init];
    [self.motionManager startDeviceMotionUpdatesToQueue:queue
                                            withHandler:^(CMDeviceMotion
*motion, NSError *error) {
        if(!error) {
            CMAttitude *attitude = motion.attitude;
            dispatch_async(dispatch_get_main_queue(), ^{
                // convert values from radians to degrees
                double pitch = attitude.pitch * 180 / M_PI;
                double roll = attitude.roll * 180 / M_PI;
                double yaw = attitude.yaw * 180 / M_PI;
                 self.pitchLabel.text = [NSString stringWithFormat:@"pitch: %.0f
°", pitch];
                  self.rollLabel.text = [NSString stringWithFormat:@"roll: %.0f
°", roll];
                 self.yawLabel.text = [NSString stringWithFormat:@"yaw: %.0f°",
yaw];
            });
        }
    }];
}
```

We also need to notify the motionManager that we no longer want to receive updates when the view is no longer used. We need to call its stopDeviceMotionUpdates method inside the view controller's dealloc method.

```
- (void)dealloc
{
    [self.motionManager stopDeviceMotionUpdates];
}
```

At this stage, if you run the `Motions` application on your iPhone and move it, the pitch, roll, and yaw labels will be updated to reflect the changes in the device motions.

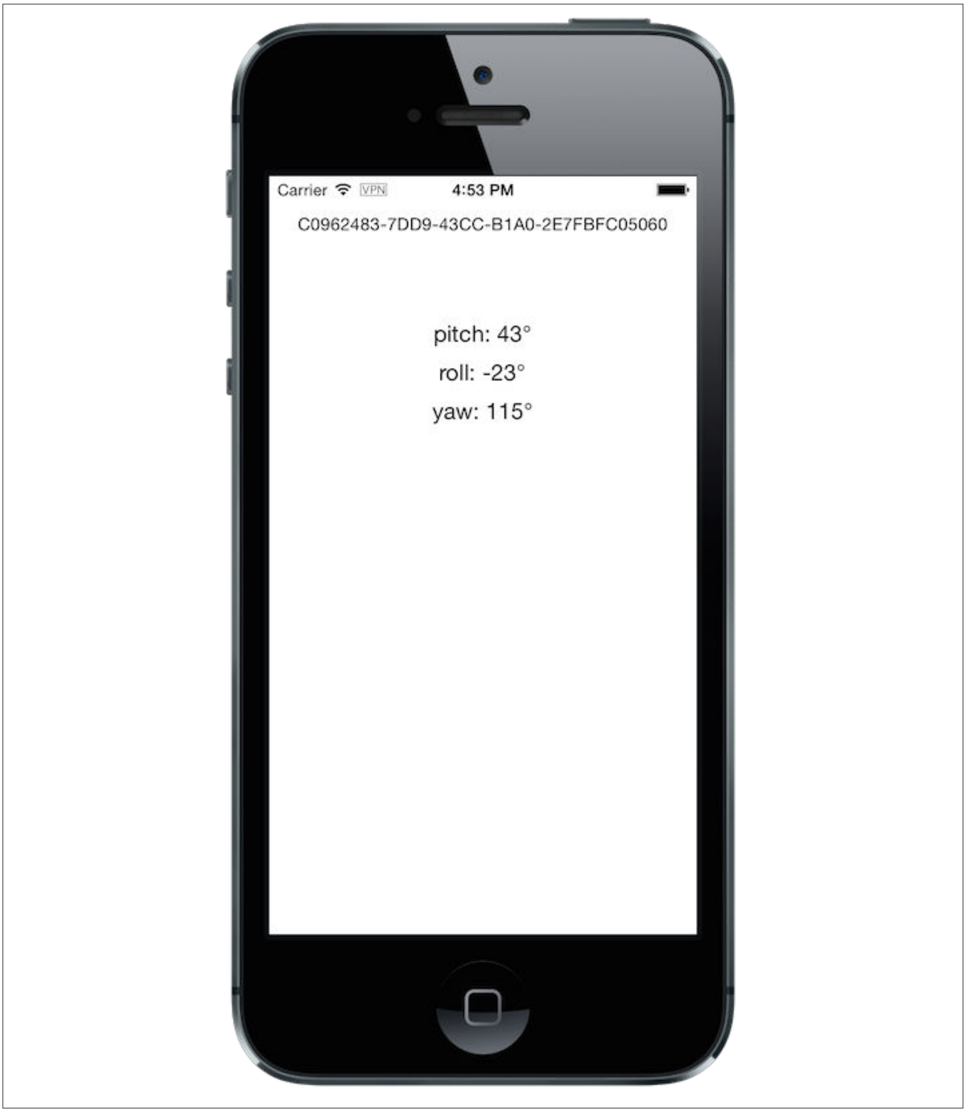


Figure 6-10. The motion values change when the device moves.

The `iOS Simulator` is not able to simulate device motions. If you run the `Motions` application in the simulator, the `motionManager` will not send any device motions updates. At the time of writing this book, the only way to test this code is to run the application on a real iOS device.

We now capture the device motions and display them. Next step is to broadcast them by sending MQTT messages.

Create a MQTT Client with MQTTKit

To send and receive message with MQTT, we must first import the `MQTTKit` library that was added to the project using CocoaPods at the beginning of this chapter.

We must import its header file `MQTTKit.h` at the top of the `MWMViewController.m` file and add a `MQTTClient` property named `client` to the `MWMViewController` private interface.

We also define a constant to represent the hostname of the MQTT broker we are using `iot.eclipse.org`.

```
#import <MQTTKit/MQTTKit.h>

#define kMqttHost @"iot.eclipse.org"

@interface MWMViewController ()

@property (strong, nonatomic) MQTTClient *client;

@end
```

We will create a new `MQTTClient` object in the `MWMViewController`'s `viewDidLoad` method. A `MQTTClient` must be uniquely identified for the MQTT brokers it connects to. We can use the `deviceID` as its client identifier.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    ...

    self.client = [[MQTTClient alloc] initWithClientId:self.deviceID];
}
```

Connect to a MQTT Broker

A `MQTTKit` client will connect to the MQTT Broker when its `connectToHost:completionHandler:` method is called. Since `MQTTKit` is event-driven, the client will be *effectively* connected when its completionHandler block is called and the return code is `MQTTConnectionReturnCode` is equal to `ConnectionAccepted`.

You can not assume that the client is connected when the `connectToHost:completionHandler:` method returns. Any actions that requires the client to be connected must happen inside the `completionHandler` block.

We will encapsulate this code in a `connect` method.

```
#pragma mark - MQTTKit Actions

- (void)connect
{
    NSLog(@"Connecting to %@...", kMqttHost);
    [self.client connectToHost:kMqttHost
             completionHandler:^(MQTTConnectionReturnCode code) {
        if (code == ConnectionAccepted) {
            NSLog(@"connected to the MQTT broker");
        } else {
            NSLog(@"Failed to connect to the MQTT broker: code=%lu", code);
        }
    }];
}
```

We will call this method from `viewDidLoad` to connect to the MQTT broker as soon as the view is loaded.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);
    self.deviceIDLabel.text = self.deviceID;

    ...

    self.client = [[MQTTClient alloc] initWithClientId:self.deviceID];
    [self connect];
}
```

Disconnect from a MQTT Broker

The `client` can disconnect from the MQTT broker by calling its `disconnectWithCompletionHandler:` method.

The `completionHandler` block as a `code` parameter that will be `0` if the disconnection was successful.

```
- (void)disconnect
{
    [self.client disconnectWithCompletionHandler:^(NSUInteger code) {
        if (code == 0) {
            NSLog(@"disconnected from the MQTT broker");
        } else {
            NSLog(@"disconnected unexpectedly...");
        }
    }];
}
```

We want to disconnect from the MQTT broker when the `MWMViewController` is no longer used. We will call the `disconnect` method from `dealloc`.

