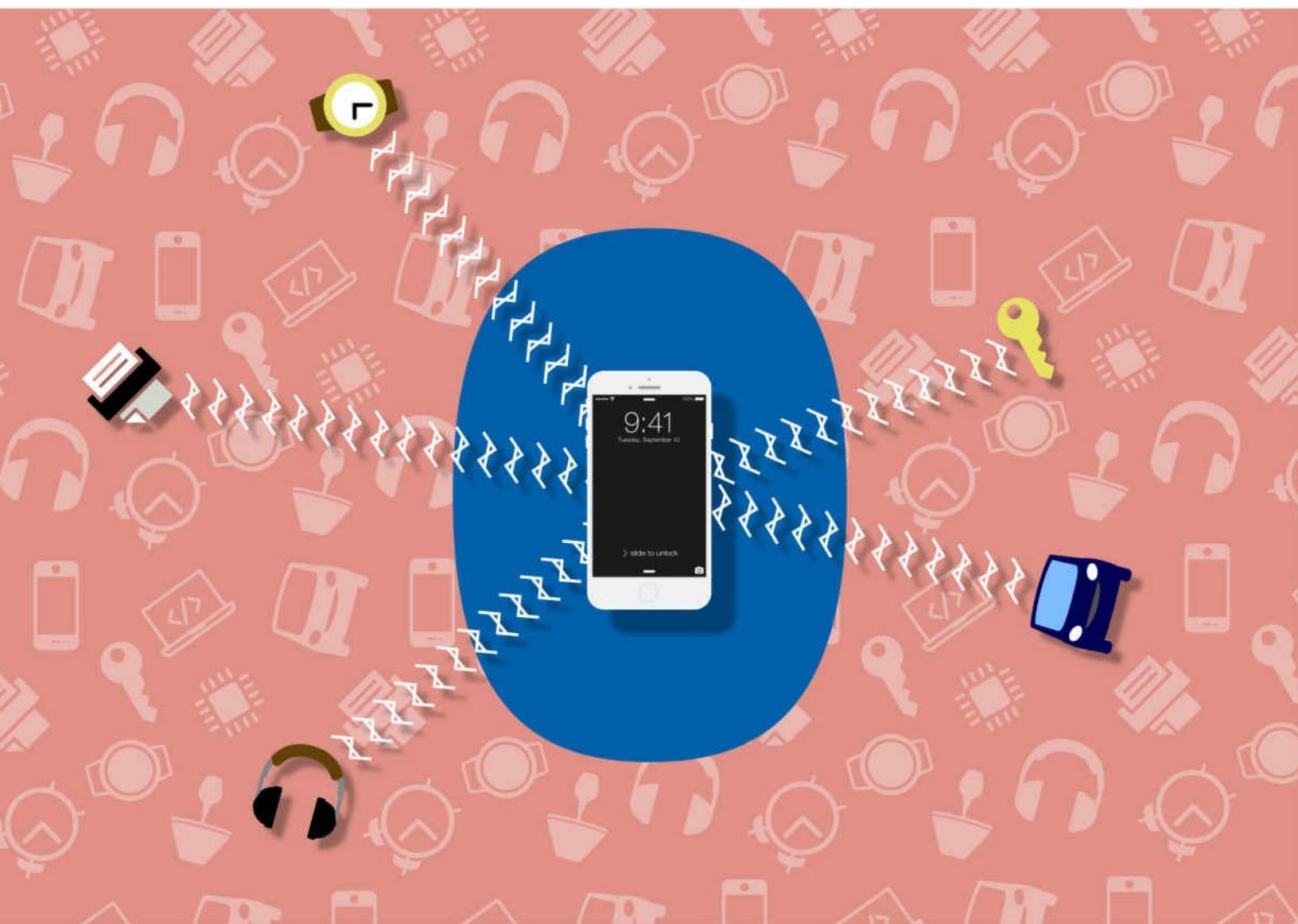


PROGRAM YOUR IPHONE TO BE A
SENSOR ● REMOTE CONTROL ● BEACON ● TRANSMITTER
USING

Bluetooth Low Energy

IN IOS SWIFT



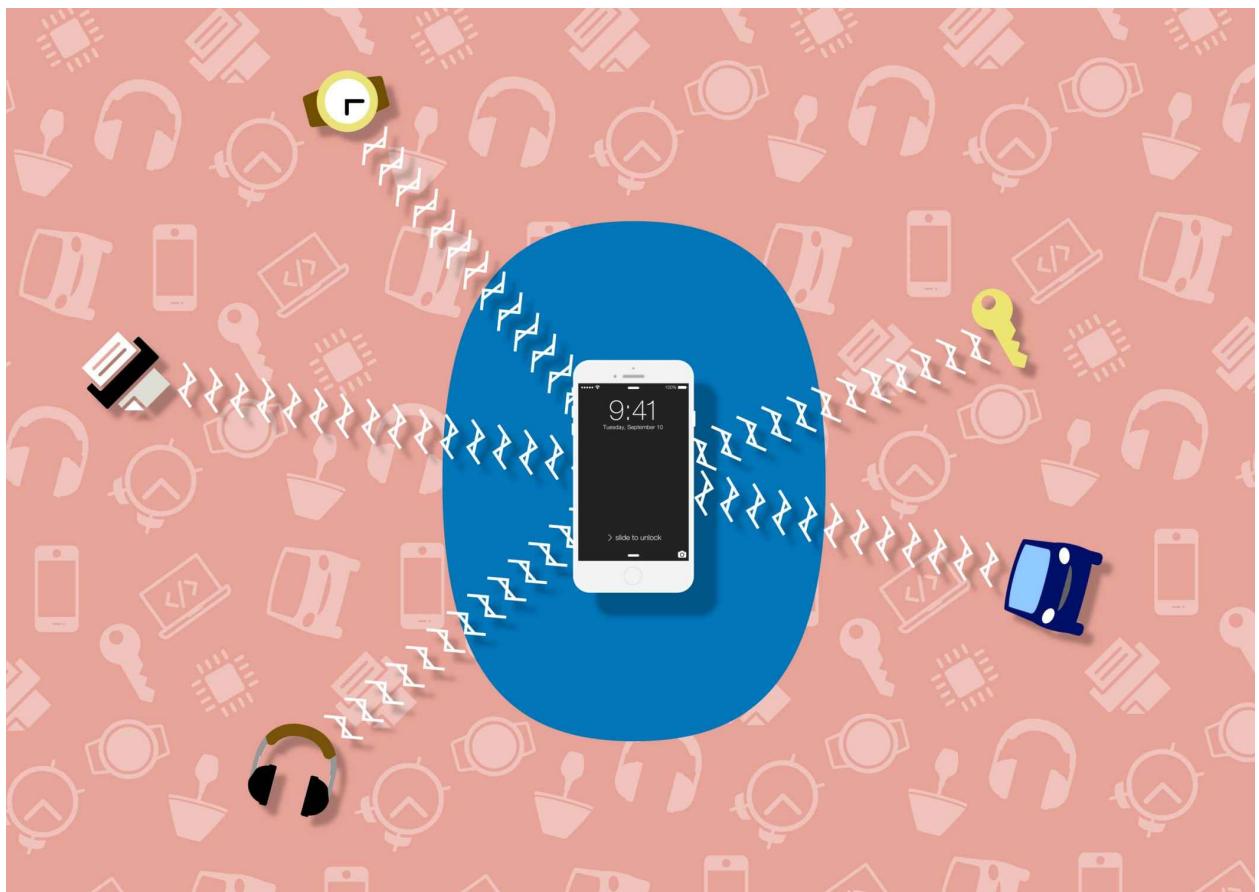
Tony Gaitatzis
2017

**TURN YOUR IPHONE INTO A
SENSOR - REMOTE CONTROL -IBEACON -
TRANSMITTER**

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Bluetooth Low Energy

IN IOS SWIFT



Tony Gaitatzis

2017

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Tony Gaitatzis

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by Tony Gaitatzis
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Dedication

*To Linda for teaching me that sharing is caring,
and Bruno for being much more thorough than I could ever be.*

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Preface

Thank you for buying this book. I'm excited to have written it and more excited that you are reading it.

I started with Bluetooth Low Energy in 2011 while making portable brain imaging technology. Later, while working on a friend's wearable electronics startup, I ended up working behind teh scenes on the TV show America's Greatest Makers in the Spring of 2016.

Coming from a web programming background, I found the mechanics and nomenclature of BLE confusing and cryptic. After immersing myself in it for a period of time I acclimated to the differences and began to appreciate the power behind this low-power technology.

Unlike other wireless technologies, BLE can be powered from a coin cell battery for months at a time - perfect for a wearable or Internet of Things (IoT) project! Because of its low power and short data transmissions, it is great for transmitting bite size information, but not great for streaming data such as sound or video.

Good luck and enjoy!

Conventions Used in This Book

Every developer has their own coding conventions. I personally believe that well-written code is self-explanatory. Moreover, consistent and organized coding conventions let developers step into each other's code much more easily, enabling them to reliably predict how the author has likely organized and implemented a feature, thereby making it easier to learn, collaborate, fix bugs and perform upgrades.

The coding conventions I used in this book is as follows:

Inline comments are as follows:

```
// inline comments
```

Multiline comments follow the Doxygen standard:

```
/**
```

```
This is a multiline comment
```

```
It features more than one line of comment
```

- Parameters:

- parameterOne: A description of what is expected for the first parameter */

Constants and variables are written in camel case:

```
let constantName = "Constant"
```

```
var normalVariable:[String]!
```


Function declarations are in Camel Case. In cases where there is not enough space for the whole function, parameters are written on another line:

```
func shortFunction() {  
}  
func longerFunction(value: String) {  
}  
func superLongFunctionName(  
    value: String, parameterOne,  
    parameterTwo: String) {  
    ...  
}
```


Introduction

In this book you will learn the basics of how to program Central and Peripheral devices that communicate over Bluetooth Low Energy using iOS in Swift. These tutorials will culminate in three projects:

- A Beacon and Scanner
- A Echo Server and Client
- A Remote Controlled Device

Through the course of the book you will learn important concepts that relate to:

- How Bluetooth Low Energy works,
- How data is sent and received
- Common paradigms for handling data

This book is an excellent read for anyone familiar with iOS programming, who wants to build an Internet of Things device or a tool that communicates with a Bluetooth device.

Overview

Bluetooth Low Energy (BLE) is a digital radio protocol. Very simply, it works by transmitting radio signals from one computer to another.

Bluetooth supports a hub-and-spoke model of connectivity. One device acts as a hub, or “Central” in Bluetooth terminology. Other devices act as “Peripherals.”

A Central may hold several simultaneous connections with a number of peripherals, but a peripheral may only hold one connection at a time (Figure 1-1). Hence the names Central and Peripheral.

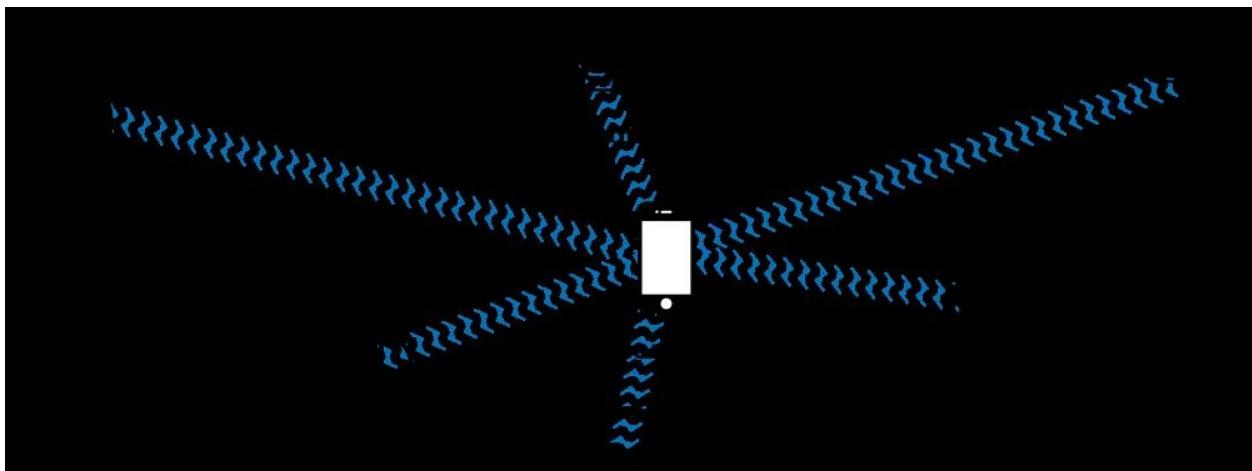


Figure 1-1. Bluetooth network topology

For example, your smartphone acts as a Central. It may connect to a Bluetooth speaker, lamp, smartwatch, and fitness tracker. Your fitness tracker and speaker, both Peripherals, can only be connected to one smartphone at a time.

The Central has two modes: scanning and connected. The Peripheral has two modes: advertising and connected. The Peripheral must be advertising for the Central to see it.

Advertising

A Peripheral advertises by advertising its device name and other information on one radio frequency, then on another in a process known as frequency hopping. In doing so, it reduces radio interference created from reflected signals or other devices.

Scanning

Similarly, the Central listens for a server's advertisement first on one radio frequency, then on another until it discovers an advertisement from a Peripheral. The process is not unlike that of trying to find a good show to watch on TV.

The time between radio frequency hops of the scanning Central happens at a different speed than the frequency hops of the advertising Peripheral. That way the scan and advertisement will eventually overlap so that the two can connect.

Each device has a unique media access control address (MAC address) that identifies it on the network. Peripherals advertise this MAC address along with other information about the Peripheral's settings.

Connecting

A Central may connect to a Peripheral after the Central has seen the Peripheral's advertisement. The connection involves some kind of handshaking which is handled by the devices at the hardware or firmware level.

While connected, the Peripheral may not connect to any other device.

Disconnecting

A Central may disconnect from a Peripheral at any time. The Peripheral is aware of the disconnection.

Communication

A Central may send and request data to a Peripheral through something called a “Characteristic.” Characteristics are provided by the Peripheral for the Central to access. A Characteristic may have one or more properties, for example READ or WRITE. Each Characteristic belongs to a Service, which is like a container for Characteristics. This paradigm is called the Bluetooth Generic Attribute Profile (GATT).

The GATT paradigm is laid out as follows (Figure 1-2).

Profile

Service

Characteristic

Characteristic

Characteristic

Service

Characteristic

Characteristic

Characteristic

Figure 1-2. Example GATT Structure

To transmit or request data from a Characteristic, a Central must first connect to the Characteristic's Service.

For example, a heart rate monitor might have the following GATT profile, allowing a Central to read the beats per minute, name, and battery life of the server (Figure 1-3).

Example Heartrate Monitor

Device Info

Name

Manufacturer

Battery Life

Heartrate Data

Beats Per Minute

Highest BPM

Lowest BPM

Figure 1-3. Example GATT structure for a heart monitor

In order to retrieve the battery life of the Characteristic, the Central must be connected also to the Peripheral’s “Device Info” Service.

Because a Characteristic is provided by a Peripheral, the terminology refers to what can be done to the Characteristic. A “write” occurs when data is sent to the Characteristic and a “read” occurs when data is downloaded from the Characteristic.

To reiterate, a Characteristic is a field that can be written to or read from. A Service is a container that may hold one or more Characteristics. GATT is the layout of these Services and Characteristics. Characteristic can be written to or read from.

Byte Order

Bluetooth orders data in both Big-Endian and Little-Endian depending on the context.

During advertisement, data is transmitted in Big Endian, with the most significant bytes of a number at the end (Figure 1-4).

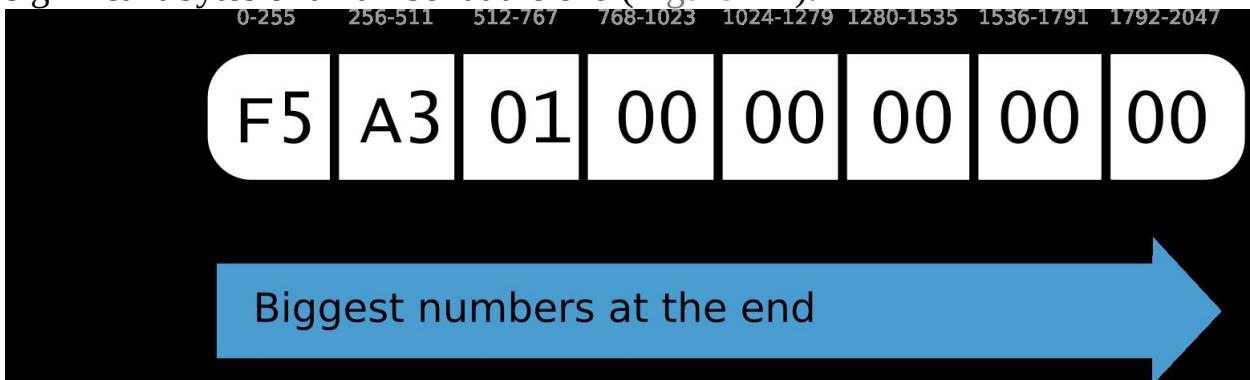


Figure 1-4. Big Endian byte order

Data transfers inside the GATT however are transmitted in Little Endian, with the least significant byte at the end (Figure 1-5).

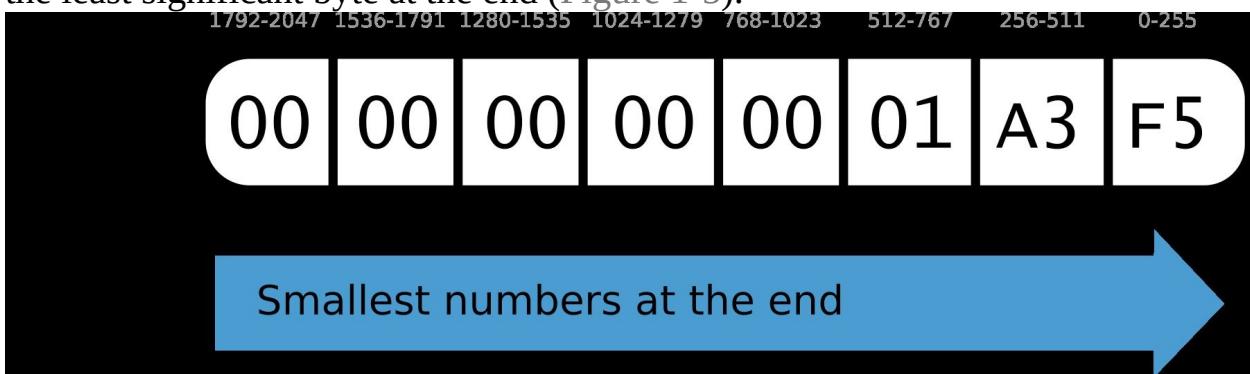


Figure 1-5. Little Endian byte order

Permissions

A Characteristic grants certain Permissions of the Central. These permissions include the ability to read and write data on the Characteristic, and to subscribe to Notifications.

Descriptors

Descriptors describe the configuration of a Characteristic. The only one that has been specified so far is the “Notification” flag, which lets a Central subscribe to Notifications.

UUIDs

A UUID, or Universally Unique IDentifier is a very long identifier that is likely to be unique, no matter when the UUID was created or who created it.

BLE uses UUIDs to label Services and Characteristics so that Services and Characteristics can be identified accurately even when switching devices or when several Characteristics share the same name.

For example, if a Peripheral has two “Temperature” Characteristics - one for Celsius and the other in Fahrenheit, UUIDs allow for the right data to be communicated.

UUIDs are usually 128-bit strings and look like this:

ca06ea56-9f42-4fc3-8b75-e31212c97123

But since BLE has very limited data transmission, 16-bit UUIDs are also supported and can look like this:

0x1815

Each Characteristic and each Service is identified by its own UUID. Certain UUIDs are reserved for specific purposes.

For example, UUID 0x180F is reserved for Services that contain battery reporting Characteristics.

Similarly, Characteristics have reserved UUIDs in the Bluetooth Specification.

For example, UUID 0x2A19 is reserved for Characteristics that report battery levels.

A list of UUIDs reserved for specific Services can be found in ***Appendix IV: Reserved GATT Services***.

A list of UUIDs reserved for specific Characteristics can be in ***Appendix V: Reserved GATT Characteristics***.

If you are unsure what UUIDs to use for a project, you are safe to choose an unassigned service (e.g. 0x180C) for a Service and generic Characteristic (0x2A56).

Although the possibility of two generated UUIDs being the same are extremely low, programmers are free to arbitrarily define UUIDs which may already exist. So long as the UUIDs defining the Services and Characteristics do not overlap in the a single GATT Profile, there is no issue in using UUIDs that exist in other contexts.

Bluetooth Hardware

All Bluetooth devices feature at least a processor and an antenna (Figure 1-6).

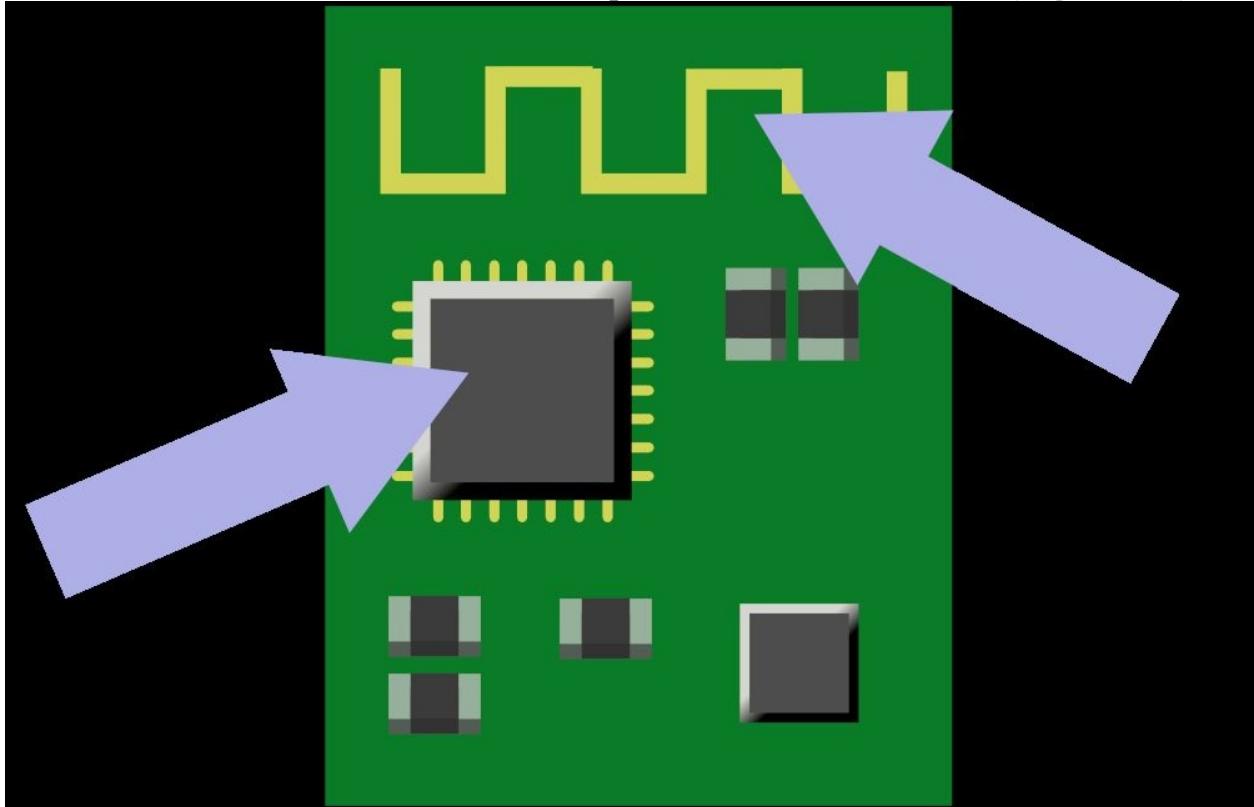


Figure 1-6. Parts of a Bluetooth device

The antenna transmits and receives radio signals. The processor responds to changes from the antenna and controls the antenna's tuning, the advertisement message, scanning, and data transmission of the BLE device.

Power and Range

BLE has 20x2 Mhz channels, with a maximum 10 mW transmission power, 20 byte packet size, and 1 Mbit/s speed.

As with any radio signal, the quality of the signal drops dramatically with distance, as shown below (Figure 1-7).

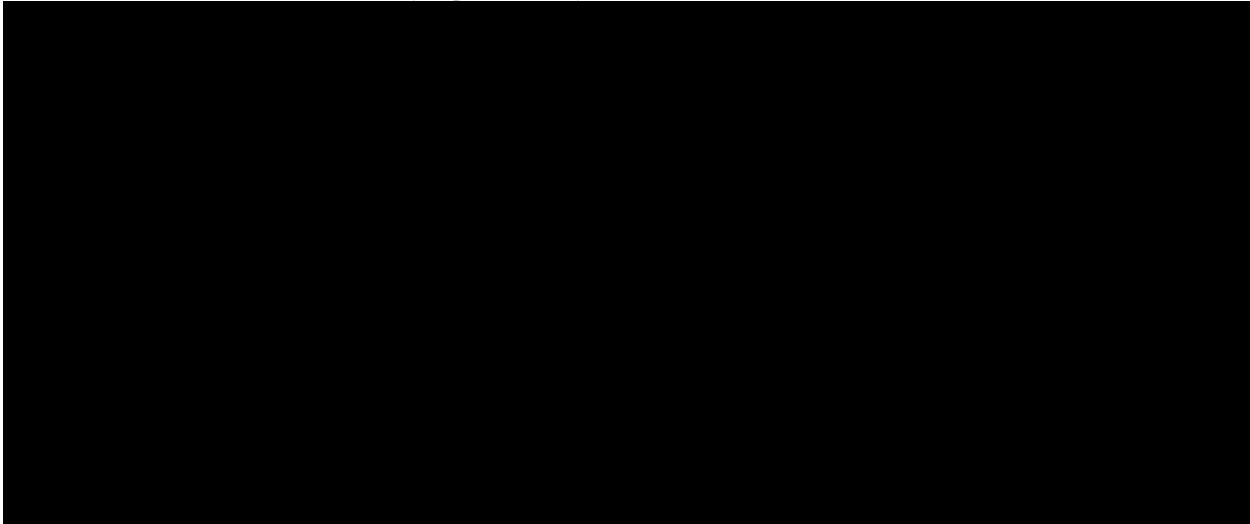


Figure 1-7. Distance versus Bluetooth Signal Strength

This signal quality is correlated the Received Signal Strength Indicator (RSSI). If the RSSI is known when the Peripheral and Central are 1 meter apart (A), as well as the RSSI at the current distance (R) and the radio propagation constant (n). The distance between the Central and the Peripheral in meters (d) can be approximated with this equation:

$$d \approx 10^{A - R10n}$$

The radio propagation constant depends on the environment, but it is typically somewhere between 2.7 in a poor environment and 4.3 in an ideal environment. Take for example a device with an RSSI of 75 at one meter, a current RSSI reading 35, with a propagation constant of 3.5:

$$d$$

≈

$$10$$

$75 - 35 = 10 \times 3.5$

$$d$$

≈

$$10$$

40 - 35

$$d \approx 14$$

Therefore the distance between the Peripheral and Central is approximately 14 meters.

Introducing iOS

iOS is an incredibly easy platform to program Bluetooth Low Energy. Apple has done most of the work necessary to get Bluetooth Low Energy projects off the ground.

Apple makes it easy for anyone with an Apple computer to get into iOS programming. Xcode is a dream to work with, there are no developer registration costs, and the Swift programming language is easy to use.

That means developers can develop and test apps rapidly. iPhones and iPads, as with all modern mobile devices, are designed to support Bluetooth Low Energy.

This book teaches how to make Bluetooth Low Energy (BLE) capable Apps using Swift for iOS. Although the examples in this book are relatively simple, the app potential of this technology is amazing.

Xcode Setup

iPhones since version 5 and iPads since version 2 are designed to support Bluetooth Low Energy.

We will be using XCode to learn how to program Bluetooth Low Energy software with iOS. Although the examples in this book are relatively simple, the app potential of this technology is amazing. To program in iOS, you will need XCode on a Mac computer.

XCode can be downloaded for free from the App Store.

Search for XCode in the App Store (

Figure 2-1).

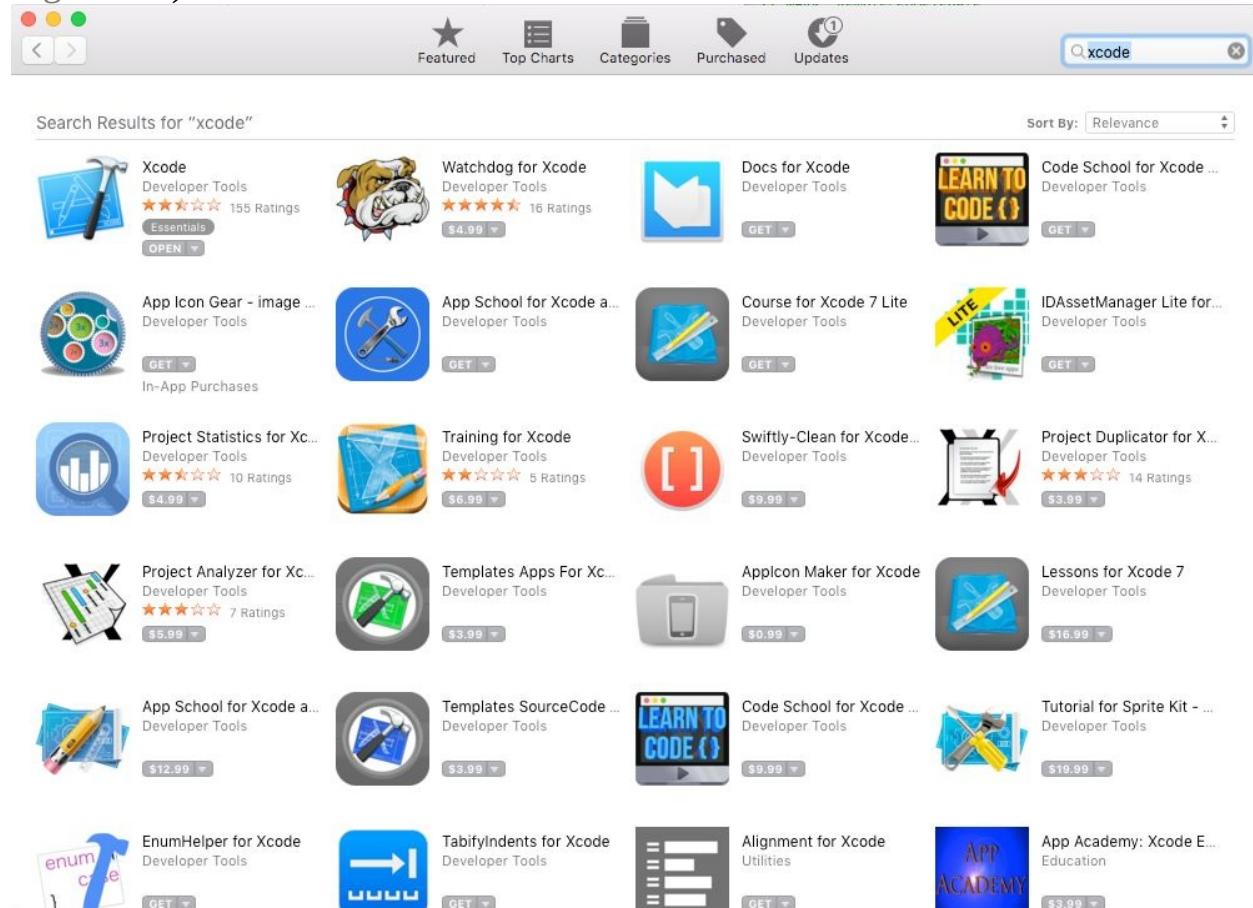


Figure 2-1. XCode listed in the App Store

Install XCode by selecting Xcode from the list and clicking the "Install" button (Figure 2-2).



Figure 2-2. XCode detail page

Running XCode will open a screen like this. Select "Create a new Xcode project" to continue (Figure 2-3).



Figure 2-3. XCode Launch Screen

Each time a new project is created, the project type must be specified. In this book, "Single View Application" will be used for all projects (Figure 2-4).

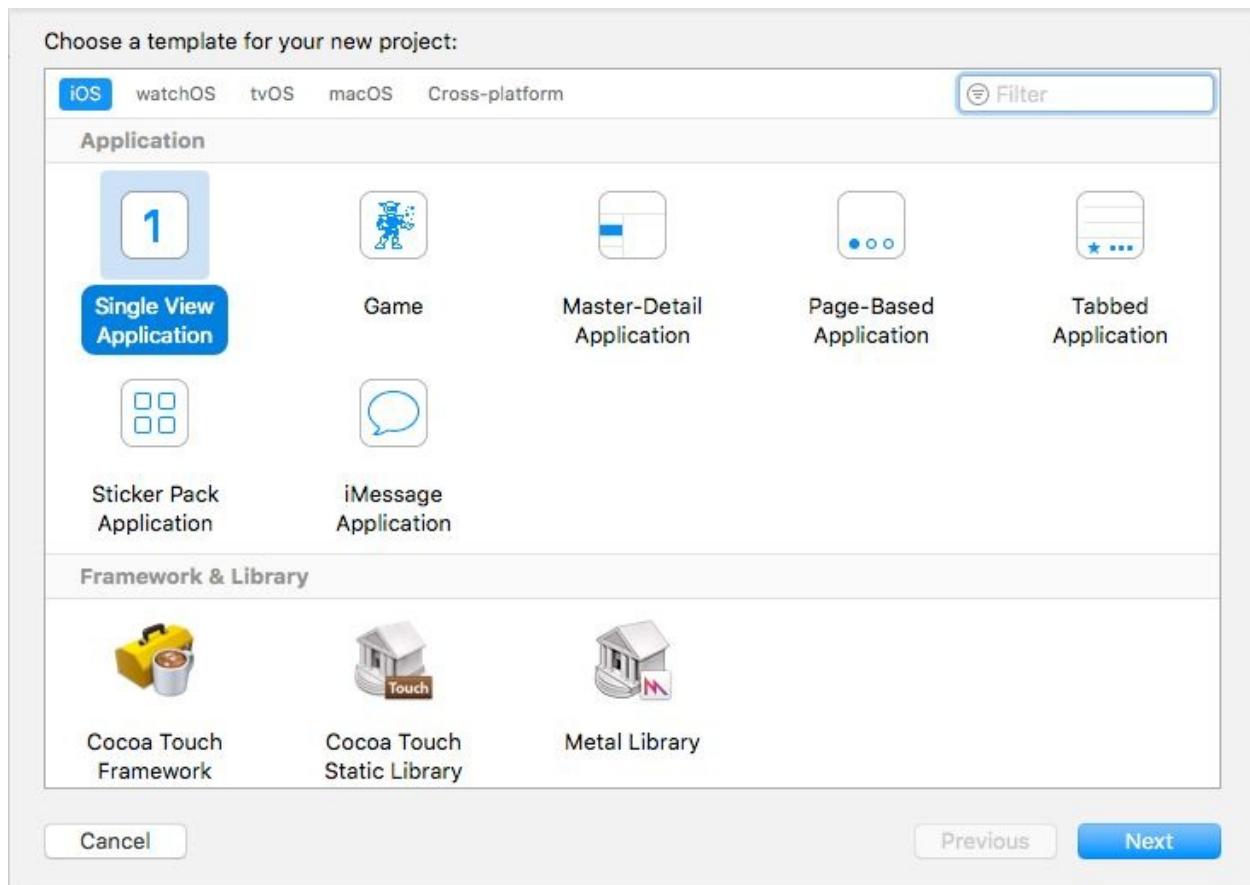


Figure 2-4. New XCode Project Type

From there, a Product Name, Team and Organization Name must be defined. These names are arbitrary. Names for each chapter project will be suggested (Figure 2-5).

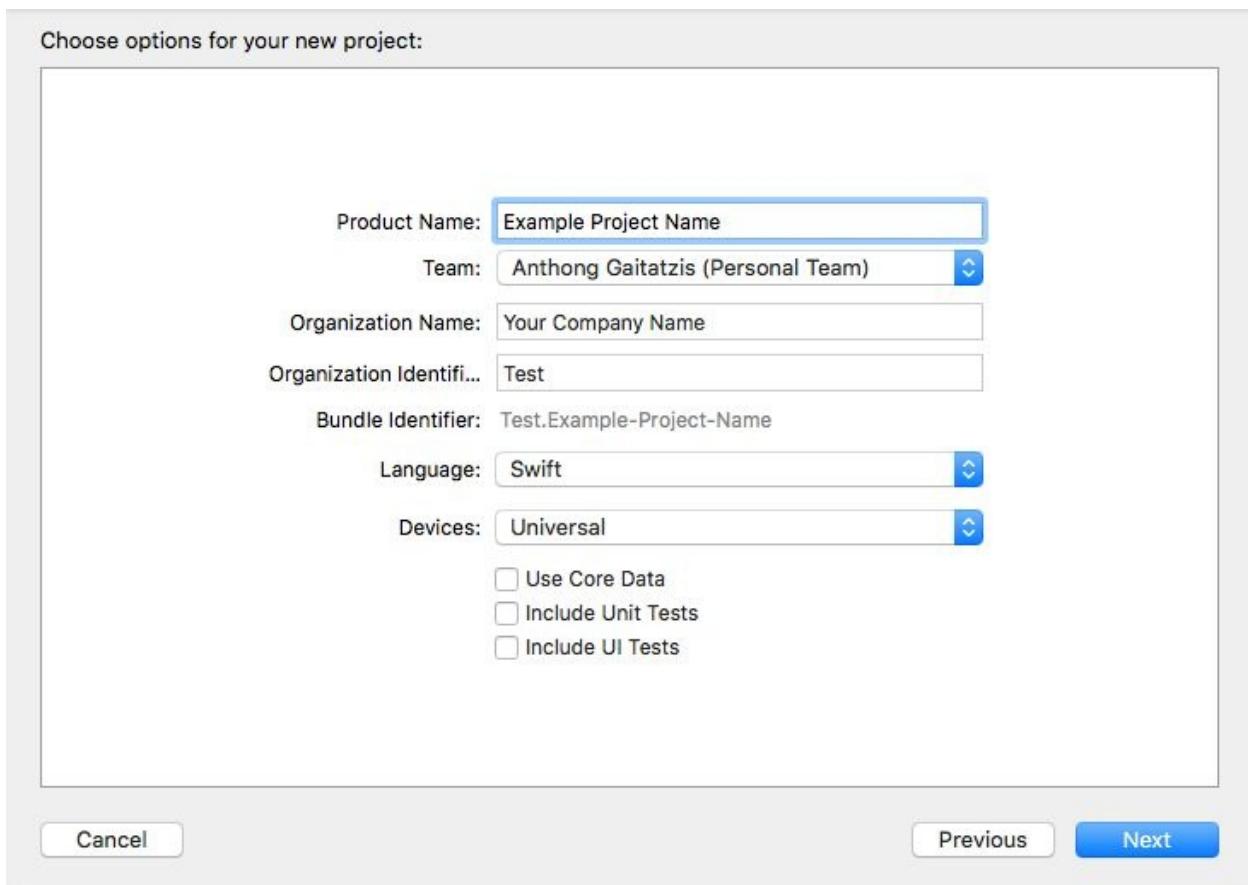


Figure 2-5. New XCode Project Name

Click "Next" and XCode will present a "Save As" modal dialog. Select which folder to save the new project and click "Create" to save the project (Figure 2-6).

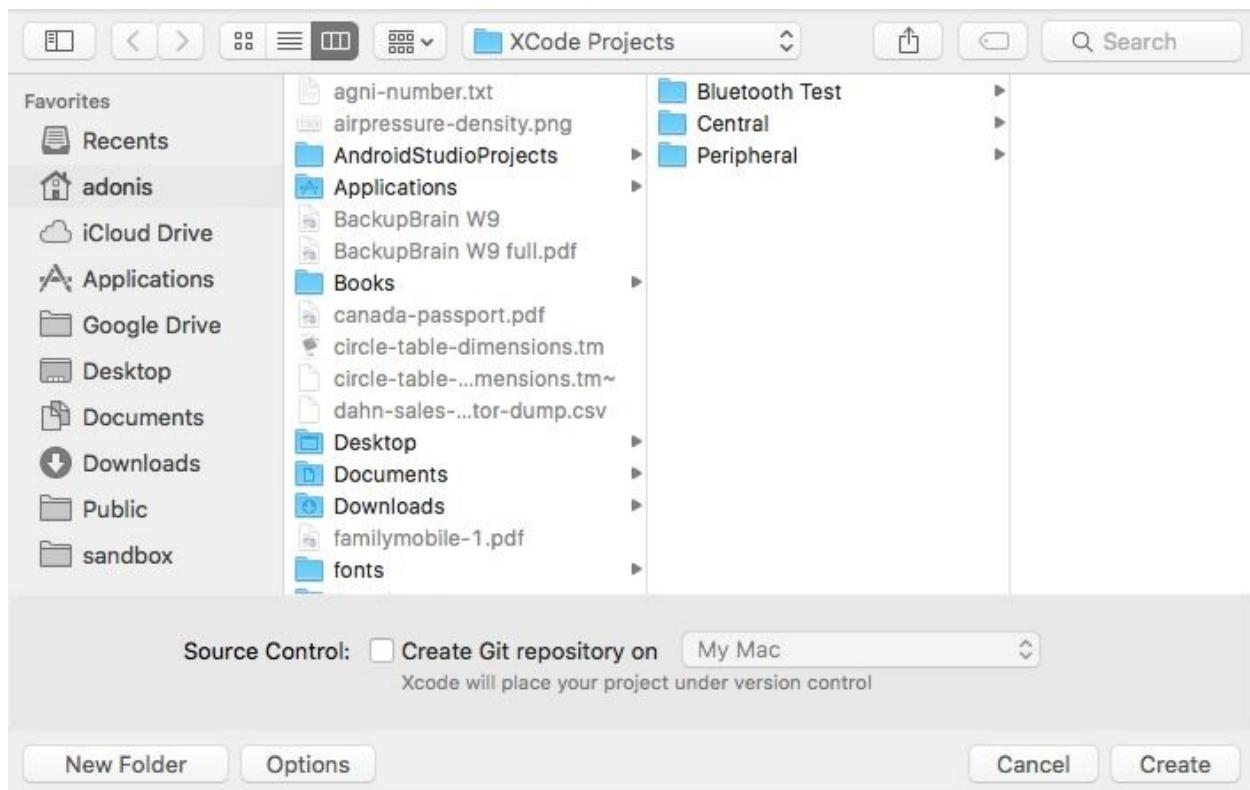


Figure 2-6. New XCode Project Folder

The next screen is the project settings, where the Project Name and Team can be changed. On the left is the project structure, where new classes and groups can be created (Figure 2-7).

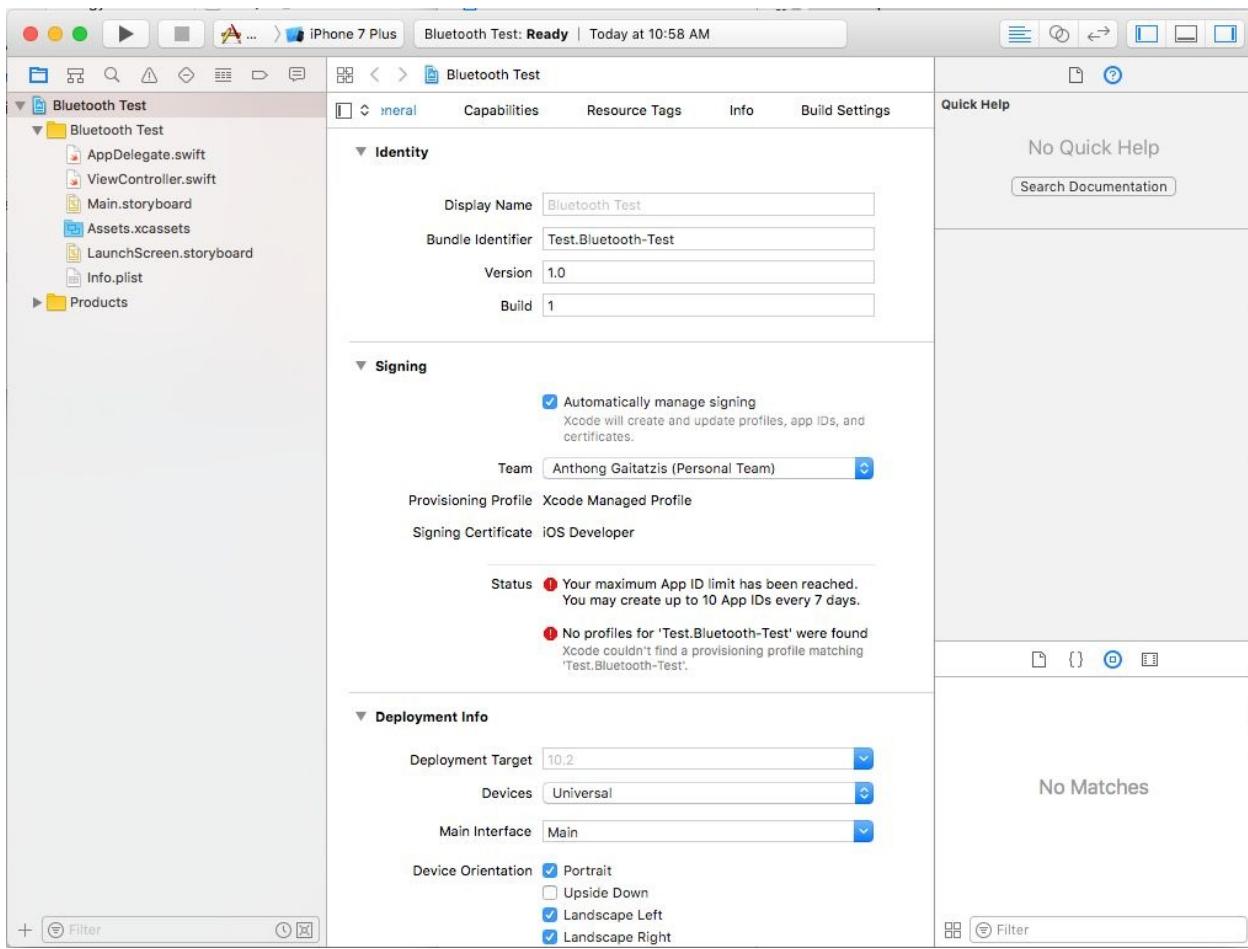


Figure 2-7. New XCode Project

The center panel is where code and storyboards are edited (Figure 2-8).

The screenshot shows the XCode interface with the code editor open. The file `ViewController.swift` is selected in the project navigator on the left. The code editor displays the following Swift code:

```
1 // ViewController.swift
2 // Bluetooth Test
3 // Created by Adonis Gaitatzis on 2/2/17.
4 // Copyright © 2017 Example Company. All rights reserved.
5 //
6 import UIKit
7
8 class ViewController: UIViewController {
9
10    override func viewDidLoad() {
11        super.viewDidLoad()
12        // Do any additional setup after loading the view, typically
13        // from a nib.
14    }
15
16    override func didReceiveMemoryWarning() {
17        super.didReceiveMemoryWarning()
18        // Dispose of any resources that can be recreated.
19    }
20
21 }
22
23
24
25
26 }
```

The right side of the interface includes a "Quick Help" panel which says "No Quick Help" and a search bar labeled "Search Documentation". Below the code editor, a search results panel shows "No Matches" and a "Filter" input field.

Figure 2-8. XCode code editor

Bootstrapping

The first thing to do in any software project is to become familiar with the environment.

Because we are working with Bluetooth, it's important to learn how to initialize the Bluetooth radio and report what the program is doing.

Both the Central and Peripheral talk to the computer over USB when being programmed. That allows you to report errors and status messages to the computer when the programs are running (Figure 3-1).

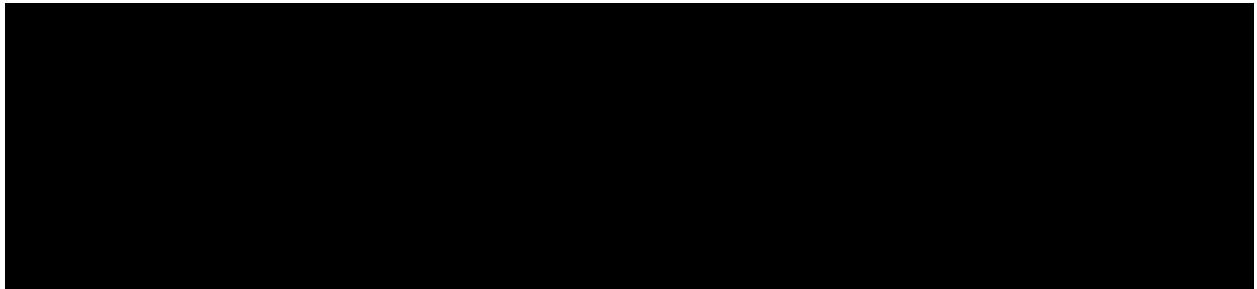


Figure 3-1. Programming configuration

Programming the Central

This chapter details how to create a Central App that turns the Bluetooth radio on. The Bluetooth radio requires the CoreBluetooth Framework and might be off by default.

Adding Bluetooth Support

Since most Apps don't require Bluetooth, and the APIs take up valuable program space, the APIs are not included by default. To add support for Bluetooth, the CoreBluetooth Framework must be included.

This is done by scrolling to the bottom of the Project Settings Screen, to the "Linked Frameworks and Libraries" section (Figure 3-2).