```
- (void)dealloc
{
    [self.motionManager stopDeviceMotionUpdates];
    [self disconnect];
}
```

Send MQTT Messages

The `MWMViewController` automatically connects to the MQTT broker when its view is loaded and disconnects when it is deallocated. Next step is to send messages every time the device motion values are updated.

The MQTT protocol is a binary protocol. The message payload must be encoded as binary data to be sent. The `MQTTKit` library provides two methods to send messages:

- The `publishData:toTopic:withQos:retain:` method expects a `NSData` object as the message payload and its `bytes` will be used.
- The `publishString:toTopic:withQos:retain:` method can also be used for the common case of sending a text message. Internally, the `NSString` that is passed in parameter is encoded as a `NSData` using the UTF-8 encoding.

In the `Motions` iOS application, we send a message with a binary payload composed of three 64-bit floats for the `pitch`, `roll`, and `yaw` values contained in a `CMAttitude` object. We will build the payload's `NSData` by converting the double values to a platform-independent format using the `CFConvertDoubleHostToSwapped` function.

The other three parameters to the `publish`… methods are the same for both the binary and text payload version.

The `topic` parameter is the name of the topic to send the message. According to "Motions Messaging Models" on page 11, the name of the topic is `/mwm/XXX/motion` where XXX is the device identifier.

The `qos` parameter corresponds to the *Quality of Service* (or QoS) to use to deliver the messages to the consumers.

Quality of Service

The MQTT protocol defines three levels of Quality of Service:

- At Most Once (with the value `0` represented by `AtMostOnce` in `MQTTKit`)
- At Least Once (with the value `1` represented by `AtLeastOnce` in `MQTTKit`)

- Exactly Once (with the value `2` represented by `ExactlyOnce` in `MQTTKit`)

These levels of QoS determine the guarantee that the MQTT broker will accept to deliver a message. With `At Most Once`, the MQTT broker guarantees that the published message will be delivered at most once to its consumers. This means that the consumers may not receive the message at all. If an error (such as a network failure or a crash) occurs while the message is sent to the broker, it is possible that it will be lost and the consumers will never receive it.

With `At Least Once`, the MQTT broker guarantees that the published message will be delivered at least once to the consumers. This also means that a consumer may receive the same message twice. If there is any error when the producer sends the message to the broker and did not receive an acknowledgement that its message has been received, it will resend it as second time as a *duplicate* (the MQTT message will have a `DUP` bit set). When the broker receives this duplicate message it will redeliver it to the consumer but it is possible that they in fact received the original message. The consumer may need to check if the `DUP` bit is set on the delivered message to know whether it is an original message (and it must process it) or a duplicate (and it can discard it)

The `At Least Once` QoS offers the guarantee that no published message will be lost but at the cost of performance and additional code on the consumer side. The performance cost is caused by the additional message (a `PUBACK` message) sent from the broker to the client to acknowledge that it has received the published message. That means that using this QoS level to publish `N` messages will involve exchanging `2*N` messages between the producer and the broker.

The highest level of delivery is provided using the `Exactly Once` QoS. With that level, the MQTT broker guarantees that the published message will be delivered *exactly* once by the consumers. There will be no lost messages or duplicate messages. This is guaranteed by additional exchange of messages between the producer and broker (`PUBREC`, `PUBREL`, `PUBCOMP` messages). That means that using this QoS level to publish `N` messages will involve exchanging `4*N` messages, requires four times more network trips than the lowest level of QoS of `At Most Once` and twice more than the `At Least Once` level.

Choosing the correct QoS depends on the type of message exchanged and the *importance* of its payload. In the `Motions` iOS application, the published message contains device motion that are updated every second. It is acceptable if a published message is *lost* because an new message with updated content will be sent just one second after. Using the `AtMostOnce` QoS is the best choice for this type of message.

All the complexities of using higher level of QoS is transparent from the application using MQTT as it is the responsibility of the client library to handle it. However you need to be aware of the cost associated to using these QoS as they can have significant impact on your application performance and the device in general (as the additional network trips will drain the battery life).

Retained Message

The final parameter of the `publish…` methods is a boolean to specify whether the published message must be *retained* by the topic.

If this flag is set on the message, the broker will deliver the message to its subscribers and keep holding the message. If a new consumer subscribes to this topic, the broker will deliver the retained message to it. This is useful as the new subscriber will not have to wait for a publisher to send a message to receive new data. The retained message contains the *Last Known Good* value.

If our case, we will publish messages with `retain` set to `YES`. If consumers subscribes to the device motion topic *after* the device stops updated its motion values, they will still be able to use the last know device motion value. This example is a bit of a stretch. A more interesting example would be an application broadcasting its location (similar to the `Locations` application). Using retained message would allow the consumers to know the last know position of the device before it stops broadcasting its position.

To sum up, the `Motions` application will send a message:

- with a binary payload composed of three 64-bits floats for the device's `pitch`, `roll`, and `yaw` values
- to the device motion topic `/mwm/XXX/motion` where `XXX` is the device identifier
- with a QoS ot `AtMostOnce` since we accept that a published message may not be delivered
- with `retain` set to `YES` so that the broker will retain the Last Known Good message to deliver it to new subscribers.

We will encapsulate this code in a `send:` method taking a `CMAttitude` parameter.

```
- (void)send:(CMAttitude *)attitude
{
    uint64_t values[3] = {
        CFConvertDoubleHostToSwapped(attitude.pitch).v,
        CFConvertDoubleHostToSwapped(attitude.roll).v,
        CFConvertDoubleHostToSwapped(attitude.yaw).v
    };
    NSData *data = [NSData dataWithBytes:&values length:sizeof(values)];
      NSString  *topic  =[NSString  stringWithFormat:@"/mwm/%@/motion",  self.devi
ceID];
    [self.client publishData:data
```

```
                     toTopic:topic
                     withQos:AtMostOnce
                      retain:YES
           completionHandler:nil];
}
```

The message will contain the motion values in radians. It will be up to the consumers to convert them in degrees if necessary.

Finally, the last step is to call this method every time a device motion value is updated by the `motionManger`. This occurs in the `viewDidLoad` method inside the `handler` block passed to the `motionManger`'s `startDeviceMotionUpdatesToQueue:withHandler:` method.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);
    self.deviceIDLabel.text = self.deviceID;

    self.motionManager = [[CMMotionManager alloc] init];
    // get the device motion updates every second.
    self.motionManager.deviceMotionUpdateInterval = 1;
    NSOperationQueue *queue = [[NSOperationQueue alloc] init];
    [self.motionManager startDeviceMotionUpdatesToQueue:queue
                                            withHandler:^(CMDeviceMotion
*motion, NSError *error) {
        if(!error) {
            CMAttitude *attitude = motion.attitude;
            dispatch_async(dispatch_get_main_queue(), ^{
                // convert values from radians to degrees
                double pitch = attitude.pitch * 180 / M_PI;
                double roll = attitude.roll * 180 / M_PI;
                double yaw = attitude.yaw * 180 / M_PI;
                 self.pitchLabel.text = [NSString stringWithFormat:@"pitch: %.0f
°", pitch];
                  self.rollLabel.text = [NSString stringWithFormat:@"roll: %.0f
°", roll];
                 self.yawLabel.text = [NSString stringWithFormat:@"yaw: %.0f°",
yaw];
            });
            [self send:attitude];
        }
    }];


    self.client = [[MQTTClient alloc] initWithClientId:self.deviceID];
}
```

We now have the Motions iOS application that is sending MQTT messages. How can we check that this is working as expected?

Conversely to STOMP, MQTT is a binary protocol and we can not use a simple telnet client to create a consumer and receive messages sent by the application.

However the Mosquitto broker provides simple command-line tool to send and receive message from a MQTT broker. The Appendix B explains how to download and install the Mosquitto broker. After it is done, we can use its mosquitto_sub command line tool to connect to a MQTT broker (hosted at iot.eclipse.org) and subscribe to the device motion topic (in my case /mwm/C0962483-7DD9-43CC-B1A0-2E7FBFC05060/motion, you will have to replace it using your own device identifier).

This tool will display the message payload. Since we are sending binary payload, we will pipe the command into the hexdump tool to display the hexadecimal representation of the binary payload.

```
$ mosquitto_sub -h iot.eclipse.org -t /mwm/C0962483-7DD9-43CC-B1A0-2E7FBFC05060/
motion | hexdump
...
0000050 aa b0 4c 3f 9b 41 0c 6b 08 35 d3 3f d2 4b 23 f2
0000060 71 1e 47 0a 3f d5 05 6a c4 37 52 16 3f d8 f7 b5
0000070 34 f6 19 ea bf d2 97 6f 1a 65 86 af 0a 3f af 23
0000080 78 91 85 1c 8d bf df b9 12 c4 78 64 1c 3f cb 3c
0000090 50 fd 05 26 5b 0a 3f d1 60 87 16 0b 12 9e bf c2
...
```

This confirms that the Motions application is effectively publishing MQTT messages.

Receive MQTT Messages

As described in "Motions Application Using MQTT" on page 9, the Motions iOS application is also a consumer from the topic /mwm/XXX/alert. When it receives a message from this topic, it must change its background color to "alert" the user.

Let's write the method that aler the user by changing the background color first. This warnUser: method takes a NSString parameter that should correspond to a color. Using UIKit animations, we will:

1. animate the controller's view to change its background color from its original color to the one created from the NSString parameter
2. we wait two seconds after the first animation is completed to revert back to the original background color.

```
# pragma mark - UI Actions
```

```
// Warn the user by changing the view's background color to the specified color
during 2 seconds
- (void)warnUser:(NSString *)colorStr
{
    // keep a reference to the original color
    UIColor *originalColor = self.view.backgroundColor;

    [UIView animateWithDuration:0.5
                          delay:0.0
                        options:0
                     animations:^{
                         // change it to the color passed in parameter
                          SEL sel = NSSelectorFromString([NSString stringWithFor
mat:@"%@Color", colorStr]);
                         UIColor* color = nil;
                         if ([UIColor respondsToSelector:sel]) {
                             color  = [UIColor performSelector:sel];
                         } else {
                             color = [UIColor redColor];
                         }
                         self.view.backgroundColor = color;
                     }
                     completion:^(BOOL finished) {
                              // after a delay of 2 seconds, revert it to the
original color
                         [UIView animateWithDuration:0.5
                                               delay:2
                                             options:0
                                          animations:^{
                                              self.view.backgroundColor =
originalColor;
                                          }
                                          completion:nil];
                     }];
}
```

To consumer messages from a MQTT broker, the `client` must:

1. subscribe to its topic of interest
2. set its `messageHandler` property that will be called every time a message is delivered.

Note that you can subscribe to many topics from the client but it has only one `messageHandler` property. If the client is subscribed to different topics, its `messageHandler` must determine which topic the message is consumed from.

Subscription

The `Motions` application will subscribe to its device alert topic `/mwm/XXX/alert` by calling the method `subscribe:withQos:completionHandler:` on its `client` property.

The first parameter is the device alert topic. We will define it at the top of the MWMView Controller.m file.

```
#define kAlertTopic @"/mwm/%@/alert"
```

The subscribe:withQos:completionHandler: method takes a qos that correspond to the quality of service that the consumer is requesting for message delivered from the topic.