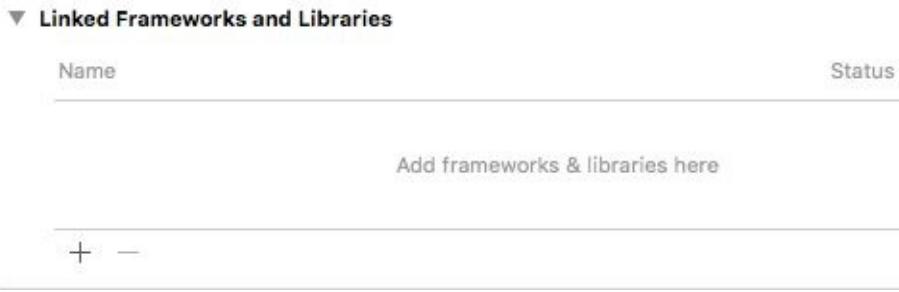


Figure 3-2.

Linked Framework List

Click the "+" button to add a new Framework. A dialog will pop up. Search for "CoreBluetooth" in the search field (Figure 3-3):

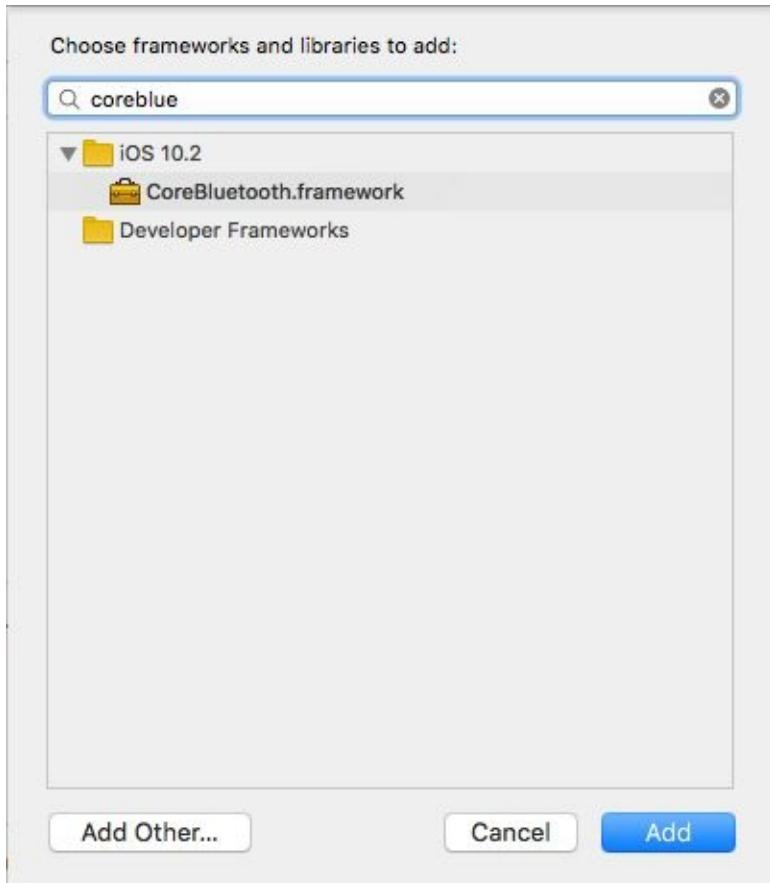


Figure 3-3. Linked

Framework List

Click on "CoreBluetooth.framework" and click the "Add" button to add Bluetooth support to a project (Figure 3-4).

Linked Frameworks and Libraries	
Name	Status
CoreBluetooth.framework	Required
+	-

Figure 3-4.

Linked Framework List

Enable Bluetooth

Before using any Bluetooth features, it is important to import the CoreBluetooth APIs at in the file header of any class that will use Bluetooth classes, and to turn on the Bluetooth radio

Importing the CoreBluetooth APIs is done like this:

```
import CoreBluetooth
```

The user might turn the Bluetooth radio off any time. Therefore, every time the App loads, it needs to check if check if Bluetooth is still enabled or has been disabled, using this function.

This is done by making a ViewController a CBCentralManagerDelegate and instantiating a CBCentralManager.

The CBCentralManager allows the iOS device to act as a Bluetooth Central, and the CBCentralManager relays CBCentralManager state changes and events to the local object.

It takes a moment for Bluetooth to turn on. To prevent trying to access Bluetooth before it's ready, the App must listen for the CentralManagerDelegate to respond with a centralManagerDidUpdateState method, which is triggered by changes in the Bluetooth radio status.

```
class ViewController: UIViewController, CBCentralManagerDelegate { var  
centralManager:CBCentralManager  
  
override func viewDidLoad() {  
super.viewDidLoad()  
centralManager = CBCentralManager(delegate: self, queue: nil)  
  
}  
  
func centralManagerDidUpdateState(_ central: CBCentralManager) {  
print("Central Manager updated: checking state") switch (central.state) {  
case .poweredOff:  
  
print ("BLE Hardware is powered off")  
bluetoothStatusLabel.text = "Bluetooth Radio Off" case .poweredOn:  
print ("BLE Hardware powered on and ready")  
bluetoothStatusLabel.text = "Bluetooth Radio On" case .resetting:  
print ("BLE Hardware is resetting...")  
bluetoothStatusLabel.text = "Bluetooth Radio Resetting..." case .unauthorized:  
print ("BLE State is unauthorized")  
bluetoothStatusLabel.text = "Bluetooth Radio Unauthorized" case .unsupported:
```

```
print ("Ble hardware is unsupported on this device") bluetoothStatusLabel.text =  
"Bluetooth Radio Unsupported" case .unknown:  
print ("Ble state is unavailable")  
bluetoothStatusLabel.text = "Bluetooth State Unknown" }  
}  
}
```

The centralManagerDidUpdateState method will include an updated CBCentralManager object, including the new CBCentralManagerState which tells the state of the Bluetooth radio and its capabilities. The new state will be one of the following:

Table 3-1 . CBManagerState

State Description

poweredOff Bluetooth is disabled

poweredOn Bluetooth is enabled

resetting Bluetooth radio is resetting

unauthorized

App is not authorized to use Bluetooth

unknown There was a problem talking to the Bluetooth radio

unsupported Bluetooth is unavailable

Putting It All Together

Create a new project called Bootstrapping. Create packages and classes so that the project structure resembles this:

Your code structure should now look like this (Figure 3-5).

```
Bootstrapping/
  UI/
    Controllers/
      ViewController.swift
      Main.storyboard
      LaunchScreen.storyboard
  Delegates/
    AppDelegate.swift
    Assets.xcassets
    Info.plist
  Frameworks/
    CoreBluetooth.framework
```

Figure 3-5. Project Structure

Storyboard

Create a UINavigationController and connect the Storyboard Entry Point to it. Add a UILabel to the UIViewController to be used to display the Bluetooth radio status (Figure 3-6):

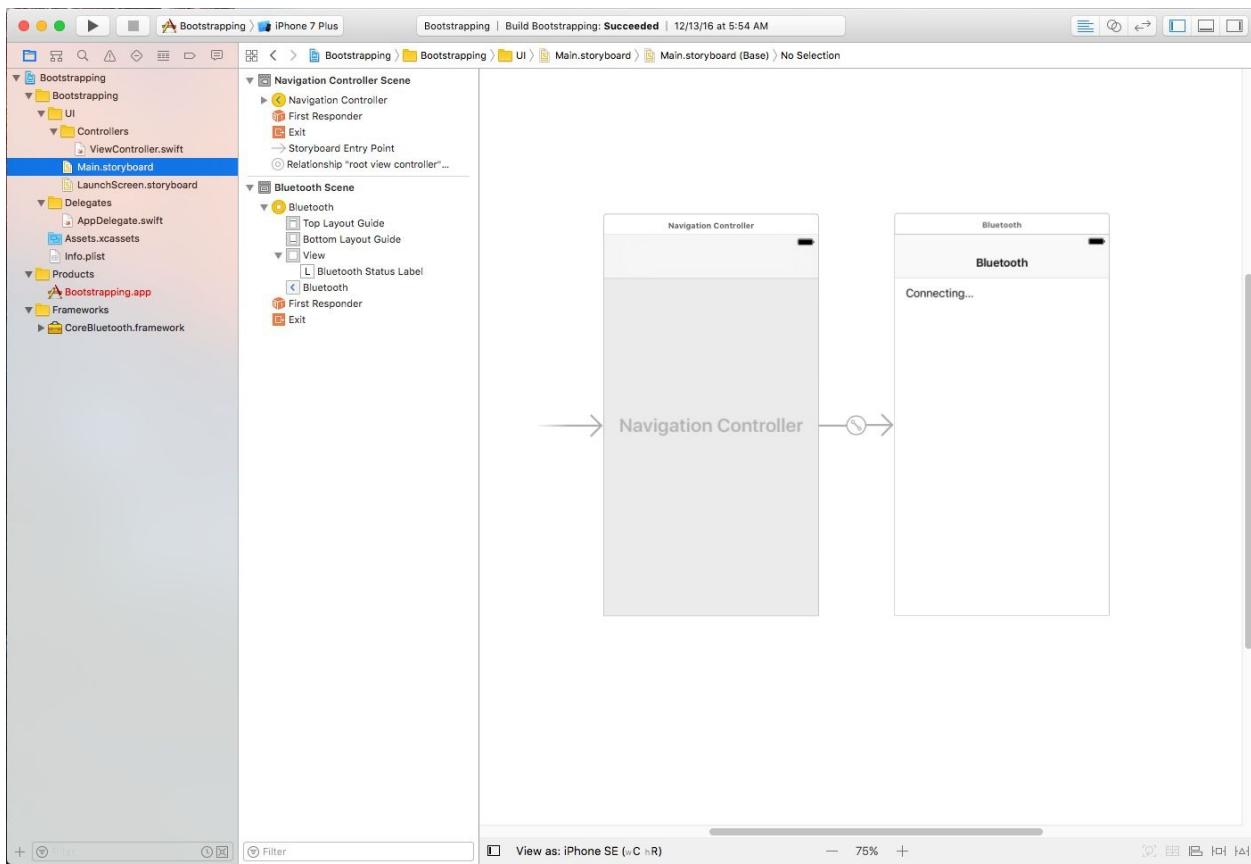


Figure 3-6. Project Storyboard Controllers

The ViewController can create a CentralManager which is alerted when the device's Bluetooth radio is turned on or off.

Therefore, the ViewController is programmed like this (Example 3-1):

Example 3-1. UI/Controllers/ViewController.swift

```
import UIKit
```

```
import CoreBluetooth
```

```
/**
```

This view attempts to turn on the Bluetooth Radio

```
*/
```

```
class ViewController: UIViewController, CBCentralManagerDelegate {
```

```
// MARK: UI Elements
```

```
@IBOutlet weak var bluetoothStatusLabel: UILabel!
```

```
// MARK: Scan Properties
```

```
var centralManager:CBCentralManager!
```

```
/**
```

View loaded. Start Bluetooth radio. */

```
override func viewDidLoad() {  
super.viewDidLoad()  
print("Initializing central manager")  
centralManager = CBCentralManager(delegate: self, queue: nil) }  
// MARK: CBCentralManagerDelegate Functions  
/**  
Bluetooth radio state changed
```

- Parameters:
- central: the reference to the central

```
*/  
  
func centralManagerDidUpdateState(_ central: CBCentralManager) {  
print("Central Manager updated: checking state")  
  
switch (central.state) {  
case .poweredOff:  
print ("BLE Hardware is powered off")  
bluetoothStatusLabel.text = "Bluetooth Radio Off" case .poweredOn:  
print ("BLE Hardware powered on and ready")  
bluetoothStatusLabel.text = "Bluetooth Radio On" case .resetting:  
print ("BLE Hardware is resetting...")  
bluetoothStatusLabel.text = "Bluetooth Radio Resetting..." case .unauthorized:  
print ("BLE State is unauthorized")  
bluetoothStatusLabel.text = "Bluetooth Radio Unauthorized" case .unsupported:  
print ("Ble hardware is unsupported on this device")  
bluetoothStatusLabel.text = "Bluetooth Radio Unsupported" case .unknown:  
print ("Ble state is unavailable")  
bluetoothStatusLabel.text = "Bluetooth State Unknown" }  
}  
}
```

The resulting app will be able to turn the Bluetooth Radio on (Figure 3-7).

●●●●○ Fido 3G

13:53

100%  ⚡

Bluetooth

Bluetooth Radio Off

**Turn On Bluetooth to Allow
“sketch” to Connect to
Accessories**

[Settings](#)

[OK](#)

●●●○○ Fido 3G

13:54

蓝牙 100%  ⚡

Bluetooth

Bluetooth Radio On

Figure 3-7. Dialog to request user's permission to enable Bluetooth and Main App Screen

Programming the Peripheral

Peripheral Mode in iOS is supported since iOS 10. It is simple to use, but requires first that the CoreBluetooth Framework is included and imported into code, and that the Bluetooth radio is turned on

Import CoreBluetooth

Link the CoreBluetooth Framework from the project Settings (Figure 3-8).



Figure 3-8. CoreBluetooth Framework linked into project

Import the CoreBluetooth library in the code header to access the Bluetooth APIs:

```
import CoreBluetooth
```

Enable Bluetooth

To turn on Bluetooth, instantiate a new CBPeripheralManager:

```
// empty dispatch queue
```

```
let dispatchQueue:DispatchQueue! = nil
```

```
let peripheralManager = \
```

```
CBPeripheralManager(delegate: self, queue: dispatchQueue)
```

The CBPeripheralManagerDelegate will execute the

peripheralManagerDidUpdateState callback, which will alert the App when the Bluetooth radio state has changed:

```
class ViewController: UIViewController, CBPeripheralManagerDelegate { ...
```

```
func peripheralManagerDidUpdateState(
```

```
    _ peripheral: CBPeripheralManager)
```

```
{ switch (state) {
```

```
case CBManagerState.poweredOn:
```

```
    print("Bluetooth on")
```

```
case CBManagerState.poweredOff:  
print("Bluetooth off")  
case CBManagerState.resetting:  
print("Bluetooth is resetting")  
case CBManagerState.unauthorized:  
print("App not authorized ot use Bluetooth") case CBManagerState.unknown:  
print("Bluetooth off")  
case CBManagerState.poweredOff:  
print("Unknown problem when talking trying to start \ Bluetooth radio")  
case CBManagerState.unsupported:  
print("Bluetooth not supported")  
}  
}  
...  
}
```

It does this by passing a CBManagerState representing the new state of the Bluetooth radio, with the following possible states:

Table 3-2 . CBManagerState

State Description

poweredOff Bluetooth is disabled

poweredOn Bluetooth is enabled

resetting Bluetooth radio is resetting

unauthorized

App is not authorized to use Bluetooth

unknown There was a problem talking to the Bluetooth radio

unsupported Bluetooth is unavailable

Putting It All Together

Create a new project called Bootstrapping with the following project structure (Figure 3-9).

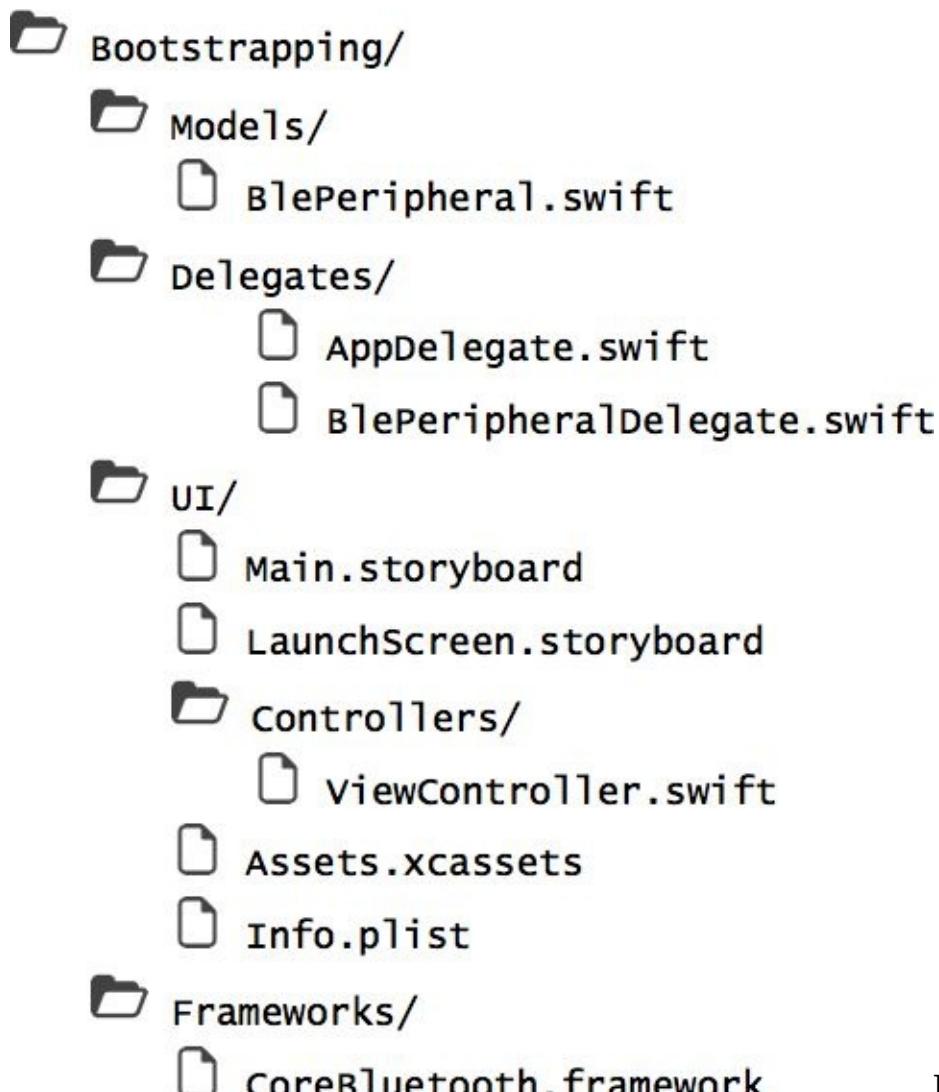


Figure 3-9. Project Structure

Structure

This project will be a single UIView app that creates a custom Bluetooth Peripheral.

Models

The BlePeripheral object will create a custom Bluetooth Peripheral and its track events and state changes (Example 3-2).

).

Example 3-2. Models/BlePeripheral.swift

```
import UIKit
import CoreBluetooth
class BlePeripheral : NSObject, CBPeripheralManagerDelegate { // MARK:
  Peripheral properties
  // Advertized name
  let advertisingName = "MyDevice"
```

```

// MARK: Peripheral State

// Peripheral Manager
var peripheralManager:CBPeripheralManager! // Connected Central
var central:CBCentral!
// delegate
var delegate:BlePeripheralDelegate!

/**
Initialize BlePeripheral with a corresponding Peripheral

- Parameters:
- delegate: The BlePeripheralDelegate
- peripheral: The discovered Peripheral

*/
init(delegate: BlePeripheralDelegate?) { super.init()
// empty dispatch queue
let dispatchQueue:DispatchQueue! = nil

self.delegate = delegate
peripheralManager = \
CBPeripheralManager(delegate: self, queue: dispatchQueue) }
// MARK: CBPeripheralManagerDelegate

/**
Peripheral will become active */
func peripheralManager(
    _ peripheral: CBPeripheralManager, willRestoreState dict: [String : Any])

{
print("restoring peripheral state")
}

/**
Bluetooth Radio state changed
*/
func peripheralManagerDidUpdateState( _ peripheral: CBPeripheralManager)

```

```
{  
    peripheralManager = peripheral  
    delegate?.blePeripheral?(stateChanged: peripheral.state)  
}  
}
```

Delegates

The BlePeripheralDelegate will relay important events from the BlePeripheral to the ViewController (Example 3-3).

Example 3-3. Delegates/BlePeripheralDelegate.swift

```
import UIKit  
import CoreBluetooth  
@objc protocol BlePeripheralDelegate : class { /*  
    Bluetooth Radio state changed
```

- Parameters:
- state: new CBManagerState */

```
@objc optional func blePeripheral(stateChanged state: CBManagerState) }
```

Controllers

The main UIView will instantiate a BlePeripheral object and print a message to the debugger when Bluetooth radio has turned on (Example 3-4).

Example 3-4. UI/Controllers/ViewController.swift

```
import UIKit  
import CoreBluetooth  
class ViewController: UIViewController, BlePeripheralDelegate {  
    // MARK: BlePeripheral  
    // BlePeripheral  
    var blePeripheral:BlePeripheral!  
  
    /**  
     UIView loaded  
    */  
  
    override func viewDidLoad() { super.viewDidLoad()  
    }
```

```
/**  
View appeared. Start the Peripheral  
*/  
  
override func viewDidAppear(_ animated: Bool) { blePeripheral =  
    BlePeripheral(delegate: self)  
}  
// MARK: BlePeripheralDelegate
```

```
/**  
Bluetooth radio state changed
```

- Parameters:
- state: the CBManagerState

```
*/
```

```
func blePeripheral(stateChanged state: CBManagerState) { switch (state) {  
case CBManagerState.poweredOn:  
  
    print("Bluetooth on")  
case CBManagerState.poweredOff:  
    print("Bluetooth off")  
default:  
    print("Bluetooth not ready yet...")  
}
```

The resulting app will be able to turn the Bluetooth Radio on (Figure 3-10).

●●●○○ Fido 3G

13:45

100%  ⚡

Figure 3-10. Main app screen

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter03>

Scanning and Advertising

The first step to any Bluetooth Low Energy interaction is for the Peripheral to make the Central aware of its existence, through a process called Advertising. During the Advertising process, a peripheral Advertises while a Central Scans.

Bluetooth devices discover each other when they are tuned to the same radio frequency, also known as a Channel. There are three channels dedicated to device discovery in Bluetooth Low Energy (Table 4-1):

Table 4-1. Bluetooth Low Energy Discovery Radio Channels

Channel Radio Frequency

37 2402 Mhz

39 2426 Mhz

39 2480 Mhz

The peripheral will advertise its name and other data over one channel and then another. This is called frequency hopping (Figure 4-1).

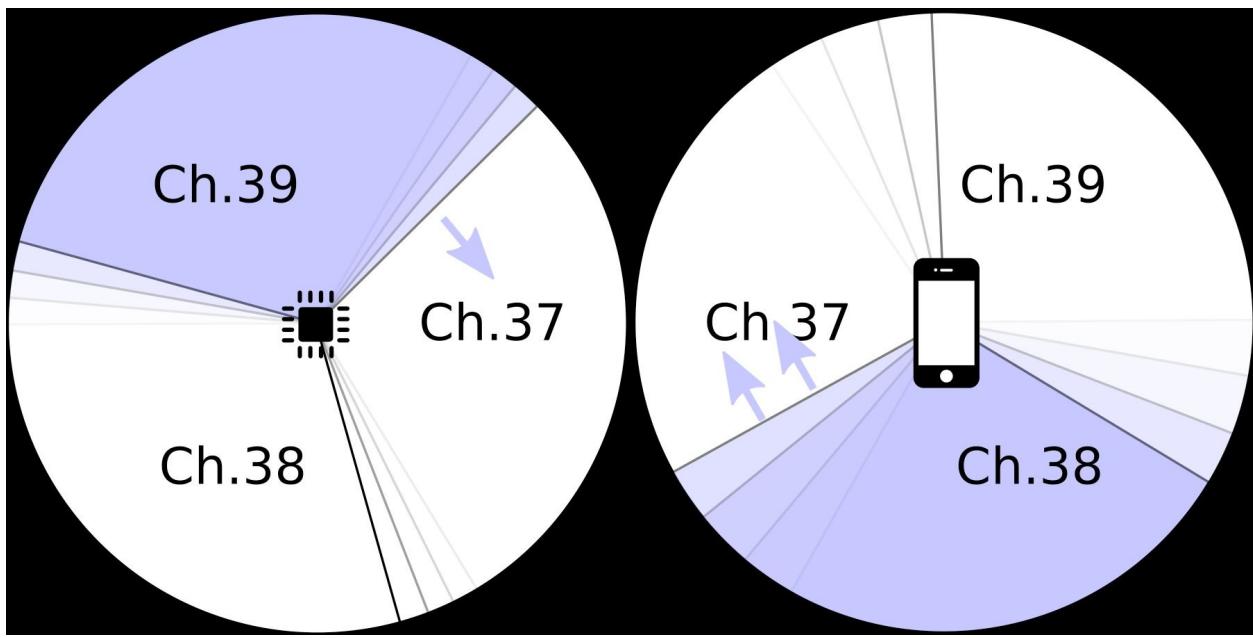


Figure 4-1. Advertise and scan processes

Similarly, the Central listens for advertisements first on one channel and then another. The Central hops frequencies faster than the Peripheral, so that the two are guaranteed to be on the same channel eventually.

Peripherals may advertise from 100ms to 100 seconds depending on their configuration, changing channels every 0.625ms (Figure 4-2).

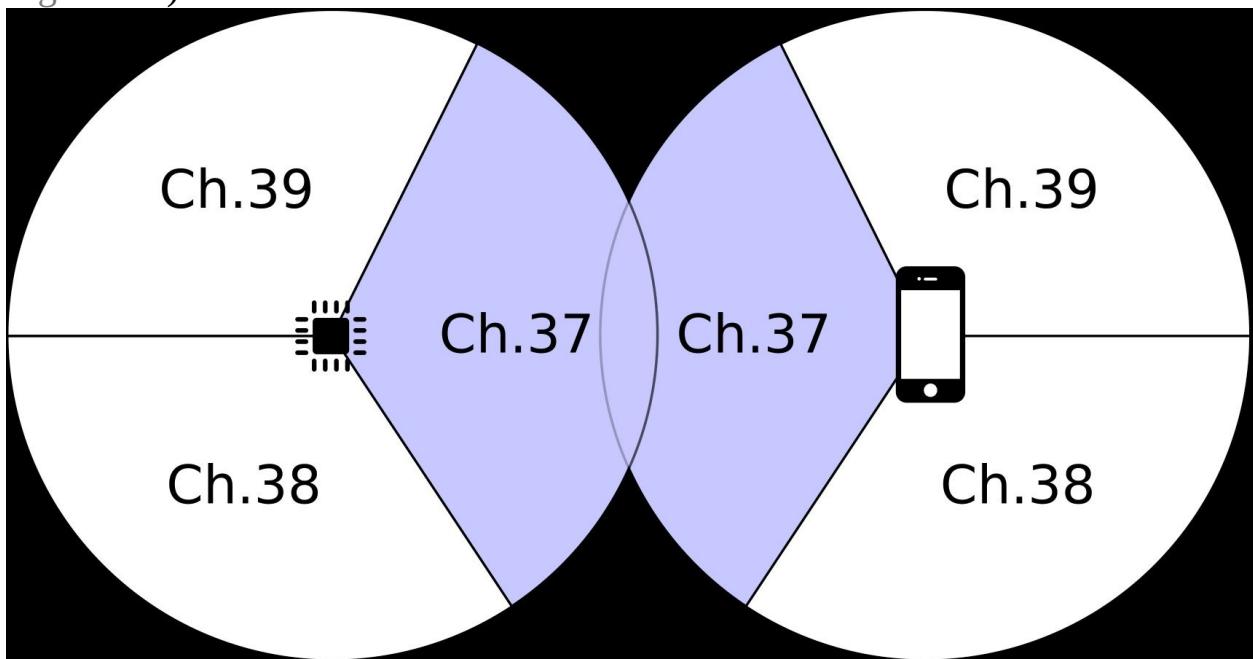


Figure 4-2. Scan finds Advertiser

Scanning settings vary wildly, for example scanning every 10ms for 100ms, or scanning for 1 second for 10 seconds.

Programming the Central

The previous chapter showed how to access the Bluetooth hardware, specifically the CBCentralManager. This chapter will show how to scan for Bluetooth devices. This is done by scanning for Peripherals for a short period of time. During that time any time a Peripheral is discovered, the system will trigger a callback function. From there discovered Peripheral can be inspected.

The CBCentralManager lets you scan for Peripherals.

```
// scan for Peripherals  
centralManager.scanForPeripherals(withServices: nil, options: nil)
```

If you happen to know one or more Service UUIDs hosted on a Peripheral your App is searching for, these UUIDs can be passed into the withServices parameter like this:

```
serviceUuids = [ "1815", "180C" ]  
centralManager.scanForPeripherals(withServices: serviceUuids, options: nil)  
Only Peripherals hosting matching Service UUIDs will be returned.  
To stop an in-progress scan, execute the stopScan function:  
centralManager.stopScan()
```

It is typical to scan for a period of time before stopping. 3-5 seconds is a reasonable amount of time to assume that most devices will be discovered during the scanning process.

This can be done with a Timer:

```
func startScan() {  
    scanCountdown = 5 // 5 seconds  
    scanTimer = Timer.scheduledTimer(  
        timeInterval: 1.0,  
        target: self,  
        selector: #selector(updateScanCounter), userInfo: nil, repeats: true  
  
    )  
  
    if let centralManager = centralManager {  
        centralManager.scanForPeripherals(withServices: nil, options: nil)
```

```
}

func updateScanCounter() {
//your code, this is an example if scanCountdown > 0 {

    scanCountdown -= 1
} else {
    centralManager?.stopScan()
}
```

As each new Peripheral is discovered, the centralManager didDiscover event is triggered, which can reveal a Peripheral's advertised name and identifier. centralManager didDiscover can be implemented like this to get the Peripheral identifier:

```
func centralManager(
    _ central: CBCentralManager,
    didDiscover peripheral: CBPeripheral, advertisementData: [String : Any], rssi
    RSSI: NSNumber)

{
let peripheralIdentifier = peripheral.identifier
}
```

For security reasons, iOS does not reveal the MAC address of a Peripheral. Instead, it creates a 32-bit UUID identifier.

The Advertised name of a Peripheral is typically buried in the GAP Advertisement data, which can be retrieved like this:

```
var advertisedName = advertisementData["kCBAdvDataLocalName"] as! String
```

Putting It All Together

Create a new project called Scanner, and copy everything from the previous example.

Create a file structure that looks like this (Figure 4-3).

```
Scanning/
  Models/
    BlePeripheral.swift
  UI/
    Main.storyboard
    LaunchScreen.storyboard
    views/
      PeripheralTableViewCell.swift
  Controllers/
    PeripheralTableViewController.swift
  Delegates/
    AppDelegate.swift
    Assets.xcassets
    Info.plist
  Frameworks/
    CoreBluetooth.framework
```

Figure

4-3. Project structure

This example will feature a UITableView to list discovered Peripherals

Models

Create a BlePeripheral class that holds information about a CBPeripheral.

Example 4-1. Models/BlePeripheral.swift

```
import UIKit
import CoreBluetooth
class BlePeripheral: NSObject {
  // MARK: Peripheral properties

  // connected Peripheral
  var peripheral: CBPeripheral! // advertised name
  var advertisedName: String! // RSSI
```

```

var rssi:NSNumber!

/** Initialize BlePeripheral with a corresponding Peripheral

- Parameters:
- delegate: The BlePeripheralDelegate
- peripheral: The discovered Peripheral

*/
init(peripheral: CBPeripheral) { super.init()
self.peripheral = peripheral

}

/** Get a broadcast name from an advertisementData packet. This may be different than the actual broadcast name */

static func getAlternateBroadcastFromAdvertisementData( advertisementData: [String : Any]) -> String?
{
// grab thekCBAAdvDataLocalName from the advertisementData // to see if there's an alternate broadcast name
if advertisementData["kCBAAdvDataLocalName"] != nil { return
(advertisementData["kCBAAdvDataLocalName"] as! String) }
return nil
}

}

```

Storyboard

Create a UITableView and connect it to the UINavigationController in place of the default UIView. Give it the class name "PeripheralTableViewCell."

Add a UITableViewCell to it, with the class name "PeripheralTableViewCell" and the Reuse Identifier of "PeripheralTableViewCell." In the PeripheralTableViewCell, create and link three UILabels to be used for describing the connected Peripheral properties (Figure 4-4):

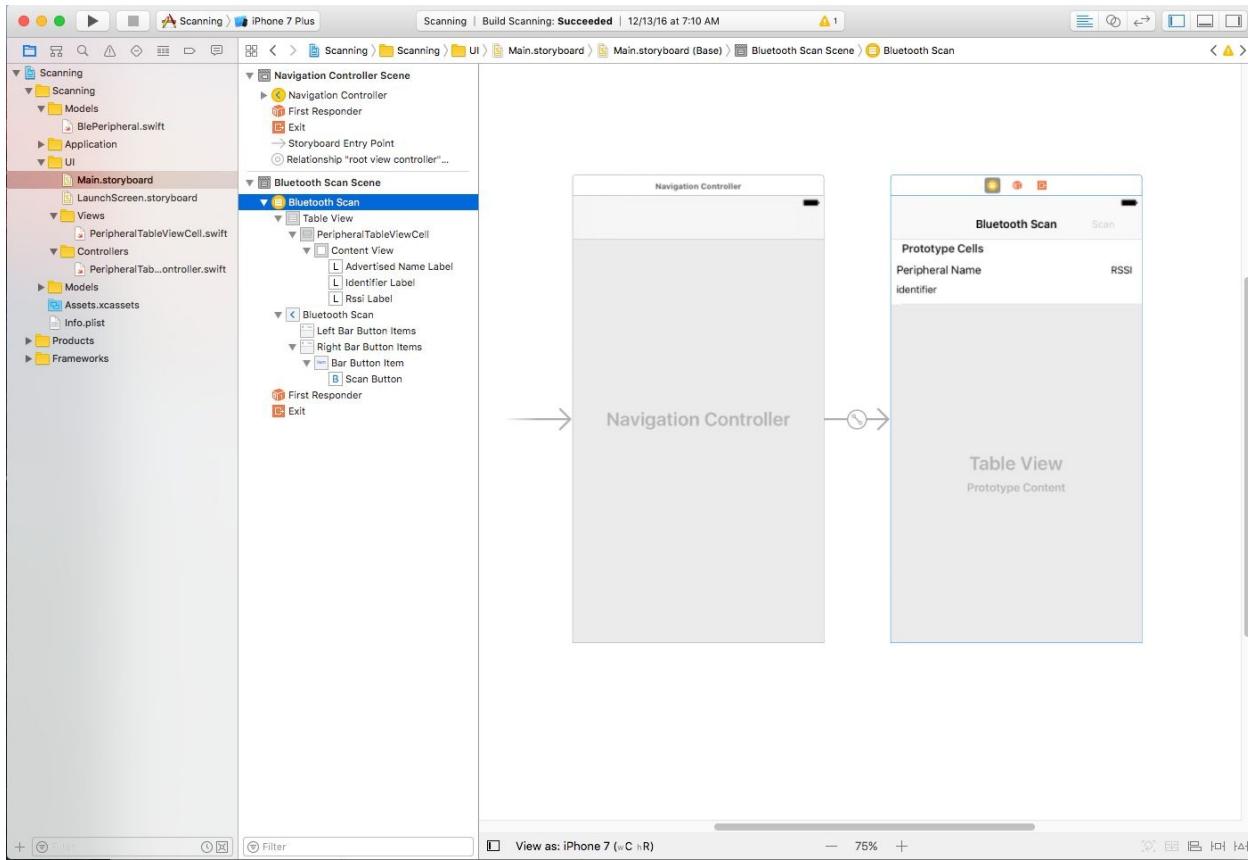


Figure 4-4. Project Storyboard

Views

Link the three UILabels from the PeripheralTableViewCell to the corresponding swift file and create a render function:

Example 4-2. UI/Views/PeripheralTableViewCell.swift

```
import UIKit
import CoreBluetooth
class PeripheralTableViewCell: UITableViewCell {
```

// MARK: UI Elements

```
@IBOutlet weak var advertisedNameLabel: UILabel!
@IBOutlet weak var identifierLabel: UILabel!
@IBOutlet weak var rssiLabel: UILabel!
```

/**

Render Cell with Peripheral properties
*/

```
func renderPeripheral(_ blePeripheral: BlePeripheral) {
    advertisedNameLabel.text = blePeripheral.advertisedName
    identifierLabel.text = blePeripheral.identifier
    rssiLabel.text = String(blePeripheral.rssi)
```

```
\
```

```
blePeripheral.peripheral.identifier.uuidString rssiLabel.text =  
blePeripheral.rssi.stringValue }  
}
```

Controllers

The View Controller must be able to initialize a scan when the user clicks the Scan button. It will scan for Peripherals for 5 seconds, an arbitrarily reasonable scanning time. The UITableView is updated with each new Peripheral as discovered.

Example 4-3. UI/Controllers/PeripheralTableViewController.swift

```
import UIKit  
import CoreBluetooth  
class PeripheralTableViewController: UITableViewController, \  
CBCentralManagerDelegate {  
  
// MARK: UI Elements  
@IBOutlet weak var scanButton: UIButton!  
// Default unknown advertisement name  
let unknownAdvertisedName = "(UNMARKED)"  
// PeripheralTableViewCell reuse identifier  
let peripheralCellReuseIdentifier = "PeripheralTableViewCell"  
  
// MARK: Scan Properties // total scan time  
let scanTimeout_s = 5; // seconds // current countdown  
var scanCountdown = 0  
// scan timer  
var scanTimer:Timer!  
// Central Bluetooth Manager  
var centralManager: CBCentralManager! // discovered peripherals  
var blePeripherals = [BlePeripheral]()  
  
/**  
View loaded. Start Bluetooth radio.  
*/  
  
override func viewDidLoad() {
```

```
super.viewDidLoad()
print("Initializing central manager")
centralManager = CBCentralManager(delegate: self, queue: nil)

}

/***
User touched the "Scan/Stop" button
***/

@IBAction func onScanButtonTouched(_ sender: UIButton) { print("scan
button clicked")
// if scanning
if scanCountdown > 0 {

stopBleScan()
} else {
startBleScan()
}
}

/***
Scan for Bluetooth peripherals

***/

func startBleScan() {
scanButton.setTitle("Stop", for: UIControlState.normal)
blePeripherals.removeAll()
tableView.reloadData()
print ("discovering devices")
scanCountdown = scanTimeout_s
scanTimer = Timer.scheduledTimer(
timeInterval: 1.0,
target: self,
selector: #selector(updateScanCounter), userInfo: nil,
repeats: true)

if let centralManager = centralManager {
centralManager.scanForPeripherals(
```

```

withServices: nil,
options: nil)

}

}

/***
Stop scanning for Bluetooth Peripherals
***/

func stopBleScan() {
if let centralManager = centralManager {
centralManager.stopScan()

}
scanTimer.invalidate()
scanCountdown = 0
scanButton.setTitle("Start", for: UIControlState.normal)

}

/***
Update the scan countdown timer */
func updateScanCounter() {

//you code, this is an example
if scanCountdown > 0 {
print("\(scanCountdown) seconds until Ble Scan ends")
scanCountdown -= 1
} else {
stopBleScan()
}
}

// MARK: CBCentralManagerDelegate Functions
/***
New Peripheral discovered

- Parameters
- central: the CentralManager for this UIView

```

- peripheral: a discovered Peripheral
- advertisementData: the Bluetooth GAP data discovered
- rssi: the radio signal strength indicator for this Peripheral

```
*/
func centralManager(
  _ central: CBCentralManager,
  didDiscover peripheral: CBPeripheral,
  advertisementData: [String : Any],
  rssi RSSI: NSNumber)
{
  print("Discovered \(peripheral.identifier.uuidString) " + \(peripheral.name)")

  // check if this peripheral has already been discovered var peripheralFound =
  false
  for blePeripheral in blePeripherals {

    if blePeripheral.peripheral.identifier == peripheral.identifier
    {
      peripheralFound = true break
    }
  }

  // don't duplicate discovered devices
  if !peripheralFound {
    print(advertisementData)
    // Broadcast name in advertisement data
    // may be different than the actual broadcast name
    // It's ideal to use the advertisement data version
    // as it's supported on programmable bluetooth devices
    var advertisedName = unknownAdvertisedName
    if let alternateName = \
      BlePeripheral.getAlternateBroadcastFromAdvertisementData(
        advertisementData: advertisementData)
    {
      if alternateName != "" {
        advertisedName = alternateName
      } else {
        if let peripheralName = peripheral.name { advertisedName = peripheralName }
      }
    }
  }
}
```

```
    }
}

let blePeripheral = BlePeripheral(peripheral: peripheral) blePeripheral.rssi =
RSSI
blePeripheral.advertisedName = advertisedName
blePeripherals.append(blePeripheral)
tableView.reloadData()

}
}
/**
```

Bluetooth radio state changed
- Parameters:
- central: the reference to the central
*/

```
func centralManagerDidUpdateState(_ central: CBCentralManager) {
print("Central Manager updated: checking state") switch (central.state) {
case .poweredOn:

print("BLE Hardware powered on and ready")
scanButton.isEnabled = true
default:
print("Bluetooth unavailable")
}
}

// MARK: - Table view data source

/**
return number of sections. Only 1 is needed
*/

override func numberOfSections(in tableView: UITableView) -> Int { return 1
}

/**
Return number of Peripheral cells
*/
```

```

override func tableView(
    _ tableView: UITableView,
    numberOfRowsInSection section: Int) -> Int

{
    return blePeripherals.count
}

/**
Return rendered Peripheral cell
*/

override func tableView(
    _ tableView: UITableView,
    cellForRowAt indexPath: IndexPath) -> UITableViewCell

{
    print("setting up table cell")
    let cell = tableView.dequeueReusableCell(
        withIdentifier: peripheralCellReuseIdentifier,
        for: indexPath) as!
    PeripheralTableViewCell
    // fetch the appropriate peripheral for the data source layout
    let peripheral = blePeripherals[indexPath.row]
    cell.renderPeripheral(peripheral)

    return cell
}

```

Compile and run the app. When it runs, you will see a screen with a scan button. When the scan button is clicked, it locates your BLE device (Figure 4-5).

◀ Google... ●●●● 3G 14:59

Bluetooth Scan 100% 🔋⚡

Bluetooth Scan

[Scan](#)

●●●●○ Fido 3G

19:25

76%  ⚡

Peripherals

Stop

(UNMARKED) -96

9C1BCA3A-EA75-43C9-9C5F-744FA0AFEE7D

MyDevice -56

ED4B9003-D4A9-4453-A731-4245167870B1

Figure 4-5. App screen prior to a Bluetooth scan and after discovering Bluetooth Peripherals

Programming the Peripheral

The previous Chapter showed how to turn on the Bluetooth radio and detect if Peripheral is supported by the iOS hardware

This chapter will show how to advertise a Bluetooth Low Energy Peripheral. Advertising is simple. Create a Dictionary of advertising parameters and pass the Dictionary into the `CBPeripheralManager.startAdvertising` method:

```
let advertisementData:[String: Any] = [
    CBAdvertisementLocalNameKey: advertisingName ]
peripheralManager.startAdvertising(advertisementData)
```

The Dictionary may contain up to two keys,
`CBAdvertisementLocalNameKey` and
`CBAdvertisementServiceUUIDsKey`:

Table 4-2 . advertisementData Dictionary

State Data Type Description

CBAdvertisementLocalNameKey String

The advertised name of a Bluetooth Peripheral

CBAdvertisementServiceUUIDsKey [CBUUID] UIDs of listed Services

As this chapter is focused on Advertising, only the first parameter will be discussed.

When the Peripheral begins to fails to Advertise, the `peripheralManagerDidStartAdvertising` callback of the `CBPeripheralManagerDelegate` will be triggered, containing an updated `CBPeripheralManager` and possible Error:

```
func peripheralManagerDidStartAdvertising( _ peripheral:
    CBPeripheralManager, error: Error?)
```

```
{
if error != nil {
    print ("Error advertising peripheral") print(error.debugDescription)
```

```
}
```

```
// store a copy of the updated Peripheral peripheralManager = peripheral
```

```
}
```

To stop Advertising, use the CBPeripheralManager.stopAdvertising method:
peripheralManager.stopAdvertising()

Putting It All Together

Create a new app called ExampleBlePeripheral, and copy everything from the previous example.

This example will add a UISwitch that shows when a Peripheral has begun Advertising.

Custom scanner callbacks will be created, which respond to events when scanning has stopped.

Models

Add an advertisingName to the BlePeripheral, functionality to start and stop Advertising, and a callback handler to handle the peripheralManagerDidStartAdvertising callback:

Example 4-4. Models/BlePeripheral.swift

```
class BlePeripheral : NSObject, CBPeripheralManagerDelegate {
```

```
// MARK: Peripheral properties
```

```
// Advertized name
```

```
let advertisingName = "MyDevice" ...
```

```
/**
```

```
Stop advertising, shut down the Peripheral */
```

```
func stop() {
```

```
    peripheralManager.stopAdvertising() }
```



```
/**
```

```
Start Bluetooth Advertising.
```

```
*/
```



```
func startAdvertising() {
```

```
    let advertisementData:[String: Any] = [
```



```
        CBAdvertisementLocalNameKey: advertisingName ]
```

```

    peripheralManager.startAdvertising(advertisementData)

}

// MARK: CBPeripheralManagerDelegate

/*
Peripheral started advertising
*/

func peripheralManagerDidStartAdvertising( _ peripheral:
CBPeripheralManager, error: Error?)

{
if error != nil {
print ("Error advertising peripheral") print(error.debugDescription)

}
self.peripheralManager = peripheral
delegate?.blePerihperal?(startedAdvertising: error)

}
...
}
```

Delegates

Add a new method to the BlePeripheralDelegate to relay the Advertising started event:

Example 4-5. Delegates/BlePeripheralDelegate.swift

```

... /**
BlePeripheral statrted adertising
```

- Parameters:
- error: the error message, if any

```
@objc optional func blePerihperal(startedAdvertising error: Error?) ...
```

Storyboard

Add a UILabel to show the Peripheral's Advertised name and a UISwitch to show the Advertising state of the Peripheral (Figure 4-6):

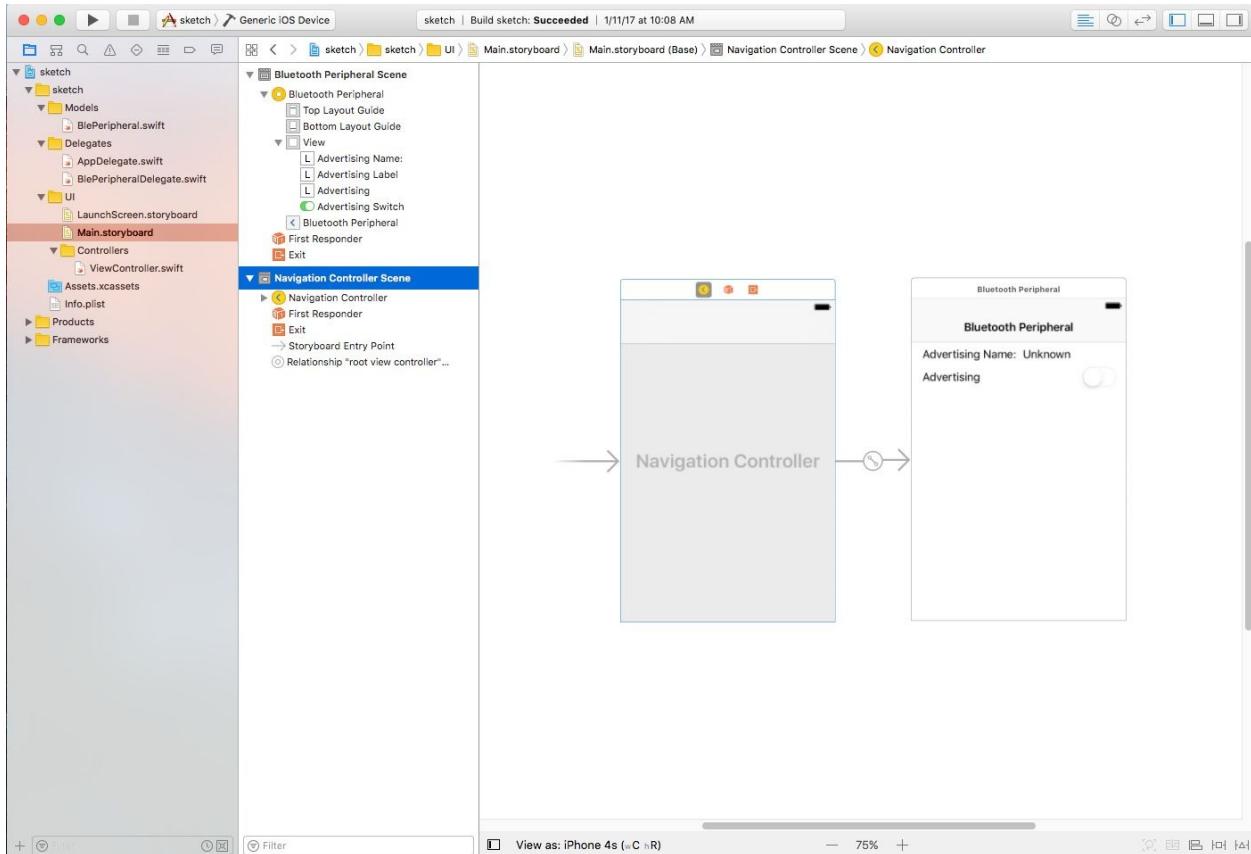


Figure 4-6. Project Storyboard Controllers

Add a UILabel to display the Advertising name and a UISwitch to show the Advertising state of the Peripheral. Add functionality in the viewWillAppear, viewWillLoad, and viewDidDisappear to change the text on the UILabel and the state of the UISwitch to reflect the state of the Peripheral. And add a callback handler for the new BlePeripheralDelegate method:

Example 4-6. UI/Controllers/ViewController.swift

...

```
// MARK: UI Elements
```

```
@IBOutlet weak var advertisingLabel: UILabel! @IBOutlet weak var
advertisingSwitch: UISwitch!
```

...

```
/**
```

```
View appeared. Start the Peripheral
*/
```

```

override func viewDidAppear(_ animated: Bool) { blePeripheral =
BlePeripheral(delegate: self) advertisingLabel.text =
blePeripheral.advertisingName

}

/***
View will appear. Stop transmitting random data */

override func viewWillDisappear(_ animated: Bool) { blePeripheral.stop()
}

/***
View disappeared. Stop advertising
*/

```

override func viewDidDisappear(_ animated: Bool) {
advertisingSwitch.setOn(false, animated: true)
}
...
/***
BlePeripheral started advertising

- Parameters:
- error: the error message, if any

```

func blePeripheral(startedAdvertising error: Error?) {
if error != nil {
print("Problem starting advertising: " + error.debugDescription)

} else {
print("advertising started")
advertisingSwitch.setOn(true, animated: true)
}
}
```

...