The completion handler will be called when the client is effectively subscribed to the topic. The handler has a grantedQos parameter that corresponds to the effective quality of service. The producer is responsible for determining the maximum quality of service that a message can be delivered at but the consumer can decide to *downgrade* the quality of service according to its usage. For example, a producer may publish a message with a QoS of ExactlyOnce but a consumer may decide that it is acceptable for it if there are message duplicates and downgrade its QoS to At Least Once.

In our case, we will request to have messages delivered with a qos set to AtLeastOnce as we do not want to lose messages but can accept duplicate messages.

```
- (void)subscribe
{
    NSString *topic = [NSString stringWithFormat:kAlertTopic, self.deviceID];
      [self.client subscribe:topic withQos:AtLeastOnce completionHandler:^(NSAr
ray *grantedQos) {
        NSLog(@"subscribed to %@ with QoS %@", topic, grantedQos);
    }];
}
```

We will subscribe to the alert topic as soon as the client is connected to the MQTT broker by calling this subscribe method from inside the completionHandler in the connect method.

```
- (void)connect
{
    NSLog(@"Connecting to %@...", kMqttHost);
    [self.client connectToHost:kMqttHost
             completionHandler:^(MQTTConnectionReturnCode code) {
        if (code == ConnectionAccepted) {
            NSLog(@"connected to the MQTT broker");
            [self subscribe];
        } else {
            NSLog(@"Failed to connect to the MQTT broker: code=%lu", code);
        }
    }];
}
```

Unsubscription

To unsubscribe from a topic and stop receiving messages from it, we will call the `unsubscribe:withCompletionHandler:` method of the `client` where the first parameter is the topic to unsubscribe from (the alert topic in our case). The second parameter is a completion handler that is called back when the client has been acknowledged by the server that it is effectively unsubscribed. We do not have any need for this information so we just pass `nil` as the handler.

```
- (void)unsubscribe
{
    NSString *topic = [NSString stringWithFormat:kAlertTopic, self.deviceID];
    [self.client unsubscribe:topic withCompletionHandler:nil];
}
```

We will call this `unsubscribe` method just before disconnecting from the MQTT broker from the `dealloc` method.

```
- (void)dealloc
{
    [self.motionManager stopDeviceMotionUpdates];
    [self unsubscribe];
    [self disconnect];
}
```

Since we disconnect just after unsubscribing, we could skip that step and just disconnect from the MQTT broker. At that moment, the MQTT broker will automatically unsubscribe the client from any topic. However it is a good practice to explicitly unsubscribe from subscribed topic. There are also many cases where unsubscribing may occur at a different time than the disconnection. In these cases, we can not rely on the client disconnection to perfom the unsubscription.

Define a MQTTMessage Handler

Subscribing to a topic is the first step to receive messages with `MQTTKit`. The secon step is to define a block that will be called every time a message is received from a subscribed topic.

The `client`'s `messageHandler` property defines a `MQTTMessageHandler` block. This block has a `MQTTMessage` parameter representing the MQTT message that is deliver to the client.

The `MQTTMessage` interface defines four properties corresponding to the message data:

- `mid` is a `unsigned short` corresponding to the *message ID*.

- `topic` is the name of the topic that this message is coming from. If the client is subscribed to many topics, we must use this property to determine which topic the received message is coming from.
- `retained` is a `BOOL` to check whether the message was retained (and contains the last known good value) or not (it is a *fresh* message)
- `payload` is a `NSData` object containing the binary content of the message payload.

Since sending and receiving text message is very common, the `MQTTMessage` interface also defines a `payloadString` method that returns a `NSString` decoded from the message binary payload using UTF-8.

In the `Motions` application, we expect to receive a text payload and will use this `payloadString` to extract the color string from the received message.

We need to set the `client`'s `messageHandler` *before* subscribing to the alert topic so that we do not miss any alert message sent after we subscribe but *before* the `messageHandler` is defined. We will do that in the `viewDidLoad` method just after creating the `client` instance.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    self.deviceID = [UIDevice currentDevice].identifierForVendor.UUIDString;
    NSLog(@"Device identifier is %@", self.deviceID);
    self.deviceIDLabel.text = self.deviceID;

    ...

    self.client = [[MQTTClient alloc] initWithClientId:self.deviceID];
    // use a weak reference to avoid a retain/release cycle in the block
    __weak MWMViewController *weakSelf = self;
    self.client.messageHandler = ^(MQTTMessage *message) {
           NSString *alertTopic = [NSString stringWithFormat:kAlertTopic, weak
Self.deviceID];
        if ([alertTopic isEqualToString:message.topic]) {
            NSString *color = message.payloadString;
            dispatch_async(dispatch_get_main_queue(), ^{
                [weakSelf warnUser:color];
            });
        }
    };

    [self connect];
}
```

We extracted the color using the message payloadString method after checking that it was indeed coming from the device alert topic. We then call the warnUser: method in a block that is run on the main queue since it contains code related to UIKit.

To avoid a retain/release cycle between self and the messageHandler block, we need to create a *weak* reference of self and uses it from the block.

How can we verify that the Motions application is effectively receiving alert messages? To verify that the application was sending messages, we used the mosquitto_sub tool. We will now use the opposite tool, mosquitto_pub, to publish a message on the alert topic and verify that the application background color changes.

The mosquitto_pub can send a text payload using the -m option. We will use this option to pass the background color (for example green).

```
$ mosquitto_pub -h iot.eclipse.org -t /mwm/C0962483-7DD9-43CC-B1A0-2E7FBFC05060/
alert -m green
```

After this message is sent, the device will receive it and change its background color to green.

Figure 6-11. Alert message is received by the Motions iOS application

Summary

In this chapter, we learn to use `MQTTKit` to send and receive MQTT messages from an iOS application.

To send a message, the application must:

1. connect to the MQTT broker

2. send the message to the topic

To consume a message, the application must

1. connect to the MQTT broker
2. subscribe to the topic
3. define a message handler block that is called every time a message is received. This block is executed on a dispath queue. If there are any code that changes the user interface, it must be wrapped in a block executed on the main queue.

We used two different types of message payloads:

- a binary payload to send the device motions values as three 64-bit floats
- a text payload to extract a background color from the messages received on the alert topic.

CHAPTER 7

Web Messaging with MQTT

In this chapter, we will write a Web application that sends and receives messages using the MQTT protocol over HTML5 Web Sockets.

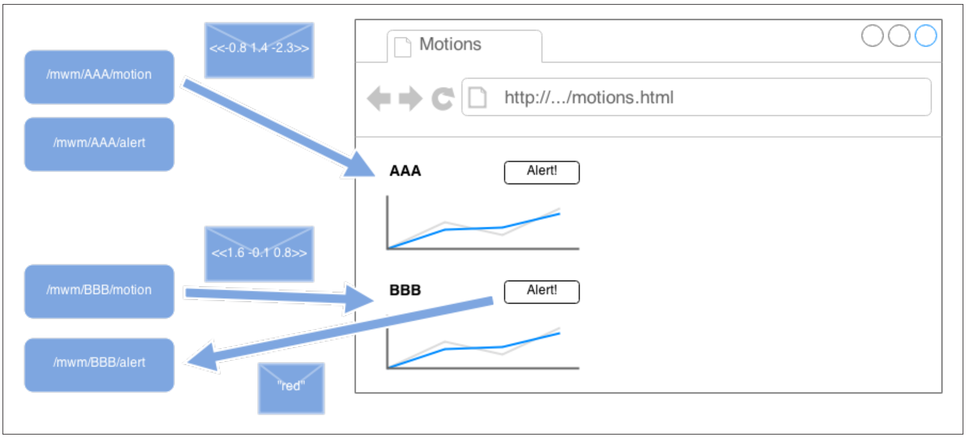


Figure 7-1. Diagram of the Motions Web application that displays data for two devices

About the Code

All along the chapter, we will show all the code required to run the application.

The whole application code can be retrieved from the GitHub repository in the `mqtt/web/` directory.

Eclipse Paho JavaScript Client

In ???, we mentioned that iot.eclipse.org provides a public MQTT broker that we use for our MQTT applications. Eclipse also provides a variety of MQTT clients for different languages and platforms. In particular, it has a JavaScript client for Web browser that uses HTML5 Web Sockets.

The source code of the project is hosted in this Git repository.

Bootstrap the motions.html Web Application

As we explained in "Motions Application Using MQTT" on page 9, this Web application will display on a Web page the motion data sent by the devices using the `Motions` iOS application written in the previous chapter. Additionnally, the Web application will also be able to send alert messages to the devices.

It will be a very simple one-page Web application that can be run from a Web server serving static pages. It does not require any server-side runtime as all the code will be executed inside the Web browser using JavaScript.

The device motions data will be displayed graphically as Sparklines. The Web application uses jQuery and a library named jQuery Sparklines to draw them.

Note however that we use jQuery for convenience but the MQTT JavaScript client does not require it at all and can be used with any JavaScript frameworks or libraries.

Let's bootstrap the Web application by creating a `motions.html` page.

Example 7-1. Template for the locations.html Web Application

```
<!DOCTYPE html>
<html>
<head>
  <meta content="width=device-width" name="viewport">
  <meta charset="utf-8">
  <title>Motions - MQTT Example</title>
   <link  rel="stylesheet"  type="text/css"  href="http://bgrins.github.com/spectrum/
spectrum.css">
</head>
<body>
  <h1>Motions - MQTT Example</h1>

  <h2>Devices</h2>
  <ul id="devices">
  </ul>

   <footer>&copy;  2014  <a  href="http://mobile-web-messaging.net">Mobile  &amp;  Web
Messaging</a></footer>

  <script src='mqttws31.js'></script>
   <script  src="http://ajax.googleapis.com/ajax/libs/jquery/1.9.0/jquery.min.js"></
script>
        <script    src="http://omnipotent.net/jquery.sparkline/2.1.2/jquery.spark
line.min.js"></script>
```

```
  <script>
$(document).ready(function() {

// We will put all the JavaScript code in this block that is called
// when the document is ready

});
  </script>
</body>
</html>
```

Create a MQTT Client with mqttws31.js

When the browser loads this page, we will create a MQTT client using the JavaScript library.

To create the client we must pass the MQTT broker host and port. In our case, it is respectively `iot.eclipse.org` and `80`. Note than in "Create a MQTT Client with MQTTKit" on page 117, the `Motions` iOS application was connecting to `iot.eclipse.org` on its default port `1883`. This default port expects a TCP socket connection. Since the Web application uses HTML5 Web Sockets, it must connect to the `80` port that will handle the HTTP Upgrade process from the initial HTTP connection.

We also need to configure a `clientID` that identifies the MQTT client. In our case, we will just use a random String.

```
$(document).ready(function() {

  var host = "iot.eclipse.org";
  var port = 80;
  var clientID = Math.random().toString(12);

  var devices = {};

  var client = new Messaging.Client(host, Number(port), clientID);
}
```

Connect to the MQTT Broker

Once the `client` is created, the next step is to connect to the MQTT broker. There are four steps to achieve that in a proper fashion:

1. define a `onConnectionLost` handler that will be called back if the connection is lost *after the client has been successfully connected.*
2. define a `onSuccess` handler that will be called if the client is successfully connected

3. define a `onFailure` handler that will be called if the client fails to connect to the broker.
4. call `client.connect()` and pass the `onSuccess` and `onFailure` handlers in an object parameter.

```
client.onConnectionLost = function(response) {
  if (response.errorCode !== 0) {
     alert(response.errorMessage + "\nclientID = " + client.clientID + " [" +
response.errorCode + "]\n");
  }
};
client.connect({onSuccess: function(frame) {
    // this function is executed after a successful connection to the MQTT brok
er.
  },
  onFailure: function(failure) {
    alert(failure.errorMessage);
  }
});
```

All these handlers are optional and you may omit them. However without them, the Web application may fail to connect or lose connection without any way to let the user be aware of it.

Receive MQTT Messages

Once the client is successfully connected to the MQTT broker (that is to say when the `onSuccess` handler is called), we can then subscribe to a topic to receive all the device motions.

Since MQTT client does not know the whole list of devices that send their motion data, it can not subscribe to specific MQTT topics.

Fortunately MQTT defines wildcards for topic that is useful for this case.

Topic Wildcards

There are three characters that have a special meaning when they are used in a MQTT topic.

Topic level separator **/**
: The forward slash (/) is used to separate each level within a topic tree and provide a hierarchical structure to the topic space. The use of the topic level separator is significant when the two wildcard characters are encountered in topics specified by subscribers.

Multi-level wildcard `#`
: The number sign (#) is a wildcard character that matches any number of levels within a topic.

Single-level wildcard `+`
: The plus sign (+) is a wildcard character that matches only one topic level.

The Web application is interested to receive any messages sent to topics of the form `/mwm/XXX/motion` where `XXX` is the device identifier. It maps to the MQTT wildcard topic `/mwm/+/motion`.

Note that it would not have been a good idea to use the more general wildcard `/mwm/#` (using the multi-level wildcard) as it would have matched both `/mwm/XXX/motion` *and* `/mwm/XXX/alert`. The Web application is not interested by the alert sent to the devices. It is better to subscribe to the most specific wildcard topic instead of being too general and filters out message later. This also preserve network bandwith and CPU usage that the broker will not deliver messages to the client that would have to process them before discarding them anyhow.

```
client.connect({onSuccess: function(frame) {
    // once the client is successfully connected,
    // subscribe to all the motions topics
   client.subscribe("/mwm/+/motion");
  },
   ...
  });
```

We have subscribed to the `/mwm/+/motion` wildcard topic but how do we handle messages that will be delivered by the broker for all the topics that matches?

The `client` object has a `onMessageArrived` property that will be called every time a message is delivered to the client. This property must be a function that takes a single `message` parameter corresponding to the MQTT message that is delivered to the client.

This `message` object defines several properties representing the MQTT message data. The `destinationName` property contains the actual name of the topic that delivered this message. Since we have chosen to use a meaningful topic names of the form `/mwm/XXX/motion`, we can extract the `deviceID` from the `destinationName`.

The `message` object defines two properties to receive its payload content:

- `payloadBytes` corresponds to a `ArrayBuffer` representation of the message payload

- `payloadString` corresponds to a UTF-8 string representation of the message payload. This property can only be used if the payload is composed of valid UTF-8 characters.

In "Motions Message Representation" on page 12, we decided to send the device motions data as an array of 3 64-bit floats corresponding to the motions pitch, roll, and yaw values.

To be able to get these values, we must use the `payloadBytes` property and use a `DataView` to retrieve the three values for this array.

Once we got these `pitch`, `roll`, and `yaw` values, we call the `updateSparklines()` method to udpate the sparkline for the given `deviceID`

```
// subscription callback
client.onMessageArrived = function(message) {
  // get the device's id from the message's destination
  var deviceID = message.destinationName.split("/")[2];

  // get the device data from the message payload as a byte array
  var data = message.payloadBytes;
   // use a DataView on the data buffer to get the 3 motions values as double
(aka Float64)
  var values = new DataView(data.buffer);
  var pitch = values.getFloat64(data.byteOffset);
   var roll = values.getFloat64(data.byteOffset + Float64Array.BYTES_PER_ELE
MENT);
   var yaw = values.getFloat64(data.byteOffset + 2 * Float64Array.BYTES_PER_ELE
MENT );

  updateSparklines(deviceID, pitch, roll, yaw);
};
```

Draw Sparklines

The `updateSparklines()` method will store the motions values in the `devices` object that was created when the page is loaded. It will create the HTML elements to display the data and use jQuery Sparklines to display them in a graphic.

The `devices` object is a map whose keys will the `deviceID` of the devices that are sending the motion data. The values will be composed of three arrays to store the received value for `pitch`, `roll`, `yaw`. We will only keep the 50 most recent values.

We will create three separate sparklines for:

- `pitch` (displayed in red)
- `roll` (diplayed in green)

- yaw (displayed in blue)

These three sparkline will be composited in a single canvas that is drawn in the <div class="data"> elment created inside the <div> element identified by the deviceID.

```
function updateSparklines(deviceID, pitch, yaw, roll) {
  var values = devices[deviceID];
  // if the device is not known, create the UI for it
  if (!values) {
    var item = $('#devices').append(
      $('<li>').attr("id", deviceID).append(
        $('<label>').text(deviceID),
        $('<button>').text("Alert!").click(function() { sendAlert(deviceID); }),
        $('<br>'),
        $('<div>').attr('class', 'data')
      )
    );
    // create an empty array to hold its values
    values = {
      "pitch" : [],
      "roll" : [],
      "yaw" : [],
    };
  }
  // add the new value at the end of the array
  values.pitch.push(pitch);
  values.roll.push(roll);
  values.yaw.push(yaw);
  // keep only the 50 more recent values
  if (values.pitch.length > 50) {
    values.pitch.splice(0,1);
    values.roll.splice(0,1);
    values.yaw.splice(0,1);
  }
  // put back the updated values in the clients map
  devices[deviceID] = values;
  // display the values as a sparkline
  $('#'+ deviceID + ' .data').sparkline(values.pitch, {
    width: values.pitch.length * 5,
    tooltipPrefix: "pitch:",
    lineColor: 'red',
    fillColor: false,
    chartRangeMin: -3,
    chartRangeMax: 3,
    height: '36px'
  });
  $('#'+ deviceID + ' .data').sparkline(values.roll, {
    tooltipPrefix: "roll:",
    lineColor: 'green',
    composite: true,
    fillColor: false,
    chartRangeMin: -3,
```