Compile and run the app. When it runs, a Bluetooth Peripheral will be advertising (

Figure 4-7).

●●●●● Fido 3G

13:43

蓝牙 88% 🔋⚡

Bluetooth Peripheral

Advertising Name: MyDevice

Advertising



Figure 4-7. App screen showing advertising Peripheral

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter04>

Connecting

Each Bluetooth Device has a unique Media Access Control (MAC) address, a 48-bit identifier value written like this

00:A0:C9:14:C8:3A

Devices advertise data on the network with the intended recipient's MAC address attached so that recipient devices can filter data packets that are intended for them.

For security reasons, iOS does not reveal the MAC address of a Peripheral.

Instead, it creates a 32-bit UUID identifier, like this:

2fe058bd-5edb-4b3f-b7bd-fc8e93e2dbc4

Once a Central has discovered a Peripheral, the central can attempt to connect. This must be done before data can be passed between the Central and Peripheral. A Central may hold several simultaneous connections with a number of peripherals, but a Peripheral may only hold one connection at a time. Hence the names Central and Peripheral (Figure 5-1).

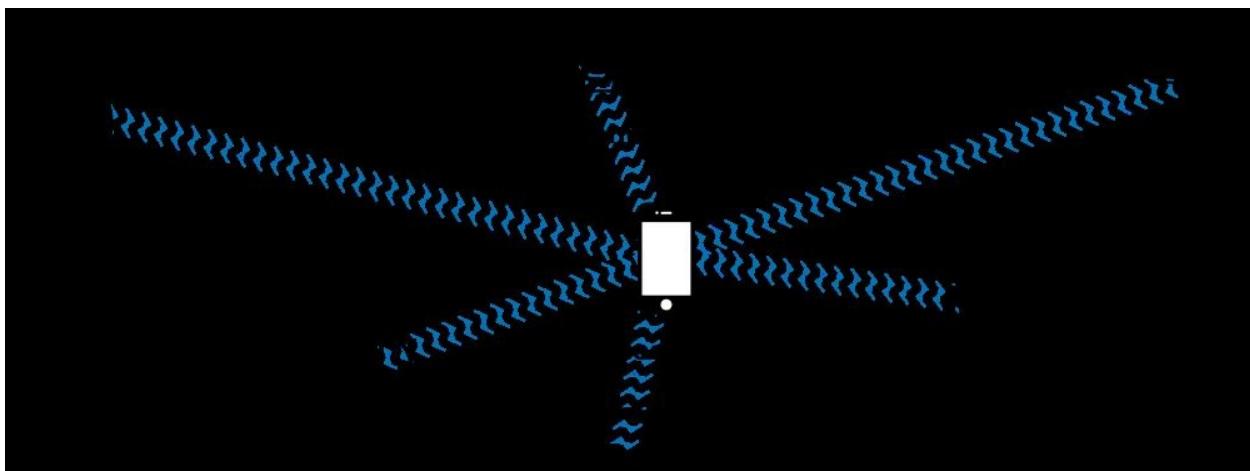


Figure 5-1. Bluetooth network topology

Bluetooth supports data 37 data channels ranging from 2404 MHz to 2478 MHz. Once the connection is established, the Central and Peripheral negotiate which of these channels to begin communicating over.

Because the Peripheral can only hold one connection at a time, it must disconnect from the Central before a new connection can be made.

The connection and disconnection process works like this (Figure 5-2).

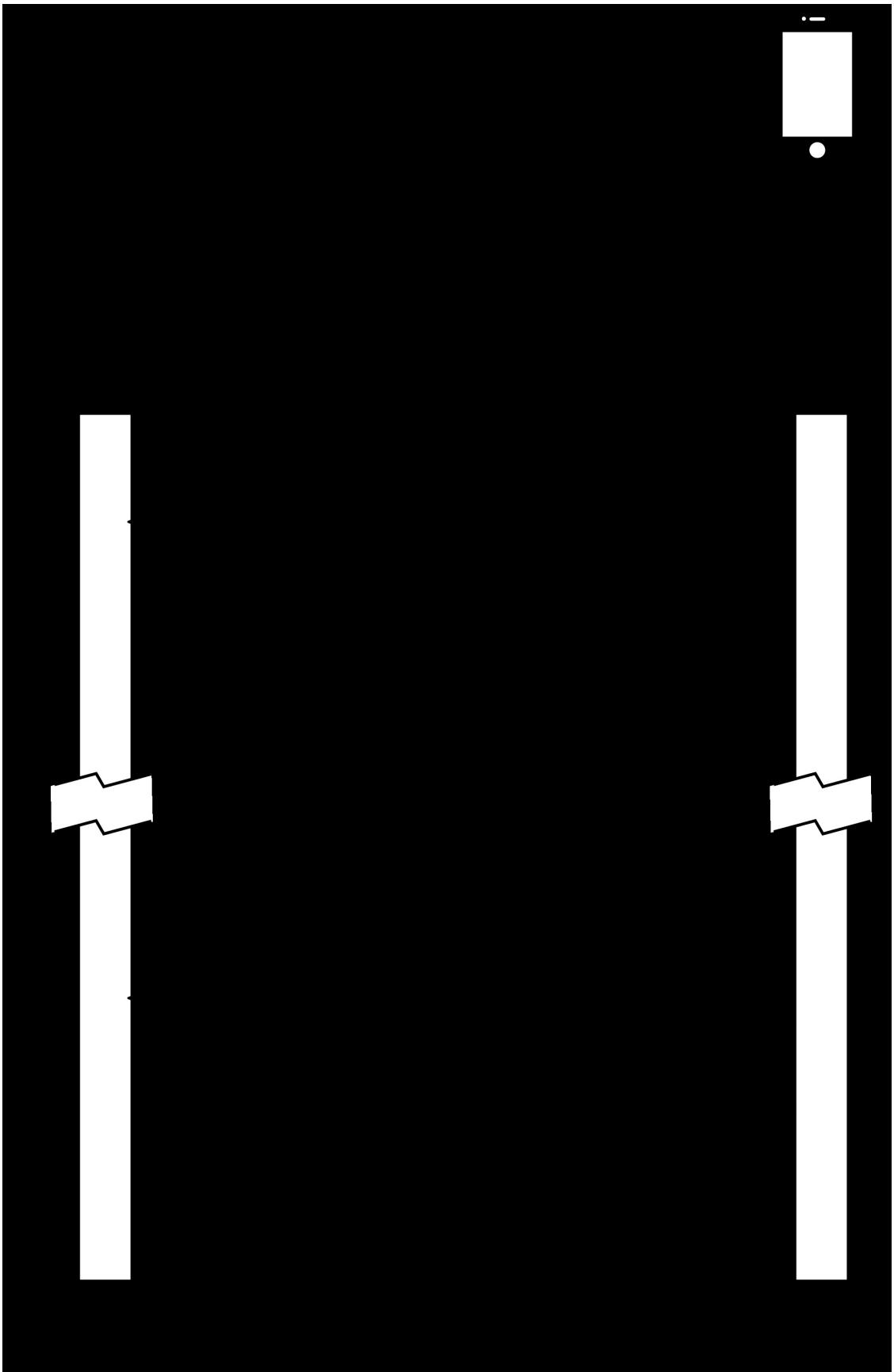


Figure 5-2. Connection and disconnection process

Programming the Central

The previous chapter's App showed how to discover nearby Peripherals. Once a Peripheral is discovered, iOS can initiate a connection like this:

```
centralManager.connect(peripheral)
```

If the connection is successful, the didConnect callback will be triggered.

```
func centralManager(  
    _ central: CBCentralManager, didConnect peripheral: CBPeripheral)  
  
{  
}  
}
```

The didFailToConnect will be triggered otherwise.

```
func centralManager(  
    _ central: CBCentralManager,  
    didFailToConnect peripheral: CBPeripheral, error: Error?)  
  
{  
}
```

A disconnection can be initiated like this:

```
centralManager.cancelPeripheralConnection(peripheral)
```

When successful, the didDisconnectPeripheral event will be triggered:

```
func centralManager(  
    _ central: CBCentralManager,  
    didDisconnectPeripheral peripheral: CBPeripheral, error: Error?)  
  
{  
}
```

Disconnecting is important. The Peripheral can only be connected to one device at a time. Sometimes, closing an Activity without disconnecting the Peripheral can leave the Peripheral in a connected state - unable to advertise or connect to a Central again in the future.

Putting It All Together

Create a new project called Connecting and copy everything from the previous example. This example will show how to create an app that looks for a “MyDevice” BLE advertisement, and connect to it.

BlePeripheral represents a remote Peripheral. PeripheralViewController will connect to the Peripheral and list the Peripheral properties.

Create a project structure that resembles this (Figure 5-3).



Figure 5-3.

Added project structure

Models

Modify the BlePeripheral to support CBPeripheralDelegate callbacks

Example 5-1. Models/BlePeripheral.swift

```
import UIKit
import CoreBluetooth
class BlePeripheral: NSObject, CBPeripheralDelegate { // MARK: Peripheral
    properties

    // delegate
    var delegate:BlePeripheralDelegate? // connected Peripheral
    var peripheral:CBPeripheral! // advertised name
    var advertisedName:String!
    // RSSI
    var rssi:NSNumber!

    /**
     Initialize BlePeripheral with a corresponding Peripheral
     - Parameters:
     - delegate: The BlePeripheralDelegate
     - peripheral: The discovered Peripheral
     */
    init(delegate: BlePeripheralDelegate?, peripheral: CBPeripheral) { super.init()
        self.peripheral = peripheral
        self.peripheral.delegate = self
        self.delegate = delegate
    }

    /**
     Notify the BlePeripheral that the peripheral has been connected
     - Parameters:
     - peripheral: The discovered Peripheral */
    func connected(peripheral: CBPeripheral) { self.peripheral = peripheral
        self.peripheral.delegate = self // check for services and the RSSI
        self.peripheral.readRSSI()

    }
```

```

/***
Get a broadcast name from an advertisementData packet. This may be different
than the actual broadcast name */

static func getAlternateBroadcastFromAdvertisementData( advertisementData:
[String : Any]) -> String?
{
// grab thekCBAdvDataLocalName from the advertisementData // to see if
there's an alternate broadcast name
if advertisementData["kCBAdvDataLocalName"] != nil { return
(advertisementData["kCBAdvDataLocalName"] as! String) }
return nil
}

/***
Determine if this peripheral is connectable
from it's advertisementData packet.
*/

static func isConnectable(advertisementData: [String: Any]) -> Bool { let
isConnectable = \
advertisementData["kCBAdvDataIsConnectable"] as! Bool return isConnectable
}
// MARK: CBPeripheralDelegate

/***
RSSI read from peripheral. */

func peripheral(
_peripheral: CBPeripheral, didReadRSSI RSSI: NSNumber, error: Error?)

{
print("RSSI: \(RSSI.stringValue)")
rssi = RSSI
delegate?.blePeripheral?(readRssi: rssi, blePeripheral: self)
}

}

```

Delegates

Create a BlePeripheralDelegate class that lets the BlePeripheral trigger events as

a result of changes in its state.

Example 5-2. Models/BlePeripheralDelegate.swift

```
import UIKit
import CoreBluetooth
@objc protocol BlePeripheralDelegate: class { /**
RSSI was read for a Peripheral

- Parameters:
- rssi: the RSSI
- blePeripheral: the BlePeripheral

*/
@objc optional func blePeripheral( readRssi rssi: NSNumber, blePeripheral: BlePeripheral)

}
```

Storyboard

Create a new UIView and give it the class name "PeripheralViewController." Add a segue between the two UIViews. Create and link three UILabels to be used for describing the connected Peripheral properties (Figure 5-4):

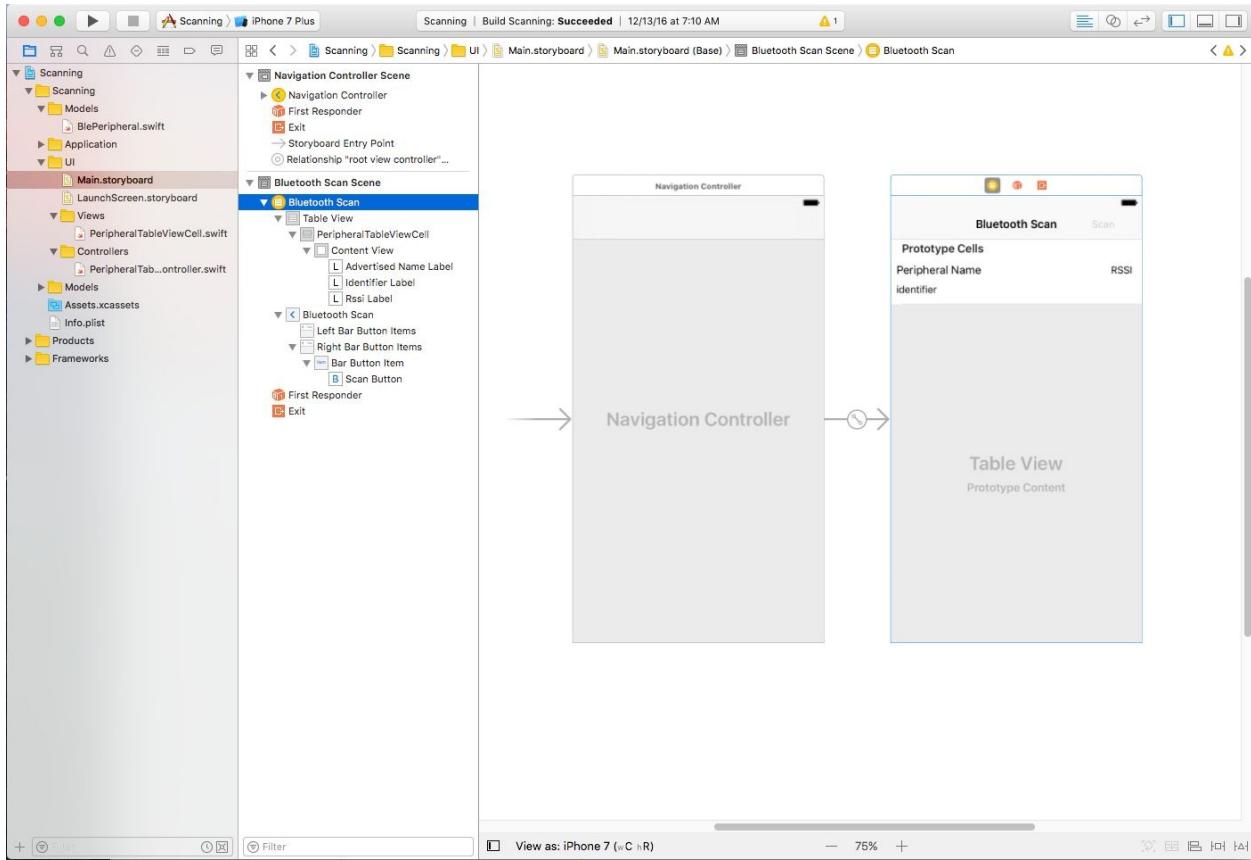


Figure 5-4. Project Storyboard Controllers

The previous app was able to detect and list nearby Peripherals. This app will allow connecting to a Peripheral when a user selects that Peripheral from the UITableView.

Add a segue and UITableViewDelegate functionality in the PeripheralTableViewCellController.

Example 5-3. UI/Controllers/PeripheralTableViewCellController.swift

```

... override func tableView(
    _ tableView: UITableView,
    didSelectRowAt indexPath: IndexPath)

{
    stopBleScan()
    let selectedRow = indexPath.row print("Row: \(selectedRow)")
    print(blePeripherals[selectedRow])

}
// MARK: - Navigation

```

```

override func prepare(for segue: UIStoryboardSegue, sender: Any?) {
    let peripheralViewController = segue.destination as! PeripheralViewController
    if let selectedIndexPath = tableView.indexPathForSelectedRow {
        let selectedRow = selectedIndexPath.row
        if selectedRow < blePeripherals.count {
            // prepare next UIView
            peripheralViewController.centralManager = centralManager
            peripheralViewController.blePeripheral = blePeripherals[selectedRow]
        }
        tableView.deselectRow(at: selectedIndexPath, animated: true)
    }
}

```

The PeripheralViewController will connect to a Peripheral and list the advertised name and identifier in UILabels

When a connection is confirmed, the user interface is updated.

Example 5-4. UI/Controllers/PeripheralViewController.swift

```

import UIKit
import CoreBluetooth
class PeripheralViewController: UIViewController, CBCentralManagerDelegate, BlePeripheralDelegate {

    // MARK: UI Elements
    @IBOutlet weak var advertisedNameLabel: UILabel!
    @IBOutlet weak var identifierLabel: UILabel!
    @IBOutlet weak var rssiLabel: UILabel!

    // MARK: Connected Peripheral Properties

    // Central Manager
    var centralManager: CBCentralManager! // connected Peripheral
    var blePeripheral: BlePeripheral!

    /**
     UIView loaded
     */
    override func viewDidLoad() {

```

```

super.viewDidLoad()
print("Will connect to " + \
"\\"(blePeripheral.peripheral.identifier.uuidString)) // Assign delegates
blePeripheral.delegate = self
centralManager.delegate = self
centralManager.connect(blePeripheral.peripheral)

}

/**
RSSI discovered. Update UI

*/
func blePeripheral(
readRssi rssi: NSNumber, blePeripheral: BlePeripheral)

{
rssLabel.text = rssi.stringValue
}

// MARK: CBCentralManagerDelegate code

/**
Peripheral connected. Update UI */

func centralManager(
_ central: CBCentralManager, didConnect peripheral: CBPeripheral)

{
print("Connected Peripheral: \(peripheral.name)") advertisedNameLabel.text =
blePeripheral.advertisedName identifierLabel.text =\
blePeripheral.peripheral.identifier.uuidString blePeripheral.connected(peripheral:
peripheral) }

/**
Connection to Peripheral failed.

*/
func centralManager(

```

```
_ central: CBCentralManager,
didFailToConnect peripheral: CBPeripheral, error: Error?)  
  
{  
print("failed to connect") print(error.debugDescription) /**  
  
Peripheral disconnected. Leave UIView  
  
*/  
func centralManager(  
_ central: CBCentralManager,  
didDisconnectPeripheral peripheral: CBPeripheral, error: Error?)  
  
{  
print("Disconnected Peripheral: \(peripheral.name)") dismiss(animated: true,  
completion: nil)  
}  
  
/**  
Bluetooth radio state changed.  
*/  
  
func centralManagerDidUpdateState(_ central: CBCentralManager) {  
print("Central Manager updated: checking state") switch (central.state) {  
case .poweredOn:  
  
print("bluetooth on")  
default:  
print("bluetooth unavailable")  
}  
}  
  
// MARK: Navigation  
override func prepare(for segue: UIStoryboardSegue, sender: Any?) {  
print("leaving view - disconnecting from peripheral")  
if let peripheral = blePeripheral.peripheral {  
centralManager.cancelPeripheralConnection(peripheral)  
}  
}
```

The resulting App will be one that can scan and connect to an advertising Peripheral (Figure 5-5).

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[!\[\]\(d0092d65031526353873c18a211a673d_img.jpg\) Peripherals](#) Peripheral

MyDevice

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ED4B9003-D4A9-4453-A731-4245167870B1

Figure 5-5. App screen after connecting to a Peripheral

Peripheral Programming

In iOS, no notifications are sent when a Peripheral is connected to. There Peripheral code remains the same as the previous chapter.

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter05>

Services and Characteristics

Before data can be transmitted back and forth between a Central and Peripheral, the Peripheral must host a GATT Profile. That is, the Peripheral must have Services and Characteristics.

Identifying Services and Characteristics

Each Service and Characteristic is identified by a Universally Unique Identifier (UUID). The UUID follows the pattern 0000XXXX-0000-1000-8000-00805f9b34fb, so that a 32-bit UUID 00002a56-0000-1000-8000-00805f9b34fb can be represented as 0x2a56.

Some UUIDs are reserved for specific use. For instance any Characteristic with the 16-bit UUID 0x2a35 (or the 32-bit UUID 00002a35-0000-1000-8000-00805f9b34fb) is implied to be a blood pressure reading.

For a list of reserved Service UUIDs, see *Appendix IV: Reserved GATT Services*.

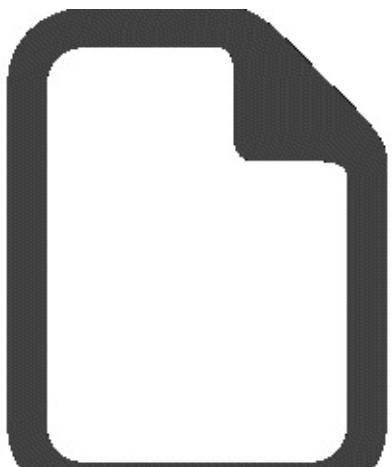
For a list of reserved Characteristic UUIDs, see *Appendix V: Reserved GATT Characteristics*.

Generic Attribute Profile

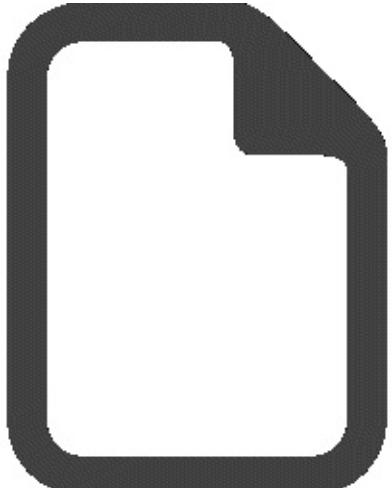
Services and Characteristics describe a tree of data access points on the peripheral. The tree of Services and Characteristics is known as the Generic Attribute (GATT) Profile. It may be useful to think of the GATT as being similar to a folder and file tree (Figure 6-1).



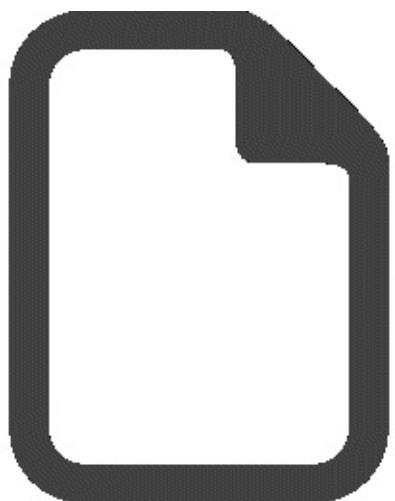
Service/



Characteristic



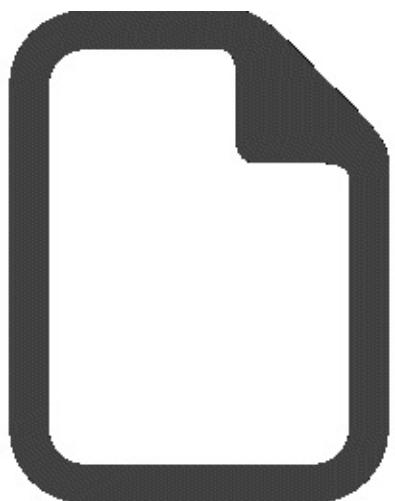
Characteristic



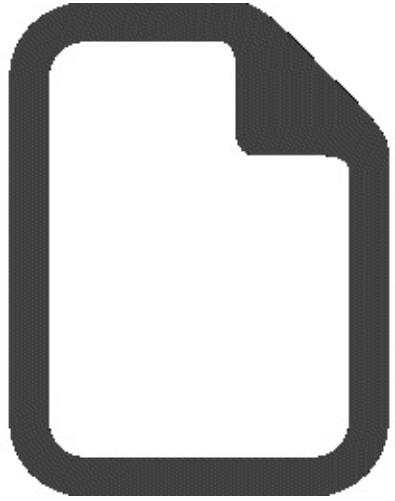
Service/



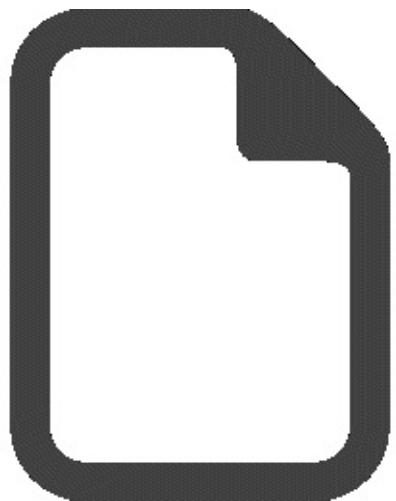
Characteristic



Characteristic



Characteristic



Characteristic

Profile

Service

Characteristic

Characteristic

Characteristic

Service

Characteristic

Characteristic

Characteristic

Figure 6-1. GATT Profile filesystem metaphor

Characteristics act as channels that can be communicated on, and Services act as containers for Characteristics. A top level Service is called a Primary service, and a Service that is within another Service is called a Secondary Service.

Permissions

Characteristics can be configured with the following attributes, which define what the Characteristic is capable of doing (Table 6-1):

Table 6-1. Characteristic Permissions

Descriptor Description

Read Central can read this Characteristic, Peripheral can set the value.

Central can write to this Characteristic, Peripheral will be notified when **Write** the Characteristic value changes and Central will be notified when the write operation has occurred.

Central can write to this Characteristic. Peripheral will be notified when **Write without Response** the Characteristic value changes but the Central will not be notified that the write operation has occurred.

Notify Central will be notified when Peripheral changes the value.

Because the GATT Profile is hosted on the Peripheral, the terms used to describe a Characteristic's permissions are relative to how the Peripheral accesses that Characteristic. Therefore, when a Central uploads data to the Peripheral, the Peripheral can "read" from the Characteristic. The Peripheral "writes" new data to the Characteristic, and can "notify" the Central that the data is altered.

Data Length and Speed

It is worth noting that Bluetooth Low Energy has a maximum data packet size of 20 bytes, with a 1 Mbit/s speed.

Programming the Central

The Central can be programmed to read the GATT Profile of the Peripheral after connection, like this:

```
peripheral.discoverServices(nil)
```

If only a subset of the Services hosted by the Peripheral are needed, those Service Uuids can be passed into the discoverServices function like this:

```
let serviceUuids = [ "1800", "1815" ] peripheral.discoverServices(serviceUuids)
```

When the Services are discovered, a callback will be executed by the CBPeripheralManagerDelegate, containing an updated CBPeripheral object. This updated object contains an array of Services:

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didDiscoverServices error: Error?)
```

```
{  
if error != nil {  
print("Discover service Error: \(error)") }  
}
```

In order for the class to access these methods, it must implement CBPeripheralManagerDelegate.

There are Primary Services and Secondary services. Secondary Services are contained within other Services; Primary Services are not. The type of Service can be discovered by inspecting the CBService.isPrimary flag.

```
boolean isPrimary = service.isPrimary
```

To discover the Characteristics hosted by these services, simply loop through the discovered Services and handle the resulting peripheral didDiscoverCharacteristicsFor callback:

```
func peripheral(  
    _ peripheral: CBPeripheral, didDiscoverServices error: Error?)  
{
```

```

if error != nil {
print("Discover service Error: \(error)")
} else {
for service in peripheral.services!{
self.peripheral.discoverCharacteristics(nil, for: service) }
}
}

func peripheral(
_peripheral: CBPeripheral,
didDiscoverCharacteristicsFor service: CBService, error: Error?)

{
let serviceIdentifier = service.uuid.uuidString if let characteristics =
service.characteristics {

for characteristic in characteristics { // do something with Characteristic
}
}
}
}

```

Each Characteristic has certain permission properties that allow the Central to read, write, or receive notifications from it (Table 6-2).

Table 6-2. CBCharacteristicProperties

Value Permission Description

read Read Central can read data altered by the Peripheral

write Write Central can send data, Peripheral reads

writeWithoutResponse Write Central can send data. No response from Peripheral

notify Notify Central is notified as a result of a change

In iOS, these properties are expressed as a binary integer which can be extracted like this:

```
let properties = characteristic.properties.rawValue
```

```
let isWritable = (properties & \
```

```
CBCharacteristicProperties.write.rawValue) != 0;
```

```
let isWritableNoResponse = (properties & \
```

```
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0; let
```

```
isReadable = (properties & \  
CBCharacteristicProperties.read.rawValue) != 0;  
let isNotifiable = (properties & \  
CBCharacteristicProperties.notify.rawValue) != 0;
```

A Note on Caching

Because Bluetooth was designed to be a low-power protocol, measures are taken to limit redundancy and power consumption through radio and CPU usage. As a result, a Peripheral's GATT Profile is cached on iOS. This is not a problem for normal use, but when developing, it can be confusing to change Characteristic permissions and not see the updates reflected on iOS.

To get around this, the iOS device must be restarted each time a Peripheral with the same Identifier has changed its GATT Profile

Putting It All Together

This app will work like the one from the previous chapter, except that once it connects to the Peripheral, it will also list the GATT Profile for that Peripheral. The GATT Profile will be displayed in a UITableView (Figure 6-2).

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Figure 6-2. GATT Profile downloaded from Peripheral

Create a new project called Services and copy everything from the previous example. (Figure 6-3).

```
📁 Services/
  📁 Models/
    ⚡ BlePeripheral.swift
  📁 Delegates/
    ⚡ AppDelegate.swift
    ⚡ BluePeripheralDelegate.swift
📁 UI/
  ⚡ Main.storyboard
  ⚡ LaunchScreen.storyboard
  📁 views/
    ⚡ PeripheralTableViewCell.swift
    ⚡ GattTableViewCell.swift
  📁 Controllers/
    ⚡ PeripheralViewController.swift
    ⚡ PeripheralTableviewController.swift
  ⚡ Assets.xcassets
  ⚡ Info.plist
📁 Frameworks/
  ⚡ CoreBluetooth.framework
```

Figure 6-3.

Project Structure

Objects

Modify BlePeripheral.swift to discover Services and Characteristics

Example 6-1. Models/BlePeripheral.swift

```
...
/***
Servicess were discovered on the connected Peripheral */
```

```

func peripheral(
  _ peripheral: CBPeripheral,
  didDiscoverServices error: Error?) {

{
print("services discovered")
// clear GATT profile - start with fresh services listing gattProfile.removeAll()
if error != nil {

print("Discover service Error: \(error)")
} else {
print("Discovered Service")
for service in peripheral.services!{
self.peripheral.discoverCharacteristics(nil, for: service)
}
print(peripheral.services!)
}
}

/***
Characteristics were discovered
for a Service on the connected Peripheral
*/
}

func peripheral(
  _ peripheral: CBPeripheral,
  didDiscoverCharacteristicsFor service: CBService, error: Error?) {

{
print("characteristics discovered")
// grab the service
let serviceIdentifier = service.uuid.uuidString print("service: \
(serviceIdentifier)")

gattProfile.append(service)
if let characteristics = service.characteristics { print("characteristics found: \
(characteristics.count)")

for characteristic in characteristics {
print("-> \(characteristic.uuid.uuidString)")
```

```

}
delegate?.blePerihperal?(  

    discoveredCharacteristics: characteristics,  

    forService: service,  

    blePeripheral: self)
}  

}  

...

```

Delegates

Add a function to the BlePeripheralDelegate to alert when Characteristics have been discovered:

Example 6-2. Delegates/BlePeripheralDelegate.swift

```
... /**

```

Characteristics were discovered for a Service

- Parameters:
- characteristics: the Characteristic list
- forService: the Service these Characteristics are under
- blePeripheral: the BlePeripheral

```
 */

```

```
@objc optional func blePerihperal(  

    discoveredCharacteristics characteristics: [CBCharacteristic], forService:  

    CBService,  

    blePeripheral: BlePeripheral)
```

Storyboard

Add a UITableView and UITableViewCell to the PeripheralViewController. Make the UITableView a "grouped" TableView and make the UITableViewCell of class "GattTableViewCell" Give it the Reuse Identifier "GattTableViewCell." In the new GattTableViewCell, create and link a UILabel to be used to hold the Characteristic UUID (Figure 6-4):

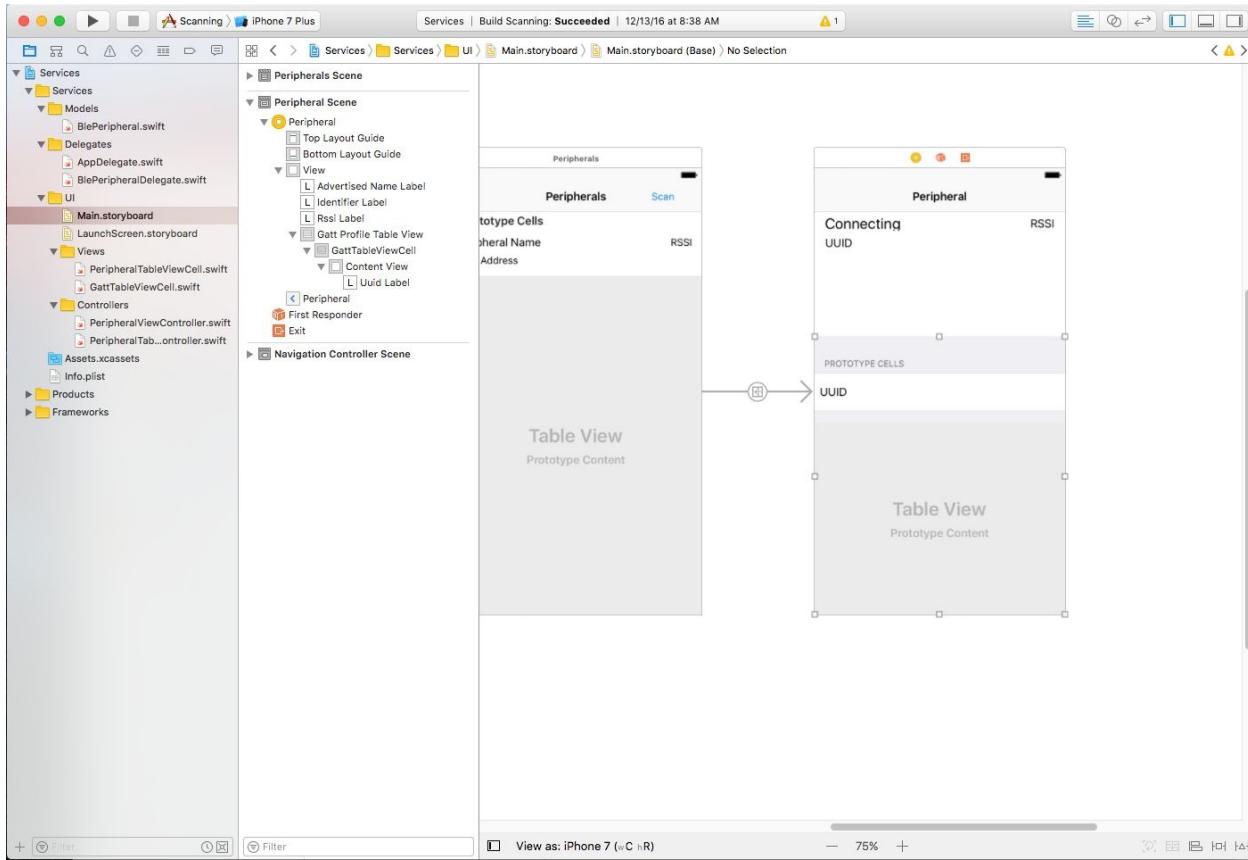


Figure 6-4. Project Storyboard

Views

The GATT Profile will be represented as a Grouped UITableView, with Services as the table header and Characteristics as the GattTableViewCell table cell.

Each GattTableViewCell will display the UUID of a Characteristic.

Example 6-3. UI/Views/GattTableViewCell.swift

```
import UIKit
import CoreBluetooth
class GattTableViewCell: UITableViewCell { @IBOutlet weak var uuidLabel: UILabel!

func renderCharacteristic(characteristic: CBCharacteristic) { uuidLabel.text = characteristic.uuid.uuidString print(characteristic.uuid.uuidString)

}
}
```

Controllers

Add functionality in the PeripheralViewController to render the GATT Profile

table and to handle the blePeripheral discoveredCharacteristics callback from the BlePeripheralDelegate class:

Example 6-4. UI/Controllers/PeripheralViewController.swift

```
class PeripheralViewController: UIViewController, UITableViewDataSource, \
UITableViewDelegate, CBCentralManagerDelegate, BlePeripheralDelegate {

    // MARK: UI Elements
    @IBOutlet weak var advertisedNameLabel: UILabel! @IBOutlet weak var
    identifierLabel: UILabel! @IBOutlet weak var rssiLabel: UILabel!
    @IBOutlet weak var gattProfileTableView: UITableView! @IBOutlet weak var
    gattTableView: UITableView!

    // Gatt Table Cell Reuse Identifier
    let gattCellReuseIdentifier = "GattTableViewCell" // MARK:
    BlePeripheralDelegate

    /**
    Characteristics were discovered. Update the UI
    */

    func blePerihperal(
        discoveredCharacteristics characteristics: [CBCharacteristic], forService:
        CBService,
        blePeripheral: BlePeripheral)

    {
        gattTableView.reloadData()
    }

    /**
    RSSI discovered. Update UI */

    func blePeripheral(
        readRssi rssi: NSNumber, blePeripheral: BlePeripheral)

    {
        rssiLabel.text = rssi.stringValue
    }
}
```

```
// MARK: UITableViewDataSource

/***
Return number of rows in Service section */

func tableView(
    _ tableView: UITableView,
    numberOfRowsInSection section: Int) -> Int

{
    print("returning num rows in section")
    if section < blePeripheral.gattProfile.count {

        if let characteristics = \
blePeripheral.gattProfile[section].characteristics

        { return characteristics.count
        }
    }
    return 0
}

/***
Return a rendered cell for a Characteristic
***/

func tableView(
    _ tableView: UITableView,
    cellForRowAt indexPath: IndexPath) -> UITableViewCell

{
    print("returning table cell")
    let cell = tableView.dequeueReusableCell(
        withIdentifier: gattCellReuseIdentifier, for: indexPath) as! GattTableViewCell
    let section = indexPath.section
    let row = indexPath.row

    if section < blePeripheral.gattProfile.count {
        if let characteristics = \

```

```

blePeripheral.gattProfile[section].characteristics {
if row < characteristics.count {
cell.renderCharacteristic(
characteristic: characteristics[row]) }

}

}

return cell

}

/** Return the number of Service sections

*/
func numberOfSections(in tableView: UITableView) -> Int { print("returning
number of sections")
print(blePeripheral)
print(blePeripheral.gattProfile)
return blePeripheral.gattProfile.count

}

/** Return the title for a Service section

*/

func tableView(
_tableView: UITableView,
titleForHeaderInSection section: Int) -> String?

{
print("returning title at section \(section)")
if section < blePeripheral.gattProfile.count {

return blePeripheral.gattProfile[section].uuid.uuidString }
return nil

}

/**
```

User selected a Characteristic table cell. Update UI and open the next UIView
*/

```
func tableView(  
    _ tableView: UITableView,  
    didSelectRowAt indexPath: IndexPath)  
  
{  
    let selectedRow = indexPath.row  
    print("Selected Row: \(selectedRow)")  
    tableView.deselectRow(at: indexPath, animated: true)  
  
}  
// MARK: Navigation  
override func prepare(for segue: UIStoryboardSegue, sender: Any?) {  
  
    print("leaving view - disconnecting from peripheral") if let peripheral =  
    blePeripheral.peripheral {  
        centralManager.cancelPeripheralConnection(peripheral) }  
    }  
}
```

The resulting app will be able to connect to a Peripheral and list the Services and Characteristics (Figure 6-5).

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[!\[\]\(012c4decba939681b6913b76af226fbe_img.jpg\) Peripherals](#) Peripheral

MyDevice

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Figure 6-5. App screen showing GATT profile from a connected Peripheral

Programming the Peripheral

The Peripheral can be programmed to host a GATT Profile - the tree structure of Services and Characteristics that a connected Central will use to communicate with the Peripheral.

Services are created and added to the CBPeripheralManager, like this:

```
// Service UUID  
let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")  
let service = CBMutableService(type: serviceUuid, primary: true)  
peripheralManager.add(service)
```

When a Service is added to the Peripheral, the peripheralManager didAdd callback will be triggered by the CBPeripheralManagerDelegate.

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager, didAdd service: CBService, error: Error?)  
  
{  
}
```

Characteristics must have defined properties. These properties allow a connected Central to read data from, write data to, and/or subscribe to notifications from a Characteristic. Some common properties are enumerated in the CBCharacteristicProperties class:

Table 6-3. Common CBCharacteristicProperties

Value Permission Description

read Read The characteristic's value can be read.

write

Write

The characteristic's value can be written, with a response from the peripheral to indicate that the write was successful.

writeWithoutResponse

Write

The characteristic's value can be written, without a response from the peripheral.

notify **Notify** Notifications of the characteristic's value are permitted.
Create the Characteristics properties by instanciating and merging
CBCharacteristicProperties:

```
// create read Characteristic properties
var characteristicProperties = CBCharacteristicProperties.read // append write
properties
characteristicProperties.formUnion(CBCharacteristicProperties.write) // append
notify support
characteristicProperties.formUnion(CBCharacteristicProperties.notify)
```

A Characteristic must also define it's attribute permissions. An example of an attribute is a flag that is set when a connected Characteristic wants to subscribe to a Characteristic.

Examples of common Attribute Permissions are enumerated in the CBAttributePermissions class.

Table 6-3. Common CBAttributePermissions

Value Description

readable The Characteristic's Attributes can be read by a connected Central.

writeable The Characteristic's Attributes can be altered by a connected Central.
Create Attribute permissions.

```
// set the Characteristic's Attribute permissions
var characteristicPermissions = CBAttributePermissions.writeable // append
permissions
characteristicPermissions.formUnion(CBAttributePermissions.readable)
```

Create a new CBMutableCharacteristic with the defined properties. Optionally an initial value can be set.

```
let characteristicUuid = \
```

```
CBUUID(string: "00002a56-0000-1000-8000-00805f9b34fb") var value:Data!
// instantiate a Characteristic
let characteristic = CBMutableCharacteristic(
    type: characteristicUuid,
    properties: characteristicProperties, value: value,
    permissions: characteristicPermissions)
```

Add one or more Characteristics to a Service by creating a [CBMutableCharacteristic] array.

```
// set the service Characterisic array service.characteristics = [ characteristic ]
```

A Note on GATT Profile Best Practices

All Peripherals should contain Device information and a Battery Service, resulting in a minimal GATT profile for any Peripheral that resembles this (Figure 6-6).

Minimal GATT Profile

Device Info (0x180a)

Device Name (0x2a00)

Model Number (0x2a24)

Serial Number (0x2a25)

Battery level (0x180f)

Battery Level (0x2a19)

Figure 6-6. Minimal GATT Profile for Peripherals

This provides Central software, surveying tools, and future developers to better understand what each Peripheral is, how to interact with it, and what the battery capabilities are.

For pedagogical reasons, many of the examples will not include this portion of the GATT Profile.

Putting It All Together

Create a new project called GattProfile and copy everything from the previous example.

Models

Modify BlePeripheral.swift to build a minimal Gatt Services profile. Build the GATT Profile structure, and handle the callback when Services are added.

Example 6-5. Models/BlePeripheral.swift

... // MARK: GATT Profile

```
// Service UUID
let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")
// Characteristic UUIDs
let characteristicUuid = CBUUID(
    string: "00002a56-0000-1000-8000-00805f9b34fb")
// Read Characteristic
var characteristic:CBMutableCharacteristic!
...

/**
Build Gatt Profile.
This must be done after Bluetooth Radio has turned on */

func buildGattProfile() {
    let service = CBMutableService(type: serviceUuid, primary: true) var
    characteristicProperties = CBCharacteristicProperties.read
    characteristicProperties.formUnion(
        CBCharacteristicProperties.notify)
    var characteristicPermissions = CBAttributePermissions.writeable
    characteristicPermissions.formUnion(CBAttributePermissions.readable)
```

```

characteristic = CBMutableCharacteristic( type: characteristicUuid,
properties: characteristicProperties, value: nil,
permissions: characteristicPermissions)

service.characteristics = [ characteristic ] peripheralManager.add(service)

}

...
/***
Peripheral added a new Service
*/
func peripheralManager(
_peripheral: CBPeripheralManager, didAdd service: CBService,
error: Error?) {
{
print("added service to peripheral") if error != nil {
print(error.debugDescription) }
}

/***
Bluetooth Radio state changed */

func peripheralManagerDidUpdateState( _ peripheral: CBPeripheralManager)
{
peripheralManager = peripheral
switch peripheral.state {
case CBManagerState.poweredOn:

buildGattProfile()
startAdvertising()
default: break
}
delegate?.blePeripheral?(stateChanged: peripheral.state) }

...

```

The resulting app will be able to host a minimal GATT Profile.

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter06>

Reading Data from a Peripheral

The real value of Bluetooth Low Energy is the ability to transmit data wirelessly.

Bluetooth Peripherals are passive, so they don't push data to a connected Central. Instead, Centrals make a request to read data from a Characteristic. This can only happen if the Characteristic enables the Read Attribute.

This is called "reading a value from a Characteristic."

Therefore, if a Peripheral changes the value of a Characteristic, then later a Central downloads data from the Peripheral, the process looks like this (Figure 7-1):

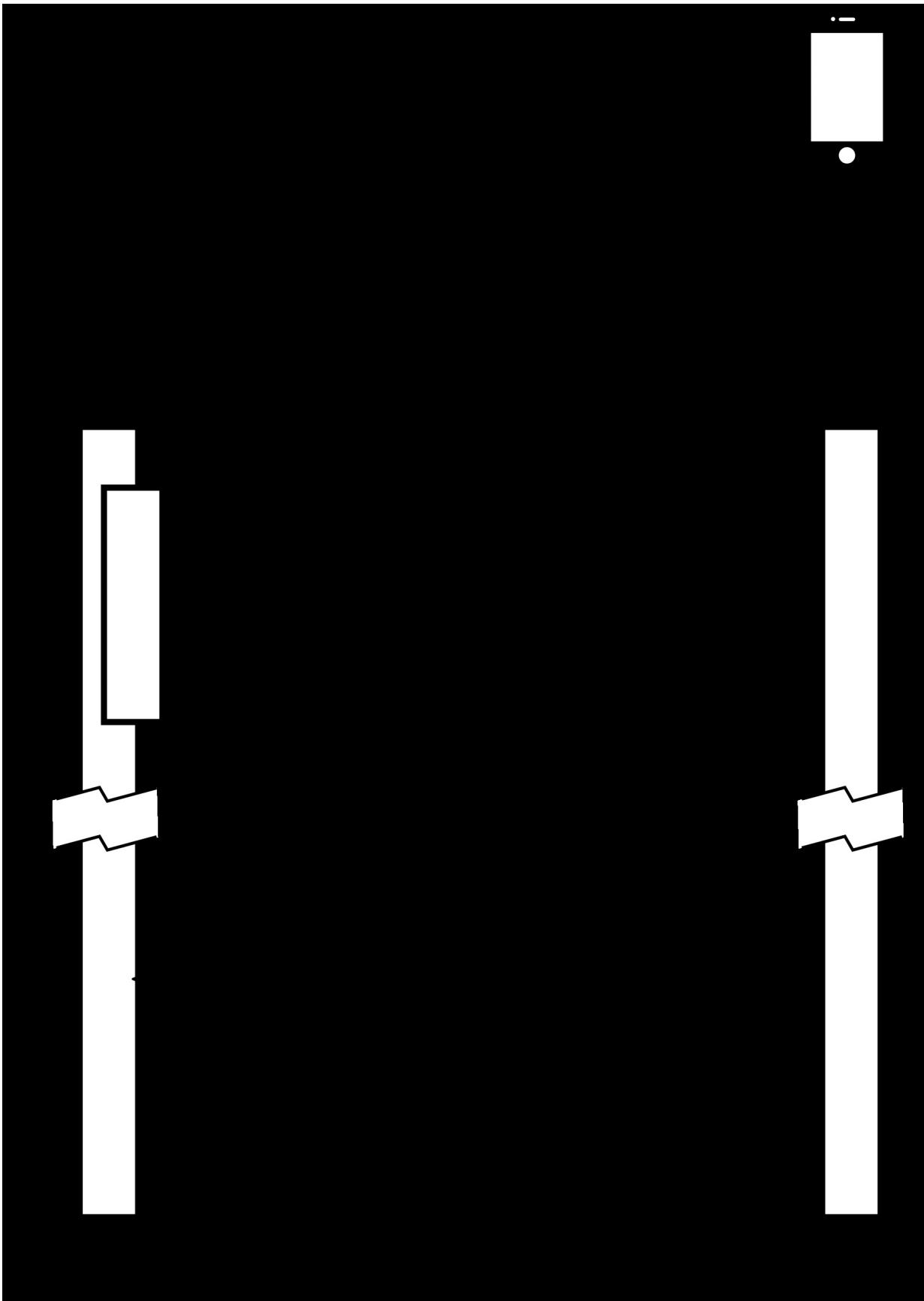


Figure 7-1. The process of a Central reading data from a Peripheral

A Central can read a Characteristic repeatedly, regardless if Characteristic's value has changed.

Programming the Central

Before reading data from a connected Peripheral, it may be useful to know if a Characteristic provides read permission. Read permission can be read by getting the Characteristic property bit map and isolating the read property from it, like this:

```
let isReadable = (characteristic.properties.rawValue & \
CBCharacteristicProperties.read.rawValue) != 0
```

Once the Central has a Bluetooth GATT connection and has access to a Characteristic with which to communicate with a connected Peripheral, the Central can request to read data from that Characteristic like this:

```
peripheral.readValue(for: characteristic)
```

This will initiate a read request from the Central to the Peripheral.