```
    chartRangeMax: 3
  });
  $('#'+ deviceID + ' .data').sparkline(values.yaw, {
    tooltipPrefix: "yaw:",
    lineColor: 'blue',
    composite: true,
    fillColor: false,
    chartRangeMin: -3,
    chartRangeMax: 3
  });
}
```

Note that we also create a button “Alert!” for each devices that calls the `sendAlert()` method with the `deviceID` when the button is clicked. We will implement this method in the next section.

At this stage, we can alreay load the application in a Web browser. If there are devices that are running the `Motions` iOS applications, we will see them appear automatically on the page.

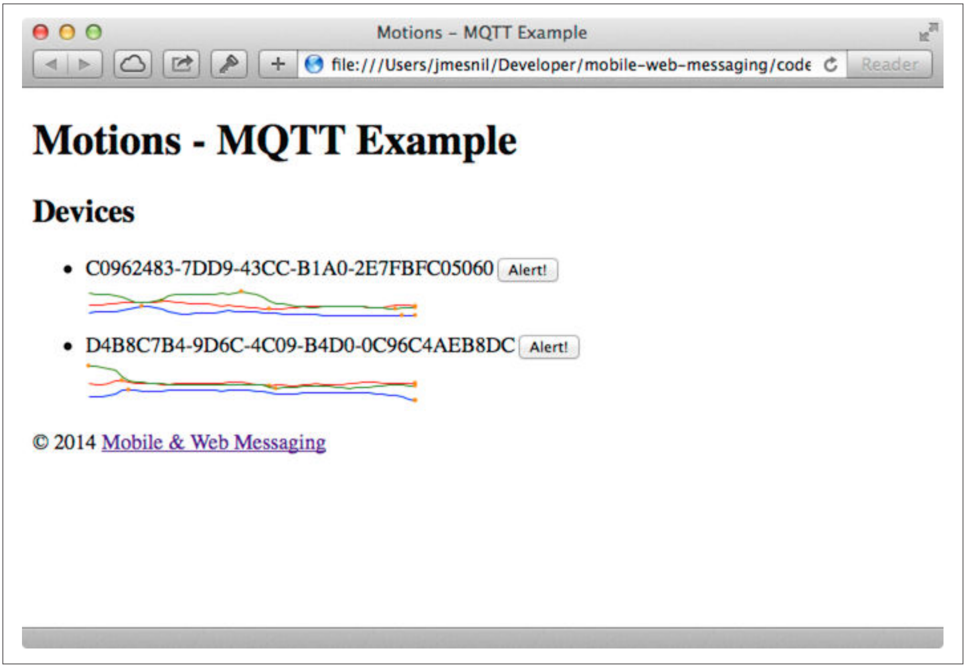


Figure 7-2. Two Motions app are publishing their device motions.

Send MQTT Messages

We now have a Web application that receives MQTT messages.

The other feature of this Web application is to *send* a MQTT message to an alert topic so that the device that subscribes to this topic will change its background color using the message payload.

When the HTML elements for a device were created, we added a `<button>` that calls `sendAlert(deviceID)` when the user clicks on it.

In this method, we will create a MQTT message object using the `new Messaging.Message()` constructor and pass a `"red"` to it to set its payload.

The message object has a `destinationName` property that must be set prior to sending the message. We use the `deviceID` to build the name of the topic corresponding to this device alert: `"/mwm/" + deviceID + "/alert"`.

Finally last step is to call `client.send()` and pass it the `message` to send it to the topic. Note that the `client` is already connected when the page was loaded.

```
function sendAlert(deviceID) {
  // create a message with an empty payload
  var message = new Messaging.Message("red");
  message.destinationName = "/mwm/" + deviceID + "/alert";
  client.send(message);
}
```

If we reload the web application and clicks on an "Alert!" button, the corresponding device will receive the message from its alert topic and the code that we wrote in "Receive MQTT Messages" on page 123 will be executed to change temporarily the background color of the device.

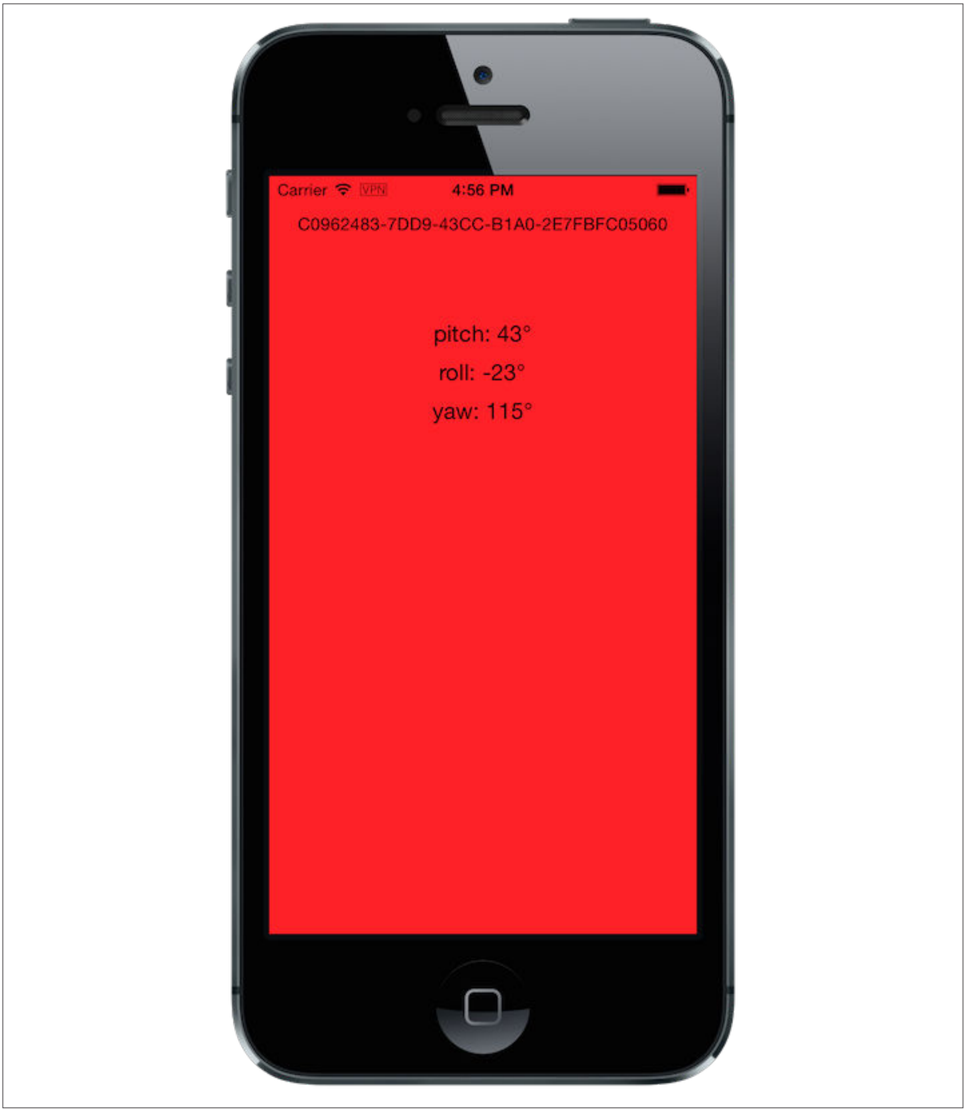


Figure 7-3. The Motions application background becomes red when an alert is received from its alert topic.

Summary

In this chapter, we learn to use MQTT over Web Socket to send and receive MQTT messages from a Web application.

We use two different types of message payload:

- a binary payload composed of three 64-bit floats
- a UTF-8 string payload

To send a message, the application must:

1. connect to the MQTT broker
2. send the message to a topic

To consume a message, the application must

1. connect to the STOMP broker
2. subscribe to a (potentially wildcard) topic and set a handler that is called every time a message is received.

In the next chapter, we will learn about more advanced features of MQTT that were not required to write this simple application. However, it is likely that you may need some of these features if your applications are more complex.

CHAPTER 8
Advanced MQTT

In the two previous chapters, we have used MQTT to send and receive messages from a native iOS application and a Web application. MQTT provides additional features that we did not use to write these applications. In this chapter, we will make a tour of all these advanced features provided by MQTT.

This chapter covers the latest version of the protocol when this book was written: MQTT v3.1 that was released on 2010, August 19th.

Authentication

In the two previous chapters, we connected to the Eclipse public MQTT broker that accepts *unauthenticated* connections. We did not need to pass any user credentials as they would not be checked by the broker anyaway.

If you are using a MQTT broker that is configured to accept secured connections, the client needs to pass a *user name* and *password* when it connects to the broker.

MQTTKit Example

The `MQTTClient` has two `NSString` properties that must be set to authenticate the client, `username` and `password`. They must be set *prior* to calling the client's `connect` methods to take effect.

If the MQTT broker requires authentication, the client can check if the connection was refused due to invalid user credentials using the `ConnectionRefusedBadUserNameOrPassword` error code from the `completionHandler`.

```
- (void)connect
{
    NSString *username = @"...";
```

```
    NSString *password = @"...";

    self.client.username = username;
    self.client.password = password;
    NSLog(@"Connecting to %@...", kMqttHost);
    [self.client connectToHost:kMqttHost
             completionHandler:^(MQTTConnectionReturnCode code) {
        if (code == ConnectionAccepted) {
            NSLog(@"connected to the MQTT broker");
            [self subscribe];
        } else if (code == ConnectionRefusedBadUserNameOrPassword) {
            NSLog(@"Failed to authenticate the user");
        } else {
             NSLog(@"Failed to connect to the MQTT broker: code=%lu", (unsigned
long)code);
        }
    }];
}
```

mqttws31.js Example

To authenticate using the `mqttws31.js` library, you must set the `userName` and `password` properties to the object passed to the client's `connect` method.

If the MQTT broker requires authentication and the client passes invalid user credentials, the client will be notified by having its `onFailure` handler called with a failure's code set to `4` (the value specified in the MQTT protocol for the error `Connection Refused: bad user name or password`).

```
var userName = "...";
var password = "...";

client.connect({onSuccess: function(frame) {
    ...
  },
  onFailure: function(failure) {
   if (failure.code === 4) {
      alert("invalid user credentials");
      return;
   }
    ...
  },
  userName: userName;
  password: password;
});
```

Error Handling

The MQTT protocol does not specify any error handling. A MQTT broker has no possible way to inform a client that an error occured. The only action that the MQTT broker can take is to close the underlying network connection so that the client is no longer connected to the broker.

MQTT libraries provides callback or handlers for these cases so that they can act when such an error occurs.

MQTTKit Example

The `MQTTClient` class has a `disconnectionHandler` property that can be set to handle any unexpected error leading to a disconnection. The disconnection can be the consequence of the MQTT broker closing the network exception (in case of abnormal errors or an administrative operation) or the network connection can be directly broken (for example if a mobile device is no longer able to receive any signal).

The `disconnectionHandler` is a block that takes a `NSUinteger code` parameter. There are no standard values for the code and you will have to consult your MQTT broker documentation if you need to act differently depending on the type of errors.

We can modify the `Motions` iOS application to handle such disconnection failures and aggressively try to reconnect the MQTT broker (assuming the root cause of the disconnection failures are transient).

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    ...

    self.client = [[MQTTClient alloc] initWithClientId:self.deviceID];

    // use a weak reference to avoid a retain/release cycle in the block
    __weak MWMViewController *weakSelf = self;
    self.client.disconnectionHandler = ^(NSUInteger code) {
        NSLog(@"client disconnected with code %lu", (unsigned long)code);
        NSLog(@"trying to reconnect...");
        // trying to reconnect;
        [weakSelf connect];
    };

    ...

    [self connect];
}
```

mqttws31.js Example

In "Connect to the MQTT Broker" on page 133, we already set a `onConnectionLost` callback on the `client` to be notified in case of connection error. The callback has a single `response` parameter object. This parameter is composed of two properties:

- `errorCode`, a numerical representation of the type of connection error
- `errorMessage`, a textual description of the error

```
client.onConnectionLost = function(response) {
  alert(response.errorMessage + "\nclientID = " + client.clientID + " [" + re
sponse.errorCode + "]\n");
};
```

Heart-beating

MQTT offers a simple mechanism to test the healthiness of the network connection betwee a client and a broker using heart-beating.

Heart-beating is enabled by specifying a *keep alive timer* when the client initially connects to the broker. This timer, measured in seconds, defines the maximum time interval between messages received from a client. It allows the client and broker to detect whether the network connection is broken without waiting for the long TCP/IP timeout. A timer value of `0` disables heart-beating.

In the absence of regular messages exchanged between them, the client and the broker automaticall send respective heart-beats (`PINGREQ` for the clien and `PINGRESP` for the broker) based on the keep alive timer to check the healthiness of the network connection.

If the client does not receive heart-beats from the broker, it will close the underlying network connection and report an error.

If the broker does not receive heart-beats from the client, it will consider that the client is disconnected.

Setting a good value for the keep alive timer is highly dependent on the application use cases and the platform it runs on.

For mobile devices that are subject to frequent intermittent network failures, using a value too small will report false failures and increase the instability of the application. It will also increase the bandwith and battery usage as heart-beats would have to be sent over the network more frequently.

MQTTKit Example

By default, `MQTTKit` defines a keep alive timer of 60 seconds.

It is possible to change this value using the `keepAlive` property on the `MQTTClient` object. The property type is a `short` and its value must be changed prior to calling the client's `connect` methods to take effect.

```
MQTTClient *client = [[MQTTClient alloc] initWithClientId:clientID];
client.keepAlive = 10; // seconds
[client connectToHost:host
    completionHandler:^(MQTTConnectionReturnCode code) {
        //...
}];
```

mqttws31.js Example

`mqttws31.js` also defines a keep aliver timer of 60 seconds by default.

The `client`'s `connect` method can take an optional `keepAliveInterval` integer to specify another value (or `0` to disable heart-beating).

```
client.connect({onSuccess: function(frame) {
    ...
  },
  onFailure: function(failure) {
    ...
  },
  keepAliveInterval: 10 // seconds
});
```

Last Will

One strength of messaging protocols is that producers and consumers are loosely coupled. They do not have to be online at the same time to exchange messages. The producer can send a message to a destination and be terminated. The messaging broker will then deliver the message to a consumer when it subscribes to this destination.

However there are cases where an application may require more information on the liveness of messaging clients.

Let's take the example of the `Motions` application that broadcasts the device position when it moves. A consumer of the device position topic will consume these messages. However, how could the consumer distinguish between receiving the messages because the device does not move or because the device is offline and has stopped broadcasting its position?

If the device is offline, the consumer may want to be notified to discard the device position from the map or show it differently from other *live* devices.

MQTT provides a *last will* feature that we could use to handle this use case.

When a MQTT client connects to the broker, it can specify a last will message that will be published to a last will topic by the broker *on behalf* of the client in case of unexpected disconnection. If the client disconnects normally, its last will message is not published. If the client uses heart-beating and the broker fails to receive its heartbeat in a timely fashion, this is considered as an unexpected disconnection and the last will message will be published.

We could use this last will to let consumers know that the Motions iOS application has been terminated abnormally or its device is no longer reachable (in case of network disconnection).

MQTTKit Example

The STOMPClient object has setWill:toTopic:withQos:retain and setWillData:toTopic:withQos:retain methods to specify the client's last will. The differences between the two methods is that the first one takes a NSString for the will message payload and the second takes a NSData. These methods must be called before the client connects to the MQTT broker to take effect.

We could improve the Motions iOS application by specifying a last will to its client object in MWMViewController.m before it connects.

The last will topic can be any MQTT topic. We will use the /mwm/lastWill topic so that a consumer would have to subscribe to this topic to be notified of any device's abnormal disconnection. The payload of the last will message is a simple JSON object with a deviceID property. We will encapsulate the setup of the last will in a setWill method.

```
- (void)setLastWill
{
    NSString *willTopic = @"/mwm/lastWill";
    NSDictionary *dict = @{ @"deviceID": self.deviceID};
    NSData *willData = [NSJSONSerialization dataWithJSONObject:dict options:0 er
ror:nil];

    [self.client setWillData:willData
                     toTopic:willTopic
                     withQos:ExactlyOnce
                      retain:NO];
}
```

We just need to call this method before connecting to the MQTT broker in connect.

```
- (void)connect
{
    [self setLastWill];
    NSLog(@"Connecting to %@...", kMqttHost);
    [self.client connectToHost:kMqttHost
             completionHandler:^(MQTTConnectionReturnCode code) {
        ...
    }];
}
```

Similarly to regular message, the last will message can specify its QoS and whether it must be retained. Last Will message may be important but infrequent. Using a QoS of exactly-once will ensure that a consumer of the last will topic will not receive false positives on the device's disconnection. We will also not retain the last will message. If it would be retained, a newly subscribed consumer would receive it and could assume that a device has been disconnecting while it reconnected in the mean time.

Before we configure the web application's own last will, we can first update it to discard data when it receives the last will message from a device.

To achieve this, we need to:

1. subscribe to the last will topic `/mwm/lastWill`
2. update the subscription callback to handle last will messages

The first step is done in the `onSuccess` callback passed to `client`*s `connect` method when we were already subscribing to the devices* motion topics.

```
var lastWillTopic = "/mwm/lastWill";

client.connect({onSuccess: function(frame) {
  // once the client is successfully connected,
  // subscribe to all the motions topics
  client.subscribe("/mwm/+/motion");
  // subscribe to the last will topic too:
  client.subscribe(lastWillTopic);
},
```

The second step requires to modify the `client`'s `onMessageArrived` callback to check whether the message is coming from the last will topic and discard the device data if that the case. Since the last will message representation is a JSON object, we must first parse it by calling `JSON.parse` on the message's `payloadString`

```
client.onMessageArrived = function(message) {
  if (message.destinationName === lastWillTopic) {
    var payload = JSON.parse(message.payloadString);
    discard(payload.deviceID);
    return;
  }
  // the rest of the function is unchanged
  ...
};
```

The `discard` function will delete the data from the `devices` dictionary and remove the HTML elements that were created to display the device.

```
function discard(deviceID) {
  console.log("discard data for " + deviceID);
  delete devices[deviceID];
```

```
    $('#'+ deviceID).remove();
  }
```

mqttws31.js Example

It is also possible to set a client's last will using `mqttws31.js`. The `client`'s `connect` method can take an optional `willMessage` object that represents the last will message to send if it disconnects unexpectedly. The value is a regular MQTT message created by calling `new Messaging.Message` constructor and specifying its `destinationName` (the last will topic), and optionally its `qos` and `retained` value.

```
var willMessage = new Messaging.Message("Web client " + clientID + " has unex
pectedly died");
willMessage.destinationName = "/mwm/lastWill/web";
willMessage.qos = 2; // exactly once
willMessage.retained = false;

// specify the last will when the client connects to the broker
client.connect({onSuccess: function(frame) {
    ...
  },
  onFailure: function(failure) {
    ...
  },
  willMessage: willMessage
});
```

Often, applications may not need to be notified of the last will of another MQTT client. However, we may still want to monitor the unexpected disconnection to be informed of the liveness of the whole system. If all MQTT clients have configured their last will, we can have a crude monitoring application by subscribing to their last will topics.

```
$ mosquitto_sub -h iot.eclipse.org -t /mwm/lastWill/# -v
...
/mwm/lastWill {"deviceID":"C0962483-7DD9-43CC-B1A0-2E7FBFC05060"}
/mwm/lastWill/web Web client 0.90778b769105b876 has unexpectedly died
```

We have subscribed to the wildcard topic `/mwm/lastWill/#` to receive messages from both `/mwm/lastWill` (that is used by the `Motions` iOS application) and any of its child including `/mwmw/lastWill/web` (that is used by the web application).

Clean Session

When a MQTT client connects to the broker, it can specify whether the broker must store its state after it disconnects and until it reconnects. The client state that is store includes its subscriptions and any in-flight message with a QoS greater or equals to `1`.

Messages with a QoS of `0` (`At Most Once`) are not stored since they are delivered on a best effort basis.

The client uses a "Clean Session" flag for this. If the flag is set, the broker will not store any state and the connection opened by the client will be *clean*. If the flag is not set, the broker will store the client state.

A client with the "Clean Session" flag set will have to subscribe again to consume messages.

A client does not set the "Clean Session" flag will consume memory on the broker side (to store its state) and the broker may also perform administrative operations to remove such state. Unless there is a strong incentive to use such a client, it is better practice to use a "Clean session" client and subscribes again after it reconnects.