When the Central finishes reading data from the Peripheral's Characteristic, the peripheral didUpdateValueFor method is triggered in the CBPeripheralManagerDelegate.

In this callback, the Characteristic's value can read as a Data object using the characteristic.value property.

```
func peripheral(
    _ peripheral: CBPeripheral,
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?)

{
    let value = characteristic.value
}
```

From here the data can be converted into any format, including a String or an Integer.

```
// convert to byte array
let byteArray = [UInt8](value)
// convert to String
let stringValue = String(data: value, encoding: .ascii)
```

```
// convert to signed integer
let intValue = value.withUnsafeBytes { (ptr: UnsafePointer<Int>) -> Int in
return ptr.pointee
}

// convert to float
let floatValue = value.withUnsafeBytes { (ptr: UnsafePointer<Float>) -> Float in
return ptr.pointee
}
```

Putting It All Together

Create a new project with the following structure (Figure 7-2).

```
📁 ReadCharacteristic/
  📁 Models/
    ⚡ BlePeripheral.swift
  📁 Delegates/
    ⚡ AppDelegate.swift
    ⚡ BluePeripheralDelegate.swift
  📁 UI/
    ⚡ Main.storyboard
    ⚡ LaunchScreen.storyboard
  📁 views/
    ⚡ PeripheralTableViewCell.swift
    ⚡ GattTableViewCell.swift
  📁 Controllers/
    ⚡ CharacteristicViewController.swift
    ⚡ PeripheralviewController.swift
    ⚡ PeripheralTableViewCellController.swift
    ⚡ Assets.xcassets
    ⚡ Info.plist
  📁 Frameworks/
    ⚡ CoreBluetooth.framework
```

Figure 7-2.

Added project files

Models

Modify the BlePeripheral class to include a method that checks if a Characteristic is readable, one that initiates a read request from a Characteristic, and one that responds to the resulting callback.

Example 7-1. Models/BlePeripheral.swift

```
...
/***
Read from a Characteristic */
func readValue(from characteristic: CBCharacteristic) {
    self.peripheral.readValue(for: characteristic)
}

/***
Check if Characteristic is readable
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is readable */
static func isCharacteristic(
    isReadable characteristic: CBCharacteristic) -< Bool {
    if (characteristic.properties.rawValue & \
        CBCharacteristicProperties.read.rawValue) != 0 {
        return true
    }
    return false
}

// MARK: CBPeripheralDelegate

/***
Value downloaded from Characteristic on connected Peripheral */

func peripheral(
    _ peripheral: CBPeripheral,
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?) {

    {
        print("characteristic updated") if let value = characteristic.value {
            print(value.debugDescription) print(value.description)

        if let stringValue = String(data: value, encoding: .ascii) { print(stringValue)
            // received response from Peripheral
            delegate?.blePeripheral?(

                characteristicRead: stringValue,
                characteristic: characteristic,
                blePeripheral: self)
        }
    }
}
```

```
}
```

```
}
```

```
}
```

```
}
```

Delegates

Add a method to the BlePeripheralDelegate that alerts subscribers of a read operation on a Characteristic.

Example 7-2. Delegates/BlePeripheralDelegate.swift

```
... /**
```

Characteristic was read

- Parameters:
- stringValue: the value read from the Characteristic
- characteristic: the Characteristic that was read
- blePeripheral: the BlePeripheral

```
*/
```

```
@objc optional func blePeripheral(  
    characteristicRead stringValue: String, characteristic: CBCharacteristic,  
    blePeripheral: BlePeripheral)
```

```
...
```

Storyboard

Create a new UIView, with class name "CharacteristicViewController" and a new segue to it from the PeripheralViewController. Create and link three UILabel in the GattTableViewCell to show the Characteristic UUID and read/no access properties. Create and link three UILabels to show the Peripheral and Characteristic identifiers, plus a UIButton and UITextView to allow the user to trigger a Characteristic read and display the result on screen (Figure 7-3):

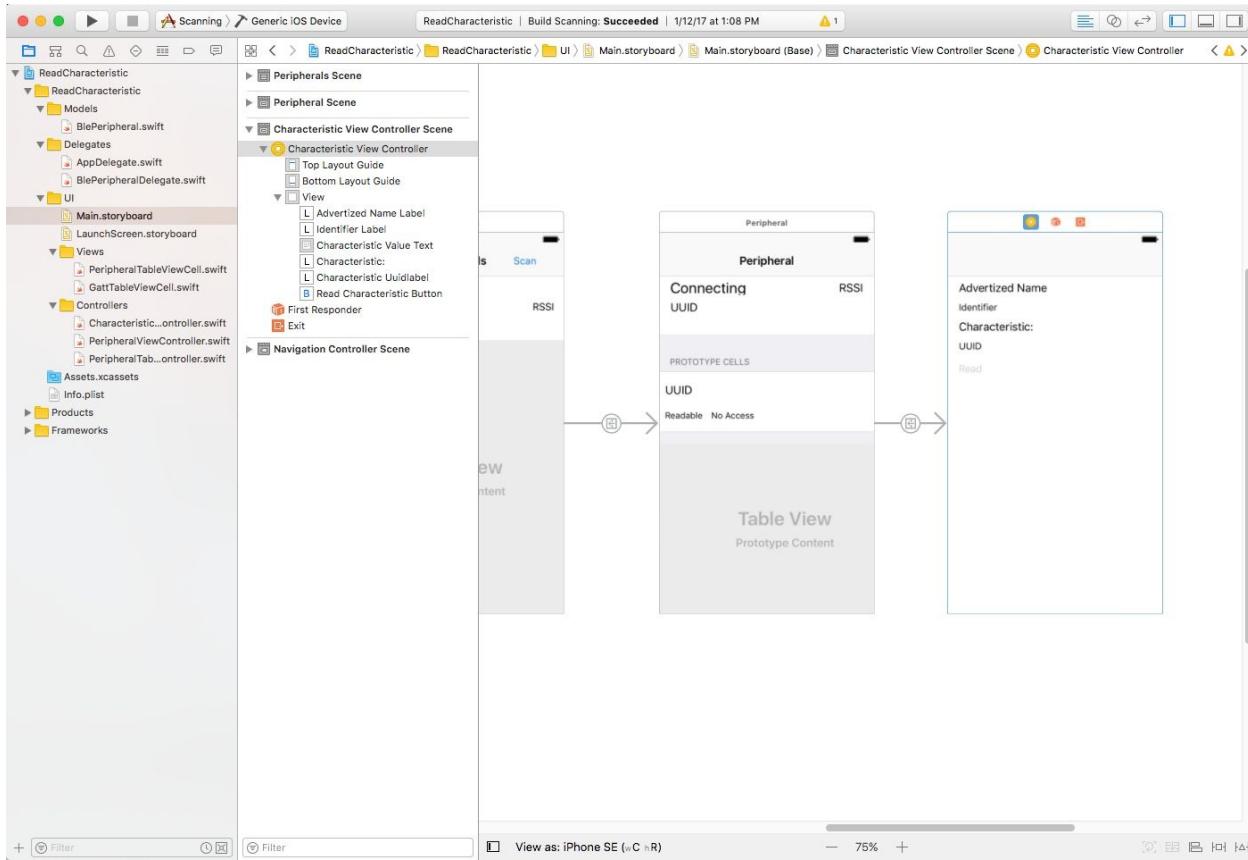


Figure 7-3. Project Storyboard

Views

Alter the renderCharacteristic method in the GattTableViewCell class to display the appropriate UILabelViews when the Characteristic is readable or not

Example 7-3. UI/Views/GattTableViewCell.swift

```
import UIKit
import CoreBluetooth
class GattTableViewCell: UITableViewCell {
```

```
// MARK: UI Elements
```

```
@IBOutlet weak var uuidLabel: UILabel! @IBOutlet weak var readableLabel: UILabel!
@IBOutlet weak var noAccessLabel: UILabel!
```

```
/**
```

Render the cell with Characteristic properties

```
*/
```

```
func renderCharacteristic(characteristic: CBCharacteristic) { uuidLabel.text =
characteristic.uuid.uuidString
let isReadable = \
```

```

BlePeripheral.isCharacteristic(isReadable: characteristic)
readableLabel.isHidden = !isReadable
if isReadable {

    noAccessLabel.isHidden = true
} else {
    noAccessLabel.isHidden = false
}
}
}
}

```

Controllers

Create a new view controller, CharacteristicViewController that will interact with a selected Characteristic. It will display the properties of the Characteristic and allow the user to trigger a read event on the BlePeripheral. The Characteristic's value will be displayed in a UITextView.

Example 7-4. UI/Controllers/CharacteristicViewController.swift

```

import UIKit
import CoreBluetooth
class CharacteristicViewController: UIViewController, \
CBCentralManagerDelegate, BlePeripheralDelegate {

    // MARK: UI elements
    @IBOutlet weak var advertizedNameLabel: UILabel! @IBOutlet weak var
    identifierLabel: UILabel!
    @IBOutlet weak var characteristicUuidlabel: UILabel! @IBOutlet weak var
    readCharacteristicButton: UIButton! @IBOutlet weak var
    characteristicValueText: UITextView!

    // MARK: Connected devices

    // Central Bluetooth Radio
    var centralManager: CBCentralManager! // Bluetooth Peripheral
    var blePeripheral: BlePeripheral!
    // Connected Characteristic
    var connectedService: CBService!
    // Connected Characteristic
    var connectedCharacteristic: CBCharacteristic!

```

```

    /**
     UIView loaded */
    override func viewDidLoad() {

        super.viewDidLoad()
        print("Will connect to device " + \

        "\blePeripheral.peripheral.identifier.uuidString") print("Will connect to
characteristic " + \
        "\connectedCharacteristic.uuid.uuidString") centralManager.delegate = self
blePeripheral.delegate = self
loadUI()
}

    /**
     Load UI elements
    */

func loadUI() {
    advertizedNameLabel.text = blePeripheral.advertisedName identifierLabel.text =
\

blePeripheral.peripheral.identifier.uuidString characteristicUuidlabel.text = \
connectedCharacteristic.uuid.uuidString
readCharacteristicButton.isEnabled = true
// characteristic is not readable
if !BlePeripheral.isCharacteristic(
isReadable: connectedCharacteristic) {
readCharacteristicButton.isHidden = true
characteristicValueText.isHidden = true
}
}

    /**
     User touched Read button. Request to read the Characteristic */
@IBAction func onReadCharacteristicButtonTouched(_ sender: UIButton) {
print("pressed button")
readCharacteristicButton.isEnabled = false
blePeripheral.readValue(from: connectedCharacteristic) // MARK:
}

```

BlePeripheralDelegate

```
/**  
Characteristic was read. Update UI */  
  
func blePeripheral(  
characteristicRead stringValue: String, characteristic: CBCharacteristic,  
blePeripheral: BlePeripheral)  
  
{  
print(stringValue)  
readCharacteristicButton.isEnabled = true  
characteristicValueText.insertText(stringValue + "\n") let stringLength =  
characteristicValueText.text.characters.count  
characteristicValueText.scrollRangeToVisible(NSMakeRange(  
stringLength-1, 0))  
}  
// MARK: CBCentralManagerDelegate  
/**  
Peripheral disconnected  
  
- Parameters:  
- central: the reference to the central  
- peripheral: the connected Peripheral  
  
*/  
func centralManager(  
_ central: CBCentralManager,  
didDisconnectPeripheral peripheral: CBPeripheral, error: Error?)  
  
{  
// disconnected. Leave print("disconnected")  
  
if let navController = navigationController {  
navController.popToRootViewController(animated: true) dismiss(animated: true,  
completion: nil)  
}  
}
```

```
/***
Bluetooth radio state changed

- Parameters:
- central: the reference to the central
*/
```

```
func centralManagerDidUpdateState(_ central: CBCentralManager) {
print("Central Manager updated: checking state") switch (central.state) {
case .poweredOn:
```

```
print("bluetooth on")
default:
print("bluetooth unavailable")
}
}
```

```
// MARK: - Navigation
```

```
/***
Animate the segue
*/
```

```
override func prepare(for segue: UIStoryboardSegue, sender: Any?) { // Get the
new view controller
```

```
// using segue.destinationViewController.
```

```
// Pass the selected object to the new view controller. if let
connectedBlePeripheral = blePeripheral {
```

```
centralManager.cancelPeripheralConnection(
connectedBlePeripheral.peripheral)
}
```

Modify the PeripheralViewController to launch the CharacteristicViewCnotroller when a table cell is clicked. Add the corresponding UITableViewDelegate methods and segue.

Example 7-5. swift/example.com.exampleble/ConnectActivity.swift

```
... /**
User selected a Characteristic table cell. Update UI and open the next UIView
*/
```

```
func tableView(
    _ tableView: UITableView,
    didSelectRowAt indexPath: IndexPath)
```

```
{
```

```
let selectedRow = indexPath.row print("Selected Row: \(selectedRow)")
```

```
}
```

```
// MARK: Navigation
```

```
/***
Handle the Segue. Prepare the next UIView with necessary information */
```

```
override func prepare(for segue: UIStoryboardSegue, sender: Any?) {
    print("leaving view - disconnecting from peripheral")
```

```
if let indexPath = gattTableViewindexPathForSelectedRow { let selectedSection =
    indexPath.section
    let selectedRow = indexPath.row
    let characteristicViewController = \
```

```
segue.destination as! CharacteristicViewController if selectedSection <
    blePeripheral.gattProfile.count { let service =
        blePeripheral.gattProfile[selectedSection] if let characteristics = \
            blePeripheral.gattProfile[selectedSection].\ characteristics
```

```
{
```

```
if selectedRow < characteristics.count { // populate next UIView with necessary
    information
    characteristicViewController.centralManager = \
        centralManager
    characteristicViewController.blePeripheral = \
        blePeripheral
    characteristicViewController.connectedService = \
        service
```

```
characteristicViewController.\nconnectedCharacteristic = \\\ncharacteristics[selectedRow]\n}\n}\n}\ngattTableView.deselectRow(at: indexPath, animated: true) } else {\nif let peripheral = blePeripheral.peripheral {\ncentralManager.cancelPeripheralConnection(peripheral) }\n}\n}\n}
```

When run, the App will be able to scan for and connect to a Peripheral. Once connected, it can list the GATT Profile - the Services and Characteristics hosted on the Peripheral. A Characteristic can be selected and values can be read from that Characteristic (Figure 7-4).

●●●○○ Fido 3G

20:12

* 99%  ⚡

[!\[\]\(5d8cb0a1f929283f21d51856f53ab91f_img.jpg\) Peripherals Peripheral](#)

MyDevice

-75

501AFEEE-AA49-4AF1-8924-E56689A4I

180A

2A56

Readable

●●●○○ Fido 3G

20:13

蓝牙 99%  ⚡

[Peripheral](#)

MyDevice

501AFEEE-AA49-4AF1-8924-E56689A4F0A8

Characteristic:

2A56

[Read](#)

CURWWY6

Figure 7-4. App screens showing GATT Profile for connected Peripheral and values read from a Characteristic on a connected Peripheral

Programming the Peripheral

This chapter will show how to create a Characteristic with read access.
A read-only Characteristic is created and added to a Primary Service like this:

```
// create Characteristic UUID
let readCharacteristicUuid = CBUUID(
    string: "00002a56-0000-1000-8000-00805f9b34fb")

// Make Characteristic readable
let characteristicProperties = CBCharacteristicProperties.read // Make Attributes
readable
let characteristicPermissions = CBAttributePermissions.readable // create the
readable Characteristic
let readCharacteristic = CBMutableCharacteristic(
    type: readCharacteristicUuid, properties: characteristicProperties, value: nil,
    permissions: characteristicPermissions)

// set the Characteristic as the only one in the Service
service.characteristics = [ readCharacteristic ]
```

When the Central requests to read data from the Peripheral's Characteristic, the peripheralManager didReceiveRead method is triggered the CBPeripheralManagerDelegate object.

```
func peripheralManager(
    _ peripheral: CBPeripheralManager, didReceiveRead request: CBATTRequest)
{
}
```

The Central cannot read the Characteristic value until the request's value is set:

```
func peripheralManager(
    _ peripheral: CBPeripheralManager, didReceiveRead request: CBATTRequest)
{
    let characteristic = request.characteristic
    if let value = characteristic.value {
```

```
// Respond to the Central with the Characteristic value let range =  
Range(uncheckedBounds: (  
lower: request.offset,  
upper: value.count - request.offset)) request.value = value.subdata(in: range) }
```

The Central needs to know if the request was successful. This is done by responding to the with a CBATTError status.

CBATTError status messages include the following:

Table 7-1. Common CBATTError values

Value Description

success Operation was successful

readNotPermitted Read request not permitted.

requestNotSupported Request was not supported.

invalidOffset Requested data offset is invalid.

For example, a successful read request warrents a CBATTError.success response:

```
... peripheral.respond(to: request, withResult: CBATTError.success)  
...
```

A full implementation looks like this:

```
func peripheralManager(  
_ peripheral: CBPeripheralManager, didReceiveRead request: CBATTRequest)  
{  
let characteristic = request.characteristic  
if let value = characteristic.value {  
  
// if the requested offset is  
// larger than the Characteristic value, send an error if request.offset >  
value.count {  
  
peripheralManager.respond(  
to: request,  
withResult: CBATTError.invalidOffset)  
  
return  
}
```

```
// Respond to the Central with the Characteristic value let range =  
Range(uncheckedBounds: (  
    lower: request.offset,  
    upper: value.count - request.offset))  
request.value = value.subdata(in: range)  
peripheral.respond(to: request, withResult: CBATTError.success) }  
}
```

Putting It All Together

Copy the previous chapter's project into a new project and modify the files below.

Models

Modify the BlePeripheral class to include build a readable Characteristic, sets a random String to the Characteristic every 5 seconds, and responds when the Central initiates a read request:

Example 7-6. Models/BlePeripheral.swift

... // MARK: GATT Profile

```
// Service UUID
let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")
// Characteristic UUIDs
let readCharacteristicUuid = CBUUID(
    string: "00002a56-0000-1000-8000-00805f9b34fb")
// Read Characteristic
var readCharacteristic:CBMutableCharacteristic!

...
/***
Build Gatt Profile.
This must be done after Bluetooth Radio has turned on
*/
func buildGattProfile() {
    let service = CBMutableService(type: serviceUuid, primary: true)
    let characteristicProperties = CBCharacteristicProperties.read
    let characteristicPermissions = CBAttributePermissions.readable
    readCharacteristic = CBMutableCharacteristic(
        type: readCharacteristicUuid,
        properties: characteristicProperties,
        value: nil, permissions: characteristicPermissions)
```

```

service.characteristics = [ readCharacteristic ]
peripheralManager.add(service)
}

/***
Set a Characteristic to some text value */

func setCharacteristicValue(
    _ characteristic: CBMutableCharacteristic, value: Data
) { characteristic.value = value
if central != nil {

    peripheralManager.writeValue( value,
for: readCharacteristic, onSubscribedCentrals: [central])

}
}

...
/***
Connected Central requested to read from a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager,
didReceiveRead request: CBATTRequest)

{
let characteristic = request.characteristic
if let value = characteristic.value {

//let stringValue = String(data: value, encoding: .utf8)! if request.offset >
value.count {
peripheralManager.respond(


to: request, withResult: CBATTError.invalidOffset) return
}
let range = Range(uncheckedBounds: (
lower: request.offset,

```

```
upper: value.count - request.offset))  
request.value = value.subdata(in: range)  
peripheral.respond(to: request, withResult: CBATTError.success) }  
delegate?.blePeripheral?(characteristicRead: request.characteristic) }  
...  
}
```

Delegates

Add a method to the BlePeripheralDelegate that sends a notification when a Characteristic has been read:

Example 7-7. Delegates/BlePeripheralDelegate.swift

... /* *

Characteristic was read

- Parameters:
 - characteristic: the Characteristic that was read */

```
@objc optional func blePeripheral(  
    characteristicRead fromCharacteristic: CBCharacteristic) ...
```

Controllers

Add a method to the BlePeripheralDelegate that sends a notification when a Characteristic has been read:

Example 7-7. UI/Controllers/ViewController.swift

... @IBOutlet weak var characteristicValueTextField: UITextField!

• • •

// MARK: Update BlePeripheral Properties

/* *

Generate a random String

- Parameters
 - length: the length of the resulting string
 - returns: random alphanumeric string

```
func randomString(length: Int) -> String {
```

```
let letters : NSString = "abcdefghijklmnopqrstuvwxyz" + \
```

```
"ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789" let len =  
UInt32(letters.length)
```

```

var randomString = ""
for _ in 0 ..< length {

let rand = arc4random_uniform(len)
var nextChar = letters.character(at: Int(rand)) randomString += \
NSString(characters: &nextChar, length: 1) as String }
return randomString

}

/***
Set Read Characteristic to some random text value */

func setRandomCharacteristicValue() {
let stringValue = randomString(
length: Int(arc4random_uniform(

```

```

UInt32(blePeripheral.readCharacteristicLength - 1)) )
)
let value:Data = stringValue.data(using: .utf8)!
blePeripheral.setCharacteristicValue(

```

```

blePeripheral.readCharacteristic,
value: value
)
characteristicValueTextField.text = stringValue }

...
/** BlePeripheral statrted adertising

```

- Parameters:
- error: the error message, if any

*/

```

func blePerihperal(startedAdvertising error: Error?) {
if error != nil {
print("Problem starting advertising: " + error.debugDescription)

} else {
print("adertising started")

```

```
advertisingSwitch.setOn(true, animated: true)
setRandomCharacteristicValue()
randomTextTimer = Timer.scheduledTimer(
    timeInterval: 5,
    target: self,
    selector: #selector(setRandomCharacteristicValue),
    userInfo: nil,
    repeats: true
)
}
}
...

```

When run, the App will be able to host a simple GATT profile with a single Characteristic that sets the Characteristic to a random String every 5 seconds (Figure 7-5).

••••• Fido 3G

14:05

98%  ⚡

Bluetooth Peripheral

Advertising Name: MyDevice

Advertising



Characteristic Value:

dInIRRYrn

Figure 7-5. App screen showing random Characteristic value on Advertising Peripheral

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter07>

Writing Data to a Peripheral

Data is sent from the Central to a Peripheral when the Central writes a value in a Characteristic hosted on the Peripheral, presuming that Characteristic has write permissions.

The process looks like this (Figure 8-1):



Figure 8-1. The process of a Central writing data to a Peripheral

Programming the Central

Before attempting to write data a Characteristic, it is useful to know if the Characteristic has “write” permissions. Write permissions can be read by accessing a Characteristic’s properties and isolating the Write properties:

```
// Characteristic supports write permissions
let properties = characteristic.properties.rawValue;
let isWriteable = (properties & \
CBCharacteristicProperties.write.rawValue) != 0 ||
(properties & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0

// Characteristic supports write (with response) permissions let
isWriteableWithResponse = (properties & \
CBCharacteristicProperties.write.rawValue) != 0
// Characteristic supports write without response permissions let
isWriteableWithoutResponse = (properties & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0 The
Characteristic is written to like this:
peripheral.writeValue(value, for: characteristic)
```

Regardless of the initial data type, the value written to the Characetric must be sent as a Data object. Here is how to convert some common data types into a Data object:

```
// convert String to Data
let stringValue = "Hello"
let arrayValue = Array(stringValue.utf8)
let stringDataValue = Data(Array(byteValue[0..<length]))

// convert Int to Data
var intValue = 8;
let intDataValue = Data(buffer: UnsafeBufferPointer(
start: &intValue,
```

```
count: 1))

// convert Float to Data
var floatValue = 10.2;
let floatDataValue = Data(buffer: UnsafeBufferPointer(
    start: &floatValue,
    count: 1))
```

If the Characteristic supports write (with response), the peripheral didWriteValueFor event gets triggered in the CBPeripheralDelegate following a write operation:

```
func peripheral(
    _ peripheral: CBPeripheral,
    didWriteValueFor characteristic: CBCharacteristic, error: Error?)

{}
```

Putting It All Together

Copy the project from the previous chapter into a new project, titled "WriteCharacteristic."

Models

Modify the BlePeripheral class to include methods to test the write permissions of a Characteristic, to write a value to a Characteristic, and to handle the resulting CBPeripheralDelegate callback:

Example 8-1. Models/BlePeripheral.swift

```
... /**
```

Write a text value to the BlePeripheral

- Parameters:
- value: the value to write to the connected Characteristic */

```
func writeValue(value: String, to characteristic: CBCharacteristic) { let
byteValue = Array(value.utf8)
// cap the outbound value length to be
// less than the characteristic length
```

```

var length = byteValue.count
if length > characteristicLength {

length = characteristicLength
}
let transmissibleValue = Data(Array(byteValue[0..<length]))
print(transmissibleValue)
var writeType = CBCharacteristicWriteType.withResponse if
BlePeripheral.isCharacteristic(


isWriteableWithoutResponse: characteristic) { writeType =
CBCharacteristicWriteType.withoutResponse }
peripheral.writeValue(
transmissibleValue,
for: characteristic,
type: writeType)
print("write request sent")
}

/***
Check if Characteristic is writeable
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is writeable */
static func isCharacteristic(
isWriteable characteristic: CBCharacteristic) -> Bool

{
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.write.rawValue) != 0 ||
(characteristic.properties.rawValue & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0 { return true

}
return false }
/***
Check if Characteristic is writeable with response
- Parameters:
- characteristic: The Characteristic to test

```

```

- returns: True if characteristic is writeable with response

*/
static func isCharacteristic(
isWriteableWithResponse characteristic: CBCharacteristic) -> Bool { if
(characteristic.properties.rawValue & \
CBCharacteristicProperties.write.rawValue) != 0 { return true
}
return false
}

/***
Check if Characteristic is writeable without response
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is writeable without response */
static func isCharacteristic(
isWriteableWithoutResponse characteristic: CBCharacteristic) -> Bool

{
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0 { return true
}
return false
}
// MARK: CBPeripheralDelegate

/***
Value was written to the Characteristic
*/
func peripheral(
_peripheral: CBPeripheral,
didWriteValueFor characteristic: CBCharacteristic, error: Error?)

{
print("data written")
delegate?.blePeripheral?(
```

```
    valueWritten: characteristic, blePeripheral: self)
}
...

```

Delegates

Add a function to the BlePeripheralDelegate to alert subscribers that a write operation happened.

Example 8-2. Delegates/BlePeripheralDelegate.swift

```
... /**
Value written to Characteristic
```

- Parameters:
- characteristic: the Characteristic that was written to
- blePeripheral: the BlePeripheral

```
*/
@objc optional func blePeripheral(
valueWritten characteristic: CBCharacteristic, blePeripheral: BlePeripheral)
```

```
...
```

Storyboard

Create and link a UILabel in the GattTableViewCell to show the write property and a UITextField and UIButton to allow a user to type and submit text to the Characteristic (Figure 8-2):

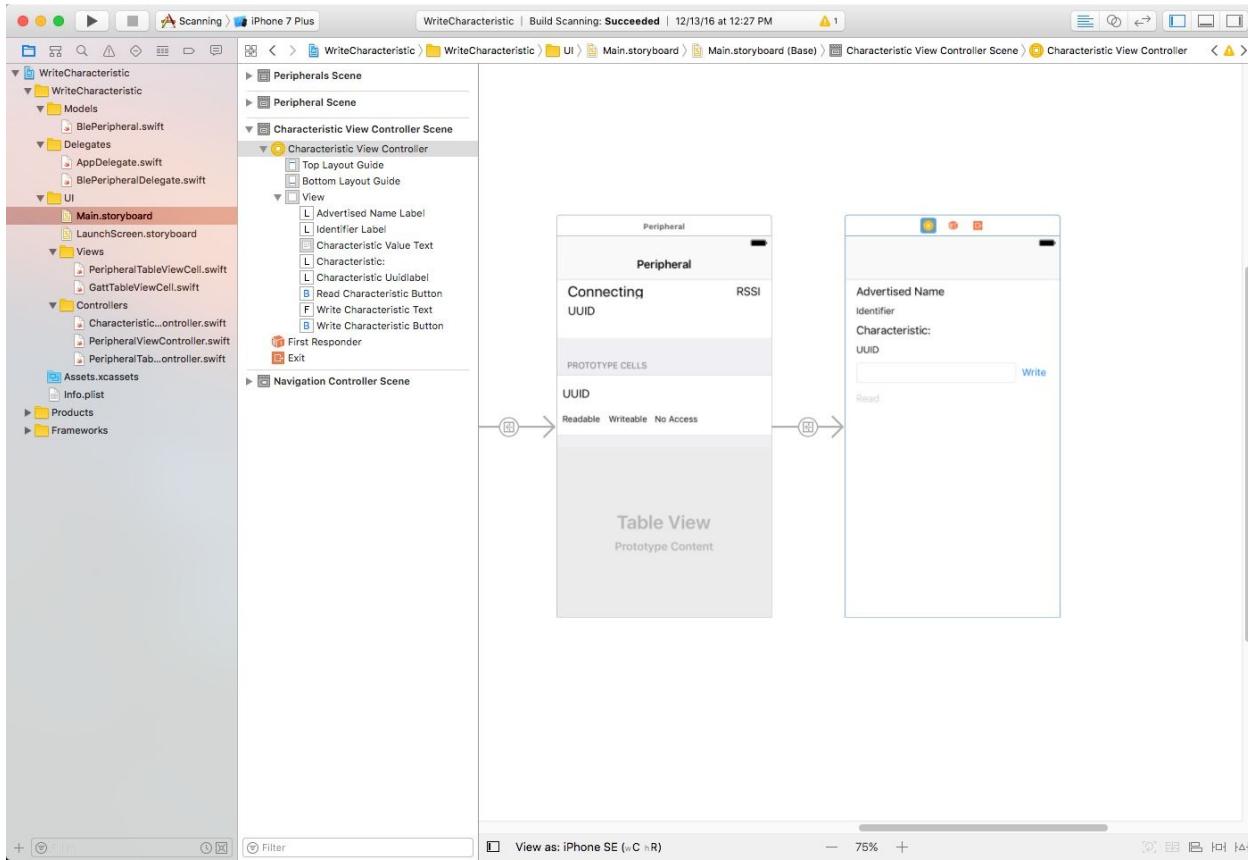


Figure 8-2. Project Storyboard

Views

Modify the GattTableViewCell to display the appropriate UILabelView when a Characteristic is writeable.

Example 8-3. UI/Views/GattTableViewCell.swift

```

... @IBOutlet weak var writeableLabel: UILabel!
...
func renderCharacteristic(characteristic: CBCharacteristic) { uuidLabel.text =
characteristic.uuid.uuidString let isReadable = BlePeripheral.isCharacteristic(
isReadable: characteristic)
let isWriteable = BlePeripheral.isCharacteristic( isWriteable: characteristic)
readableLabel.isHidden = !isReadable
writeableLabel.isHidden = !isWriteable
if isReadable || isWriteable {
noAccessLabel.isHidden = true
} else {
noAccessLabel.isHidden = false
}

```

```
}
```

```
...
```

Controllers

Add functionality to the CharacteristicViewController to display new UI elements to handle write operations, as well as an implementation of the new BlePeripheralDelegate method listed above.

Example 8-4. UI/Controllers/CharacteristicViewController.swift

```
... @IBOutlet weak var writeCharacteristicButton: UIButton! @IBOutlet weak  
var writeCharacteristicText: UITextField!
```

```
...
```

```
/**
```

```
Load UI elements
```

```
*/
```

```
func loadUI() {  
    advertisedNameLabel.text = blePeripheral.advertisedName  
    identifierLabel.text = \  
    \
```

```
blePeripheral.peripheral.identifier.uuidString  
characteristicUuidlabel.text = \  
connectedCharacteristic.uuid.uuidString  
readCharacteristicButton.isEnabled =  
true
```

```
// characteristic is not readable
```

```
if !BlePeripheral.isCharacteristic(  
isReadable: connectedCharacteristic) {  
    readCharacteristicButton.isHidden = true  
    characteristicValueText.isHidden = true }
```

```
// characteristic is not writeable
```

```
if !BlePeripheral.isCharacteristic(  
isWriteable: connectedCharacteristic) {  
    writeCharacteristicText.isHidden = true  
    writeCharacteristicButton.isHidden = true }
```

```
}
```

```
...
```

```
/**
```

```
User touched Read button. Request to write to the Characteristic */
```

```
@IBAction func onWriteCharacteristicButtonTouched(_ sender: UIButton) {  
    print("write button pressed")  
    writeCharacteristicButton.isEnabled = false  
    if let stringValue = writeCharacteristicText.text {  
        print(stringValue)  
        blePeripheral.writeValue(  
            value: stringValue,  
            to: connectedCharacteristic) writeCharacteristicText.text = "" }  
    }  
    ...  
    /**/  
    Characteristic was written to. Update UI */  
    func blePeripheral(  
        valueWritten characteristic: CBCharacteristic, blePeripheral: BlePeripheral)  
    {  
        print("value written to characteristic!") writeCharacteristicButton.isEnabled =  
        true }  
    ...
```

Compile and run. The updated app will be able to scan for and connect to a Peripheral. Once connected, it lists services and characteristics, connect to Characteristics and send and data (Figure 8-3).

●●○○ Fido 3G

20:37

⚡ 100%  ⚡

[!\[\]\(dfa57f70fcabb9b88e908f6929b525b2_img.jpg\) Peripherals](#) Peripheral

MyDevice

-67

501AFEEE-AA49-4AF1-8924-E56689A4I

180A

2A56

Writeable



Figure 8-3. App screens showing GATT Profile of connected Peripheral with Write access to a Characteristic, and an interface to send text to a Characteristic

Programming the Peripheral

This chapter will show how to create a Characteristic with read access. A writeable Characteristic is has the CBCharacteristicProperties.write property:

```
// Characteristic is writable
var characteristicProperties = CBCharacteristicProperties.write
```

It is possible to append other properties to additionally make the Characteristic readable:

```
// Read support
characteristicProperties.formUnion(CBCharacteristicProperties.read)
// add write support
characteristicProperties.formUnion(CBCharacteristicProperties.notify)
```

Everything else about creating the Characteristic remains the same as for a readable Characteristic:

```
// Characteristic Attributes are readable
var characterisitcPermissions = CBAtributePermissions.readable
// Set Characteristic UUID
let readWriteCharacteristicUuid = CBUUID( string: "00002a56-0000-1000-
8000-00805f9b34fb")
```

```
// Create a writeable Characteristic
readWriteCharacteristic = CBMutableCharacteristic( type:
readWriteCharacteristicUuid,
properties: characteristicProperties,
value: nil,
permissions: characterisitcPermissions)
```

```
// Set the Characteristic as belonging to the Service service.characteristics = [
readWriteCharacteristic ]
```

When a connected Central attempts to write to a Characteristic, the peripheralManager didReceiveWrite callback is triggered by the CBPeripheralManagerDelegate object. If the Characteristic has the CBCharacteristicProperties.write property, it is important to respond to the Central with a CBATTError status.

CBATTError status messages include the following:

Table 8-1. Common CBATTError values

Value Description

success Operation was successful

writeNotPermitted Write request was not permitted.

readNotPermitted Read request not permitted.

requestNotSupported Request was not supported.

invalidOffset Requested data offset is invalid.

More than one request may come in at a time, so it is useful to iterate through and deal with each request separately.

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager, didReceiveWrite requests:  
    [CBATTRequest])  
  
{  
    for request in requests {  
        peripheral.respond(to: request, withResult: CBATTError.success) // do  
        something with the incoming data  
  
    }  
}
```

Putting It All Together

Create a new project called WriteCharacteristic and copy the files from the previous chapter's project.

The Peripheral will be modified to support writes.

Models

Modify the BlePeripheral class to create a writeable Characteristic and to handle incoming write requests:

Example 8-5. Models/BlePeripheral.swift

```
... // Service UUID  
let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")  
// Characteristic UUIDs  
let readWriteCharacteristicUuid = CBUUID(  
  
string: "00002a56-0000-1000-8000-00805f9b34fb")  
// Read Characteristic
```

```

var readWriteCharacteristic:CBMutableCharacteristic!

...
/***
Build Gatt Profile.
This must be done after Bluetooth Radio has turned on
*/
func buildGattProfile() {
let service = CBMutableService(type: serviceUuid, primary: true) var
characteristicProperties = CBCharacteristicProperties.read
characteristicProperties.formUnion(
    CBCharacteristicProperties.notify)
var characteristicPermissions = CBAttributePermissions.writeable
characteristicPermissions.formUnion(CBAttributePermissions.readable)
readWriteCharacteristic = CBMutableCharacteristic(
    type: readWriteCharacteristicUuid,
    properties: characteristicProperties, value: nil,
    permissions: characteristicPermissions)

service.characteristics = [ readWriteCharacteristic ]
peripheralManager.add(service)

}
...
/***
Connected Central requested to write to a Characteristic */
func peripheralManager(
    _ peripheral: CBPeripheralManager,
    didReceiveWrite requests: [CBATTRequest])
{
for request in requests {
    peripheral.respond(to: request, withResult: CBATTError.success) if let value =
    request.value {
        delegate?.blePeripheral?(
            valueWritten: value,
            toCharacteristic: request.characteristic) }
    }
}

```

```
}
```

```
...
```

Delegates

Add a method to the BlePeripheralDelegate to process successful writes to a Characteristic:

Example 8-6. Delegates/BlePeripheralDelegate.swift

```
... /** Value written to Characteristic
```

- Parameters:

- value: the Data value written to the Charactersitic

- characteristic: the Characteristic that was written to

```
*/
```

```
@objc optional func blePeripheral(
```

```
valueWritten value: Data,
```

```
toCharacteristic: CBCharacteristic)
```

```
...
```

Storyboard

Add a UILabel and UITextView to show the Characteristic Log in the UIView in the Main.storyboard to create the App's user interface (Figure 8-4):

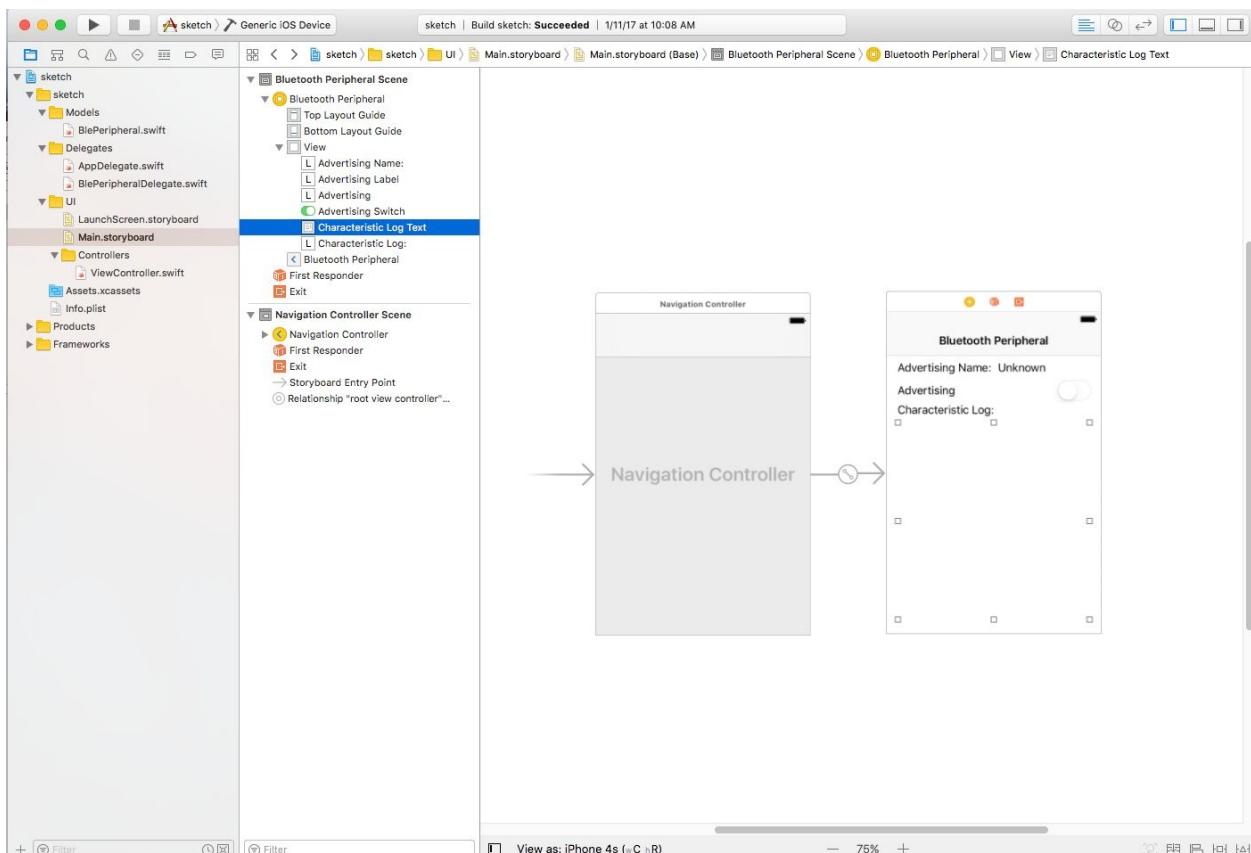


Figure 8-4. Project Storyboard Controllers

Add a UITextView that logs the incoming Characteristic values, and a callback handler for the the BlePeripheral writes:

Example 8-7. UI/Controllers/ViewController.swift

```
...
@IBOutlet weak var characteristicLogText: UITextView!
```

```
...
```

```
/**
```

Value written to Characteristic

- Parameters:
- stringValue: the value read from the Charactersitic
- characteristic: the Characteristic that was written to

```
*/
```

```
func blePeripheral(
    valueWritten value: Data,
```

```
toCharacteristic: CBCharacteristic)
```

```
{  
//let stringValue = String(data: value, encoding: .utf8) let hexValue =  
value.hexEncodedString()  
characteristicLogText.text = characteristicLogText.text + \  
"\n" + hexValue  
if !characteristicLogText.text.isEmpty {  
characteristicLogText.scrollRangeToVisible(NSMakeRange(0, 1)) }  
}  
}
```

Compile and run. The updated app will host a simple GATT Profile featuring a writeonly Characteristic.

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter08>

Using Notifications

Being able to read from the Central has limited value if the Central does not know when new data is available.

Notifications solve this problem. A Characteristic can issue a notification when its value has changed. A Central that subscribes to these notifications will know when the Characteristic's value has changed, but not what that new value is. The Central can then read the latest data from the Characteristic.

The whole process looks something like this (Figure 9-1):

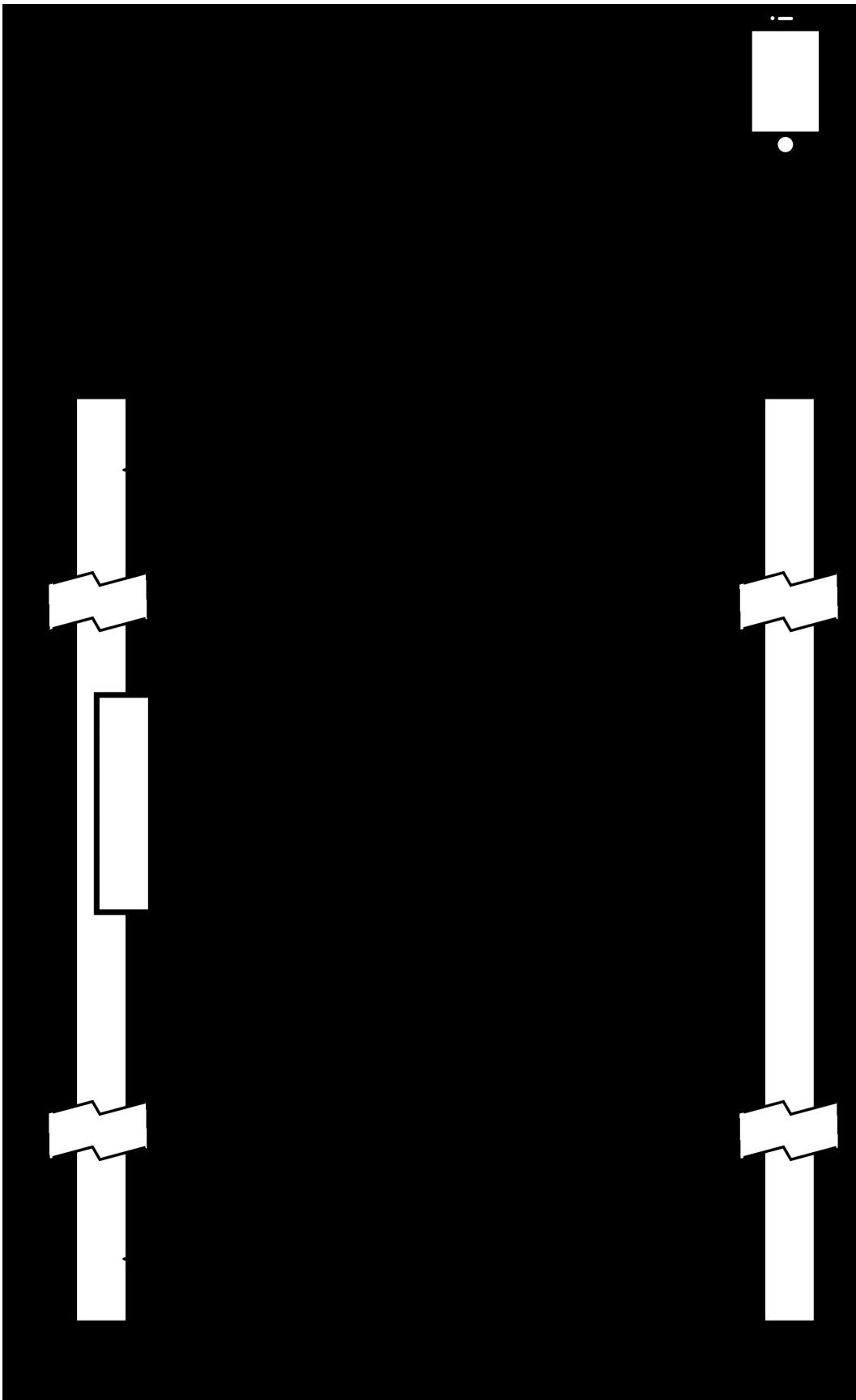


Figure 9-1. The process of a Peripheral notifying a connected Central of changes to a Characteristic

Programming the Central

Before the Central can subscribe to the Characteristic's notifications, it is useful to know if the Characteristic supports notifications. To determine if notifications are enabled, get the properties of the Characteristic and isolate the `notify` property.

```
let isNotifiable = (characteristic.properties.rawValue & \  
CBCharacteristicProperties.notify.rawValue) != 0
```

The Central can subscribe to or unsubscribe from a Characteristic's notifications by passing a boolean to the `CBPeripheral.setNotifyValue()` method:

```
// subscribe to a Characteristic  
peripheral.setNotifyValue(true, for: characteristic)  
// unsubscribe from a Characteristic  
peripheral.setNotifyValue(false, for: characteristic)
```

When the Characteristic has been subscribed to or unsubscribed from, the `peripheral didUpdateNotificationStateFor` callback is triggered in the `CBPeripheralDelegate`.

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didUpdateNotificationStateFor characteristic: CBCharacteristic, error: Error?)
```

```
{  
}
```

Once subscribed, any changes to a Characteristic automatically trigger the `peripheral didUpdateValueFor` method in the `CBPeripheralDelegate`.

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?)
```

```
{  
}
```

Putting It All Together

These features will be added to `BlePeripheral` to subscribe to notifications, and

we will alter TalkActivity to display a checkbox to subscribe and unsubscribe from the notifications and respond to notification alerts.

Models

Add methods to BlePeripheral to test if a Characteristic is notifiable, to subscribe and unsubscribe from a Characterstic, and to handle the resulting callback from CBPeripheralManagerDelegate:

Example 9-1. Models/BlePeripheral.swift

```
... /**
Subscribe to the connected characteristic.  
When change is successful, delegate.subscriptionStateChanged() called */  
func subscribeTo(characteristic: CBCharacteristic) {  
    self.peripheral.setNotifyValue(true, for: characteristic) }  
/**  
Unsubscribe from the connected characteristic.  
When change is successful, delegate.subscriptionStateChanged() called */  
func unsubscribeFrom(characteristic: CBCharacteristic) {  
    self.peripheral.setNotifyValue(false, for: characteristic)  
}  
...  
/**  
Check if Characteristic is notifiable  
  
- Parameters:  
- characteristic: The Characteristic to test  
- returns: True if characteristic is notifiable  
  
*/  
static func isCharacteristic(  
    isNotifiable characteristic: CBCharacteristic) -> Bool { if  
(characteristic.properties.rawValue & \  
    CBCharacteristicProperties.notify.rawValue) != 0 {  
    return true }  
    return false }  
  
// MARK: CBPeripheralDelegate
```

```

/** Characteristic has been subscribed to or unsubscribed from */

func peripheral(
    _ peripheral: CBPeripheral,
    didUpdateNotificationStateFor characteristic: CBCharacteristic, error: Error?)