MQTTKit Example

By default, MQTT clients created using `MQTTKit` have the "Clean Session" flag set (their state is not stored by the broker after they disconnect). It is also possible to change this behaviour by using the `MQTTClient`'s `initWithClientID:cleanSession:` initializer and passing `NO` to its `cleanSession` parameter.

```
- (void)viewDidLoad
{
    [super viewDidLoad];

    ...

    // do not clean the session in the broker when the client disconnects
    self.client = [[MQTTClient alloc] initWithClientID:self.deviceID
                                          cleanSession:NO];

    ...

    [self connect];
}
```

If the `Motions` iOS application is modified this way, we can test it by connecting to the broker (so that the broker knows that it must store its state) and closing the application.

While the application is closed, we will modify the `motions.html` Web application to send an alert message to the device alert topic with a QoS of `1` (`At Least Once`).

```
function sendAlert(deviceID) {
  var message = new Messaging.Message("red");
  message.destinationName = "/mwm/" + deviceID + "/alert";
  // send the alert with a QoS of at-least-once
  message.qos = 1;
```

```
    client.send(message);
  }
```

The client will not be available to receive the message so the broker must store it to deliver when the client reconnects.

If we open the `Motions` iOS application again, the broker will then deliver the message to the client.

mqttws31.js Example

The clients created by the `mqttws31.js` library also connects by default with the "Clean Session" flag set. It is possible to change this behaviour by adding a `cleanSession` property set to `false` in the properties passed to the client's `connect` method.

```
// specify that the session must not be cleaned when the client connects to the
broker
client.connect({onSuccess: function(frame) {
    ...
  },
  onFailure: function(failure) {
    ...
  },
  cleanSession: false
});
```

Beyond MQTT?

MQTT is a simple protocol well suited for a limited set of applications that can be modeled using Publish/Subscribe.

Its small set of features makes it simple to understand and use but it lacks some flexibility and you have to consider carefully if it meets your requirements.

One missing feature of MQTT is the lack of headers in the message representation.

MQTT defines a fixed set of headers for its command messages (used to connect to the broker, send a message, create a subscription, etc.) but there is no general notion of a header that the application or the broker could add to the messages.

This impacts the expressiveness of the messages that are delivered using MQTT. As a simple example, the absence of headers mean that there is no way to know what type of data to expect from the payload. HTTP and STOMP defines a `content-type` header that can be queried to know the MIME type of the payload and extract it accordingly. MQTT does not allow this and the consumer must have *a priori* knowledge of the payload type for a message before being able to read it.

The absence of headers also imply that the MQTT broker can not provide additional features not covered by the protocol in an unobtrusive way. As we saw in Chapter 5, STOMP brokers can provide additional features such as persistence, priority, expiration, etc. and the client can use them by adding headers to the messages. There is no such mechanism for MQTT in its current version. There are some ongoing discussion to add application-specific headers in a future version of the protocol but no agreement has been reached at the time of this writing.

If you plan to use MQTT in your applications, you should consider carefully whether its features match your requirements.

If you require features that are not provided by the protocol (or another messaging model than *Publish/Subscribe*), you may lose all the benefits of using this simple protocol and write brittle code that puts all the complexity in your applications instead of relying on the broker's set of features. But if your requirements are fullfilled by MQTT features (as is the case for a lot of applications), you will be all set to use messaging in your applications.

Summary

MQTT is a simple protocol that provides few advanced features. However these features can be handy to solve common issues encountered by messaging applications.

In this chapter, we learn to use:

- *authentication* to ensure that only authenticated clients can communicate with the MQTT broker
- *error handling* to face unexpected connection issues and eventually reconnect to the broker
- *heart-beating* to ensure that the network connection between the client and broker is healthy and kill the connection if that is not the case
- *last will* to let the broker sent a message on behalf of the client in case of unexpected disconnection
- *clean session* to preserve client state on the broker between connections

PART III

Appendixes

APPENDIX A
Apache ActiveMQ

In this appendix, we describe how to install and configure Apache ActiveMQ to support STOMP and MQTT protocols.

Apache ActiveMQ is a popular and powerful Open Source messaging server. It is fast, supports many cross Language clients and protocols. In this book, we will connect to it from the Objective-C and JavaScript languages using two messaging protocols: STOMP and MQTT.

Download and Installation

Apache ActiveMQ latest release at the time of writing this book is 5.9.0. It can be downloaded from its download page and the getting started page contains all the information to install it.

For our setup, ActiveMQ will be installed in the directory `~/mobilewebmsg/mybroker`.

Once you have download the archive for ActiveMQ, it can be installed and started by running the commands:

```
$ tar zxvf apache-activemq-5.9.0-bin.tar.gz
$ cd apache-activemq-5.9.0
$ mkdir ~/mobilewebmsg/
$ ./bin/activemq create ~/mobilewebmsg/mybroker
...
$ cd ~/mobilewebmsg/mybroker
$ ./bin/mybroker start
...
$ tail data/activemq.log
...
2014-06-11  15:17:17,113  |  INFO   |  Apache  ActiveMQ  5.9.0  (mybroker,
ID:jeff.local-50723-1402492636703-0:1) started | org.apache.activemq.broker.Bro-
```

```
kerService | main
...
```

To stop the broker, run the following command:

```
$ ./bin/mybroker stop
...
Stopping broker: mybroker
.... FINISHED
```

Administration Web Console

When the broker is started, it can be administrated and managed using its Web console running at *http://localhost:8161/hawtio*. Out of the box, you can log into the admin console using the **`admin`** / **`admin`** credentials.

Once you are logged in, you can check the `mybroker` resource in the ActiveMQ tree.

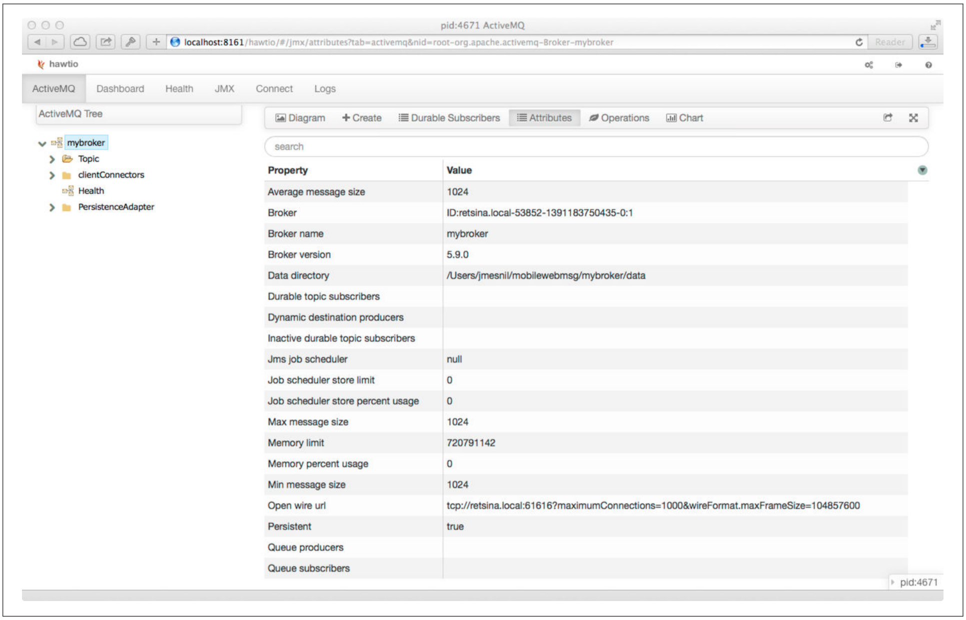


Figure A-1. The mybroker Resource in ActiveMQ Web Console

One interesting attribute is `transportConnectors`. If you click on the attribute value, a pop up screen opens and display all the protocols supported by ActiveMQ out of the box.

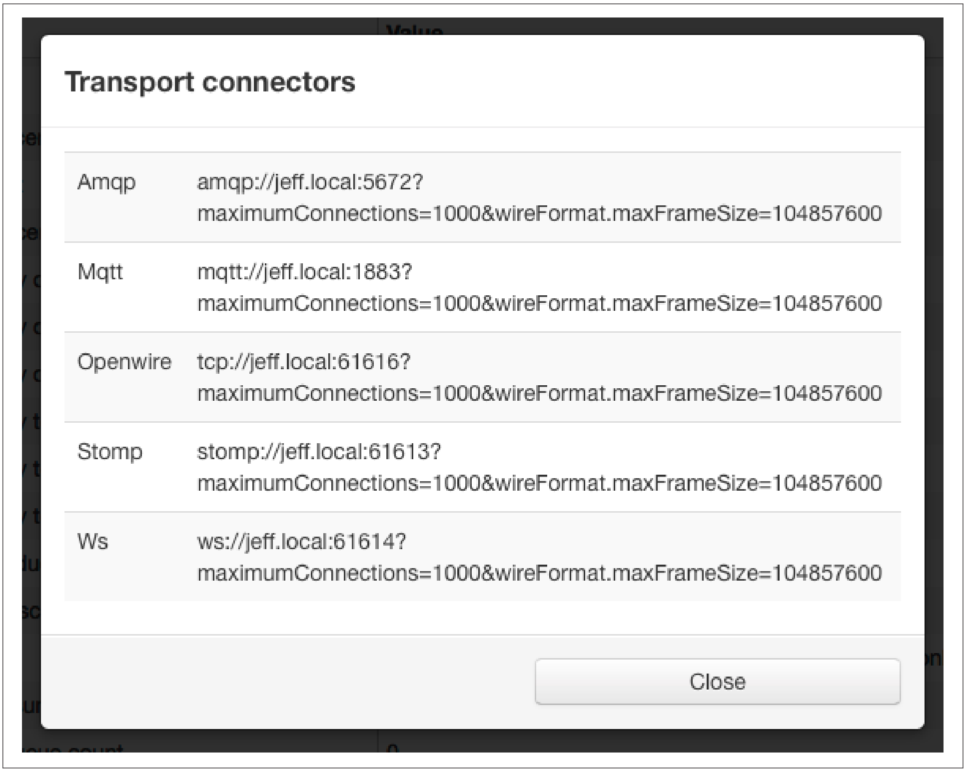


Figure A-2. ActiveMQ Default Transport Connectors.

For this book, the important ones are:

- Stomp: `stomp://jeff.local:61613`
- Mqtt: `mqtt://jeff.local:1883`
- Ws: `ws://jeff.local:61614`

They mean that to connect to ActiveMQ using the STOMP protocol we must connect to the `jeff.local` host - this is the name of my machine on my local network, your ActiveMQ installation will have another value - on the port `61613`.

Likewise, to connect to ActiveMQ using the MQTT protocol, we must use again the `jeff.local` host but on the port `1883` this time.

Finally, there is also the Web Socket connector that must be used to connect from a Web browser, *regardless* of the messaging protocol that we use. We will use to connect to the `61614` port from the Web browser for our Web applications that are using either STOMP or MQTT.

APPENDIX B
Mosquitto

In this appendix, we describe how to install the Mosquitto broker and its tools to produce and consume MQTT messages from the command line.

Download and Installation

Mosquitto is an Open Source message broker that implements the MQTT protocol. The public MQTT broker hosted on `iot.eclipse.org` that we used in Chapter 6 and Chapter 7 is an instance of Mosquitto.

Mosquitto also comes with two command lines tools to send and receive MQTT messages. These tools are handy when writing an application using MQTT to be able to quickly produce and consume messages and check that the application is working as expected.

To install Mosquitto on your operating system, please consult its documentation page that contains instructions for various operation systems and package managers.

Produce Messages with mosquitto_pub

The `mosquitto_pub` command-line tool can be used to produce MQTT messages.

In this book, we use it in the simplest fashion to send a message. The parameters we must pass to the tool are:

- `-h host` to specify the host of the MQTT broker
- `-t topic` to specify the topic of the MQTT message
- `-m message` to specify the message payload to send

For example to send a message with the text `yellow` for payload on the topic `/mwm/XYZ/alert` on the broker hosted on `iot.eclipse.org`, the command line is:

```
$ mosquitto_pub -h iot.eclipse.org -t /mwm/XYZ/alert -m yellow
```

The full list of the `mosquitto_pub` parameters is available by calling `mosquitto_pub --help`.

```
$ mosquitto_pub --help
mosquitto_pub is a simple mqtt client that will publish a message on a single
topic and exit.
mosquitto_pub version 1.3.1 running on libmosquitto 1.3.1.

Usage: mosquitto_pub [-h host] [-p port] [-q qos] [-r] {-f file | -l | -n | -m
message} -t topic
                     [-A bind_address] [-S]
                     [-i id] [-I id_prefix]
                     [-d] [--quiet]
                     [-M max_inflight]
                     [-u username [-P password]]
                      [--will-topic [--will-payload payload] [--will-qos qos] [--
will-retain]]
                     [{--cafile file | --capath dir} [--cert file] [--key file]
                      [--ciphers ciphers] [--insecure]]
                     [--psk hex-key --psk-identity identity [--ciphers ciphers]]
       mosquitto_pub --help

 -A : bind the outgoing socket to this host/ip address. Use to control which
interface
      the client communicates over.
 -d : enable debug messages.
 -f : send the contents of a file as the message.
 -h : mqtt host to connect to. Defaults to localhost.
 -i : id to use for this client. Defaults to mosquitto_pub_ appended with the
process id.
 -I : define the client id as id_prefix appended with the process id. Useful
for when the
      broker is using the clientid_prefixes option.
 -l : read messages from stdin, sending a separate message for each line.
 -m : message payload to send.
 -M : the maximum inflight messages for QoS 1/2..
 -n : send a null (zero length) message.
 -p : network port to connect to. Defaults to 1883.
 -q : quality of service level to use for all messages. Defaults to 0.
 -r : message should be retained.
 -s : read message from stdin, sending the entire input as a message.
 -S : use SRV lookups to determine which host to connect to.
 -t : mqtt topic to publish to.
 -u : provide a username (requires MQTT 3.1 broker)
 -P : provide a password (requires MQTT 3.1 broker)
 --help : display this message.
 --quiet : don't print error messages.
```

```
 --will-payload : payload for the client Will, which is sent by the broker in
case of
                  unexpected disconnection. If not given and will-topic is set,
a zero
                  length message will be sent.
 --will-qos : QoS level for the client Will.
 --will-retain : if given, make the client Will retained.
 --will-topic : the topic on which to publish the client Will.
 --cafile : path to a file containing trusted CA certificates to enable encryp-
ted
            communication.
 --capath : path to a directory containing trusted CA certificates to enable en-
crypted
            communication.
 --cert : client certificate for authentication, if required by server.
 --key : client private key for authentication, if required by server.
 --ciphers : openssl compatible list of TLS ciphers to support.
 --tls-version : TLS protocol version, can be one of tlsv1.2 tlsv1.1 or tlsv1.
                 Defaults to tlsv1.2 if available.
 --insecure : do not check that the server certificate hostname matches the re-
mote
              hostname. Using this option means that you cannot be sure that the
               remote host is the server you wish to connect to and so is inse-
cure.
              Do not use this option in a production environment.
 --psk : pre-shared-key in hexadecimal (no leading 0x) to enable TLS-PSK mode.
 --psk-identity : client identity string for TLS-PSK mode.

See http://mosquitto.org/ for more information.
```

Consume Messages with mosquitto_sub

The `mosquitto_sub` command-line tool can be used to consume MQTT messages.

The minimal parameters we must pass to the tool are:

- `-h host` to specify the host of the MQTT broker
- `-t topic` to specify the topic to consume from

For example to consume messages from the topic `/mwm/XYZ/alert` on the broker hosted on `iot.eclipse.org`, the command line is:

```
$ mosquitto_sub -h iot.eclipse.org -t /mwm/XYZ/alert
...
yellow
```

Each message that is consumed by the tool will be displayed on a new line. You can use type `ctrl + c` to exit the tool and stop consuming messages.

The full list of the mosquitto_sub parameters is available by calling mosquitto_sub --help.

```
$ mosquitto_sub --help
mosquitto_sub is a simple mqtt client that will subscribe to a single topic and
print all messages it receives.
mosquitto_sub version 1.3.1 running on libmosquitto 1.3.1.

Usage: mosquitto_sub [-c] [-h host] [-k keepalive] [-p port] [-q qos] [-R] -t
topic ...
                     [-T filter_out]
                     [-A bind_address] [-S]
                     [-i id] [-I id_prefix]
                     [-d] [-N] [--quiet] [-v]
                     [-u username [-P password]]
                      [--will-topic [--will-payload payload] [--will-qos qos] [--
will-retain]]
                     [{--cafile file | --capath dir} [--cert file] [--key file]
                      [--ciphers ciphers] [--insecure]]
                     [--psk hex-key --psk-identity identity [--ciphers ciphers]]
       mosquitto_sub --help

 -A : bind the outgoing socket to this host/ip address. Use to control which
interface
      the client communicates over.
 -c : disable 'clean session' (store subscription and pending messages when cli-
ent disconnects).
 -d : enable debug messages.
 -h : mqtt host to connect to. Defaults to localhost.
 -i : id to use for this client. Defaults to mosquitto_sub_ appended with the
process id.
 -I : define the client id as id_prefix appended with the process id. Useful
for when the
      broker is using the clientid_prefixes option.
 -k : keep alive in seconds for this client. Defaults to 60.
 -N : do not add an end of line character when printing the payload.
 -p : network port to connect to. Defaults to 1883.
 -q : quality of service level to use for the subscription. Defaults to 0.
 -R : do not print stale messages (those with retain set).
 -S : use SRV lookups to determine which host to connect to.
 -t : mqtt topic to subscribe to. May be repeated multiple times.
 -u : provide a username (requires MQTT 3.1 broker)
 -v : print published messages verbosely.
 -P : provide a password (requires MQTT 3.1 broker)
 --help : display this message.
 --quiet : don't print error messages.
 --will-payload : payload for the client Will, which is sent by the broker in
case of
                  unexpected disconnection. If not given and will-topic is set,
a zero
                  length message will be sent.
 --will-qos : QoS level for the client Will.
```

```
 --will-retain : if given, make the client Will retained.
 --will-topic : the topic on which to publish the client Will.
 --cafile : path to a file containing trusted CA certificates to enable encryp-
ted
            certificate based communication.
 --capath : path to a directory containing trusted CA certificates to enable en-
crypted
            communication.
 --cert : client certificate for authentication, if required by server.
 --key : client private key for authentication, if required by server.
 --ciphers : openssl compatible list of TLS ciphers to support.
 --tls-version : TLS protocol version, can be one of tlsv1.2 tlsv1.1 or tlsv1.
                 Defaults to tlsv1.2 if available.
 --insecure : do not check that the server certificate hostname matches the re-
mote
              hostname. Using this option means that you cannot be sure that the
               remote host is the server you wish to connect to and so is inse-
cure.
              Do not use this option in a production environment.
 --psk : pre-shared-key in hexadecimal (no leading 0x) to enable TLS-PSK mode.
 --psk-identity : client identity string for TLS-PSK mode.

See http://mosquitto.org/ for more information.
```

Bibliography

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Colophon

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