{
    print("Notification state updated for: " +
        "\u2022(characteristic.uuid.uuidString)")
    print("New state: \u2022(characteristic.isNotifying)") delegate?.blePeripheral?(

        subscriptionStateChanged: characteristic.isNotifying, characteristic:
            characteristic,
        blePeripheral: self)

    if let errorValue = error {
        print("error subscribing to notification: ") print(errorValue.localizedDescription)
    }
}
...

```

Delegates

Add a method to the BlePeripheralDelegate to notify subscribers that a Characteristic has been subscribed to or unsubscribed from:

Example 9-2. Delegates/BlePeripheralDelegate.swift

```
... /** A subscription state has changed on a Characteristic
```

- Parameters:
- subscribed: true if subscribed, false if unsubscribed
- characteristic: the Characteristic that was subscribed/unsubscribed
- blePeripheral: the BlePeripheral

```
*/
@objc optional func blePeripheral(
    subscriptionStateChanged subscribed: Bool,
    characteristic: CBCharacteristic,
```

blePeripheral: BlePeripheral)

...

Storyboard

Create and link a UILabel in the GattTableViewCell to show the notification property and a UILabel and UISwitch to show the Characteristic subscription state (and a UILabel and UISwitch to show the Characteristic subscription state (2)):

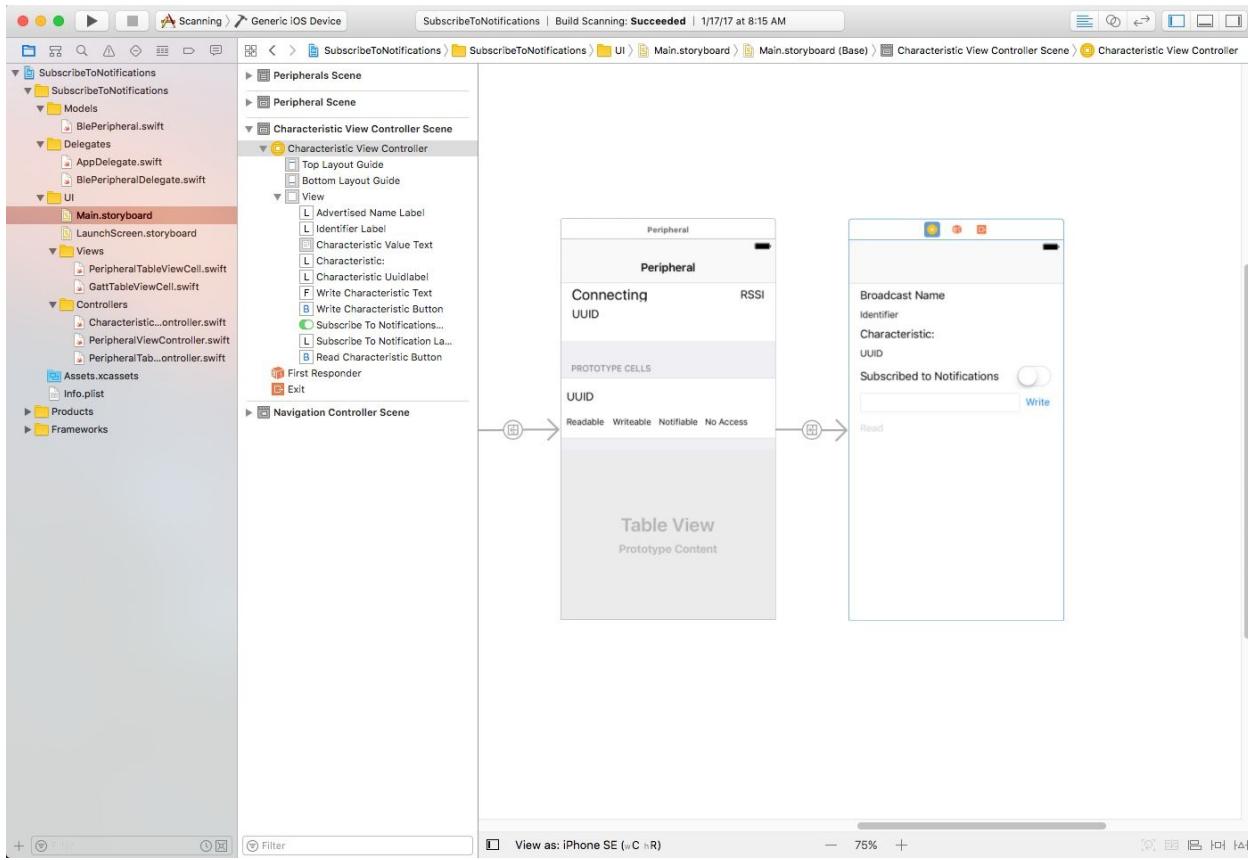


Figure 9-2. Project Storyboard Views

Modify the `GattTableViewCell` to hold a `UILabel` that shows the notification permissions for a Characteristic, as well as functionality to show or hide the `UILabel` to reflect the Characteristic permissions:

Example 9-3. UI/Views/GattTableViewCell.swift

```

... @IBOutlet weak var notifiableLabel: UILabel!
...
func renderCharacteristic(characteristic: CBCharacteristic) { uuidLabel.text =
characteristic.uuid.uuidString
print(characteristic.uuid.uuidString)
var isReadable = false
var isWriteable = false
var isNotifiable = false
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.read.rawValue) != 0 {
print("readable")
}

```

```

isReadable = true
}
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.write.rawValue) != 0 ||
(characteristic.properties.rawValue & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0 {
print("writable")
isWriteable = true
}
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.notify.rawValue) != 0 { print("notifiable")
isNotifiable = true
}
readableLabel.isHidden = !isReadable
writeableLabel.isHidden = !isWriteable
notifiableLabel.isHidden = !isNotifiable
if isReadable || isWriteable || isNotifiable {
noAccessLabel.isHidden = true
} else {
noAccessLabel.isHidden = false
}
}
}

...

```

Controllers

Modify the CharacteristicViewController to show a Subscribe to Notifications UISwitch and UILabel, plus interactions for the switch. Implement the BlePeripheralDelegate method subscriptionStateChanged to handle changes in the notification state of the Characteristic:

Example 9-4. UI/Controllers/CharacteristicViewController.swift

```
... @IBOutlet weak var subscribeToNotificationLabel: UILabel! @IBOutlet
weak var subscribeToNotificationsSwitch: UISwitch!
```

```
...
func loadUI() {
advertisedNameLabel.text = blePeripheral.advertisedName identifierLabel.text =
```

```
\
```

```
blePeripheral.peripheral.identifier.uuidString
```

```
characteristicUuidlabel.text = \  
connectedCharacteristic.uuid.uuidString  
readCharacteristicButton.isEnabled = true
```

```
// characteristic is not readable  
if !BlePeripheral.isCharacteristic(  
isReadable: connectedCharacteristic) {  
readCharacteristicButton.isHidden = true  
characteristicValueText.isHidden = true }
```

```
// characteristic is not writeable  
if !BlePeripheral.isCharacteristic( isWriteable: connectedCharacteristic) {  
writeCharacteristicText.isHidden = true writeCharacteristicButton.isHidden =  
true }
```

```
// characteristic is not writeable  
if !BlePeripheral.isCharacteristic(  
isNotifiable: connectedCharacteristic) {  
subscribeToNotificationsSwitch.isHidden = true  
subscribeToNotificationLabel.isHidden = true }  
}
```

```
...
```

```
/**
```

```
User toggled the notification switch.
```

```
Request to subscribe or unsubscribe from the Characteristic */
```

```
@IBAction func onSubscriptionToNotificationSwitchChanged(_ sender:  
UISwitch)  
{  
print("Notification Switch toggled")  
subscribeToNotificationsSwitch.isEnabled = false if sender.isOn {  
blePeripheral.subscribeTo(  
characteristic: connectedCharacteristic) } else {  
blePeripheral.unsubscribeFrom(  
characteristic: connectedCharacteristic) }
```

```
} ...
/** Characteristic subscription status changed. Update UI */
func blePeripheral(
subscriptionStateChanged subscribed: Bool, characteristic: CBCharacteristic,
blePeripheral: BlePeripheral) {
if characteristic.isNotifying {
subscribeToNotificationsSwitch.isOn = true
} else {
subscribeToNotificationsSwitch.isOn = false
}
subscribeToNotificationsSwitch.isEnabled = true
...
}
```

Compile and run. The app can scan for and connect to a Peripheral. Once connected, it can display the GATT profile of the Peripheral. It can connect to Characteristics, Subscribe to notifications, and receive data without polling.

When you hit the “Subscribe to Notifications” button, the text field should begin populating with random text generated on the Peripheral (Figure 9-3).

●●○○ Fido 3G

20:12

⚡ 100%  ⚡

[!\[\]\(9bd6096e18445cd917f84686136e40b3_img.jpg\) Peripherals](#) Peripheral

MyDevice

-65

501AFEEE-AA49-4AF1-8924-E56689A4I

180A

2A56

Readable

Notifiable

●●●○○ Fido 3G

20:13

蓝牙 99%  ⚡

[!\[\]\(4a6d7479716fa4cb779f645c87270a1e_img.jpg\) Peripheral](#)

MyDevice

501AFEEE-AA49-4AF1-8924-E56689A4F0A8

Characteristic:

2A56

Subscribed to Notifications



[Read](#)

SV0H0AT

JLG3HBV

H4XLYUB

Figure 9-3. Apps screen showing GATT Profile of connected Peripheral with Notifications available in a Characteristic, and text read from a Characteristic

Programming the Peripheral

Often, battery life is at a premium on Bluetooth Peripherals. For this reason, it is useful to notify a connected Central when a Characteristic's value has changed, but not send the new data to the Central. Waking up the Bluetooth radio to send one byte consumes less battery than sending 20 or more bytes.

Creating the Characteristic

A Characteristic that supports notifications must have a `CBCharacteristicProperties.notify` property:

```
var characteristicProperties = CBCharacteristicProperties.notify
```

It is possible to append other properties to additionally make the Characteristic readable or writable:

```
// notification support
```

```
var characteristicProperties = CBCharacteristicProperties.notify
```

```
// add read support
```

```
characteristicProperties.formUnion(CBCharacteristicProperties.read)
```

```
// add write support
```

```
characteristicProperties.formUnion(CBCharacteristicProperties.write)
```

Additionally, the Characteristic's Attributes must be readable and writeable:

```
// Characteristic Attributes are readable
```

```
var characteristicPermissions = CBAttributePermissions.readable
```

```
characteristicPermissions.formUnion(CBAttributePermissions.writeable)
```

Just as before, the Characteristic is created by instantiating a `CBMutableCharacteristic` object:

```
// Set Characteristic UUID
```

```
let readWriteNotifyCharacteristicUuid = CBUUID(string: "00002a56-0000-1000-8000-00805f9b34fb")
```

```
// Create a writeable Characteristic
```

```
let readWriteNotifyCharacteristic = CBMutableCharacteristic(type: readWriteNotifyCharacteristicUuid, properties: characteristicProperties, value: nil, permissions: characteristicPermissions)
```

Responding to Callbacks

When a Central subscribes to a Characteristic, the peripheralManager didSubscribeTo method is triggered by the CBPeripheralManagerDelegate object. One of the parameters is a CBCentral, the Central that is subscribed to the Characteristic. It is important to save this reference to the Central as its a requirement in sending a notification.

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager,  
    central: CBCentral,  
    didSubscribeTo characteristic: CBCharacteristic)  
  
{  
    // save a copy of the Central self.central = central  
  
}
```

When a Central unsubscribes from a Characterstic, peripheralManager didUnsubscribeFrom method is triggered by the CBPeripheralManagerDelegate object:

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager,  
    central: CBCentral,  
    didUnsubscribeFrom characteristic: CBCharacteristic)  
  
{  
    // remove reference to the Central self.central = null  
  
}
```

Just prior to the Characteristic sending out a notification, the peripheralManagerIsReady method is triggered:

```
func peripheralManagerIsReady(  
    toUpdateSubscribers peripheral: CBPeripheralManager)  
{  
}
```

Sending Notifications

Notifications are automatically sent when the CBPeripheralManager calls the updateValue method:

```
peripheralManager.updateValue(  
    value,  
    for: readWriteNotifyCharacteristic, onSubscribedCentrals: [central])
```

Putting It All Together

These features will be added to BlePeripheral to allow notification subscriptions from Characteristics.

Models

Add a reference to the connected Central, build a GATT Profile with a notification support, and callback handlers to process Characteristic subscription and unsubscription by a Central:

Example 9-5. Models/BlePeripheral.swift

```
... // MARK: GATT Profile
```

```
// Service UUID
```

```
let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")
```

```
// Characteristic UUIDs
```

```
let readWriteNotifyCharacteristicUuid = CBUUID(
```

```
string: "00002a56-0000-1000-8000-00805f9b34fb")
```

```
// Read Characteristic
```

```
var readWriteNotifyCharacteristic:CBMutableCharacteristic!
```

```
// Connected Central var central:CBCentral!
```

```
...
```

```
/**
```

Build Gatt Profile.

This must be done after Bluetooth Radio has turned on

```
*/
```

```
func buildGattProfile() {
```

```
let service = CBMutableService(type: serviceUuid, primary: true) var
```

```
characteristicProperties = CBCharacteristicProperties.read
```

```

characteristicProperties.formUnion(
    CBCharacteristicProperties.notify)
var characteristicPermissions = CBAttributePermissions.writeable
characteristicPermissions.formUnion(CBAttributePermissions.readable)

readWriteNotifyCharacteristic = CBMutableCharacteristic( type:
    readWriteNotifyCharacteristicUuid, properties: characteristicProperties,
    value: nil,
    permissions: characteristicPermissions)

service.characteristics = [ readWriteNotifyCharacteristic ]
peripheralManager.add(service)
randomTextTimer = Timer.scheduledTimer(
    timeInterval: 5,
    target: self,
    selector: #selector(setRandomCharacteristicValue), userInfo: nil,
    repeats: true)

}

/**
Generate a random String
- Parameters
- length: the length of the resulting string

- returns: random alphanumeric string
*/
func randomString(length: Int) -> String {

let letters : NSString = \
"abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ012345
let len = UInt32(letters.length)
var randomString = ""
for _ in 0 ..< length {
    let rand = arc4random_uniform(len)
    var nextChar = letters.character(at: Int(rand))
    randomString += \
        NSString(characters: &nextChar, length: 1) as String
}

```

```

return randomString
}

/***
Set Read Characteristic to some random text value */

func setRandomCharacteristicValue() {
let stringValue = randomString(
length: Int(arc4random_uniform(
UInt32(readCharacteristicLength - 1))) )
let value:Data = stringValue.data(using: .utf8)!

readWriteNotifyCharacteristic.value = value if central != nil {

peripheralManager.updateValue(
value,
for: readWriteNotifyCharacteristic, onSubscribedCentrals: [central])

}
print("writing " + stringValue + " to characteristic")

}
...
/***
Connected Central subscribed to a Characteristic */
func peripheralManager(
_peripheral: CBPeripheralManager,
central: CBCentral,
didSubscribeTo characteristic: CBCharacteristic)
{
self.central = central
delegate?.blePeripheral?(

subscriptionStateChangedForCharacteristic: characteristic, subscribed: true)
}

/***
Connected Central unsubscribed from a Characteristic */

func peripheralManager(
_peripheral: CBPeripheralManager,

```

```

central: CBCentral,
didUnsubscribeFrom characteristic: CBCharacteristic)

{
self.central = central
delegate?.blePeripheral?(

subscriptionStateChangedForCharacteristic: characteristic, subscribed: false) }

/*
Peripheral is about to notify subscribers of changes to a Characteristic
*/

func peripheralManagerIsReady(
toUpdateSubscribers peripheral: CBPeripheralManager)

{
print("Peripheral about to update subscribers")
}
...
```

Delegates

Add a method to the BlePeripheralDelegate to relay changes in a Characteristic's subscription state:

Example 9-6. Delegates/BlePeripheralDelegate.swift

```

... /**
A subscription state has changed on a Characteristic
```

- Parameters:
- characteristic: the Characteristic that was subscribed/unsubscribed
- subscribed: true if subscribed, false if unsubscribed

```

*/
@objc optional func blePeripheral(
subscriptionStateChangedForCharacteristic \
characteristic: CBCharacteristic,
subscribed: Bool)
...
```

Storyboard

Add a UILabel and UISwitch to show the Notification state (Figure 9-4).

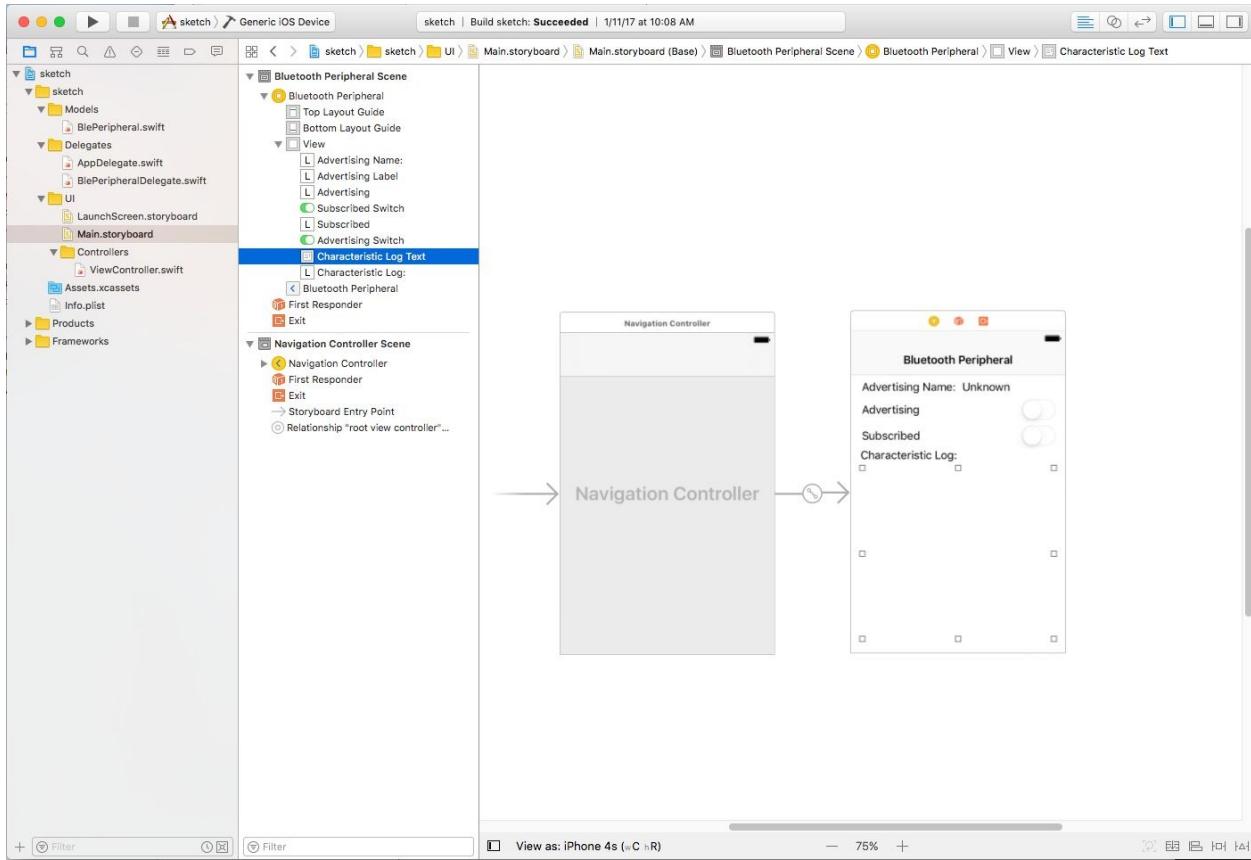


Figure 9-4. Project Storyboard

Add a UISwitch to show the subscribed state of the Characteristic, and a callback handler to process the changes to the Characteristic subscription state.

Example 9-7. UI/Controllers/ViewController.swift

```

...
@IBOutlet weak var subscribedSwitch: UISwitch!
...
/***
View disappeared. Stop advertising
*/
override func viewDidDisappear(_ animated: Bool) {
    subscribedSwitch.setOn(false, animated: true) advertisingSwitch.setOn(false,
    animated: true)
}
...
/***
A subscription state has changed on a Characteristic

```

- Parameters:

- characteristic: the Characteristic that was subscribed/unsubscribed
- subscribed: true if subscribed, false if unsubscribed

```
 */
func blePeripheral(
subscriptionStateChangedForCharacteristic: CBCharacteristic, subscribed: Bool)

{
subscribedSwitch.setOn(subscribed, animated: true)
}

...
```

Compile and run. The app can handle subscriptions to a Characteristic and send notifications when the Characteristic's value has changed (Figure 9-5).

●●●○○ Fido 3G

16:19

96%  ⚡

Bluetooth Peripheral

Advertising Name: MyDevice

Advertising



Subscribed



Characteristic Log:

FMZAp

GG0RPFNU7KYJCNJKp

G665p

Figure 9-5. App screen Advertising Peripheral with updates a Characteristic

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter09>

Streaming Data

The maximum packet size you can send over Bluetooth Low Energy is 20 bytes. More data can be sent by dividing a message into packets of 20 bytes or smaller, and sending them one at a time

These packets can be sent at a certain speed.

Bluetooth Low Energy transmits at 1 Mb/s. Between the data transmission time and the time it may take for a Peripheral to process incoming data, there is a time delay between when one packet is sent and when the next one is ready to be sent.

To send several packets of data, a queue/notification system must be employed, which alerts the Central when the Peripheral is ready to receive the next packet.

There are many ways to do this. One way is to set up a Characteristic with read, write, and notify permissions, and to flag the Characteristic as “ready” after a write has been processed by the Peripheral. This sends a notification to the Central, which sends the next packet. That way, only one Characteristic is required for a single data transmission.

This process can be visualized like this (Figure 10-1).

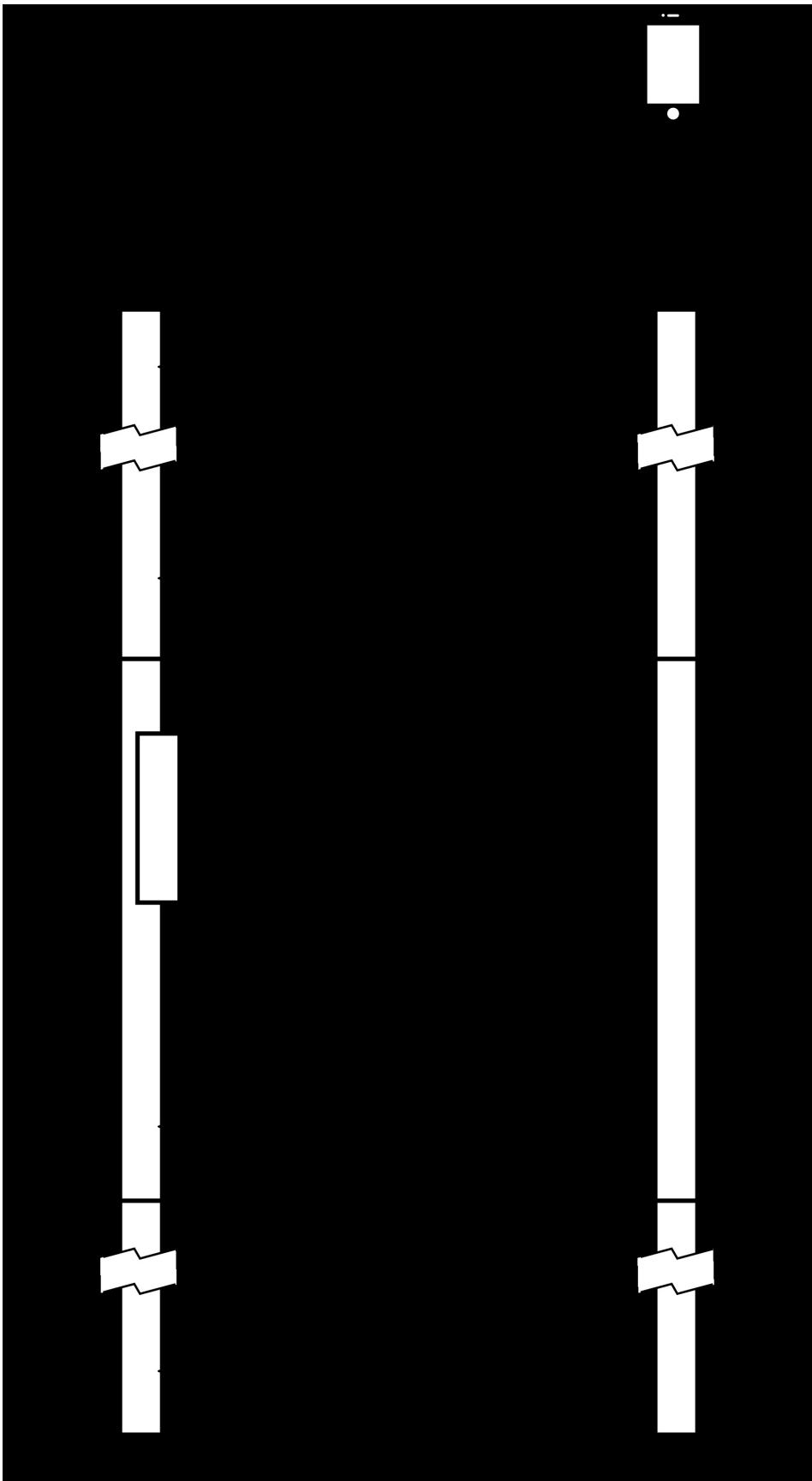


Figure 10-1. The process of using notifications to handle flow control on a multi-packed data transfer

Programming the Central

The Central in this example waits for the Peripheral to change the Characteristic value to the “ready” flow control message and to send a notification indicating the change. This process signals to the Central that the Characteristic is ready to receive the next packet of data.

Set up the parameters of the flow control and packet queue like this:

```
// Flow control response  
let flowControlMessage = "ready"  
// outbound value to be sent to the Characteristic var outboundByteArray:  
[UInt8]!  
// packet offset in multi-packet value var packetOffset = 0
```

The flow control works by requesting a Characteristic read event when a notification callback is triggered:

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?)  
  
{  
    print("characteristic updated")  
    if let value = characteristic.value {  
  
        if let stringValue = String(data: value, encoding: .ascii) { if stringValue ==  
            flowControlMessage {  
                packetOffset += characteristicLength  
                if packetOffset < outboundByteArray.count {  
  
                    writePartialValue(  
                        value: outboundByteArray,  
                        offset: packetOffset, to: characteristic)  
  
                } else {  
                    // done writing message  
                }  
            }  
        }  
    }  
}
```

```
}
```

The first packet of data is initialized and sent:

```
func writeValue(value: String, to characteristic: CBCharacteristic) { // get the  
characteristic length  
let writeableValue = value + "\0"  
packetOffset = 0  
// get the data for the current offset  
outboundByteArray = Array(writeableValue.utf8)  
writePartialValue(  
  
value: outboundByteArray,  
offset: packetOffset,  
to: characteristic)  
  
}
```

Subsequent packets are sent one at a time until there are no more left:

```
func writePartialValue(  
value: [UInt8],  
offset: Int,  
to characteristic: CBCharacteristic)  
  
{  
// don't go past the total value size  
var end = offset + characteristicLength  
if end > outboundByteArray.count {  
  
end = outboundByteArray.count  
}  
let transmissibleValue = Data(Array(outboundByteArray[offset..<end]))  
peripheral.writeValue(transmissibleValue, for: characteristic)
```

Putting It All Together

Models

Add methods to the BlePeripheral to handle partial writes, properties to track flow control, and modify the peripheral didUpdateValueFor method to handle

the inbound flow control value:

Example 10-1. Models/BlePeripheral.swift

... // MARK: Flow control

```
// Flow control response
let flowControlMessage = "ready"
// outbound value to be sent to the Characteristic var outboundByteArray:
[UInt8]!
// packet offset in multi-packet value
var packetOffset = 0
```

```
...
/**
```

Write a text value to the BlePeripheral

- Parameters:

- value: the value to write to the connected Characteristic */

```
func writeValue(value: String, to characteristic: CBCharacteristic) { // get the
characteristic length
```

```
let writeableValue = value + "\0"
```

```
packetOffset = 0
```

```
// get the data for the current offset
```

```
outboundByteArray = Array(writeableValue.utf8)
```

```
writePartialValue(
```

```
value: outboundByteArray,
```

```
offset: packetOffset,
```

```
to: characteristic) }
```

```
/**
```

Write a partial value to the BlePeripheral

- Parameters:

- value: the full value to write to the connected Characteristic

- offset: the packet offset

```
*/
```

```
func writePartialValue(
```

```
value: [UInt8],
```

```

offset: Int,
to characteristic: CBCharacteristic)

{
// don't go past the total value size
var end = offset + characteristicLength
if end > outboundByteArray.count {

end = outboundByteArray.count
}
let transmissibleValue = \

Data(Array(outboundByteArray[offset..<end])) print("writing partial value: \
(offset)-\\"(end)"") print(transmissibleValue)
var writeType = CBCharacteristicWriteType.withResponse if
BlePeripheral.isCharacteristic(
    isWriteableWithoutResponse: characteristic) { writeType =
CBCharacteristicWriteType.withoutResponse }
peripheral.writeValue(
transmissibleValue,
for: characteristic,
type: writeType)
print("write request sent")
}

...
/***
Value downloaded from Characteristic on connected Peripheral */
func peripheral(
    _ peripheral: CBPeripheral,
didUpdateValueFor characteristic: CBCharacteristic, error: Error?)
{
print("characteristic updated") if let value = characteristic.value {
print(value.debugDescription) print(value.description)

// Note: if we need to work with byte arrays
// instead of Strings, we can do this
// let byteArray = [UInt8](value)
// or this:
}

```

```

// let byteArray:[UInt8] = Array(outboundValue.withCString) if let stringValue =
String(data: value, encoding: .ascii) {

print(stringValue)
// received response from Peripheral
delegate?.blePeripheral?(

characteristicRead: stringValue,
characteristic: characteristic,
blePeripheral: self)

if stringValue == flowControlMessage {
packetOffset += characteristicLength
if packetOffset < outboundByteArray.count {

writePartialValue(
value: outboundByteArray,
offset: packetOffset, to: characteristic)

} else {
print("value write complete")
// done writing message
delegate?.blePeripheral?(

valueWritten: characteristic,
blePeripheral: self) }

}

}

}

}

}

...

The resulting app can send larger amounts of data to a connected Peripheral by
queueing and transmitting packets one at a time (
Figure 10-2).

```

●●○○ Fido 3G

20:12

⌚ 100%  ⚡

[!\[\]\(a1b84dd4c9f84fb8a8b04343846de95a_img.jpg\) Peripherals](#) Peripheral

MyDevice

-65

501AFEEE-AA49-4AF1-8924-E56689A4I

180A

2A56

Readable Writeable Notifiable

●●●○ Fido 3G

20:52

蓝牙 100%  ⚡

Peripheral

MyDevice

501AFEEE-AA49-4AF1-8924-E56689A4F...

Characteristic: 2A56

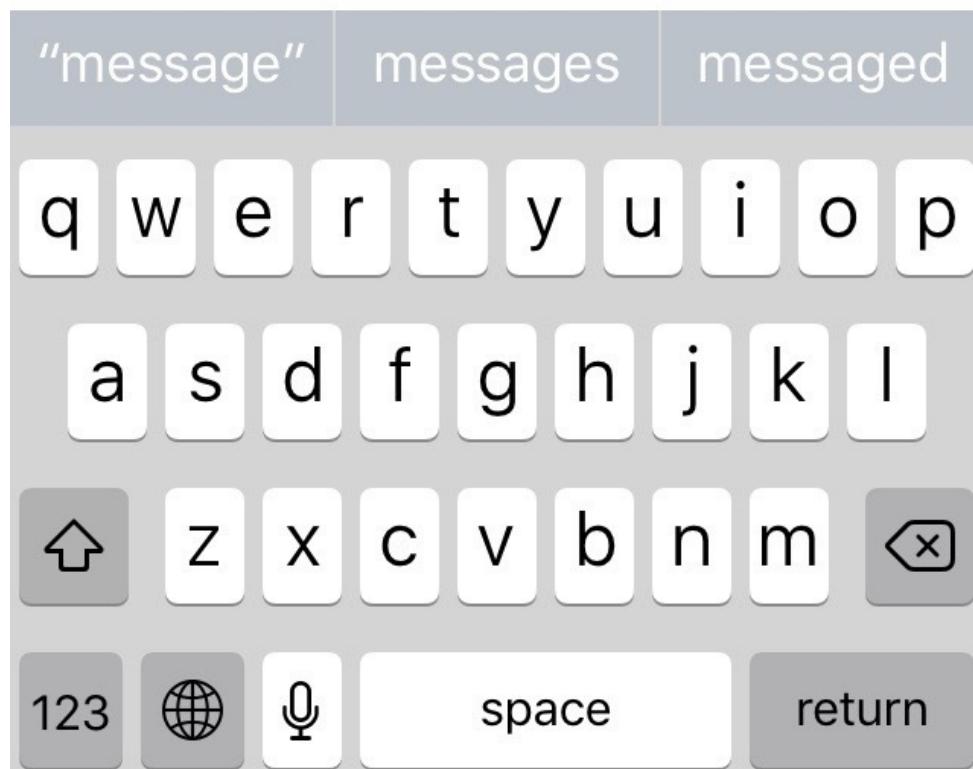
Subscribe to Characteristic



this is a super long message

Write

Read



The image shows a virtual keyboard interface. At the top, there is a text input field containing the placeholder text "this is a super long message". To the right of the input field is a blue "Write" button. Below the input field, the word "Read" is displayed in blue text. The keyboard itself is a standard QWERTY layout with the following key mapping:

- Row 1: q, w, e, r, t, y, u, i, o, p
- Row 2: a, s, d, f, g, h, j, k, l
- Row 3: backspace, z, x, c, v, b, n, m, delete
- Row 4: 123, globe, microphone, space, return

Each key is a white rectangle with a black outline. The function keys (123, globe, microphone) are located in the bottom-left corner of the keyboard area.

Figure 10-2. App screens showing GATT Profile for the Advertising Peripheral and multipart value queued to be sent to a Characteristic.

Programming the Peripheral

The Peripheral in this example processes a value written to a Characteristic, then sets the Characteristic's value to the "ready" flow control message, and sends a notification to the Central. In this way, the Central is triggered to read the Characteristic. When the Central reads the flow control message, it knows when to send the next packet of data.

When the Peripheral's Characteristic is written to, the peripheralManager didReceiveWrite method is triggered in the CBPeripheralManagerDelegate object. Once the incoming data is processed, the flow control value can be written to the Characteristic locally and the notification sent to the Central notifying it of the change.

The implementation looks like this:

Set up the parameters of the flow control:

```
let flowControlString = "ready"
```

The flowControlString is written to the Characteristic and a notification is sent after the Central initiates a write request:

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager, didReceiveWrite requests:  
    [CBATTRequest])  
  
{  
    for request in requests {  
        // Do something with the incoming request.value  
        // notify the Central of a successful write  
        peripheral.respond(to: request, withResult: CBATTError.success) // convert flow  
        control into a Data object  
        let flowControlValue:Data = flowControlString.data(using: .utf8)! // send flow  
        control value  
        peripheralManager.updateValue(  
  
            flowControlValue,  
            for: readWriteNotifyCharacteristic,  
            onSubscribedCentrals: [request.central])  
    }  
}
```

```
}
```

Putting It All Together

Copy the previous chapter's project into a new project.

Models

Add functionality to BlePeripheral to describe the flow control value, and to send the flow control message when a write request is triggered:

Example 10-2. Models/BlePeripheral.swift

```
... // HARK: Flow Control
let flowControlString = "ready"

...
/***
Connected Central requested to write to a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    didReceiveWrite requests: [CBATTRequest]) {

    for request in requests {
        peripheral.respond(to: request, withResult: CBATTError.success) // convert flow
        control into a Data object
        let flowControlValue:Data = flowControlString.data(
            using: .utf8)!
        // send flow control value
        peripheralManager.updateValue(
            flowControlValue,
            for: readWriteNotifyCharacteristic,
            onSubscribedCentrals: [request.central])

        if let value = request.value {
            delegate?.blePeripheral?(
                valueWritten: value,
                toCharacteristic: request.characteristic) }
    }
}
```

```
 }  
 }
```

...

The resulting app can receive a queued stream of data from a Central by issuing a receive/response flow control on the Characteristic (Figure 10-3).

●●○○○ Fido 3G

15:10

蓝牙 49% 🔋⚡

Bluetooth Peripheral

Advertising Name: MyDevice

Advertising



Subscribed



Characteristic Log:

this is a super
long message

Figure 10-3. App screen showing multipart value queued to be sent to a Characteristic.

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter10>

Project: iBeacon

Beacons can be used for range finding or spacial awareness. iBeacons are a special type of Beacon that is widely supported by the industry. It supports certain data that identifies the iBeacons to makes range finding and spacial awareness easier across platforms.

Due to the nature of how radio signals diminish in intensity with distance, Bluetooth Peripherals can be used both for range finding and spacial awareness.

Range Finding

Bluetooth signals can be used to approximate the distance between a Peripheral and a Central because the radio signal quality drops off in a predictable way with distance. The diagram below shows how the signal might drop as distance increases (Figure 11-1).

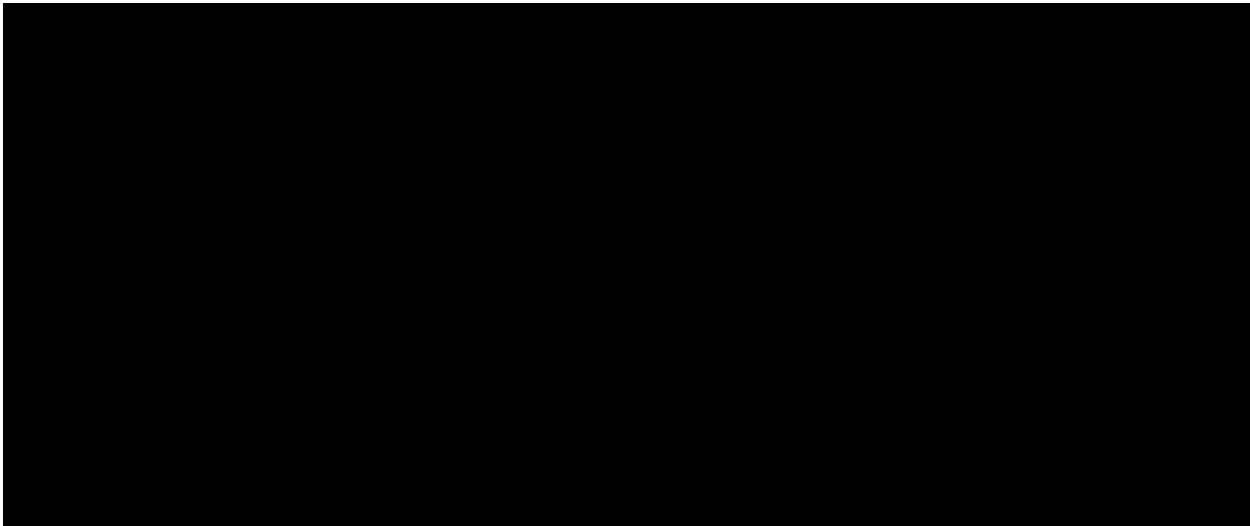


Figure 11-1. Distance versus Bluetooth Signal Strength

This drop-off rate, known as the Inverse-Square Law, is universal with electromagnetic radiation.

Due to radio interference and absorption from surrounding items, the radio signal propagation varies a lot from environment to environment, and even step to step. This makes it very difficult to know the precise distance between a Central and an iBeacon.

One or more Centrals can approximate their distance from a single iBeacon without connecting.

Spacial Awareness

A Central can approximate its position in space using a process called trilateration. Trilateration works by computing a series of equations when both the distance from and location of nearby iBeacons are known (Figure 11-2).

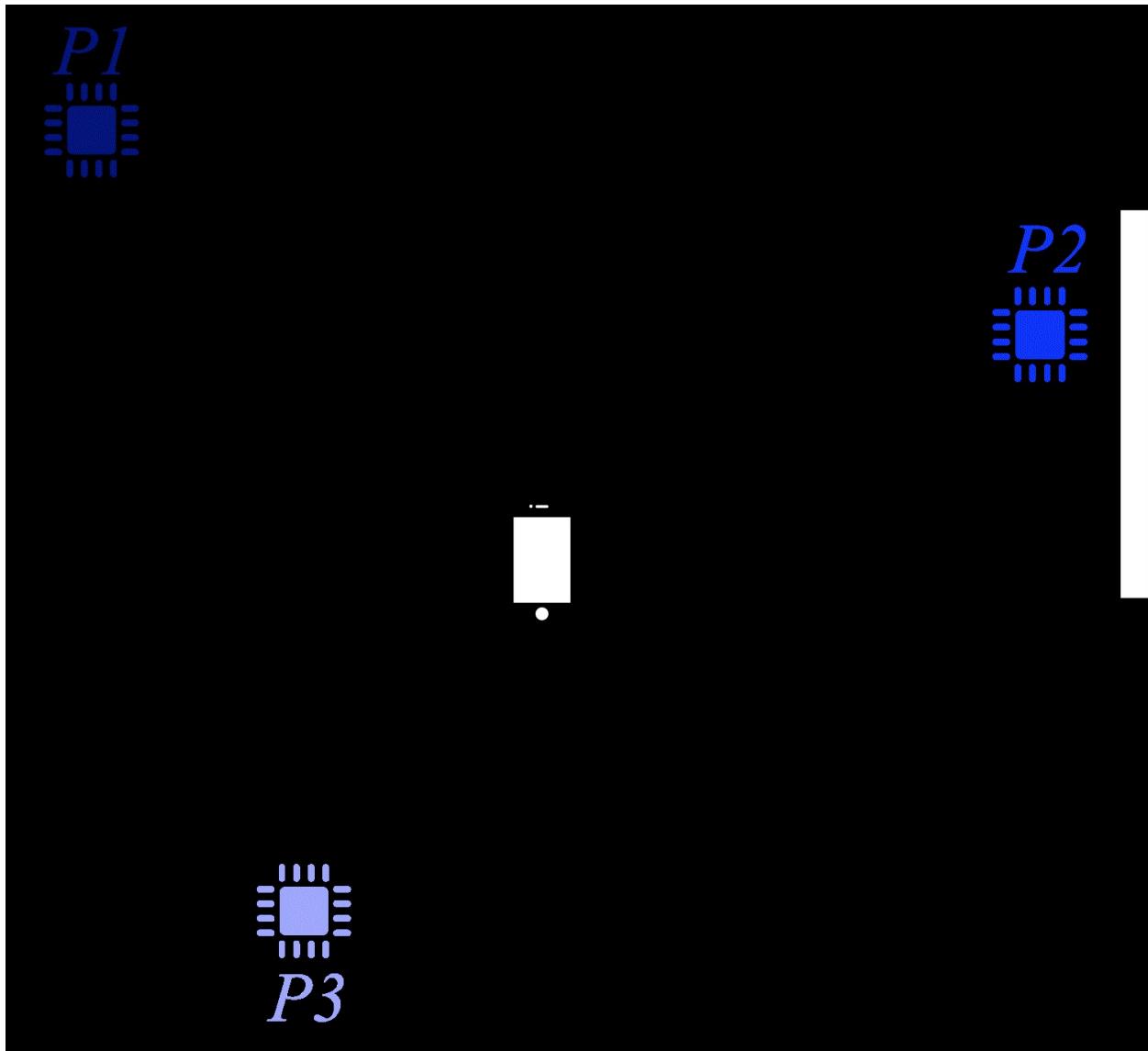


Figure 11-2. Example Central and iBeacon positions in a room

This is a pretty math-intensive process, but it's all based on the Pythagorus Theorem. By calculating the shape of the triangles made from the relative positions of all the iBeacons and the Central, one can determine the location of the Central (iBeacons and the Central, one can determine the location of the Central (3).

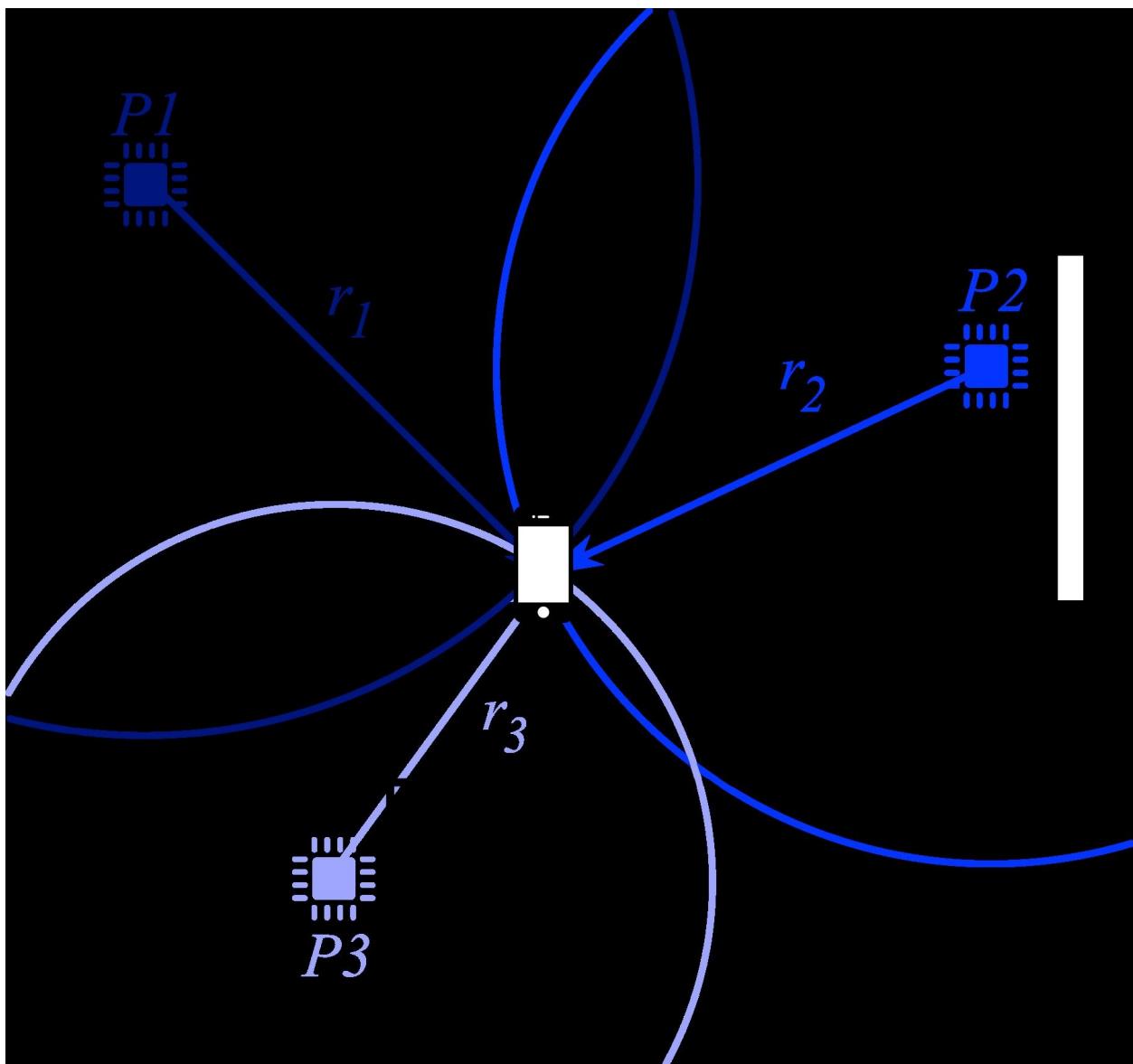


Figure 11-3. Distances from iBeacons to Central

iBeacons

The Scan Result allows a Central to read information from a Peripheral without connecting to it, in much the same way that the advertising name is read.

Although iOS supports iBeacon scanning, it does not support iBeacon advertising. Therefore it is possible to build an app that discovers iBeacons but not possible to create an iBeacon in iOS

iBeacons are beacons that advertise information about their location and advertise intensity using the Scan Result feature of Bluetooth Low Energy. The Scan Result allows a Central to read information from a Peripheral without connecting to it, in much the same way that the Device name is advertised. There are only two tricks to creating an iBeacon client in iOS:

1. All iBeacons for the same location service have the same UUID.
2. iBeacons have Major and Minor numbers for a sort of layered identification. What the Major and Minor numbers represent are dependant on the iBeacon administrator, but typically a Major number represents iBeacons for a particular organization or building, and a Minor number represents iBeacons from a specific area or floor of a building, etc.
3. The distance to the iBeacon is calculated based on the RSSI. iBeacons do this by advertising certain data that can be referenced when looking up where the iBeacons are located.

An example implementation is a museum that has iBeacons at each exhibit in the museum. All iBeacons in the exhibit share the same UUID. The museum uses Major numbers to identify floors and Minor numbers to identify rooms of the exhibit.

The museum's smartphone app has an internal data set relating Major and Minor values to the floors and rooms of the exhibit. It scans for all iBeacons with a specific UUID. The nearby iBeacons are discovered and read. The discovered iBeacons' Major and Minor numbers are looked up to learn that the user is in a specific room on a specific floor in the museum. Relevant content is accessed from the museum's API and loaded in the smartphone app.

Programming the Central

There are two parts to working with iBeacon on iOS:

1. Requesting Access to the CoreLocation Framework
2. Searching for iBeacons

Requesting Access to CoreLocation

iOS provides an iBeacon API in the CoreLocation Framework. In order to work with iBeacons, the CoreLocation Framework must be imported, and the working class must implement CLLocationManagerDelegate:

▼ Linked Frameworks and Libraries	
Name	Status
 CoreLocation.framework	Required ▾
+	-

Figure 11-4. CoreLocation Frameworks linked into project

Import the CoreLocation API in the code header to access both the Bluetooth and iBeacon APIs:

```
// import CoreLocation Framework
import CoreLocation
...
class GameViewController: UIViewController, CLLocationManagerDelegate { }
```

Before doing anything, the user must authorized the device to use the CoreLocation library. This is done by checking the current CLAuthorizationStatus, which states if the app is allowed to access the CoreLocation Framework:

```
// If location services are not enabled, request authorization if
(CLLocationManager.authorizationStatus() != \
CLAuthorizationStatus.authorizedWhenInUse) {
locationManager.requestWhenInUseAuthorization() } else {
// location manager already authorized. proceed }
```

If this is the first time the app is run, or if the user has changed the location settings, they will be prompted to authorize the location manager. Their choice will propagate an updated CLAuthorizationStatus.

The new authorization status can be one of several defined by CLAuthorizationStatus:

Table 11-1. CLAuthorizationStatus

Value Description

notDetermined

restricted

denied

authorizedAlways

authorizedWhenInUse

The user has not yet made a choice regarding whether this app can use location services.

This app is not authorized to use location services due to active restrictions.

The user explicitly denied the use of location services for this app or location services are currently disabled in Settings.

This app is authorized to start location services at any time, including monitoring for location changes in the background.

This app is authorized to start most location services while running in the foreground, but not when in the background.

The new CLAuthorizationStatus will come back when the locationManager didChangeAuthorization callback is triggered by the CLLocationManagerDelegate.

```
func locationManager(  
    _ manager: CLLocationManager,  
    didChangeAuthorization status: CLAuthorizationStatus)  
  
{  
    if status == .authorizedAlways {  
  
        // location manager is authorized all the time for this app. proceed } else if status  
        == .authorizedWhenInUse){  
        // location manager is authorized when the app is // in the foreground. proceed  
    } else {
```

```
// location manager is unauthorized  
}  
}
```

Once the app is allowed to access the CoreLocation framework, it is possible to check if the iBeacon Ranging feature is available:

```
if CLLocationManager.isMonitoringAvailable(for: CLBeaconRegion.self) { if  
CLLocationManager.isRangingAvailable() {  
  
// Ranging feature is available. Start scanning } else {  
// Ranging feature is unavailable  
}  
}
```

Scanning for iBeacons

In iOS, the process of scanning for iBeacons is called Ranging. As similar iBeacons have the same UUID, a Range is created using a known UUID to narrow down the iBeacon search to those that are expected to contain useful information to the App:

```
// only look for specific iBeacon UUIDs (known as a Proximity UUID) let  
proximityUuid = UUID(uuidString: "E20A39F4-73F5-4BC4-A12F-  
17D1AD07A961") // build one or more iBeacon "region" to search for  
// using the Proximity UUID. Each has a unique identifier for reuse later let  
beaconRegion = CLBeaconRegion(proximityUUID: UUID(  
  
uuidString: proximityUuid!,  
identifier: "regionUniqueId")
```

iBeacons may contain Major or Minor numbers as well, which further identify groups of iBeacons. It is possible to create an iBeacon Region that isolates both the Proximity UUID and the Major number:

```
let beaconRegion = CLBeaconRegion( proximityUUID: proximityUuid, major:  
1122,  
identifier: "anotherRegionUniqueId")
```

Or a Region that isolates the UUID, Major number, and Minor number:

```
let beaconRegion = CLBeaconRegion( proximityUUID: proximityUuid, major: 1122, minor: 3344, identifier: "anotherRegionUniqueId")
```

Begin Ranging for iBeacons using the the startMonitoring and startRangingBeacons functions in the CLLocationManager class:

```
let locationManager = CLLocationManager()
locationManager.startMonitoring(for: beaconRegion)
locationManager.startRangingBeacons(in: beaconRegion)
```

When iBeacons are discovered during Ranging, the locationManager didRangeBeacons callback is triggered by the CLLocationManagerDelegate.

This method will return a CLBeacon array periodically. This array may have zero or more elements, representing all the iBeacons it found during the Ranging process. This may include iBeacons that it found during the previous Ranging scan, so watch out for duplicates.

```
func locationManager(
    _ manager: CLLocationManager, didRangeBeacons beacons: [CLBeacon], in
    region: CLBeaconRegion)

{
    //beacons will contain an array of 0 or more CLBeacons
    //Each scan may contain CLBeacons that were contained in the
    //last time locationManager didRangeBeacons was triggered

}
```

The iBeacon major number and minor number can be retrieved from the CLBeacon object:

Property Data Type Value

.major NSNumber iBeacon Major Number

.minor NSNumber iBeacon Minor Number

.proximityUUID UUID iBeacon Proximity UUID

For security reasons, iOS does not reveal the transmission power of an iBeacon, which can be used to determine the distance between the Central and the iBeacon.

An iBeacon's distance from the Ranging Central can be approximated using the CLBeacon.proximity property

Table 11-2. CLProximity

Value Signal Strength Approximate Distance

immediate Strong Up to a few centimeters

near Medium Up to a few meters

far Weak More than a few meters

unknown Extremely weak Impossible to determine

This can be implemented in code like this:

```
func getProximityString(fromBeacon: CLBeacon) -> String { switch  
beacon.proximity {  
case .unknown:  
  
return "Unknown"  
case .immediate:  
return "Immediate"  
case .near:  
return "Near"  
case .far:  
return "Far"  
}  
}
```

If the transmission power of the iBeacon is known, that can be useful for determining how far away the iBeacon is.

Calculate Distance From iBeacons

Approximate the distance from a Central to an iBeacon using the RSSI reported at that distance, a reference RSSI at 1 meter, and an approximate propagation constant, using this equation:

$$d$$

\approx

$$10$$

$A - R \cdot 10n$

where d = distance between iBeacon peripheral and central A = RSSI when central and peripheral are 1 meter apart

R = RSSI at distance d

n = The radio propagation constant; typically between 2.7 and 4.3

This is expressed in code as follows:

```
func getDistanceFromRssi(  
    rssi: Int, referenceRssi: Int, propagationConstant: Float) -> Double  
  
{  
    let exponent=Double(referenceRssi-rssi)/(10*propagationConstant);  
    let distance=pow(10.0,exponent)  
    return distance  
  
}
```

Due to radio interference and absorption from surrounding items, the radio propagation constant, n, varies a lot from environment to environment and even step to step. This makes it very difficult to know the exact distance between a Central and an iBeacon. The radio propagation constant can be approximated by testing the iBeacon's RSSI at 1 meter in conditions similar to what is expected in the field.

Spacial Awareness

Following a few equations derived from Pythagorus' Theorem, it is possible to determine the location of the Central from 3 known iBeacon locations.

List Known Variables

Imagine a room with known iBeacon's locations, P1, P2, and P3 as x,y coordinates (Figure 11-5).

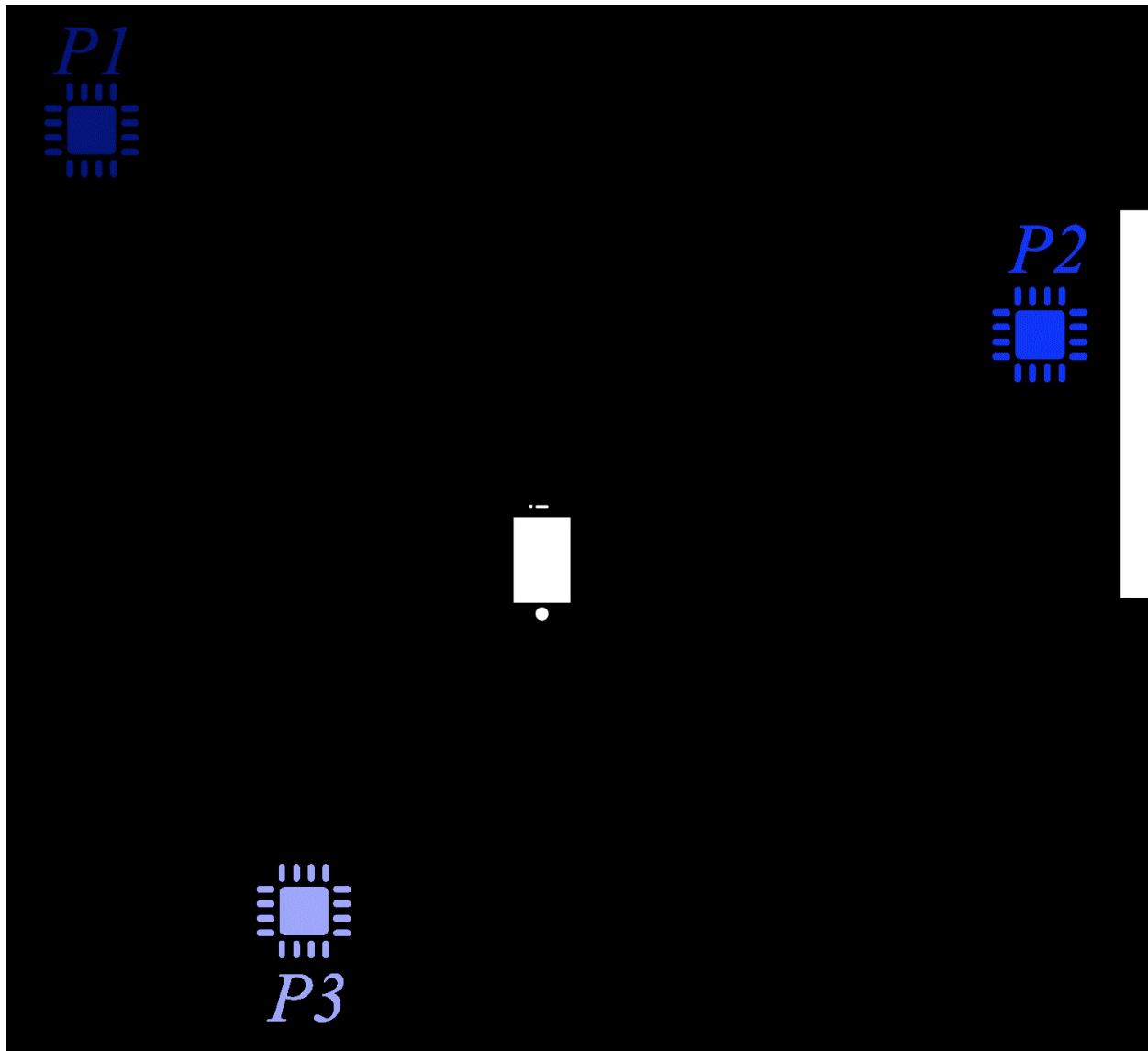
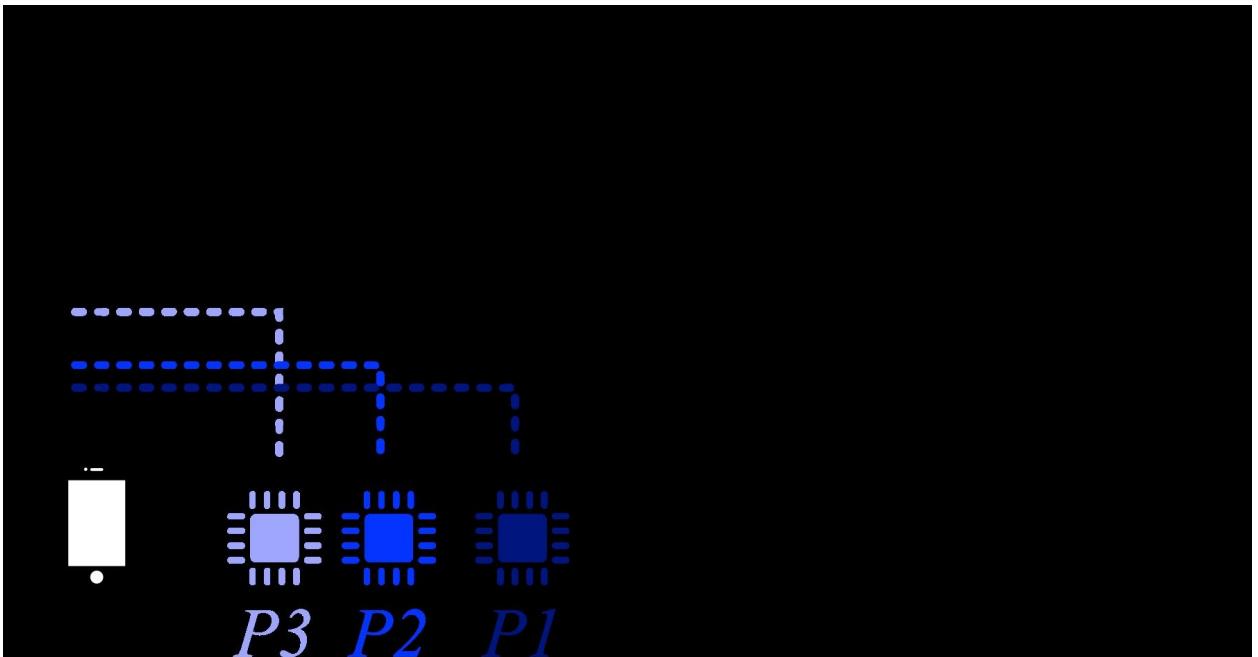


Figure 11-5. Example iBeacon positions in a room

```
// three iBeacons with known distances from a fixed spot let p1 = new  
CGPoint(x: 10, y: 10)  
let p2 = new CGPoint(x: 50, y: 30)  
let p3 = new CGPoint(x: 35, y: 50)
```

Using the `getDistanceFromRssi` method, the distance between each iBeacon and the Central has been derived as r1, r2, r3 (Figure 11-6).



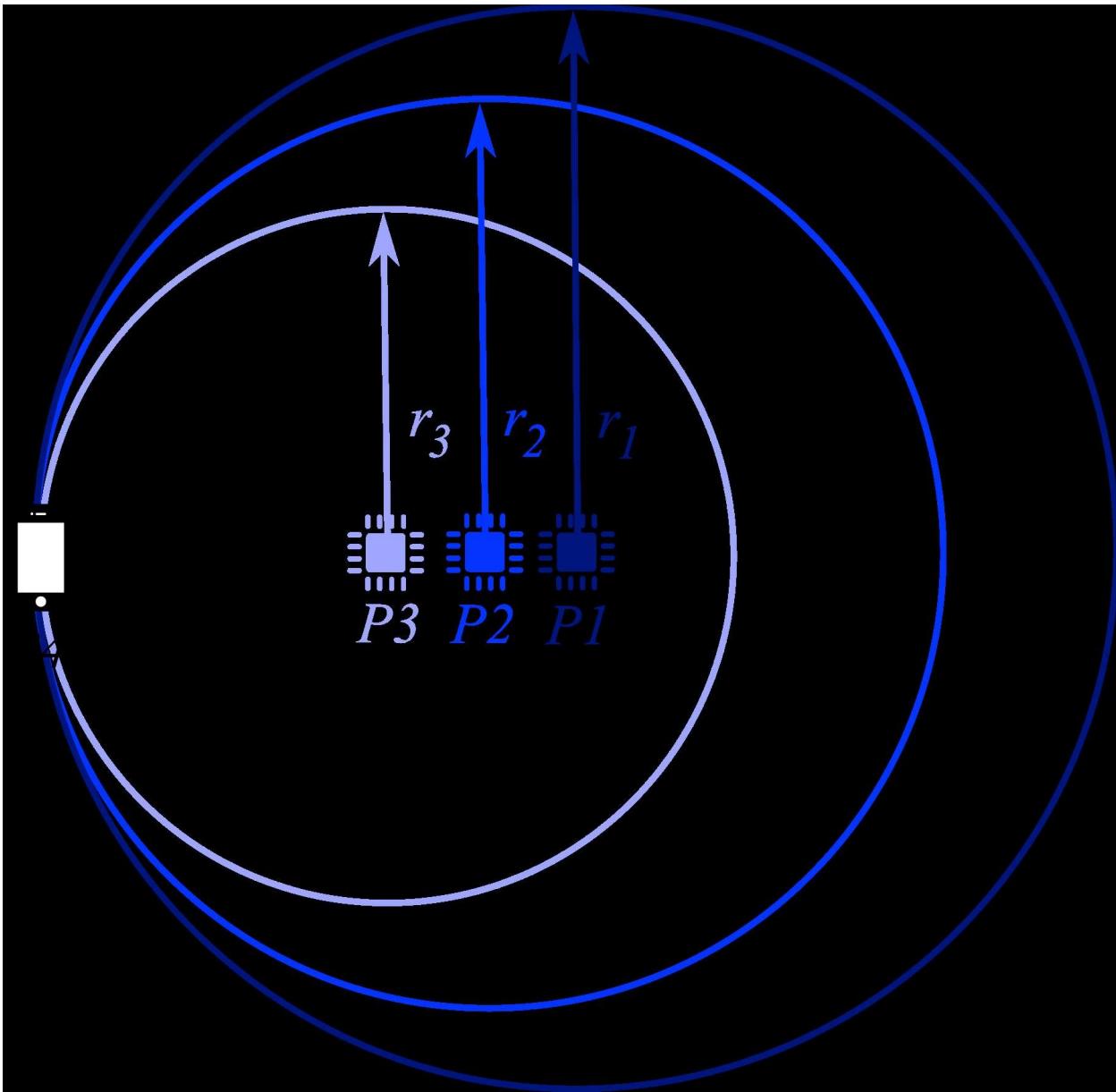


Figure 11-6. Beacon distances from Central derived from their singal strengths

```
// distance to each of the iBeacons has already been calculated let r1 = 13.2,  
let r2 = 10.8,  
let r3 = 7.7;
```

Calculate Distance Between iBeacons

Calculate the distance between iBeacons P1 and P2 using Pythagorean Theorem (Figure 11-7).

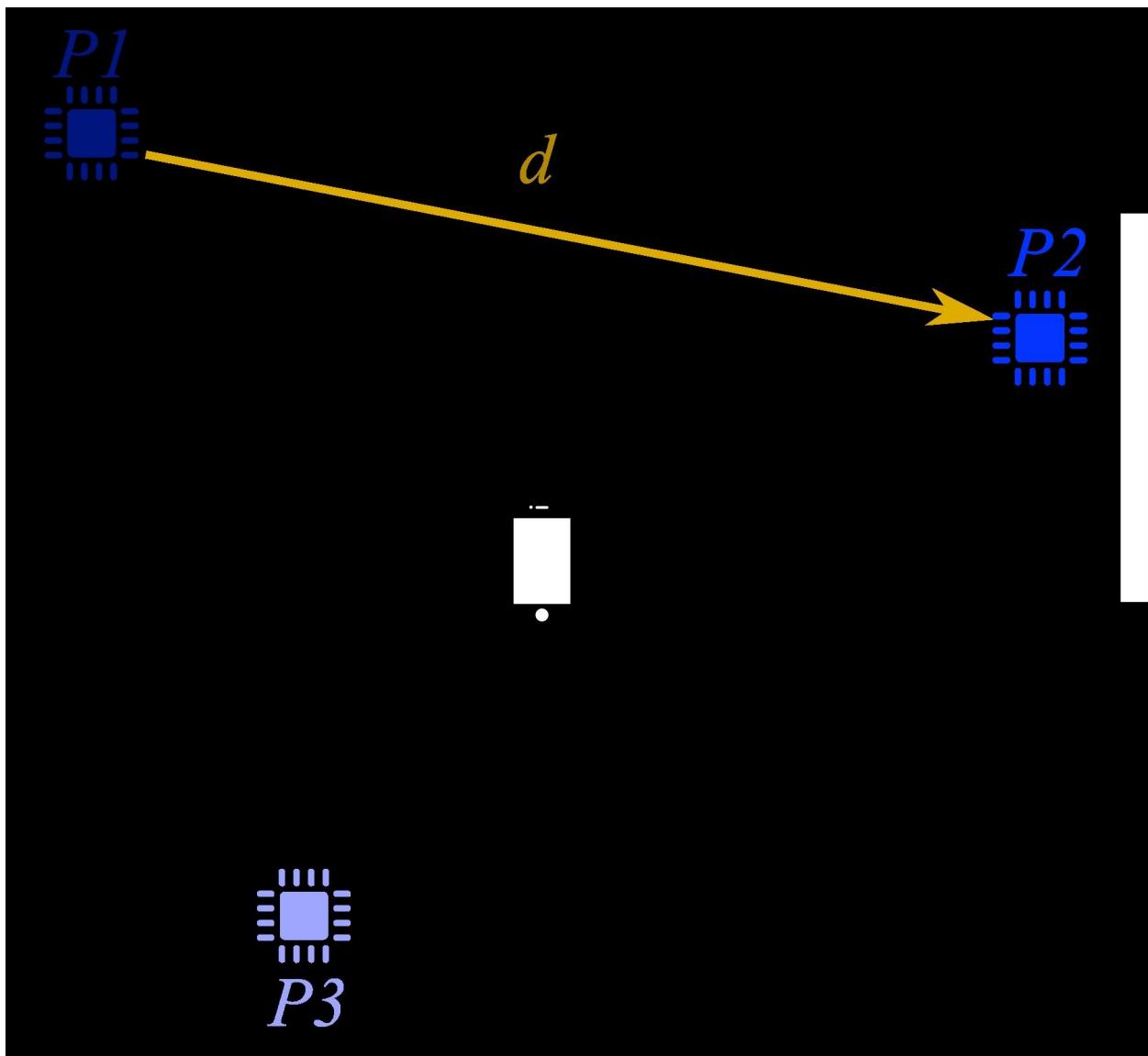


Figure 11-7. Derived distance from iBeacon 1 to iBeacon 2

$$d = P2 - P1$$

Which is short-hand for this:

$$d = (P2_x - P1_x)^2 + (P2_y - P1_y)^2$$

This is expressed in code as follows:

```
let adjacent = p2.x - p1.x  
let opposite = p2.y - p1.y  
let d = sqrt( pow(adjacent, 2) + pow(opposite, 2) )
```

Calculate the Unit Vector between P1 and P2

A unit vector represents a direction, but not a distance. Here we calculate the unit vector between P1 and P2, which shows which direction P2 is relative to P1 (Figure 11-8).

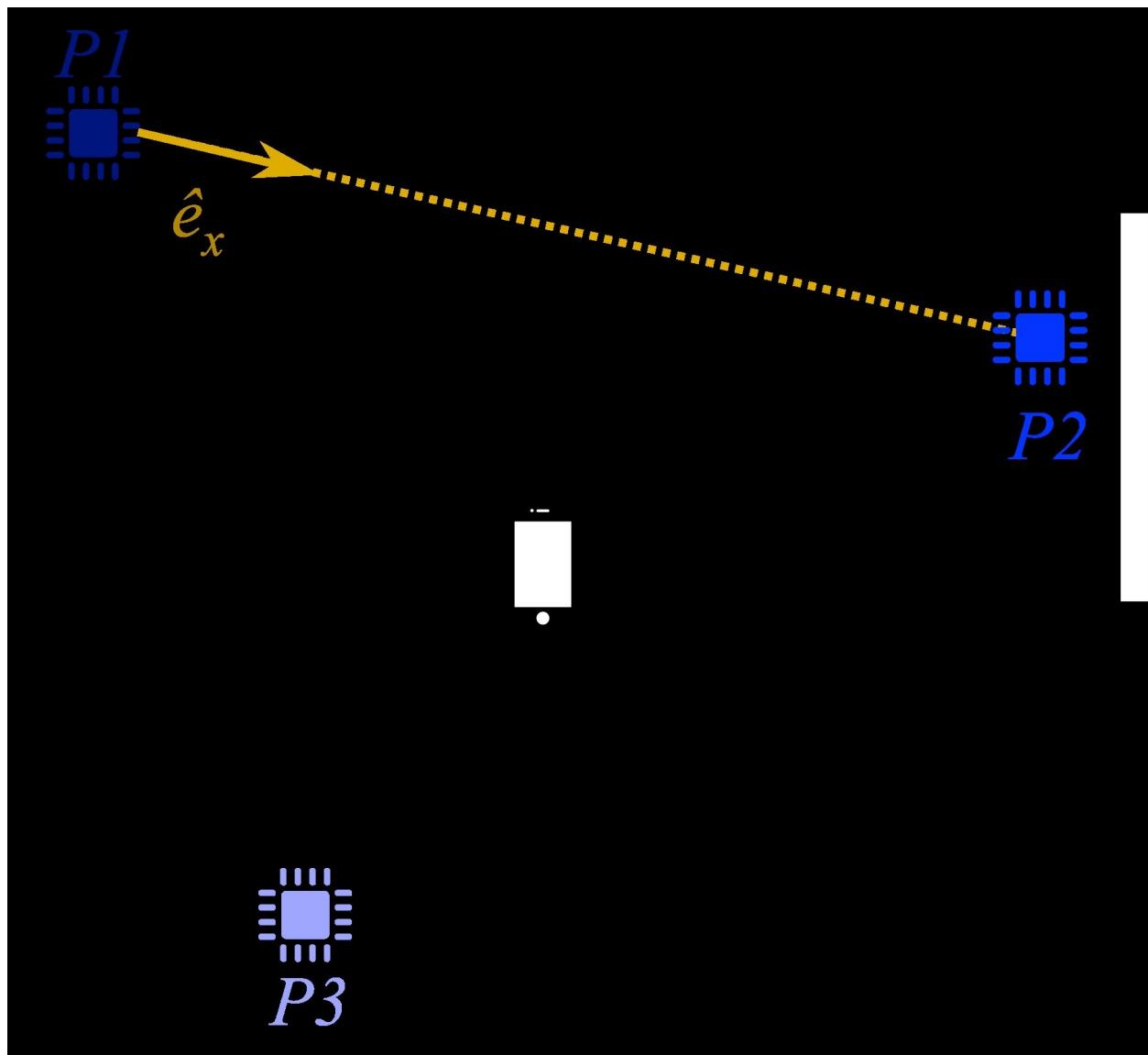


Figure 11-8. Derived direction from iBeacon 1 to iBeacon 2

$$e_x =$$

$$\frac{P2 - P1}{|P2 - P1|}$$

$$e_x = \frac{P2 - P1}{|P2 - P1|} \cdot \left(\begin{array}{c} \cos \theta \\ \sin \theta \end{array} \right)$$

d

,
 $P2_y - P1_{yx} - P1_x$

d)

let exx = $(p2.x - p1.x) / d$ let exy = $(p2.y - p1.y) / d$

Calculate Magnitude of Distance from P1 to P3

Find the magnitude i of the distance between P1 and P3 in the x direction (Find the magnitude i of the distance between P1 and P3 in the x direction (9).

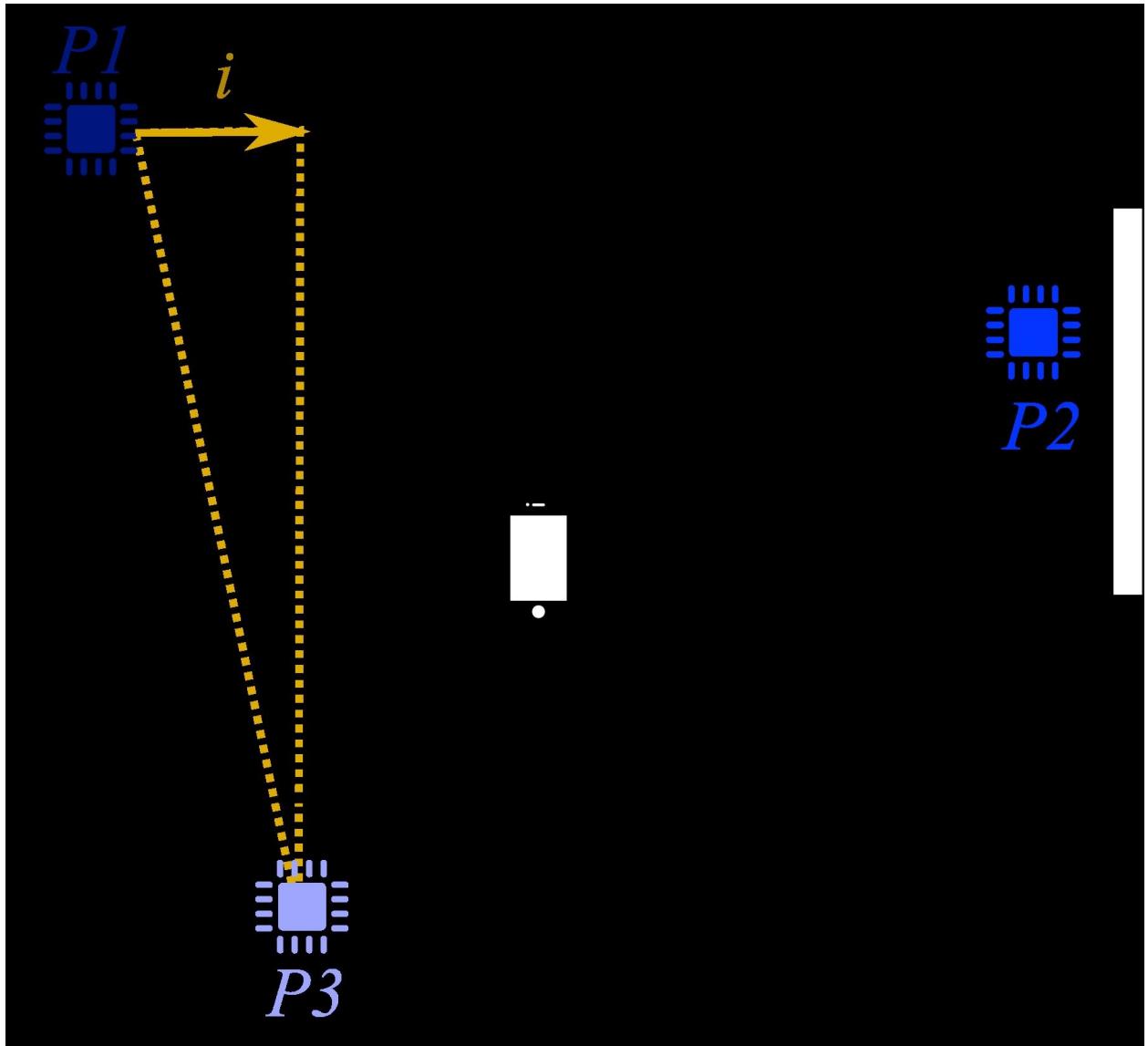


Figure 11-9. Derived horizontal component of distance from Beacon 1 to Beacon 2

$$i = e_x \cdot (P3 - P1)$$

$$i = e_{xx}(P3_x - P1_x) + e_{xy}(P3_y - P1_y)$$

$$\text{let } i = \text{exx} * (\text{p3.x} - \text{p1.x}) + \text{exy} * (\text{p3.y} - \text{p1.y})$$

Calculate Unit Vector between P1 and P3

Calculate the unit vector \hat{e}_y between P1 and P3, showing the direction between P1 and P3 (Figure 11-10).

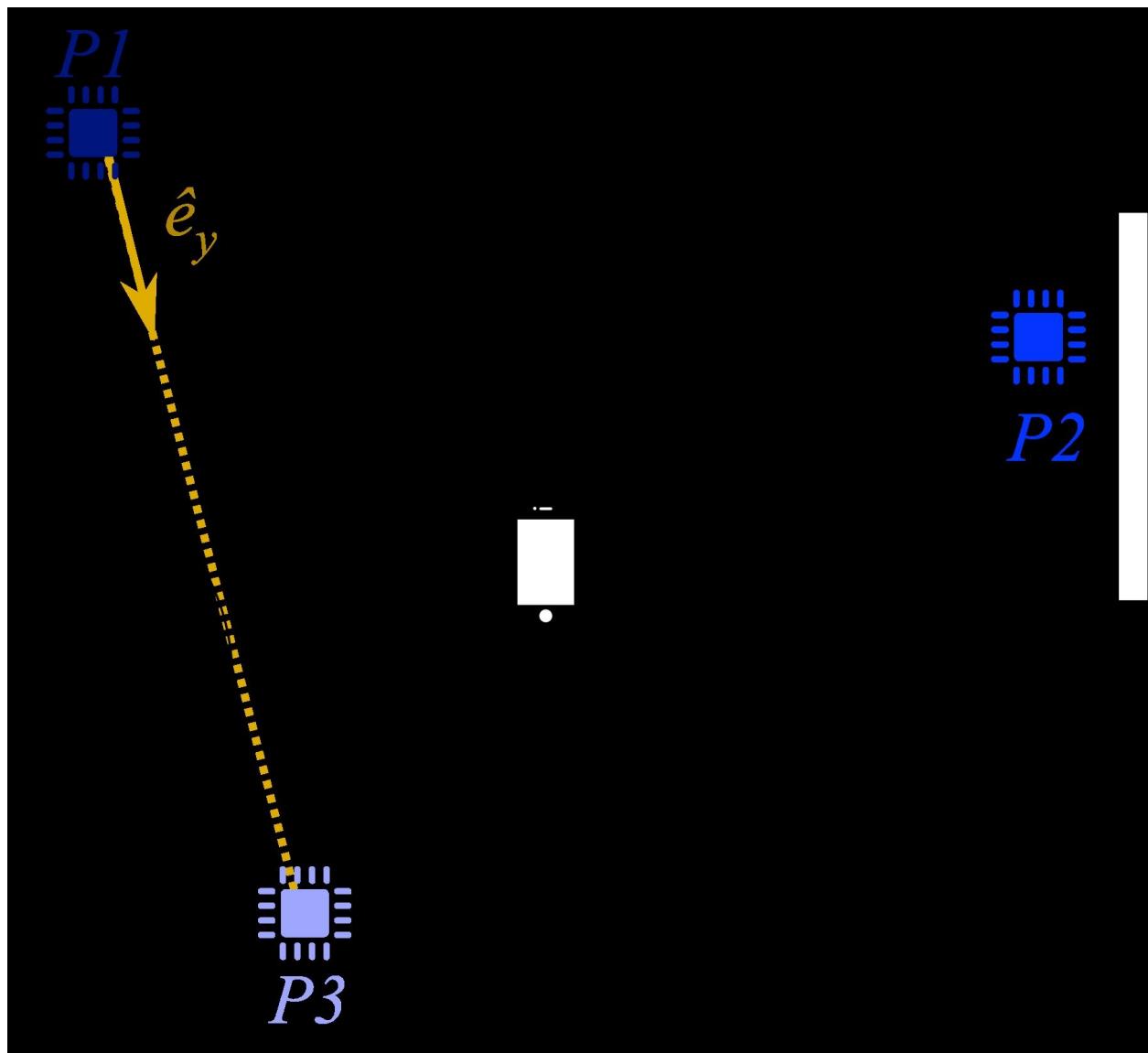


Figure 11-10. Derived direction from iBeacon 1 and iBeacon 3

e

y

=

$$P3 - P1 - \hat{i}_x$$

P

3

-

P

1

-

i

ex

e

y

=

$$P3_x - P1_x - ie_{xx}, y - P1_y - ie_y P3$$

2 2 2 2

$$(P3_x - P1_x - ie_{xx}) + (P3_y - P1_y - ie_{xy})(P3_x - P1_x - ie_{xx}) + (P3_y - P1_y - ie_{xy})$$

let eyx = (p3.x - p1.x - i * exx) / sqrt(pow(p3.x - p1.x - i * exx, 2) +

pow(p3.y - p1.y - i * exy, 2)

)

let eyy = sqrt(

pow(p3.x - p1.x - i * exx, 2) +

pow(p3.y - p1.y - i * exy, 2)

)

let eyy = (p3.y - p1.y - i * exy) / eyy_denominator

Calculate Magnitude of Distance between P1 and P3

Calculate magnitude *j* of the distance between P1 and P3 in the y direction, showing how far apart they are (Figure 11-11).

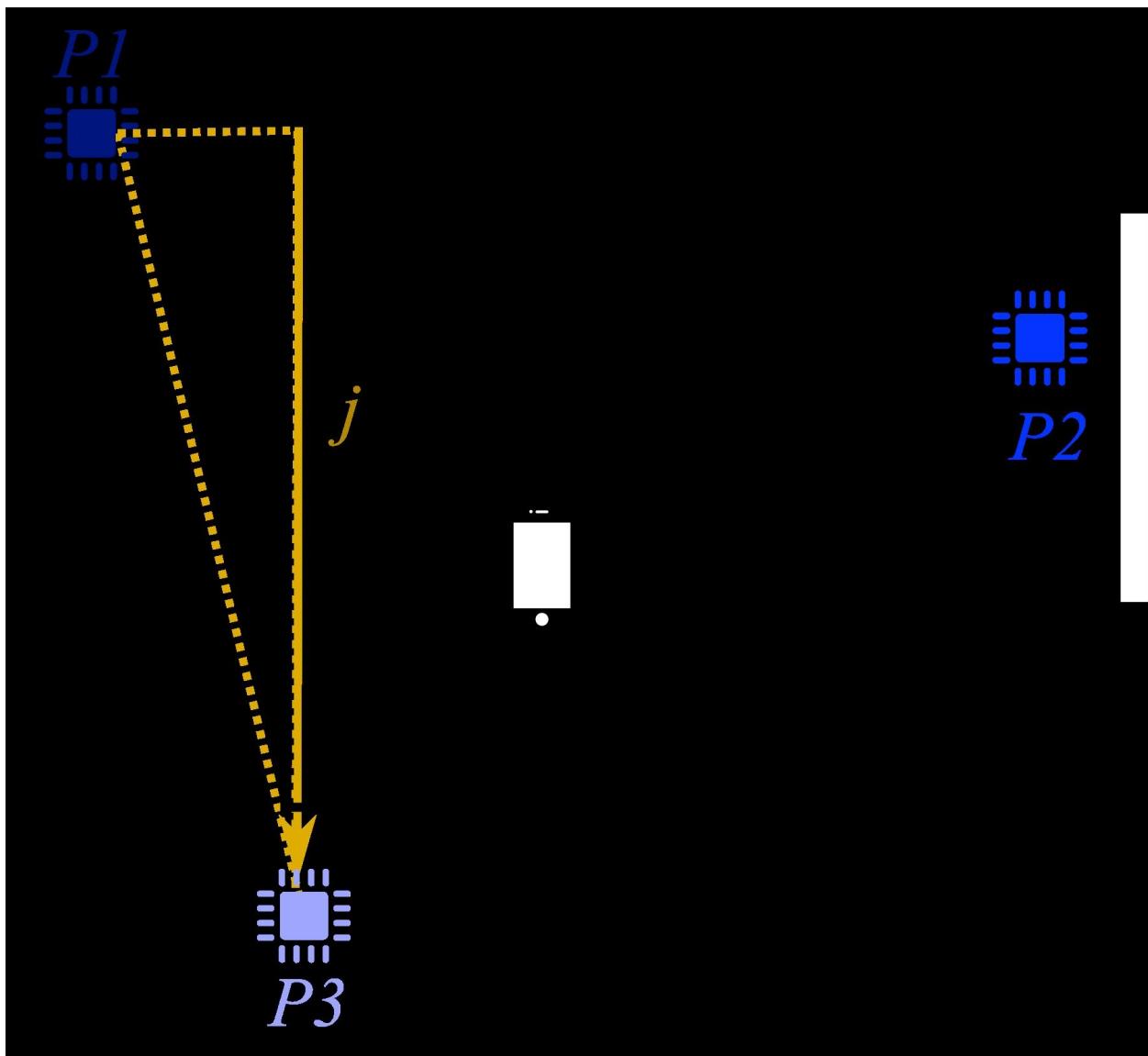


Figure 11-11. Derived Vertical component of distance between iBeacon 1 and iBeacon 3

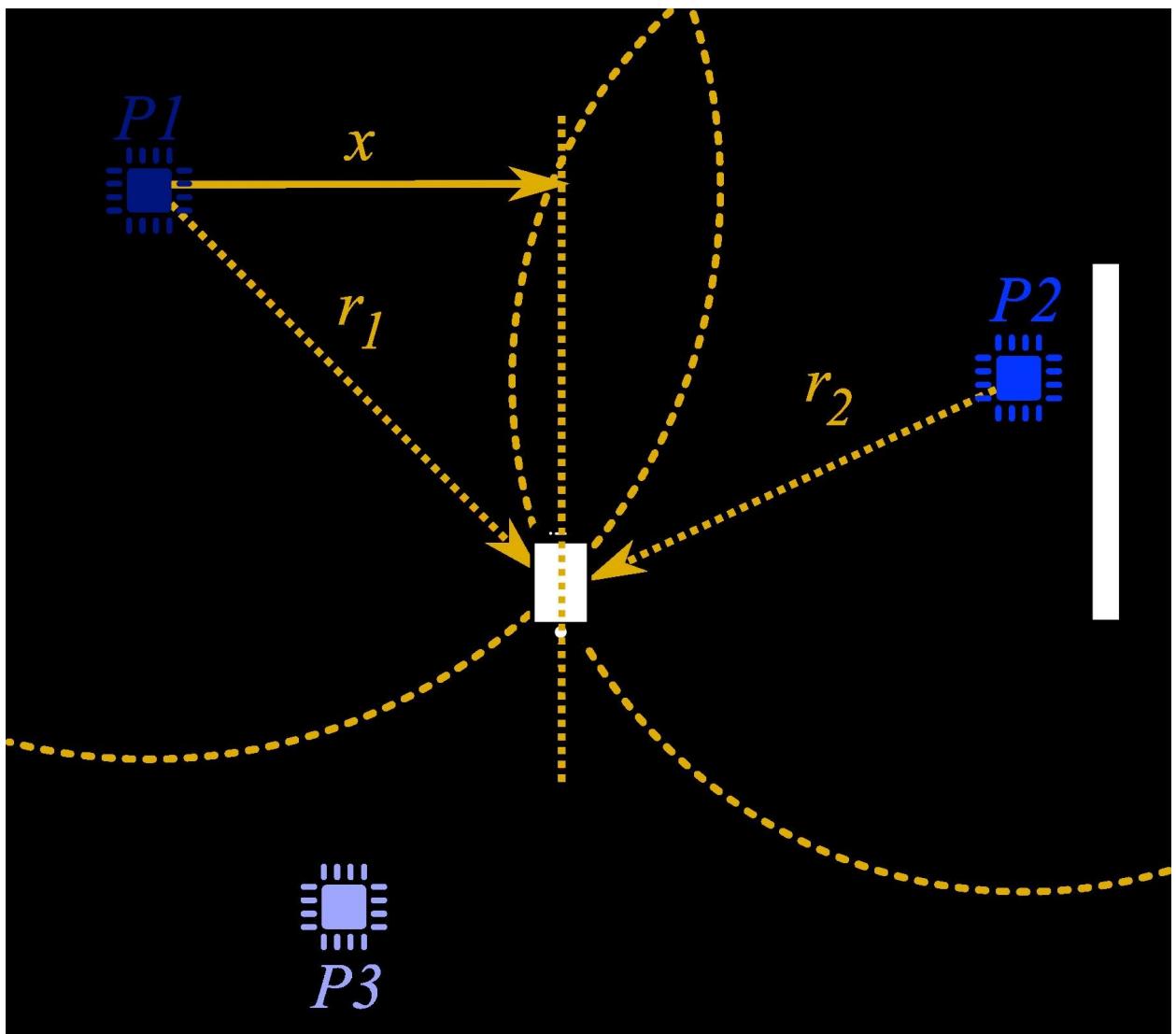
$$j = e_y \cdot (P3 - P1)$$

$$j = e_{yx}(P3_x - P1_x) + e_{yy}(P3_y - P1_y)$$

$$\text{let } j = exy * (p2.x - p3.x) + eyy * (p3.y - p1.y)$$

Find Relative Distances from Central to iBeacons

Use the relative distances from the Central to iBeacons P1, P2, and P3 to find relative distances x and y from each iBeacon (Figure 11-12).



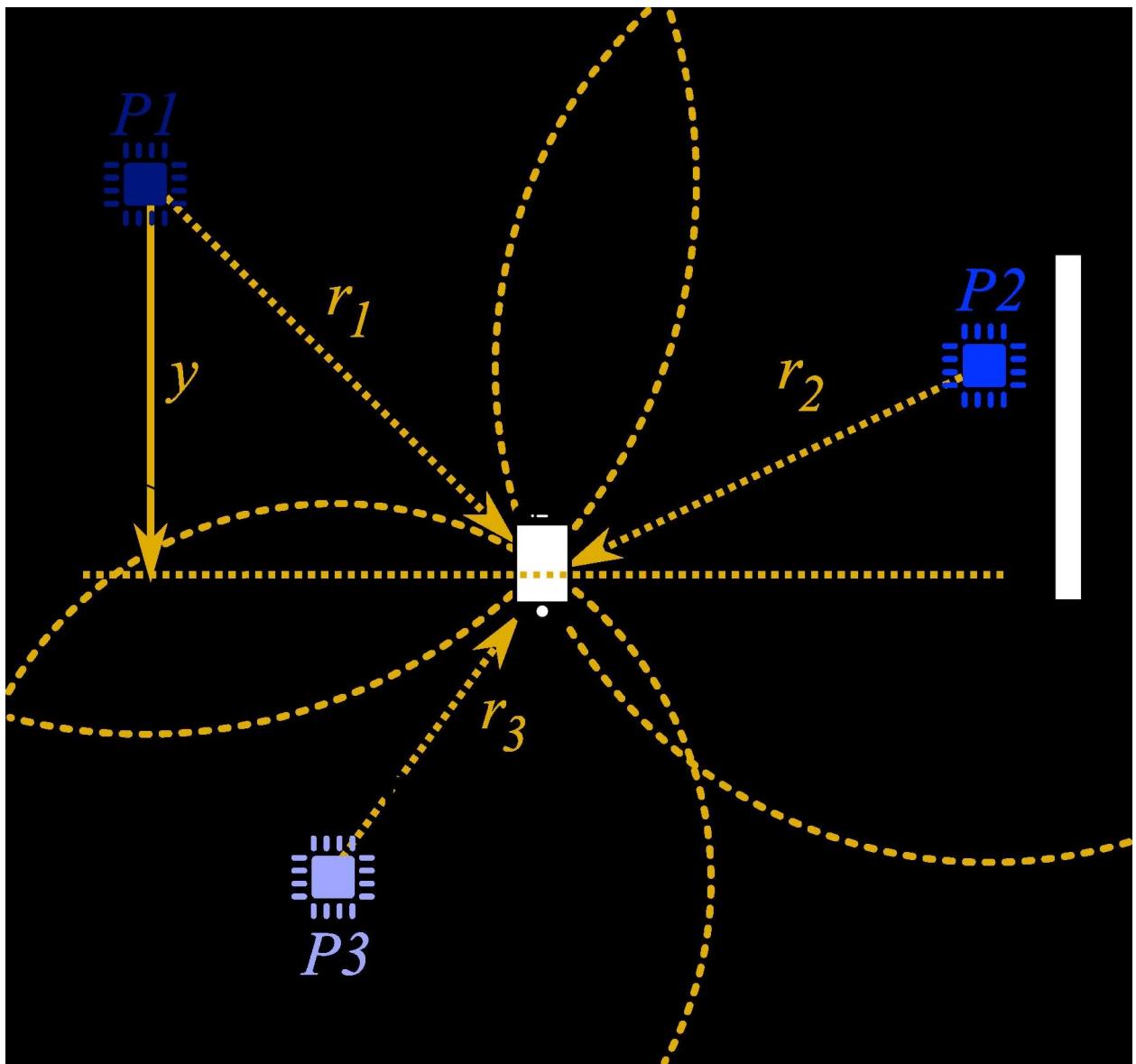


Figure 11-12. Derived positions of each iBeacon with horizontal position of Central

This is done by solving for x and y in the following equations:

$$x = \sqrt{r^2 - r^2 + d_{12}^2}$$

$$2d$$

$$y = \sqrt{r^2 - r^2 + i^2 + j^2} - i_{13}$$

$$2j - j x$$

```
let x = (pow(Double(r1), 2) - pow(Double(r2), 2) + pow(d, 2)) / (2 * d) let y =  
  (pow(Double(r1), 2) - pow(Double(r3), 2) + pow(i, 2) + \ pow(j, 2)) / (2 * j) - i *  
  x / j
```

Calculate Absolute Position of Central at P4

Finally, find the position of the Central at P4 by adding the distance between P4 and P1 to the relative position of P1 (Figure 11-13).

Figure 11-13. Derived Central position

P

4 =

P

1 +

x

$x + y^{\wedge}$

e ey

P

4 =

(

P

1

x

+

x

e

x

+

y

e

y

x

,

P

1

y

+

x

e

x
 y
 $+ y e^{\hat{e}}$
 $y_y)$

```
let finalX = p1.x + x * exx + y * eyx
let finalY = p1.y + x * exy + y * eyy
let centralPosition = new CGPoint(x: finalX, y: finalY)
```

That is how to trilaterate the position of a Central from three known iBeacon positions.

Putting It All Together

The following code will create an App that graphs the position of nearby iBeacons, lists their properties, and attempts to find its own location relative to the iBeacons.

Create a new app called BeaconLocator. Create the following package structure and copy files from the previous examples where they exist.

The final file structure should resemble this (Figure 11-14).

Figure 11-14. Project Structure

Frameworks

Import the CoreLocation Framework (Figure 11-15).

Linked Frameworks and Libraries	
Name	Status
 CoreLocation.framework	Required
+	-

Figure 11-15.

CoreLocation Framework linked into project

Import the CoreLocation APIs in the code header:

```
import CoreLocation
```

Models

The iBeacon class encapsulates a known iBeacon type and allows for the insertion of the physical location and transmission power of those iBeacons.

Example 11-1. Models/iBeacon.swift

```
import UIKit
import CoreLocation
```

```

class IBeacon: NSObject {
static let uuid = UUID(
uuidString: "e20a39f4-73f5-4bc4-a12f-17d1ad07a961")

// Bluetooth transmit power programmed into the device in dB let referenceRssi
= -57
// Beacon Peripheral
var beacon:CLBeacon!
// Beacon's position in physical space
var xPosition_m:Double = 0
var yPosition_m:Double = 0
/**/

Initialize the IBEacon
*/
init(withBeacon beacon: CLBeacon) { self.beacon = beacon
}
/**/

Get Beacon distance from Central in meters */
func getDistance() -> Int {

return beacon.proximity.rawValue }
/**/
Compare beacons
- Parameters:
- to: An IBeacon to compare
- Returns: true if same beacon, false otherwise.
*/
func isEqual(to: IBeacon) -> Bool {
if let thisBeacon = beacon {

if let thatBeacon = to.beacon {
return thisBeacon.major == thatBeacon.major && \ thisBeacon.minor ==
thatBeacon.minor && \ thisBeacon.proximityUUID ==
thatBeacon.proximityUUID

}
}

```

```
return false
```

```
}
```

The CentralLocator trilaterates the user's device from known iBeacon locations.

Example 11-2. Models/CentralLocator.swift

```
import UIKit
```

```
class CentralLocator: NSObject {
```

```
/**
```

```
Trilaterates a Central position from three known Beacon positions */
```

```
static func trilaterate(_ iBeacons: [IBeacon]) -> CGPoint? { if iBeacons.count < 3 {
```

```
return nil
```

```
}
```

```
// establish known values let p1 = iBeacons[0] let p2 = iBeacons[1] let p3 = iBeacons[2] let r1 = p1.getDistance() let r2 = p2.getDistance() let r3 = p3.getDistance()
```

```
//unit vector in a direction from point1 to point 2 let p1p2Distance = sqrt( pow(p2.xPosition_m - p1.xPosition_m, 2) + pow(p2.yPosition_m - p1.yPosition_m, 2) )
```

```
let exx = (p2.xPosition_m - p1.xPosition_m) / p1p2Distance let exy = (p2.yPosition_m - p1.yPosition_m) / p1p2Distance
```

```
//signed magnitude of the x component
```

```
let i = exx * (p3.xPosition_m - p1.xPosition_m) + exy * \
```

```
(p3.yPosition_m - p1.yPosition_m)
```

```
//the unit vector in the y direction.
```

```
let eyx = (p3.xPosition_m - p1.xPosition_m - i * exx) / sqrt(
```

```
pow(p3.xPosition_m - p1.xPosition_m - i * exx, 2) + pow(p3.yPosition_m - p1.yPosition_m - i * exy, 2) )
```

```
let eyy_denominator = sqrt(
```

```
pow(p3.xPosition_m - p1.xPosition_m - i * exx, 2) + pow(p3.yPosition_m - p1.yPosition_m - i * exy, 2) )
```

```
let eyy = (p3.yPosition_m - p1.yPosition_m - i * exy) / \ eyy_denominator
```

```
//the signed magnitude of the y component
```

```
let j = exy * (p2.xPosition_m - p3.xPosition_m) + eyy * \ (p3.yPosition_m -
```

```

p1.yPosition_m)
// coordinates
let x = (pow(Double(r1), 2) - pow(Double(r2), 2) + \ pow(p1p2Distance, 2) ) / (2
* p1p2Distance)
let y = (pow(Double(r1), 2) - pow(Double(r3), 2) + pow(i, 2) + \ pow(j, 2)) / (2 *
j) - i * x / j

// result coordinates
let finalX = p1.xPosition_m + x * exx + y * eyx let finalY = p1.yPosition_m + x
* exy + y * eyy

return CGPoint(x: finalX, y: finalY) }

```

Storyboard

Create and link a UITableView, UITableViewCell, and UILabels in the UIView in the Main.storyboard to create the App's user interface. Be sure that the UITableViewCell is of class "BeaconTableViewCell" and the Reuse Identifier is "BeaconTableViewCell" (Figure 11-16).

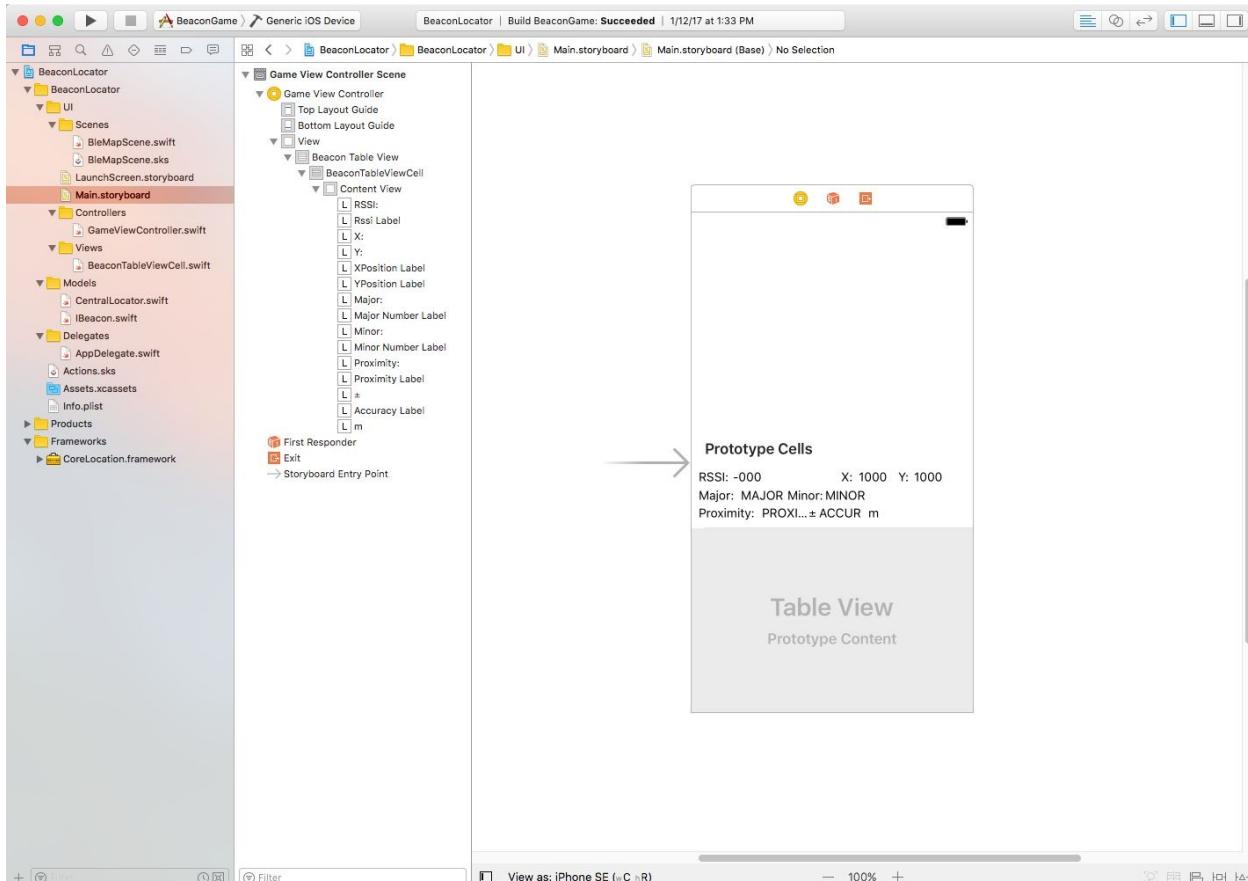


Figure 11-16. Project Storyboard

Views

Create a BeaconTableViewCell that displays information about a discovered iBeacon in a series of UILabels.

Example 11-3. UI/Views/BeaconTableViewCell.swift

```
import UIKit
import CoreLocation
class BeaconTableViewCell: UITableViewCell {
```

// MARK: UI Elements

```
@IBOutlet weak var rssiLabel: UILabel! @IBOutlet weak var xPositionLabel: UILabel!
@IBOutlet weak var yPositionLabel: UILabel! @IBOutlet weak var majorNumberLabel: UILabel!
@IBOutlet weak var minorNumberLabel: UILabel! @IBOutlet weak var proximityLabel: UILabel!
@IBOutlet weak var accuracyLabel: UILabel!
```

```
/**
```

Render the cell with Beacon properties

```
*/
```

```

func renderBeacon(_ iBeacon: IBeacon) {
    majorNumberLabel.text = iBeacon.beacon.major.stringValue
    minorNumberLabel.text = iBeacon.beacon.minor.stringValue
    rssiLabel.text = String(iBeacon.beacon.rssi)
    proximityLabel.text = String(iBeacon.beacon.proximity.rawValue)
    accuracyLabel.text = String(iBeacon.beacon.accuracy)

    xPositionLabel.text = String(iBeacon.xPosition_m) yPositionLabel.text =
    String(iBeacon.yPosition_m) }
```

Controllers

Create an iBeaconMapLayout class that displays iBeacon and Central positions on the screen.

Example 11-4. UI/Controllers/GameViewController.swift

```

import UIKit
import SpriteKit import GameplayKit import CoreLocation

class GameViewController: UIViewController, UITableViewDelegateDataSource, \
CLLocationManagerDelegate {

    // MARK: UI Elements
    @IBOutlet weak var beaconTableView: UITableView! // Beacon Map Scene
    var scene:BleMapScene!
    // Beacon TableView Cell Reuse Identifier
    let beaconCellReuseIdentifier = "BeaconTableViewCell"

    // MARK: Beacons and Bluetooth

    // Location Manager includes Beacon functionality
    let locationManager = CLLocationManager() // discovered Beacons
    var foundBeacons = [IBeacon]()
    // Central's position
    var centralPosition:CGPoint!
    // number of beacons mapped
    var numBeaconsLoaded = 0
    // Beacon Region - the proximityUUID matches // the identifier of the iBeacon
    let beaconRegion = CLBeaconRegion(
        proximityUUID: IBeacon.uuid!,
```

```
identifier: "beaconRange")

/**
View Loaded
*/

override func viewDidLoad() {
super.viewDidLoad()
// load the MapScene
if let skView = view as! SKView? {

skView.isMultipleTouchEnabled = true
scene = BleMapScene(size: skView.bounds.size) scene.scaleMode = .aspectFill
skView.presentScene(scene)

}
// set up Location Manager
locationManager.delegate = self;
// If location services are not enabled, request authorization if
(CLLocationManager.authorizationStatus() != \
CLAuthorizationStatus.authorizedWhenInUse) {
locationManager.requestWhenInUseAuthorization()

} else {
startScanning()
}
}

/***
Start scanning for Beacons
***/

func startScanning() {
print("starting scan")
locationManager.startMonitoring(for: beaconRegion)
locationManager.startRangingBeacons(in: beaconRegion)

}
/***
```

```

Map the Beacons and Central if possible. */
func mapBeacons() {
for beacon in foundBeacons {

mapBeacon(beacon)
}
if foundBeacons.count > 3 {

// for this demo, we are done locating the Central
locationManager.stopMonitoring(for: beaconRegion)
locationManager.stopRangingBeacons(in: beaconRegion) mapCentralPosition()

}
}

/***
Put a Beacon on the map
*/
func mapBeacon(_ iBeacon: IBeacon) {
if scene != nil {
let position = CGPoint(
x: iBeacon.xPosition_m,
y: iBeacon.yPosition_m)
scene.addBeacon(
position: position,
radius: CGFloat(iBeacon.getDistance())))
}
}

/***
Put the Central on the map
*/
func mapCentralPosition() {
centralPosition = CentralLocator.trilaterate(foundBeacons) if let centralPosition
= centralPosition {

print("mapping location")
if let scene = scene {
scene.addCentral(position: centralPosition) } }
}

```

```

}

// MARK: CLLocationManagerDelegate callbacks

/***
Beacons discovered by Location Manager */

func locationManager(
    _ manager: CLLocationManager, didRangeBeacons beacons: [CLBeacon], in
    region: CLBeaconRegion)

{
    // inspect previously discovered beacons
    print(beacons.count)
    for beacon in beacons {

        print(beacon.proximityUUID.uuidString) let iBeacon = IBeacon(withBeacon:
            beacon) // if a beacon is already discovered, update. // Otherwise add to the list
        var beaconFound = false
        for i in 0..<foundBeacons.count {

            if foundBeacons[i].isEqual(to: iBeacon) { beaconFound = true
                foundBeacons[i].beacon = beacon

            }
        }
        if !beaconFound {

            foundBeacons.append(iBeacon)
        }
    }
    mapBeacons()
    beaconTableView.reloadData()
    /**

```

User enabled Location Services

```

*/
func locationManager(
    _ manager: CLLocationManager,
    didChangeAuthorization status: CLAuthorizationStatus)
```

```
{  
if (status == .authorizedAlways) ||  
  
(status == CLAuthorizationStatus.authorizedWhenInUse) { print("location  
manager authorized")  
if CLLocationManager.isMonitoringAvailable(  
  
for: CLBeaconRegion.self) {  
if CLLocationManager.isRangingAvailable() { startScanning()  
  
} else {  
print("ranging unavailable")  
}  
}  
}  
}  
}  
}  
  
// MARK: UITableViewDataSource  
  
/**  
Number of Table sections  
*/  
  
func numberOfSections(in tableView: UITableView) -> Int { return 1  
}  
  
/**  
Number of iBeacons in table */  
  
func tableView(  
    _ tableView: UITableView,  
    numberOfRowsInSection section: Int) -> Int  
  
{  
    return foundBeacons.count  
}  
  
/**
```

```

Render Beacon Table cell
*/
func tableView(
    _ tableView: UITableView,
    cellForRowAt indexPath: IndexPath) -> UITableViewCell
{
    // create a new Beacon Table View cell let cell =
    tableView.dequeueReusableCell(
        withIdentifier: beaconCellReuseIdentifier, for: indexPath) as!
    BeaconTableViewCell // render cell
    let iBeacon = foundBeacons[indexPath.row]
    cell.renderBeacon(iBeacon)
    return cell
}

```

```

/***
User selected a cell
*/

```

```

private func tableView(
    tableView: UITableView,
    didSelectRowAt indexPath: IndexPath)

{
    tableView.deselectRow(at: indexPath, animated: true)
}

```

Scenes

Create a BeaconMapScene, which will plot the iBeacon and Central locations on a map.

Example 11-5. Scenes/BeaconMapScene.swift

```

import SpriteKit import GameplayKit
class BleMapScene: SKScene {

    // sprite scale
    let iconScale = CGFloat(0.1)
    // size of room in meters - must same x/y ratio as screen bounds let roomBounds

```

```

= CGSizeMake(width: 50, height: 37)

/*
Initialize Map Scene with a coder (required but not implemented) */

required init?(coder aDecoder: NSCoder) {
fatalError("init(coder:) has not been implemented")
}

/*
Initialize Map Scene
*/
override init(size: CGSize) { super.init(size: size)
backgroundColor = SKColor.white

}

/*
Update scene
*/
override func update(_ currentTime: TimeInterval) { super.update(currentTime)
}

/*
Add Central to map
- Parameters:
- position: the x,y location of the central in meters from origin
*/
func addCentral(position: CGPoint) {
// load sprite
let central = SKSpriteNode(imageNamed: "central")
// scale and position sprite
central.size = CGSize(
width: central.size.width * iconScale,
height: central.size.height * iconScale)
central.position = getMapPosition(position)
// add sprite to map
addChild(central)
}

```

```

/***
Add a Beacon to the Map

- Parameters:
- position: the x,y location of the Beacon in meters from origin
- radius: the beacon's distance from the central in meters

*/
func addBeacon(position: CGPoint, radius: CGFloat) {
// load sprite
let peripheral = SKSpriteNode(imageNamed: "peripheral") // scale sprite
peripheral.size = CGSize(
    width: peripheral.size.width * iconScale,
    height: peripheral.size.height * iconScale)
let mapPosition = getMapPosition(position)

// position and add sprite to map
peripheral.position = mapPosition
addChild(peripheral)
// add a circle for central's distance from beacon let circle = SKShapeNode(
    circleOfRadius: CGFloat(getMapScale(radius))) circle.position = mapPosition
circle.strokeColor = SKColor.blue
addChild(circle)

}

/***
Convert Real world coordinates into map coordinates */

private func getMapPosition(_ position: CGPoint) -> CGPoint { var xPosition =
getMapScale(position.x)
var yPosition = getMapScale(position.y)
// offset by 50% of screen
xPosition -= 0 // (size.width / 2)
yPosition -= (size.height + 50)
yPosition *= -1
return CGPoint(x: xPosition, y: yPosition)
}

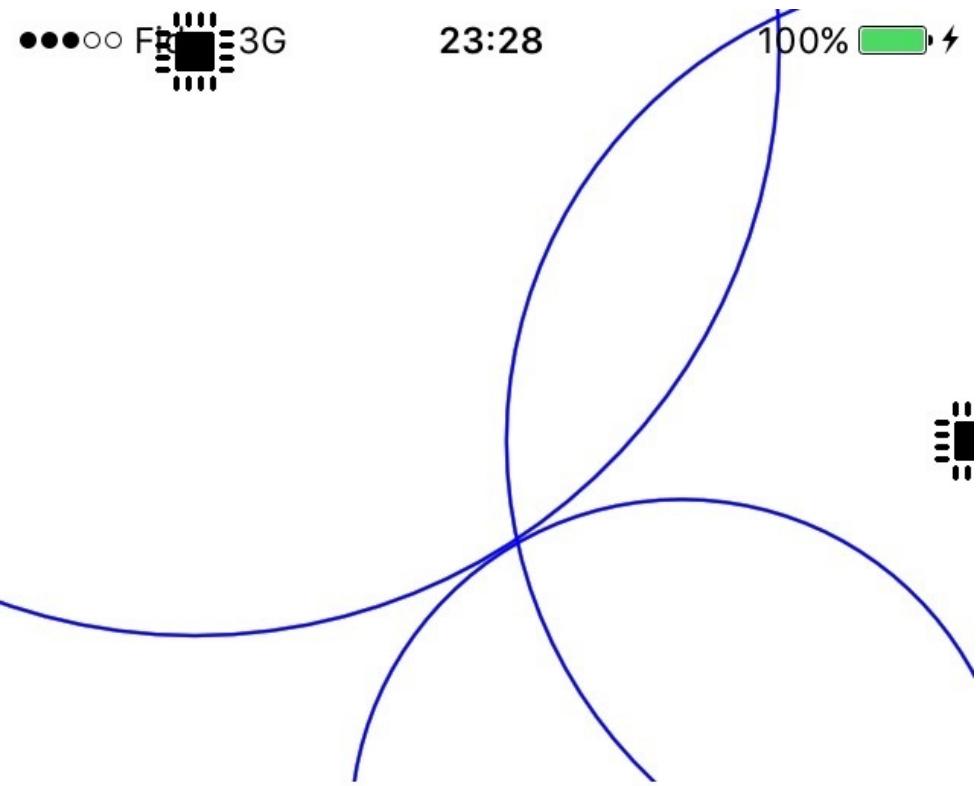
```

```
}

/***
Convert real world distances into map distances */

private func getMapScale(_ scalar: CGFloat) -> CGFloat { return scalar *
size.width / roomBounds.width
}
}
```

The resulting app will be able to locate iBeacons and, if there are three or more iBeacons nearby, it can approximate its own location (Figure 11-17).



RSSI: -37 X: 10.0 Y: 10.0
Major: 1122 Minor: 3344
Proximity: 3 ± 3 m

RSSI: -37 X: 50.0 Y: 30.0
Major: 1122 Minor: 3344
Proximity: 3 ± 3 m

RSSI: -37 X: 35.0 Y: 50.0
Major: 1122 Minor: 3344
Proximity: 3 ± 3 m

RSSI: -37 X: 10.0 Y: 10.0
Major: 1122 Minor: 3344
Proximity: 3 ± 3 m

Figure 11-17. App screen showing derived iBeacon and Central positions

Programming the Peripheral

An iBeacon is relatively simple to implement in iOS using the CoreLocation and CoreBluetooth Frameworks.

Import CoreBluetooth and CoreLocation

Link the CoreBluetooth and CoreLocation Frameworks from the project Settings (Figure 11-18).



Name	Status
CoreBluetooth.framework	Required ▾
CoreLocation.framework	Required ▾

+ -

Figure 11-18. CoreBluetooth and CoreLocation Frameworks linked into project

Import the CoreBluetooth and CoreLocation APIs in the code header to access both the Bluetooth and iBeacon APIs. The working class must also implement CBPeripheralManagerDelegate:

```
Import CoreBluetooth  
import CoreLocation
```

```
class ViewController: UIViewController, CBPeripheralManagerDelegate { ... }
```

Implementation

Instantiate the CBPeripheralManager.

```
// Instantiate a CBPeripheralManager with the current object as the delegate  
let peripheralManager = CBPeripheralManager(  
delegate: self,  
queue: nil, options: nil)
```

Define the CBPeripheralManagerDelegate callback that's triggered when the

Bluetooth radio activates:

```
func peripheralManagerDidUpdateState(_ peripheral: CBPeripheralManager) {  
    peripheralManager = peripheral  
    switch peripheral.state {  
        case CBManagerState.poweredOn:  
  
            startAdvertising()  
        case CBManagerState.poweredOff:  
            stopAdvertising()  
        default: break  
    }  
    delegate?.iBeaconPeripheral?(stateChanged: peripheral.state) }
```

Each iBeacon uses a UUID plus Major and Minor numbers for identification. iBeacons belonging to the same organizational unit also share the same UUID. For instance all iBeacons belonging to a grocery store chain.

```
// UUID  
let beaconUuid = UUID(uuidString: "e20a39f4-73f5-4bc4-a12f-17d1ad07a961")
```

Major numbers are typically used to identify iBeacons sharing the same purpose typically have the same Major number, ones that identify each grocery store in that chain.

```
// Major Number  
let majorNumber:CLBeaconMajorValue = UInt16(1122)
```

The Minor numbers are typically unique between Major numbers, so that a user can track their movement around the grocery store using the iBeacon minor numbers for identification.

```
// Minor Number  
let minorNumber:CLBeaconMinorValue = UInt16(3344)
```

The transmission power is important in both in setting the range of the iBeacon and in allowing the Central to determine how close it is to an iBeacon

```
// Transmission power  
let transmissionPower_db:NSNumber? = -56
```

Create an iBeacon region:

```
// Range identifier  
let rangeIdentifier = "customUniqueIdentifier"
```

```
let beaconRegion = CLBeaconRegion( proximityUUID: beaconUuid!, major:  
majorNumber,  
minor: minorNumber,  
identifier: rangeIdentifier)
```

Based on the iBeacon Region created earlier, create the Advertisement Data that includes the iBeacon UUID, Major Number, Minor Number, and transmission power:

```
let advertisementDictionary = beaconRegion.peripheralData(  
withMeasuredPower: transmissionPower_db)  
var advertisementData = [String: Any]()  
for (key, value) in advertisementDictionary {  
advertisementData[key as! String] = value  
}  
peripheralManager.startAdvertising(advertisementData as [String:Any])
```

Define the callback function that's called when the iBeacon begins advertising:

```
func peripheralManagerDidStartAdvertising( _ peripheral:  
CBPeripheralManager, error: Error?)
```

```
{  
if error != nil {  
print ("Error advertising peripheral")  
print(error.debugDescription)  
}  
self.peripheralManager = peripheral  
delegate?.iBeaconPeripheral?(startedAdvertising: error)  
}
```

Stop advertising when the user closes the App:

```
override func viewWillDisappear(_ animated: Bool) {  
peripheralManager.stopAdvertising()  
}
```

Putting It All Together

Create a new project called iBeacon with the following project structure (Create a new project called iBeacon with the following project structure (18)).

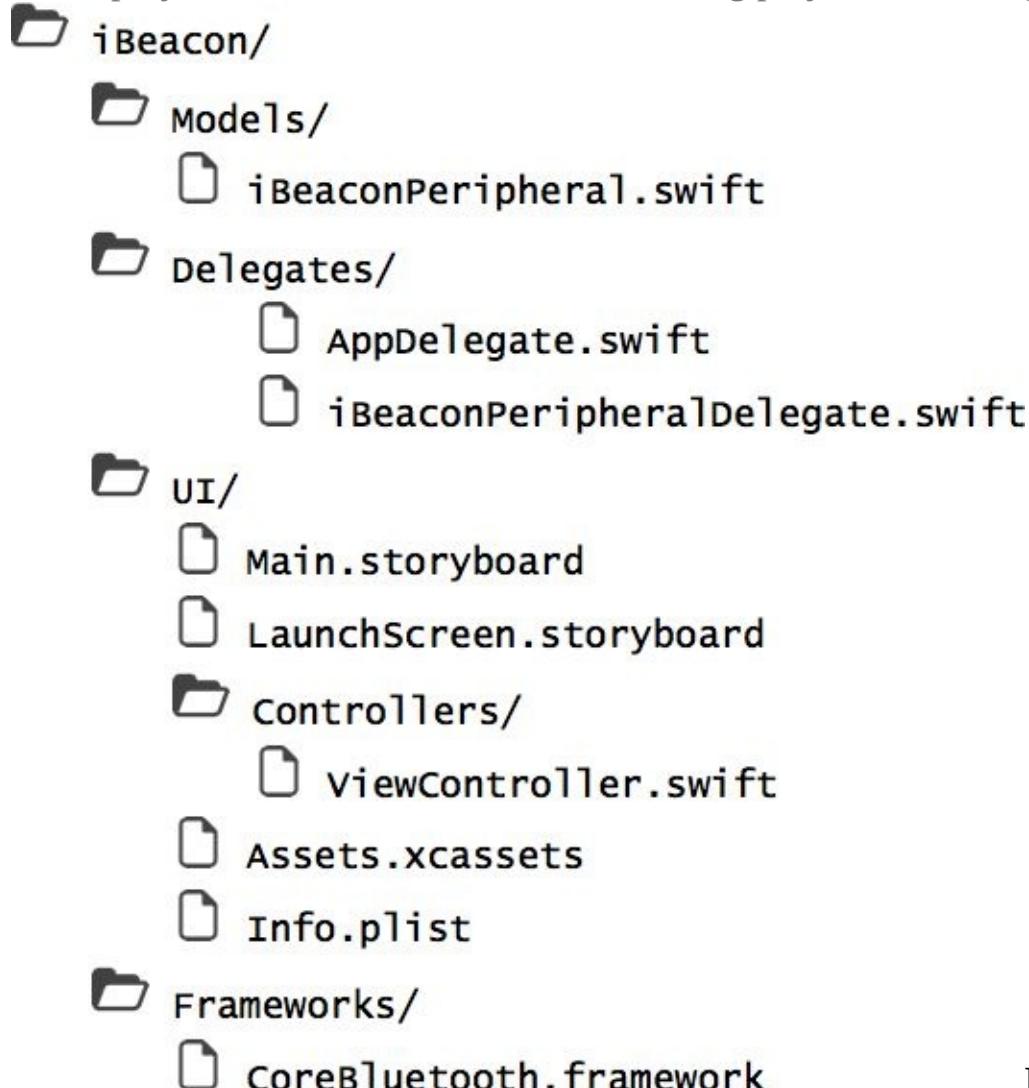


Figure 11-18.

Project Structure

Frameworks

Import the CoreBluetooth and CoreLocation Frameworks (Figure 11-19):

Linked Frameworks and Libraries	
Name	Status
CoreBluetooth.framework	Required
CoreLocation.framework	Required
+	-

Figure 11-19.

CoreBluetooth and CoreLocation Frameworks linked into project

Import the CoreBluetooth and CoreLocation APIs in the code header:

```
import CoreBluetooth import CoreLocation
```

Models

Create an iBeaconPeripheral class that has a Major Number, Minor Number, and UUID. It will begin advertising as soon as the Bluetooth radio turns on:

Example 11-6. Models/iBeaconPeripheral.swift

```
import UIKit
import CoreBluetooth import CoreLocation

class IBeaconPeripheral: NSObject, CBPeripheralManagerDelegate {
    // MARK: iBeacon properties

    // Advertized name
    let advertisingName = "LedRemote"
    // Device identifier
    let beaconIdentifier = "com.example.ibeacon" // UUID
    let beaconUuid = UUID(
        uuidString: "e20a39f4-73f5-4bc4-a12f-17d1ad07a961") // Major Number
    let majorNumber:CLBeaconMajorValue = UInt16(1122) // Minor Number
    let minorNumber:CLBeaconMinorValue = UInt16(3344) // Transmission power
    let transmissionPower_db:NSNumber? = -56
    // MARK: Peripheral State

    // Beacon Region
    var beaconRegion: CLBeaconRegion!
    // Peripheral Manager
    var peripheralManager:CBPeripheralManager! // Connected Central
    var central:CBCentral!
    // delegate
    var delegate:IBeaconPeripheralDelegate!

    /**
     Initialize BlePeripheral with a corresponding Peripheral
     - Parameters:
     - delegate: The BlePeripheralDelegate
     - peripheral: The discovered Peripheral
     */
}
```

```

init(delegate: IBeaconPeripheralDelegate?) { super.init()
self.delegate = delegate
print("initializing beacon region") if let beaconUuid = beaconUuid {
    beaconRegion = CLBeaconRegion(
        proximityUUID: beaconUuid, major: majorNumber,
        minor: minorNumber,
        identifier: beaconIdentifier)

    print("initializing peripheral manager") peripheralManager =
        CBPeripheralManager( delegate: self,
        queue: nil,
        options: nil)
} else {
    print("invalid UUID")
}

/***
Stop advertising, shut down the Peripheral */

func stopAdvertising() {
    peripheralManager.stopAdvertising()
    delegate?.iBeaconPeripheralStoppedAdvertising?()

}
/***
Start Bluetooth Advertising. This must be after building the GATT profile

*/
func startAdvertising() {
    print("loading peripheral data")
    let advertisementDictionary = beaconRegion.peripheralData(
        withMeasuredPower: transmissionPower_db)
    print("building advertisement data")
    var advertisementData = [String: Any]()
    for (key, value) in advertisementDictionary {

        advertisementData[key as! String] = value
    }
}

```

```
print("begininng advertising")
peripheralManager.startAdvertising(
    advertisementData as [String:Any])
}

// MARK: CBPeripheralManagerDelegate

/**
Peripheral will become active
*/

func peripheralManager(
    _ peripheral: CBPeripheralManager, willRestoreState dict: [String : Any]) {

    { print("restoring peripheral state")
    }

    /**
Peripheral started advertising
*/
}

func peripheralManagerDidStartAdvertising( _ peripheral:
    CBPeripheralManager, error: Error?) {

    {
        if error != nil {
            print ("Error advertising peripheral")
            print(error.debugDescription)

        }
        self.peripheralManager = peripheral
        delegate?.iBeaconPeripheral?(startedAdvertising: error)
    }

    /**
Bluetooth Radio state changed
*/
}

func peripheralManagerDidUpdateState( _ peripheral: CBPeripheralManager)
```

```

{
peripheralManager = peripheral
switch peripheral.state {
case CBManagerState.poweredOn:
startAdvertising()
case CBManagerState.poweredOff:
stopAdvertising()
default: break
}
delegate?.iBeaconPeripheral?(stateChanged: peripheral.state)
}

```

Delegates

Create an iBeaconPeripheralDelegate class that relays iBeacon state changes:

Example 11-7. Delegates/iBeaconPeripheralDelegate.swift

```

import UIKit
import CoreBluetooth
@objc protocol IBeaconPeripheralDelegate : class {
/**
iBeacon State Changed

```

- Parameters:
- rssi: the RSSI
- blePeripheral: the BlePeripheral

```

*/
@objc optional func iBeaconPeripheral( stateChanged state: CBManagerState)
/**
iBeacon statrted advertising

```

- Parameters:
- error: the error message, if any

```

@objc optional func iBeaconPeripheral(startedAdvertising error: Error?)

/**
iBeacon stopped advertising
*/

```

```
@objc optional func iBeaconPeripheralStoppedAdvertising()
```

Storyboard

Create the UISwitches, UITextView, and UILabels in the UIView in the Main.storyboard to create the App's user interface (Figure 11-20).

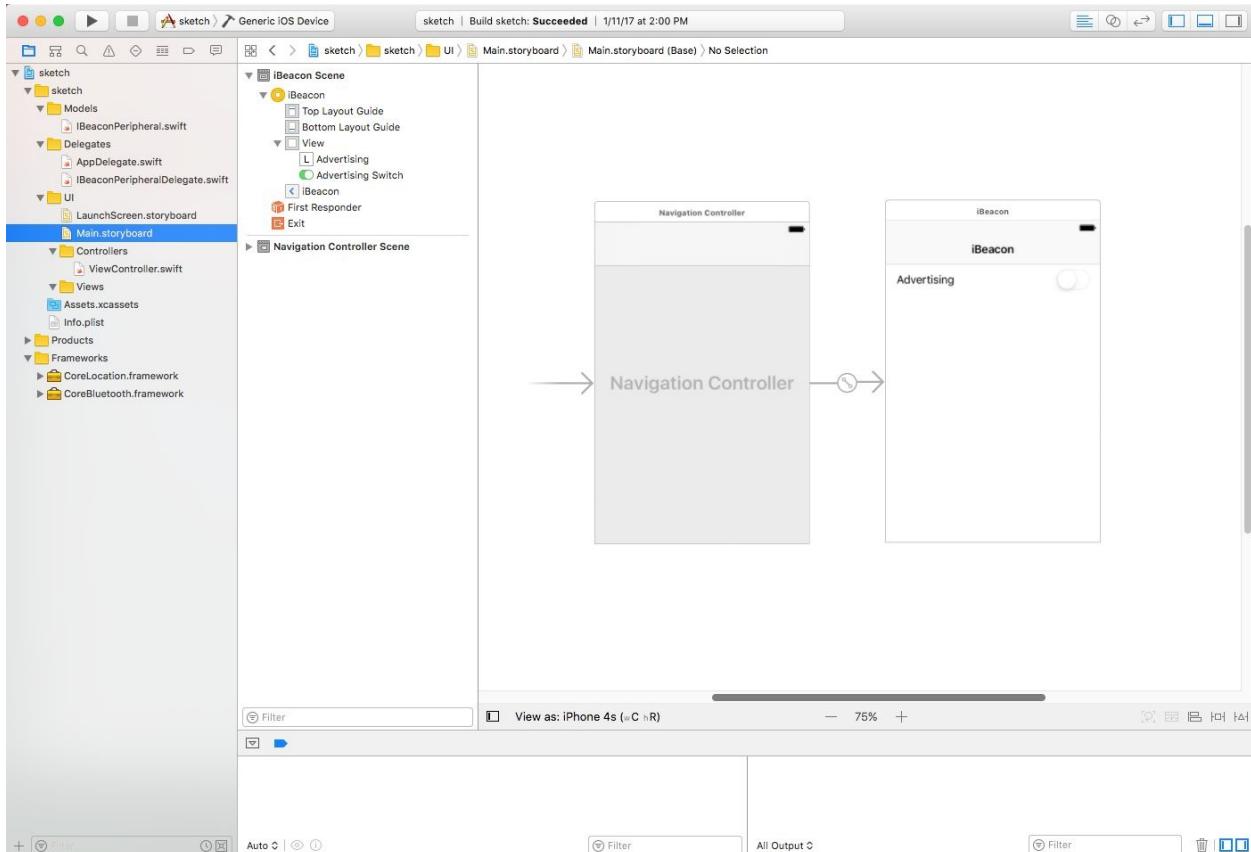


Figure 11-20. Project Storyboard Controllers

The ViewController instantiates the iBeacon, starts Advertising as soon as the Bluetooth radio turns on, and shows the Advertising state in a UISwitch :

Example 11-8. UI/Controllers/ViewController.swift

```

import UIKit
import CoreBluetooth
import AVFoundation
class ViewController: UIViewController, IBeaconPeripheralDelegate {

    // MARK: UI Elements
    @IBOutlet weak var advertisingSwitch: UISwitch!
    // MARK: BlePeripheral
    // BlePeripheral
    var iBeacon:IBeaconPeripheral!

    /**
    UIView loaded
    */

```

```

override func viewDidLoad() { super.viewDidLoad()
}

/***
View appeared. Start the Peripheral
***/

override func viewDidAppear(_ animated: Bool) { iBeacon =
IBeaconPeripheral(delegate: self)
}

/***
View will appear. Stop transmitting random data */

override func viewWillDisappear(_ animated: Bool) { iBeacon.stopAdvertising()
}

/***
View disappeared. Stop advertising
***/

override func viewDidDisappear(_ animated: Bool) {
advertisingSwitch.setOn(false, animated: true) }
// MARK: IBeaconPeripheralDelegate
/***
RemoteLed state changed

- Parameters:
- state: the CBManagerState representing the new state */

func iBeaconPeripheral(stateChanged state: CBManagerState) { switch (state) {
case CBManagerState.poweredOn:

print("Bluetooth on")
case CBManagerState.poweredOff:
print("Bluetooth off")
default:
print("Bluetooth not ready yet...")
}
}

```

```
/**  
RemoteLed statrted adertising
```

- Parameters:
- error: the error message, if any

```
*/  
  
func iBeaconPeripheral(startedAdvertising error: Error?) { if error != nil {  
print("Problem starting advertising: " + error.debugDescription)  
  
} else {  
print("adertising started")  
advertisingSwitch.setOn(true, animated: true)  
  
}  
}  
  
/**  
RemoteLed statrted adertising  
*/  
  
func iBeaconPeripheralStoppedAdvertising() { print("adertising stopped")  
}  
}
```

The resulting app can broadcast as a single iBeacon (Figure 11-21).

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iBeacon

Advertising



Figure 11-21. App screen showing Advertising state of the iBeacon

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter11>

Project: Echo Client and Server

An Echo Server is the “Hello World” of network programming. It has the minimum features required to transmit, store, and respond to data on a network - the core features required for any network application.

And yet it must support all the features you’ve learned so far in this book - advertising, reads, writes, notifications, segmented data transfer, and encryption. It’s a sophisticated program!

The Echo Server works like this:

In this example, the Peripheral acts as a server, the “Echo Server” and the Central acts as a client (Figure 12-1).

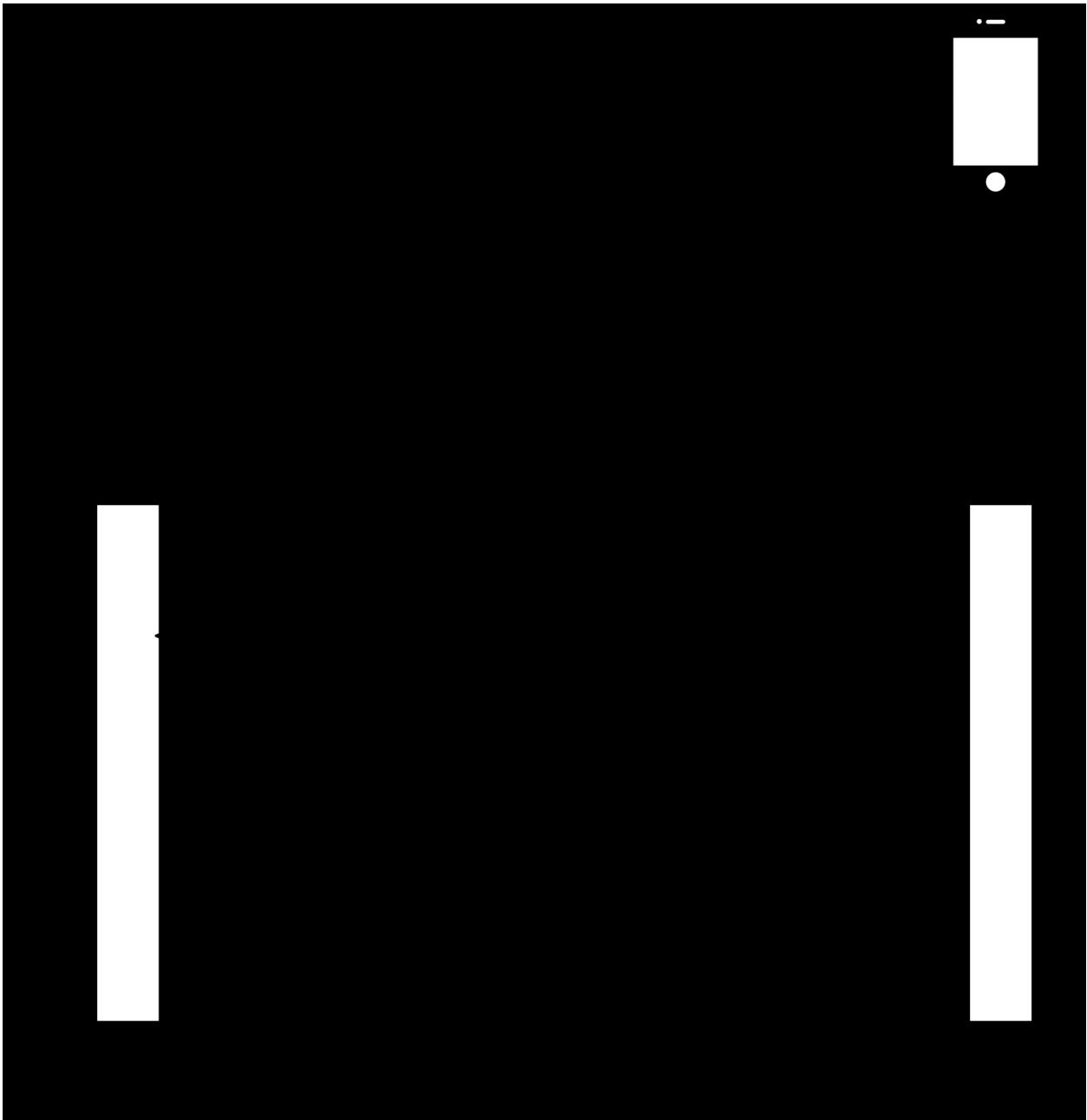


Figure 12-1. How an Echo Server works

This project is based heavily on code seen up until Chapter 10, so there shouldn't be any surprises.

Programming the Central

The Echo Client will read and write messages on a Characteristic and will notify the Central when it is ready for new messages.

The Echo Server sends and receives text. Text is complicated because computers communicate using binary data, not text. As a result, there are a couple things that need to be done to protect the data from errors.

Data Formatting

Bluetooth has a 20-byte maximum packet size. Longer messages must be divided and sent in parts. Both the client and server need a way to know if the data being transmitted belongs to part of a larger transmission.

One easy way to do this with text is to append a newline character to the end of the outbound transmission.

```
let partialMessage = "Hello World" let message = partialMessage + "\n"  
When the message is broken apart for transmission, the parts are reassembled  
properly and the new line at the end separates new messages into new lines.  
Everything else works the same way as any other Bluetooth app.
```

GATT Profile

The GATT Profile will be set up as a digital input/output under the Automation IO (0x1815) Service, which commands to and responses from the Peripheral on separate Characteristics.

```
// the Service UUID  
static let serviceUuid = CBUUID(string: "180C")  
// The Characteristic UUID used to read echoes from the Peripheral static let  
responseCharacteristicUuid = CBUUID(string: "2A56")  
// The Characteristic UUID used to write text to the Peripheral static let  
writeCharacteristicUuid = CBUUID(string: "2A57")
```

Enable Bluetooth Radio

To turn on the Bluetooth radio programmatically, also enable Bluetooth admin permissions:

```
let centralManager = CBCentralManager(delegate: self, queue: nil) When the
Bluetooth radio turns on, begin scanning:
func centralManagerDidUpdateState(_ central: CBCentralManager) {

switch (central.state) {
case .poweredOn:
    central.scanForPeripherals(withServices: [serviceUuid], options: nil) default:
}
}
```

Whenever a device is discovered, the centralManager didDiscover callback is triggered by the CBPeripheralManager. If the Advertised name matches the desired EchoServer name, connect:

```
func getNameFromAdvertisementData(
advertisementData: [String : Any]) -> String?
{
// grab thekCBAdvDataLocalName from the advertisementData // to see if
there's an alternate broadcast name if
advertisementData["kCBAdvDataLocalName"] != nil { return
(advertisementData["kCBAdvDataLocalName"] as! String)
}
return nil
}

func centralManager(
    _ central: CBCentralManager,
    didDiscover peripheral: CBPeripheral,
    advertisementData: [String : Any],
    rssi RSSI: NSNumber)

{
// find the advertised name
if let advertisedName = getNameFromAdvertisementData(
    advertisementData: advertisementData) {
if advertisedName == "EchoServer" {
```

```
centralManager.connect(peripheral, options: nil) }  
}  
}
```

Connecting

Once a Peripheral is connected, the centralManager didConnect callback is triggered by the CBPeripheralManager. Use this to build a map of the GATT profile, starting with the Services:

```
var connectedPeripheral:CBPeripheral! func centralManager(  
    _ central: CBCentralManager,  
    didConnect peripheral: CBPeripheral) {  
    // store a copy of the connected Peripheral so it isn't tossed  
    connectedPeripheral = peripheral;  
    connectedPeripheral.delegate = self;  
    peripheral.discoverServices(serviceUuid) }
```

Discovering GATT

Once services are discovered, the peripheral didDiscoverServices callback is triggered by the CBPeripheralDelegate. Since the EchoServer is known to have a Service with UUID 0x180C, search for that service and request discovery of the two known Characteristics, 0x2a56 and 0x2a57:

```
func peripheral(  
    _ peripheral: CBPeripheral, didDiscoverServices error: Error?)  
  
{  
    // update the local copy of the Peripheral  
    connectedPeripheral = peripheral  
    if error != nil {  
  
        // error  
    } else {  
        for service in peripheral.services!{  
            if service.uuid == serviceUuid {  
                connectedPeripheral.discoverCharacteristics([readCharacteristicUuid,  
                    writeCharacteristicUuid],
```

```
for: service)
}
}
}
```

A list of Characteristics for each Service will come back in the peripheral didDiscoverCharacteristicsFor callback in CBPeripheralManagerDelegate. Use this to subscribe to the Read Characteristics and to save references to each Characteristic:

```
func peripheral(
    _ peripheral: CBPeripheral,
    didDiscoverCharacteristicsFor service: CBService, error: Error?)

{
    // update local copy of the peripheral
    connectedPeripheral = peripheral
    connectedPeripheral.delegate = self
    // grab the service
    let serviceIdentifier = service.uuid.uuidString
    if let characteristics = service.characteristics {

        for characteristic in characteristics {
            if characteristic.uuid.uuidString == writeCharacteristicUuid { writeCharacteristic
                = characteristic

            } else if characteristic.uuid.uuidString == \
                readCharacteristicUuid {
                readCharacteristic = characteristic
                connectedPeripheral.setNotifyValue(
                    true,
                    for: characteristic)
            }
        }
    }
}
```

Writing Messages

To write a message to the Characteristic, convert the String message into a Data object and write the value using the CBPeripheral.writeValue method:

```
// Flow control response
let flowControlMessage = "ready"
// outbound value to be sent to the Characteristic var outboundByteArray:
[UInt8]!
// packet offset in multi-packet value var packetOffset = 0

func writeValue(value: String) {
    // Append a newline to the end of the string for formatting purposes let
    writeableValue = value + "\n\0"
    packetOffset = 0
    // get the data for the current offset
    outboundByteArray = Array(writeableValue.utf8)
    // begin the write process
    writePartialValue(value: outboundByteArray, offset: packetOffset)

}

func writePartialValue(value: [UInt8], offset: Int) {
    // don't go past the total value size
    var end = offset + characteristicLength
    if end > outboundByteArray.count {

        end = outboundByteArray.count
    }
    let transmissibleValue = Data(Array(outboundByteArray[offset..<end]))
    connectedPeripheral.writeValue(
        transmissibleValue,
        for: writeCharacteristic)
```

Receiving Messages

When the EchoServer Peripheral responds with on the Read Characteristic (0x2a56), the peripheral didUpdateValueFor callback is triggered from the CBPeripheralManagerDelegate. Send the next packet of data in response, until there is nothing left to send:

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?)  
  
{  
    if let value = characteristic.value {  
        let byteArray = [UInt8](value)  
        if let stringValue = String(data: value, encoding: .ascii) {  
  
            packetOffset += characteristicLength  
            if packetOffset < outboundByteArray.count { writePartialValue(  
                value: outboundByteArray,  
                offset: packetOffset)  
            }  
        }  
    }  
}
```

Putting It All Together

The following code will create an App that connects to a Peripheral, allows a user to type a message, send that message to the Peripheral, and then prints the Peripheral's response.

Create a new project called EchoClient with the following structure (Figure 12-2).

```
Folder EchoClient/
  Folder Models/
    File EchoServer.swift
  Folder Delegates/
    File AppDelegate.swift
    File EchoServerDelegate.swift
  Folder UI/
    File Main.storyboard
    File LaunchScreen.storyboard
    Folder Controllers/
      File CharacteristicViewController.swift
    File Assets.xcassets
    File Info.plist
  Folder Frameworks/
    File CoreBluetooth.framework
```

Figure 12-2.

Project Structure

Frameworks

Import the CoreBluetooth Framework (Figure 12-3).

Linked Frameworks and Libraries	
Name	Status
CoreBluetooth.framework	Required
+	-

Figure 12-3.

CoreBluetooth Framework linked into project

Import the CoreBluetooth APIs in the code header:

import CoreBluetooth

Models

The BleCommManager turns the Bluetooth radio on and scans for nearby Peripherals.

Example 12-1. Models/EchoServer.swift

```
import UIKit
import CoreBluetooth
class EchoServer: NSObject, CBPeripheralDelegate {
// MARK: Peripheral properties

// The Broadcast name of the Perihperal
static let advertisedName = "EchoServer"
// the Service UUID
static let serviceUuid = CBUUID(string: "180C")
// The Characteristic UUID used to write text to the Peripheral static let
readCharacteristicUuid = CBUUID(string: "2A56") // the Characteristic UUID
used to read echoes from the Peripheral static let writeCharacteristicUuid =
CBUUID(string: "2A57") // the size of the characteristic
let characteristicLength = 20

// MARK: Flow control
// FLow control response
let flowControlMessage = "ready"

// outbound value to be sent to the Characteristic var outboundByteArray:
[UInt8]!
// packet offset in multi-packet value var packetOffset = 0

// MARK: connected device

// EchoServerDelegate
var delegate:EchoServerDelegate! // connected Peripheral
var connectedPeripheral:CBPeripheral! // connected Characteristic
var readCharacteristic:CBCharacteristic! var
writeCharacteristic:CBCharacteristic

/**
```

Initialize EchoServer with a corresponding Peripheral

- Parameters:
- delegate: The EchoServerDelegate
- peripheral: The discovered Peripheral

```

*/
init(delegate: EchoServerDelegate, peripheral: CBPeripheral) { super.init()
connectedPeripheral = peripheral
connectedPeripheral.delegate = self
self.delegate = delegate

}

/***
Notify the EchoServer that the peripheral has been connected */

func connected(peripheral: CBPeripheral) {
connectedPeripheral = peripheral
connectedPeripheral.delegate = self
connectedPeripheral.discoverServices([EchoServer.serviceUuid])

}

/***
Get a advertised name from an advertisementData packet. This may be different
than the actual Peripheral name */

static func getNameFromAdvertisement(
advertisementData: [String : Any]) -> String?
{
// grab thekCBAdvDataLocalName from the advertisementData // to see if
there's an alternate broadcast name
if advertisementData["kCBAdvDataLocalName"] != nil { return
(advertisementData["kCBAdvDataLocalName"] as! String) }
return nil
}

/***
Write a text value to the EchoServer

- Parameters:
- value: the value to write to the connected Characteristic
*/
func writeValue(value: String) {
// get the characteristic length
let writeableValue = value + "\n\0"

```

```

packetOffset = 0
// get the data for the current offset
outboundByteArray = Array(writeableValue.utf8) writePartialValue(value:
outboundByteArray, offset: packetOffset) }

/**
Write a partial value to the EchoServer
- Parameters:
- value: the full value to write to the connected Characteristic
- offset: the packet offset

*/
func writePartialValue(value: [UInt8], offset: Int) { // don't go past the total value
size
var end = offset + characteristicLength
if end > outboundByteArray.count {

end = outboundByteArray.count
}
let transmissibleValue = \
Data(Array(outboundByteArray[offset..<end])) print("writing partial value: \
(offset)-\((end)") print(transmissibleValue)
var writeType = CBCharacteristicWriteType.withResponse if
EchoServer.isCharacteristic(
isWriteableWithoutResponse: writeCharacteristic)

{
writeType = CBCharacteristicWriteType.withoutResponse
}
connectedPeripheral.writeValue(
transmissibleValue,
for: writeCharacteristic,
type: writeType)
print("write request sent")
}

/**
Check if Characteristic is readable

```

- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is readable */
 static func isCharacteristic(
 isReadable characteristic: CBCharacteristic) -> Bool {
 if (characteristic.properties.rawValue &
 CBCharacteristicProperties.read.rawValue) != 0 {
 print("readable")
 return true
 }
 return false
 }

 /**
 Check if Characteristic is writeable
 - Parameters:
 - characteristic: The Characteristic to test
 - returns: True if characteristic is writeable */
 static func isCharacteristic(
 isWriteable characteristic: CBCharacteristic) -> Bool

 {
 print("testing if characteristic is writeable")
 if (characteristic.properties.rawValue &
 CBCharacteristicProperties.write.rawValue != 0 ||
 (characteristic.properties.rawValue &
 CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0

 {
 print("characteristic is writeable") return true
 }
 print("characteristic is not writeable") return false
 }

 /**

Check if Characteristic is writeable with response

- Parameters:

- characteristic: The Characteristic to test

- returns: True if characteristic is writeable with response */

```
static func isCharacteristic(
```

```
isWriteableWithResponse characteristic: CBCharacteristic) -> Bool {
```

```
if (characteristic.properties.rawValue &
```

```
CBCharacteristicProperties.write.rawValue) != 0 {
```

```
return true }
```

```
return false }
```

```
/**
```

Check if Characteristic is writeable without response

- Parameters:

- characteristic: The Characteristic to test

- returns: True if characteristic is writeable without response

```
*/
```

```
static func isCharacteristic(
```

```
isWriteableWithoutResponse characteristic: CBCharacteristic) -> Bool {
```

```
if (characteristic.properties.rawValue &
```

```
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0 {
```

```
return true }
```

```
return false }
```

```
/** Check if Characteristic is notifiable
```

- Parameters:

- characteristic: The Characteristic to test

- returns: True if characteristic is notifiable */

```
static func isCharacteristic(
```

```
isNotifiable characteristic: CBCharacteristic) -> Bool {
```

```
if (characteristic.properties.rawValue &
```

```
CBCharacteristicProperties.notify.rawValue) != 0 {
```

```
print("characteristic is notifiable")
```

```
return true
```

```
}
```

```
return false
```

```
}
```

```
// MARK: CBPeripheralDelegate
```

```
/**
```

```
Characteristic has been subscribed to or unsubscribed from */
```

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didUpdateNotificationStateFor characteristic: CBCharacteristic, error: Error?)
```

```
{
```

```
connectedPeripheral = peripheral  
connectedPeripheral.delegate = self  
print("Notification state updated for: " + \
```

```
"\n(characteristic.uuid.uuidString)") print("New state: \  
(characteristic.isNotifying)") if let errorValue = error {
```

```
print("error subscribing to notification: ") print(errorValue.localizedDescription)  
}  
}
```

```
/**
```

```
Value was written to the Characteristic */
```

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didWriteValueFor descriptor: CBDescriptor, error: Error?)
```

```
{
```

```
print("data written")  
}
```

```
/**
```

```
Value downloaded from Characteristic on connected Peripheral */
```

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?)
```

```
{  
print("characteristic updated")  
if let value = characteristic.value {  
  
print(value.debugDescription)  
print(value.description)  
let byteArray = [UInt8](value)  
if let stringValue = String(data: value, encoding: .ascii) {  
  
print(stringValue)  
packetOffset += characteristicLength  
print("new packet offset: \(packetOffset)")  
print("new packet offset: \(packetOffset)")  
if packetOffset < outboundByteArray.count {  
  
print("sending new packet: " + \  
"\(packetOffset)-\(byteArray.count)" writePartialValue(  
value: outboundByteArray,  
offset: packetOffset)  
  
}  
if delegate != nil {  
delegate.echoServer(messageReceived: stringValue) }  
}  
}  
}  
}  
  
/**  
Servicess were discovered on the connected Peripheral */
```

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didDiscoverServices error: Error?)  
  
{  
print("services discovered")  
connectedPeripheral = peripheral  
connectedPeripheral.delegate = self  
if error != nil {
```

```

print("Discover service Error: \error)"} else {
print("Discovered Service")
for service in peripheral.services!{
if service.uuid == EchoServer.serviceUuid {
connectedPeripheral.discoverCharacteristics(
[EchoServer.readCharacteristicUuid, EchoServer.writeCharacteristicUuid], for:
service)
}
}
print(peripheral.services!)
print("DONE")
}
/**
Characteristics were discovered
for a Service on the connected Peripheral
*/
func peripheral(
_peripheral: CBPeripheral,
didDiscoverCharacteristicsFor service: CBService,
error: Error?) {
print("characteristics discovered")
connectedPeripheral = peripheral
connectedPeripheral.delegate = self
// grab the service
let serviceIdentifier = service.uuid.uuidString
print("service: \(serviceIdentifier)")
if let characteristics = service.characteristics { print("characteristics found: \
(characteristics.count)") for characteristic in characteristics {
print("-> \(characteristic.uuid.uuidString)") if characteristic.uuid.uuidString == \
EchoServer.writeCharacteristicUuid.uuidString {
print("matching uuid found for characteristic") writeCharacteristic =
characteristic
} else if characteristic.uuid.uuidString == \
EchoServer.readCharacteristicUuid.uuidString {
readCharacteristic = characteristic if EchoServer.isCharacteristic( isNotifiable:
characteristic) {
connectedPeripheral.setNotifyValue( true,
for: characteristic)
}
}
}
}
}

```

```
}

}

// notify the delegate
if readCharacteristic != nil && writeCharacteristic != nil {
    if delegate != nil {
        delegate.echoServer(connectedToCharacteristics: [readCharacteristic,
            writeCharacteristic])
    }
}
}
}
}
}
```

Delegates

Create an EchoServerDelegate that relays important events from the EchoServer.

Example 12-2. Delegates/EchoServerDelegate.swift

```
import UIKit
import CoreBluetooth
protocol EchoServerDelegate {
    /**
     Message received from Echo Server
```

- Parameters:
 - stringValue: the value read from the Characteristic */

```
func echoServer(messageReceived stringValue: String)  
/** Connection to characteristics was successful
```

- Parameters:
 - characteristic: the Characteristic that was subscribed/unsubscribed */

```
func echoServer(  
    connectedToCharacteristics characteristics: [CBCharacteristic]) {
```

Storyboard

Create and link the `UIButtons`, `UILabels`, `UITextViews`, and `UITextField`s in the `UIView` in the `Main.storyboard` to create the App's user interface (Figure 12-4).

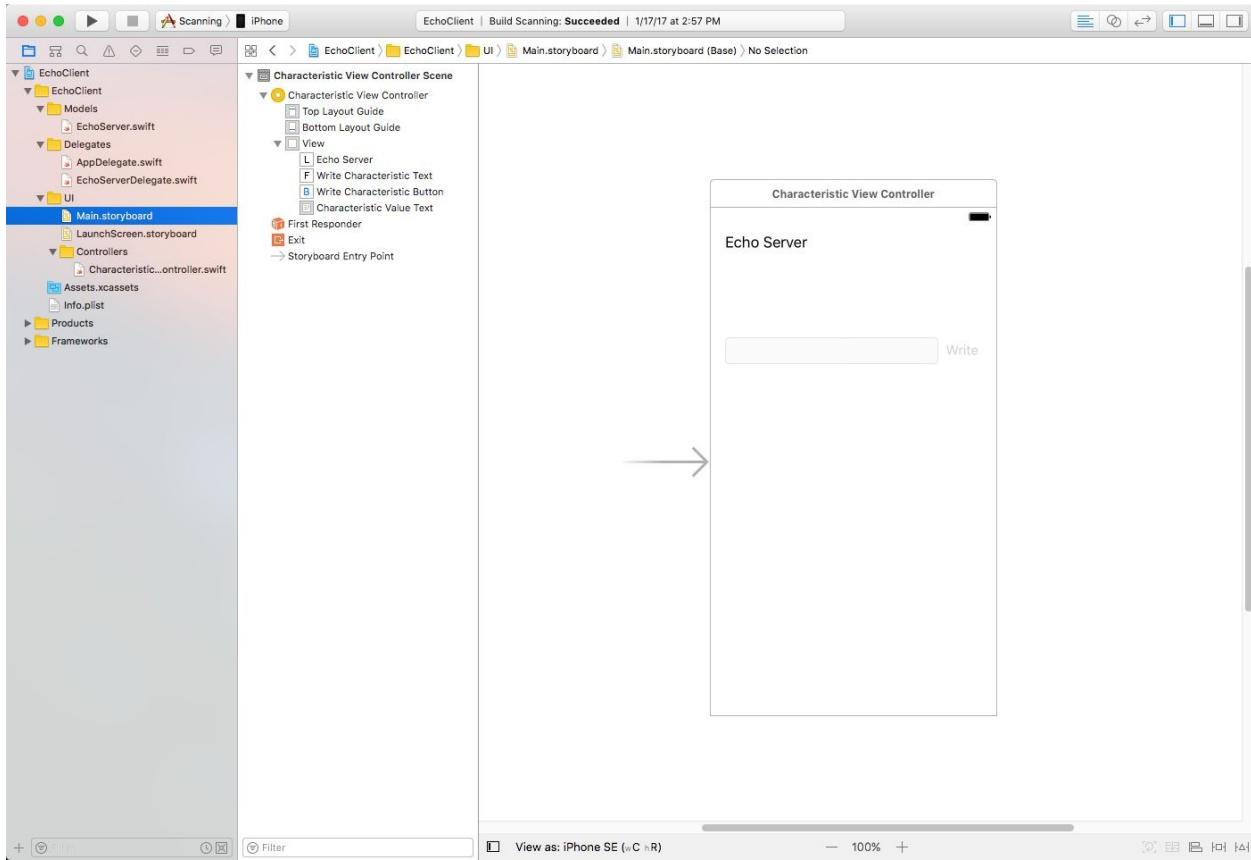


Figure 12-4. Project Storyboard Controllers

The App will indicate a connection status prior to connecting to the Peripheral. After connection, UIButtons and UITextFields are displayed that enable interaction with the Peripheral.

Example 12-3. UI/Controllers/CharacteristicViewController.swift

```
import UIKit
import CoreBluetooth
class CharacteristicViewController: UIViewController, \
CBCentralManagerDelegate, EchoServerDelegate {

// MARK: UI Elements
@IBOutlet weak var characteristicValueText: UITextView!
@IBOutlet weak var writeCharacteristicButton: UIButton!
@IBOutlet weak var writeCharacteristicText: UITextField!

// MARK: Bluetooth stuff
```

```
// Bluetooth features
var centralManager:CBCentralManager! // the EchoServer
var echoServer:EchoServer!

< /**
View loaded
 */

override func viewDidLoad() {
super.viewDidLoad()
centralManager = CBCentralManager(delegate: self, queue: nil)

}

< /**
Write button pressed

 */

@IBAction func onWriteCharacteristicButtonTouchUp(_ sender: UIButton) {
print("write button pressed")
if let string = writeCharacteristicText.text {

print(string)
echoServer.writeValue(value: string)
writeCharacteristicText.text = ""

}
}
// MARK: EchoServerDelegate

< /**
Message received from EchoServer. Update UI
 */

func echoServer(messageReceived stringValue: String) {
characteristicValueText.insertText(stringValue)
let stringLength = characteristicValueText.text.characters.count
characteristicValueText.scrollRangeToVisible(
NSMakeRange(stringLength-1, 0))
}
```

```

/***
Characteristic was connected on the EchoServer. Update UI */

func echoServer(
connectedToCharacteristics characteristics: [CBCharacteristic])
{
for characteristic in characteristics {
print(" characteristic: -> " + \
"\(characteristic.uuid.uuidString): " + \
"\(characteristic.properties.rawValue)")
if EchoServer.isCharacteristic(isWriteable: characteristic) {
writeCharacteristicText.isEnabled = true
writeCharacteristicButton.isEnabled = true
}
}
}

// MARK: CBCentralManagerDelegate
/***
centralManager is called each time a new Peripheral is discovered

- parameters
- central: the CentralManager for this UIView
- peripheral: A discovered Peripheral
- advertisementData: Bluetooth advertisement discovered with Peripheral
- rssi: the radio signal strength indicator for this Peripheral

*/
func centralManager(
    _ central: CBCentralManager,
    didDiscover peripheral: CBPeripheral,
    advertisementData: [String : Any], rssi RSSI: NSNumber)

{
print("Discovered \(peripheral.identifier.uuidString) " +
"\(peripheral.name))")
echoServer = EchoServer(delegate: self, peripheral: peripheral) // find the
advertised name
}

```

```
if let advertisedName = EchoServer.getNameFromAdvertisementData(  
    advertisementData: advertisementData)  
  
{  
    if advertisedName == EchoServer.advertisedName { print("connecting to  
peripheral...") centralManager.connect(peripheral, options: nil)  
  
}  
}  
}  
}**
```

Peripheral connected.

- Parameters:
- central: the reference to the central
- peripheral: the connected Peripheral */

```
func centralManager(  
    _ central: CBCentralManager, didConnect peripheral: CBPeripheral)  
  
{  
    print("Connected Peripheral: \(peripheral.name)") // Do any additional setup  
after loading the view. echoServer.connected(peripheral: peripheral)  
  
}  
}**
```

Peripheral disconnected

- Parameters:
- central: the reference to the central
- peripheral: the connected Peripheral

```
*/  
func centralManager(  
    _ central: CBCentralManager,  
didDisconnectPeripheral peripheral: CBPeripheral, error: Error?)  
  
{  
    // disconnected. Leave
```

```
print("disconnected")
writeCharacteristicButton.isEnabled = false

}

/**
```

Bluetooth radio state changed

- Parameters:
- central: the reference to the central */

```
func centralManagerDidUpdateState(_ central: CBCentralManager) {
print("Central Manager updated: checking state") switch (central.state) {
case .poweredOn:

print("bluetooth on")
central.scanForPeripherals(
withServices: [EchoServer.serviceUuid], options: nil)

default:
print("bluetooth unavailable")
}
}
}
```

The resulting Central App can scan for and connect to a Bluetooth Low Energy Peripheral. Once connected, the Central can send and receive messages to the Peripheral.

If a user types “hello” into the bottom TextView and hit the Subscribe button, the word “hello” will appear above in the upper Text View (Figure 12-5).

●●●○○ Fido 3G

21:07

⚡ 100% 🔋 ⚡

Echo Server

hello

Write



Figure 12-5. App screen showing interface to read from and write to the Echo Server

Programming the Peripheral

The Echo Server will handle incoming writes on one Characteristic (0x2a57) and echo back messages on another Characteristic (0x2a56). It will also host a minimal GATT Profile that includes a battery percentage, device name, model number, and serial number.

Advertising and GATT Profile

The Peripheral must advertise and host a GATT Profile, which will include a minimal GATT profile.

The Peripheral will host a read-only, notifiable Characteristic on UUID 0x2a56 and a write-only Characteristic on UUID 0x2a57:

```
// service UUIDs
let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")
// Characteristic UUIDs
let readCharacteristicUuid = CBUUID(
    string: "00002a56-0000-1000-8000-00805f9b34fb")

let writeCharacteristicUuid = CBUUID(
    string: "00002a57-0000-1000-8000-00805f9b34fb")
// Read Characteristic
var readCharacteristic:CBMutableCharacteristic!
// Write Characteristic
var writeCharacteristic:CBMutableCharacteristic!

let service = CBMutableService(type: serviceUuid, primary: true) var rProperties
= CBCharacteristicProperties.read
rProperties.formUnion(CBCharacteristicProperties.notify) var rPermissions =
CBAttributePermissions.writeable
rPermissions.formUnion(CBAttributePermissions.readable)

readCharacteristic = CBMutableCharacteristic( type: readCharacteristicUuid,
properties: rProperties,
value: nil,
permissions: rPermissions)

let wProperties = CBCharacteristicProperties.write let wPermissions =
```

```

CBAttributePermissions.writeable writeCharacteristic =
CBMutableCharacteristic(
    type: writeCharacteristicUuid,
    properties: wProperties,
    value: nil,
    permissions: wPermissions)

// add Characteristics to the Service
service.characteristics = [ readCharacteristic, writeCharacteristic ] // add Service
to Peripheral
peripheralManager.add(service)

```

It will advertise as "EchoServer" to be discoverable by the corresponding Central:

```

// Advertized name
let advertisingName = "EchoServer"

// Build Advertisement Data
let serviceUuids = [serviceUuid]
let advertisementData:[String: Any] = [
    CBAdvertisementLocalNameKey: advertisingName,
    CBAdvertisementServiceUUIDsKey: serviceUuids ]
// Start advertising
peripheralManager.startAdvertising(advertisementData)

```

Handling Reads, Writes, and Subscriptions

When a Central subscribes to the read Characteristic (0x2a56), the peripheralManager didSubscribeTo callback is triggered. Here a reference to the connected Central is stored for later use:

```

/**
Connected Central subscribed to a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    central: CBCentral,

```

```
didSubscribeTo characteristic: CBCharacteristic)
```

```
{  
self.central = central  
}
```

When a Central unsubscribes, the reference is removed:

```
/**  
Connected Central unsubscribed from a Characteristic */
```

```
func peripheralManager(  
_ peripheral: CBPeripheralManager,  
central: CBCentral,  
didUnsubscribeFrom characteristic: CBCharacteristic)  
  
{  
self.central = central  
}
```

Once Central initiates a connection, it can subscribe to the read Characteristic, triggering the peripheralManager didReceiveRead callback. It can also send write requests to the write Characteristic, triggering the peripheralManager didReceiveWrite callback.

Write requests are handled by setting the read Characteristic (0x2a56) to the newly written value, thereby notifying the subscribed Centrals.

```
/**  
Connected Central requested to write to a Characteristic */
```

```
func peripheralManager(  
_ peripheral: CBPeripheralManager,  
didReceiveWrite requests: [CBATTRequest])  
  
{  
for request in requests {  
peripheral.respond(to: request, withResult: CBATTError.success) print("new  
request")  
if let value = request.value {
```

```

// update readCharacteristic
print("updating characteristic")
readCharacteristic.value = value
// notify subscribers
print("notifying characteristic")
peripheralManager.updateValue(
    value,
    for: readCharacteristic,
    onSubscribedCentrals: [central])
}

}
}

```

Read requests are handled by responding with a status message regarding the outcome of the read request and the value of the Characteristic if the read request was successful:

```

/**
Connected Central requested to read from a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager, didReceiveRead request: CBATTRequest)

{
    let characteristic = request.characteristic
    if (characteristic.uuid == readCharacteristic.uuid) {

        if let value = characteristic.value {
            if request.offset > value.count {
                peripheralManager.respond(
                    to: request,
                    withResult: CBATTError.invalidOffset)
                return
            }

            let range = Range(uncheckedBounds: (
                lower: request.offset,
                upper: value.count - request.offset))
        }
    }
}

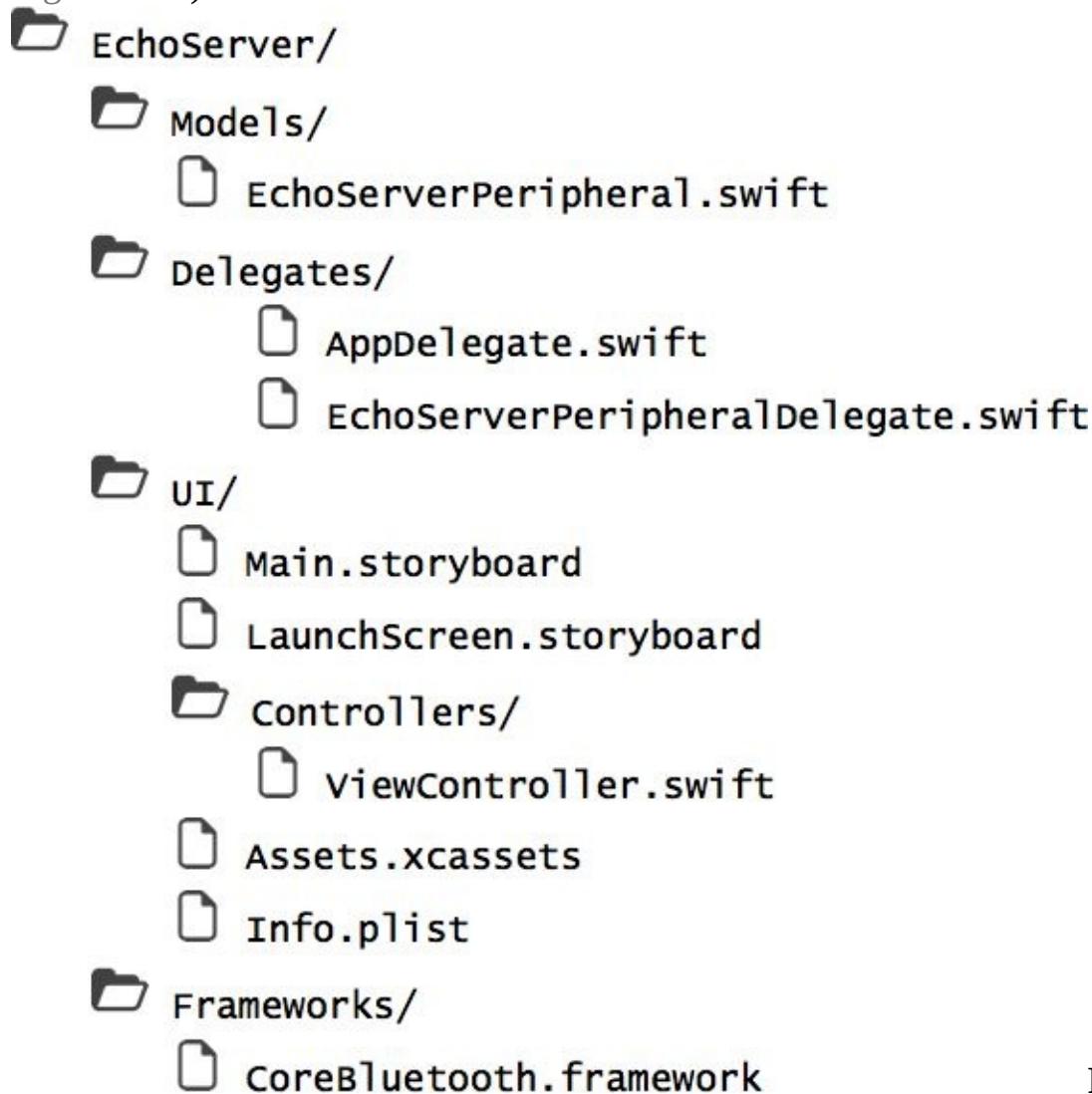
```

```
request.value = value.subdata(in: range)
peripheral.respond(to: request, withResult: CBATTError.success) }
}
}
```

Putting It All Together

The following code will create an App that advertises a Peripheral, allows a Central to connect and write values to a writeable Characteristic, and will respond by copying that value to a readable, notifiable Characteristic.

Create a new project called EchoServer and create the following file structure (Figure 12-6):



12-6. Project Structure

Figure

Frameworks

Import the CoreBluetooth Framework (Figure 12-7).

Linked Frameworks and Libraries	
Name	Status
 CoreBluetooth.framework	Required ▾
+	-

Figure 3-7.

CoreBluetooth Framework linked into project

Import the CoreBluetooth APIs in the code header:

```
import CoreBluetooth
```

Models

The EchoServer class will define the GATT Profile of the Echo Server, and will react to subscriptions, reads, and write events. Write events will set read Characteristic to the newly written Characteristic value and notify the connected Central of the change.

Example 12-4. Models/EchoServerPeripheral.swift

```
import UIKit
import CoreBluetooth
class EchoServerPeripheral : NSObject, CBPeripheralManagerDelegate {
    // MARK: Peripheral properties
    // Advertized name
    let advertisingName = "EchoServer"
    // Device identifier
    let peripheralIdentifier = "8f68d89b-448c-4b14-aa9a-f8de6d8a4753"
    // MARK: GATT Profile
    // Service UUID
    let serviceUuid = CBUUID(string: "0000180c-0000-1000-8000-00805f9b34fb")
    // Characteristic UUIDs
    let readCharacteristicUuid = CBUUID(
        string: "00002a56-0000-1000-8000-00805f9b34fb") let writeCharacteristicUuid =
    CBUUID(
        string: "00002a57-0000-1000-8000-00805f9b34fb")
    // Read Characteristic
    var readCharacteristic:CBMutableCharacteristic!
    // Write Characteristic
```

```

var writeCharacteristic:CBMutableCharacteristic!

// the size of a Characteristic let readCharacteristicLength = 20 let
writeCharacteristicLength = 20

// MARK: Peripheral State
// Peripheral Manager
var peripheralManager:CBPeripheralManager!
// Connected Central var central:CBCentral!
// delegate
var delegate:EchoServerPeripheralDelegate!
/***
Initialize BlePeripheral with a corresponding Peripheral

- Parameters:
- delegate: The BlePeripheralDelegate
- peripheral: The discovered Peripheral

*/
init(delegate: EchoServerPeripheralDelegate?) { super.init()
// empty dispatch queue let dispatchQueue:DispatchQueue! = nil

// Build Advertising options
let options:[String : Any] = [
//
CBPeripheralManagerOptionShowPowerAlertKey: true,
// Peripheral unique identifier
fier CBPeripheralManagerOptionRestoreIdentifierKey: peripheralIdentifi
]

peripheralManager = CBPeripheralManager(
delegate: self,
queue: dispatchQueue,
options: options)
self.delegate = delegate
}

/***
Stop advertising, shut down the Peripheral */

```

```

func stop() {
peripheralManager.stopAdvertising()
}

/***
Start Bluetooth Advertising.
This must be after building the GATT profile
**/

func startAdvertising() {
let serviceUuids = [serviceUuid]
let advertisementData:[String: Any] = [
    CBAdvertisementDataLocalNameKey: advertisingName,
    CBAdvertisementDataServiceUUIDsKey: serviceUuids ]
peripheralManager.startAdvertising(advertisementData) }

/***
Build Gatt Profile.
This must be done after Bluetooth Radio has turned on
**/

func buildGattProfile() {
let service = CBMutableService(type: serviceUuid, primary: true)

var rProperties = CBCharacteristicProperties.read
rProperties.formUnion(CBCharacteristicProperties.notify) var rPermissions =
CBAttributePermissions.writeable
rPermissions.formUnion(CBAttributePermissions.readable) readCharacteristic =
CBMutableCharacteristic(
    type: readCharacteristicUuid,
    properties: rProperties,
    value: nil,
    permissions: rPermissions)

let wProperties = CBCharacteristicProperties.write let wPermissions =
CBAttributePermissions.writeable writeCharacteristic =
CBMutableCharacteristic(
    type: writeCharacteristicUuid,
    properties: wProperties,
```

```
value: nil,
permissions: wPermissions)

service.characteristics = [ readCharacteristic, writeCharacteristic
]

peripheralManager.add(service) }
// MARK: CBPeripheralManagerDelegate

/** Peripheral will become active
*/
func peripheralManager(
    _ peripheral: CBPeripheralManager, willRestoreState dict: [String : Any])
{
    print("restoring peripheral state")
}

/**
Peripheral added a new Service
*/
func peripheralManager(
    _ peripheral: CBPeripheralManager, didAdd service: CBService,
    error: Error?)
{
    print("added service to peripheral") if error != nil {
        print(error.debugDescription)
    }

    /**
Peripheral started advertising
*/
func peripheralManagerDidStartAdvertising( _ peripheral:
    CBPeripheralManager, error: Error?)
```

```

{
if error != nil {
print ("Error advertising peripheral") print(error.debugDescription)

}
self.peripheralManager = peripheral delegate?.echoServerPeripheral?
(startedAdvertising: error) }

/***
Connected Central requested to read from a Characteristic */

func peripheralManager(
_peripheral: CBPeripheralManager,
didReceiveRead request: CBATTRequest)

{
let characteristic = request.characteristic if (characteristic.uuid ==
readCharacteristic.uuid) {

if let value = characteristic.value {
if request.offset > value.count {
peripheralManager.respond(
to: request,
withResult: CBATTError.invalidOffset) return

}
let range = Range(uncheckedBounds: ( lower: request.offset,
upper: value.count - request.offset)) request.value = value.subdata(in: range)

peripheral.respond(
to: request,
withResult: CBATTError.success)

}
}

}

/***
Connected Central requested to write to a Characteristic */

```

```

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    didReceiveWrite requests: [CBATTRequest])

{
    for request in requests {
        peripheral.respond(to: request, withResult: CBATTError.success) print("new
request")
        if let value = request.value {

            print("notifying delegate")
            delegate?.echoServerPeripheral?(

                valueWritten: value,
                toCharacteristic: request.characteristic)

            // update readCharacteristic print("updating characteristic")
            readCharacteristic.value = value // notify subscribers
            print("notifying characteristic") peripheralManager.updateValue(


                value,
                for: readCharacteristic, onSubscribedCentrals: nil)

        }
    }
}

/***
Connected Central subscribed to a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    central: CBCentral,
    didSubscribeTo characteristic: CBCharacteristic)

{
    self.central = central
}

/** Connected Central unsubscribed from a Characteristic */

```

```

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    central: CBCentral,
    didUnsubscribeFrom characteristic: CBCharacteristic)

{
    self.central = central
}

/** Peripheral is about to notify subscribers of changes to a Characteristic */

func peripheralManagerIsReady(
    toUpdateSubscribers peripheral: CBPeripheralManager)
{
    print("Peripheral about to update subscribers")
}

/** Bluetooth Radio state changed */

func peripheralManagerDidUpdateState( _ peripheral: CBPeripheralManager)
{
    peripheralManager = peripheral
    switch peripheral.state {
        case CBManagerState.poweredOn:
            buildGattProfile()
            startAdvertising()
        default: break
    }
    delegate?.echoServerPeripheral?(stateChanged: peripheral.state)
}

}

```

Delegates

The BlePeripheralDelegate relays state changes and events from the Echo

Server, such as when the Echo Server begins Advertising and when data has been written:

Example 12-5. Delegates/EchoServerPeripheralDelegate.swift

```
import UIKit
import CoreBluetooth
@objc protocol EchoServerPeripheralDelegate : class {
    /**
     Echo Server State Changed
```

- Parameters:
- rssi: the RSSI
- blePeripheral: the BlePeripheral

```
    */
    @objc optional func echoServerPeripheral( stateChanged state:
        CBManagerState)
    /**
     Echo Server statrted advertising
```

- Parameters:
- error: the error message, if any */

```
@objc optional func echoServerPeripheral( startedAdvertising error: Error?)
```

Value written to Characteristic

- Parameters:
- value: the Data value written to the Charactersitic
- characteristic: the Characteristic that was written to */

```
@objc optional func echoServerPeripheral(
    valueWritten value: Data,
    toCharacteristic: CBCharacteristic)
```

```
}
```

Storyboard

Create the UISwitches, UITextView, and UILabels in the UIView in the Main.storyboard to create the App's user interface (Figure 12-8).

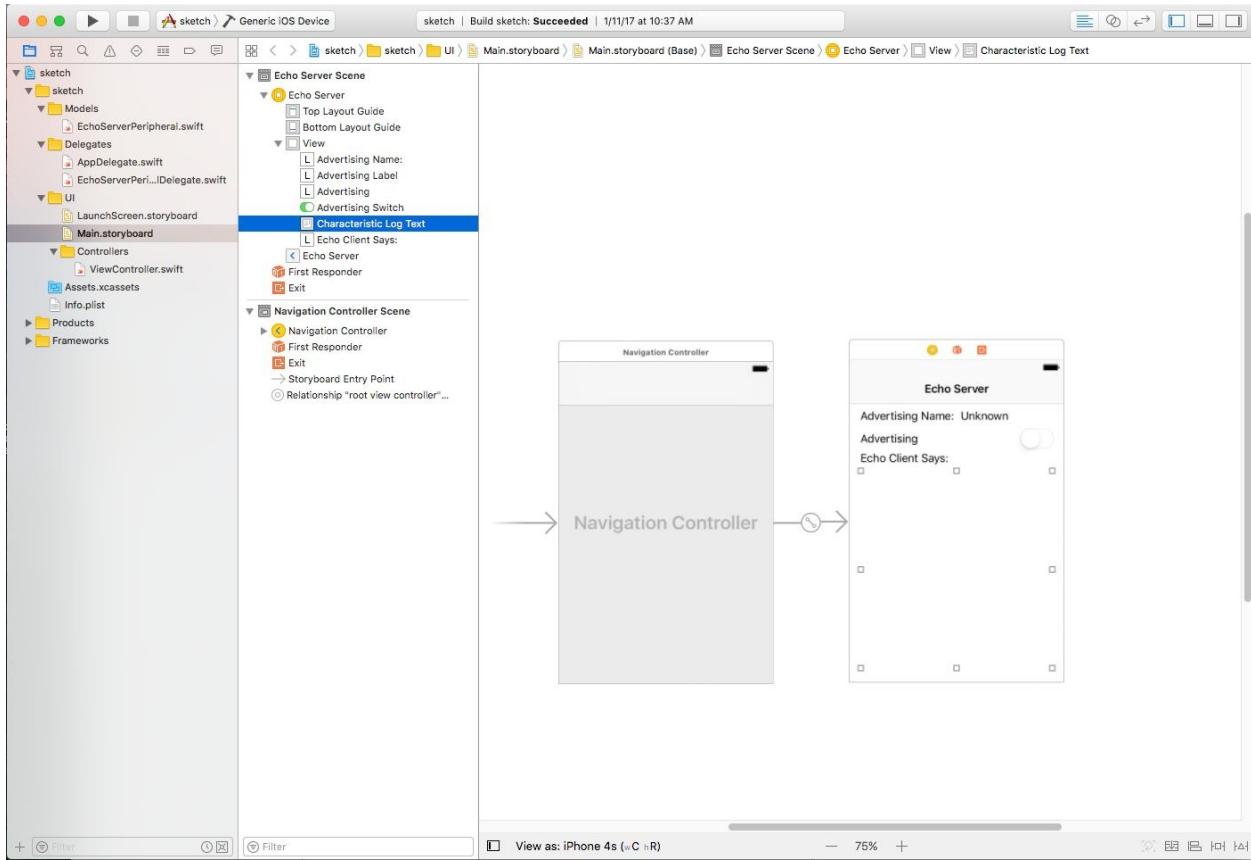


Figure 12-8. Project Storyboard Controllers

The View will display a log of the incoming text written to the EchoServer's write Characteristic (0x2a57) as well as a switch indicating the Advertising state of the EchoServer (Figure 12-9).

Example 12-6. UI/Controllers/ViewController.swift

```
import UIKit
import CoreBluetooth
class ViewController: UIViewController, EchoServerPeripheralDelegate {

    // MARK: UI Elements
    @IBOutlet weak var advertisingLabel: UILabel!
    @IBOutlet weak var advertisingSwitch: UISwitch!
    @IBOutlet weak var characteristicLogText: UITextView!

    // MARK: BlePeripheral
    // BlePeripheral
    var echoServer: EchoServerPeripheral!
```

```

/**
UIView loaded
*/
override func viewDidLoad() { super.viewDidLoad()
}

/**
View appeared. Start the Peripheral
*/
override func viewDidAppear(_ animated: Bool) { echoServer =
EchoServerPeripheral(delegate: self) advertisingLabel.text =
echoServer.advertisingName }

/**
View will appear. Stop transmitting random data */
override func viewWillDisappear(_ animated: Bool) { echoServer.stop()
}

/**
View disappeared. Stop advertising
*/
override func viewDidDisappear(_ animated: Bool) {
advertisingSwitch.setOn(false, animated: true)
}

// MARK: BlePeripheralDelegate
/**
Echo Server state changed
- Parameters:
- state: the CBManagerState representing the new state */

func echoServerPeripheral(stateChanged state: CBManagerState) { switch
(state) {
case CBManagerState.poweredOn:

```

```
print("Bluetooth on")
case CBManagerState.poweredOff:
print("Bluetooth off")
default:
print("Bluetooth not ready yet...")
}
}
/**
EchoServerPeripheral started advertising
```

- Parameters:
- error: the error message, if any

```
func echoServerPeripheral(startedAdvertising error: Error?) { if error != nil {
```

```
print("Problem starting advertising: " + error.debugDescription)
```

```
} else {
print("advertising started")
advertisingSwitch.setOn(true, animated: true)
```

```
}
}
/**
Value written to Characteristic
```

- Parameters:
- stringValue: the value read from the Characteristic
- characteristic: the Characteristic that was written to

```
*/
```

```
func echoServerPeripheral(
valueWritten value: Data,
toCharacteristic: CBCharacteristic)
```

```
{
print("converting data to String")
let stringValue = String(data: value, encoding: .utf8) if let stringValue =
stringValue {
```

```
print("writing to textView")
characteristicLogText.text = characteristicLogText.text + "\n" + stringValue
if !characteristicLogText.text.isEmpty {
    characteristicLogText.scrollRangeToVisible( NSMakeRange(0, 1))
} }
```

The resulting Peripheral App can respond to incoming Characteristic write requests by echoing the value back through a second Characteristic, so that the connected Central can read it back (Figure 12-9).

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.bluetooth 44% ⚡

Echo Server

Advertising Name: EchoServer

Advertising



Echo Client Says:

hello

Figure 12-9. App screen showing interface to read from and write to the Echo Server

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter12>

Project: Remote Control LED

So far, this book has worked a lot with text data rather than binary data, because it's easy to text without using specialized tools such as oscilloscopes or logic analyzers.

Most real-world projects transmit binary instead of text. Binary is much more efficient in transmitting information.

Because binary data it is the language of computers, it is easier to work with than text. There is no need to worry about character sets, null characters, or cut-off words.

This project will show how to remotely control an LED on a Peripheral using software on a Central.

The LED Remote works like this (Figure 13-1).

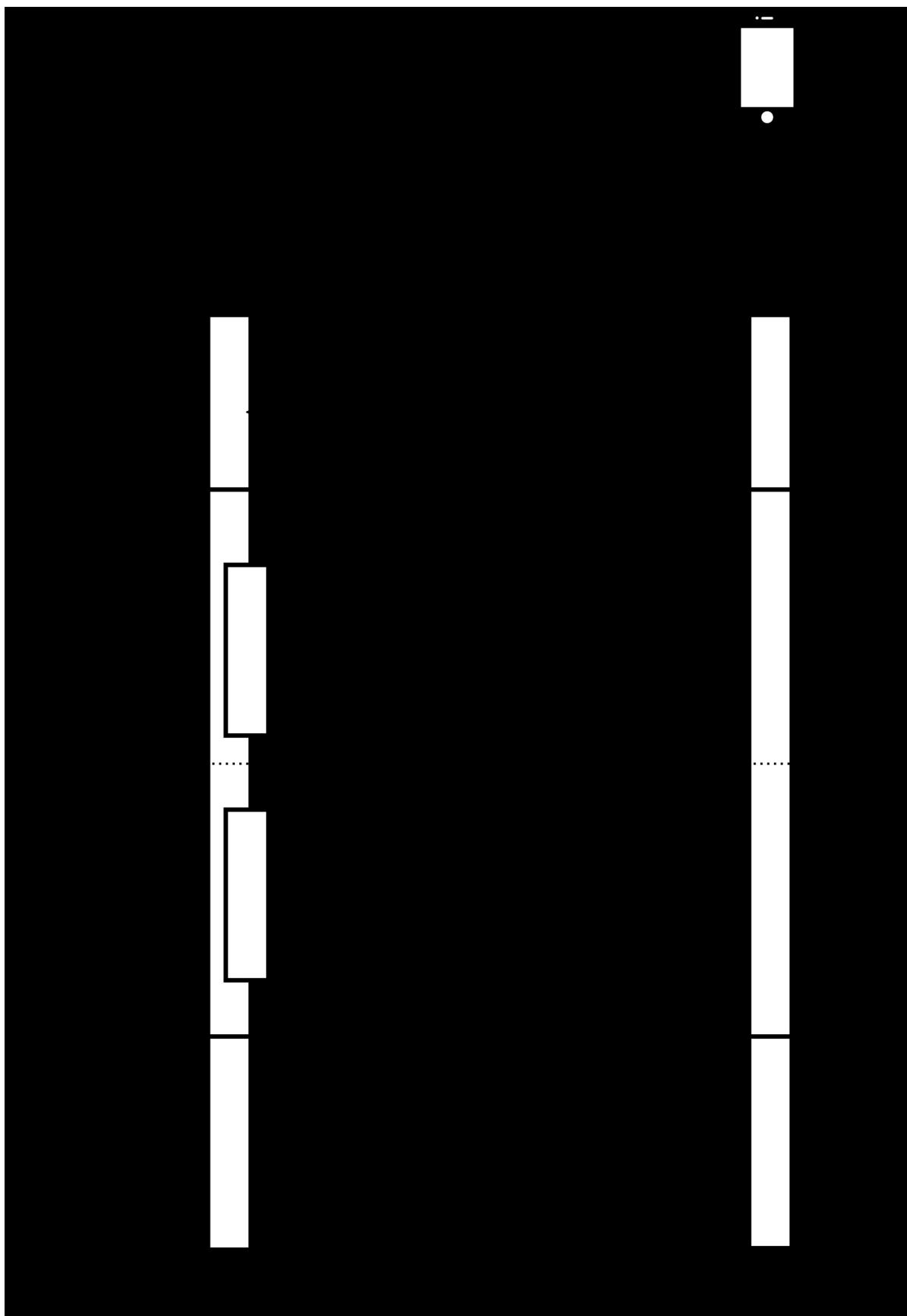


Figure 13-1. How a Remote Control LED works

In all the other examples, text was being sent between Central and Peripheral. In order for the Central and Peripheral to understand each other, they need shared language between them. In this case, a data packet format.

Sending Commands to Peripheral

When the Central sends a message, it should be able to specify if it is sending a command or an error. We can do this in two bytes, like this (Figure 13-2).

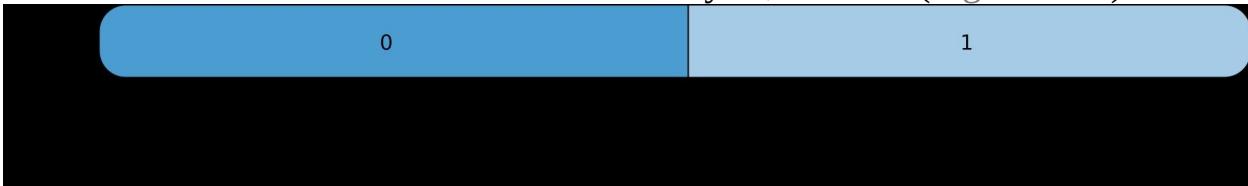


Figure 13-2. Packet structure for commands

The Peripheral reads the footer byte of the incoming message to determine the type of message, i.e., an error or a command. For example, define the message types as:

Table 13-1. Footer Values

Name Value Description

bleResponseError 0 The Central is sending an error

bleResponseConfirmation 1 The Central is sending a confirmation

bleResponseCommand 2 The Central is sending a command

The Peripheral reads the first byte to determine the type of error or command.

For example, define the commands as:

Table 13-2. Command Values

Name Value Description

bleCommandLedOff 1 Turn off the Peripheral's LED

bleCommandLedOn 2 Turn on the Peripheral's LED

The Peripheral then responds to the Central with a status message regarding the success or failure to execute the command. This can also be expressed as two bytes (Figure 13-3).

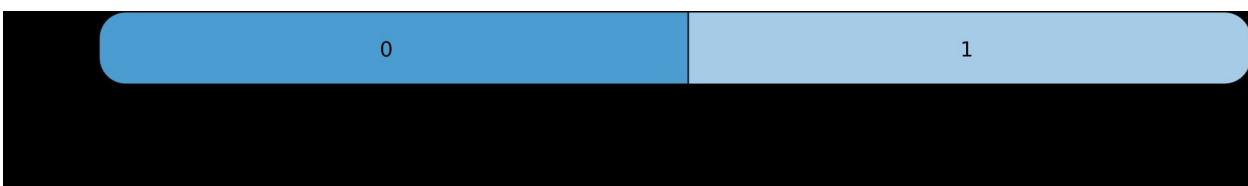


Figure 13-3. Packet structure for responses

If the Peripheral sends a confirmation that the LED state has changed, then the Central inspects the first byte of the message to determine what the current state of the Peripheral's LED is:

Table 13-3. Confirmation Values

Name Value Description

ledStateOff 1 The Peripheral's LED is off

ledStateOn 2 The Peripheral's LED is on

In this way, a common language is established between the Central and the Peripheral.

Gatt Profile

The Bluetooth Low Energy specification provides a special Service, the Automation IO Service (0x1815), specifically for remote control devices such as this. It is a best practice to use each Characteristic for a single purpose. For this reason, Characteristic 0x2a56 will be used for sending commands to the Peripheral and Characteristic 0x2a57 will be used for responses from the Peripheral:

Table 13-4. Characteristic Usages

UUID Use

0x2a56 Send commands from Central to Peripheral **0x2a57** Send responses from Peripheral to Central

Programming the Central

This project shows how to send commands to a Peripheral from a Central.

GATT Profile

The GATT Profile will be set up as a digital input/output under the Automation IO (0x1815) Service, which commands to and responses from the Peripheral on separate Characteristics.

```
// the Service UUID  
static let serviceUuid = CBUUID(string: "1815")  
// The Characteristic UUID used to write commands to the Peripheral static let  
commandCharacteristicUuid = CBUUID(string: "2A56")  
// The Characteristic UUID used to write commands to the Peripheral static let  
responseCharacteristicUuid = CBUUID(string: "2A57")
```

Data Formatting

In order to read and write binary commands to the Peripheral, it and the Central must understand the same messages and formatting.

```
// the size of the characteristic let characteristicLength = 2
```

```
// MARK: Command Data Format  
let bleCommandFooterPosition:Int = 1 let bleCommandDataPosition:Int = 0 let  
bleCommandFooter:UInt8 = 1 let bleCommandLedOn:UInt8 = 1 let  
bleCommandLedOff:UInt8 = 2
```

```
// MARK: Response Data Format  
let bleResponseFooterPosition:Int = 1 let bleResponseDataPosition:Int = 0 let  
bleResponseErrorFooter = 0  
let bleResponseConfirmationFooter:UInt8 = 1 static let  
bleResponseLedError:UInt8 = 0 static let bleResponseLedOn:UInt8 = 1 static let  
bleResponseLedOff:UInt8 = 2
```

Enable Bluetooth

To turn on the Bluetooth radio programmatically, also enable Bluetooth admin permissions:

```
let centralManager = CBCentralManager(delegate: self, queue: nil) When the
Bluetooth radio turns on, begin scanning:
func centralManagerDidUpdateState(_ central: CBCentralManager) {

switch (central.state) {
case .poweredOn:
    central.scanForPeripherals(withServices: [serviceUuid], options: nil) default:
}
}
```

Whenever a device is discovered, the centralManager didDiscover callback is triggered by the CBPeripheralManager. If the Advertised name matches the desired RemoteLed name, connect:

```
func getNameFromAdvertisementData(
advertisementData: [String : Any]) -> String?
{
// grab thekCBAdvDataLocalName from the advertisementData // to see if
there's an alternate broadcast name
if advertisementData["kCBAdvDataLocalName"] != nil { return
(advertisementData["kCBAdvDataLocalName"] as! String) }
return nil
}

func centralManager(
    _ central: CBCentralManager,
    didDiscover peripheral: CBPeripheral,
    advertisementData: [String : Any],
    rssi RSSI: NSNumber)

{
// find the advertised name
if let advertisedName = getNameFromAdvertisementData(
    advertisementData: advertisementData) {
if advertisedName == "RemoteLed" {
    centralManager.connect(peripheral, options: nil)
}}
```

```
}
```

```
}
```

```
}
```

Connecting

Once a Peripheral is connected, the centralManager didConnect callback is triggered by the CBPeripheralManager. Use this to build a map of the GATT profile, starting with the Services:

```
var connectedPeripheral:CBPeripheral! func centralManager(  
    _ central: CBCentralManager,  
    didConnect peripheral: CBPeripheral) {  
    // store a copy of the connected Peripheral so it isn't tossed  
    connectedPeripheral = peripheral;  
    connectedPeripheral.delegate = self;  
    peripheral.discoverServices(serviceUuid)  
}
```

Discovering GATT

Once services are discovered, the peripheral didDiscoverServices callback is triggered by the CBPeripheralDelegate. Since the Remote is known to have a Service with UUID 0x1815, search for that service and request discovery of the two known Characteristics, 0x2a56 and 0x2a57:

```
func peripheral(  
    _ peripheral: CBPeripheral, didDiscoverServices error: Error?)  
  
{  
    // update the local copy of the Peripheral connectedPeripheral = peripheral  
  
    if error != nil {  
        // error  
    } else {  
        for service in peripheral.services!{  
            if service.uuid == serviceUuid {  
                connectedPeripheral.discoverCharacteristics([readCharacteristicUuid,  
                    writeCharacteristicUuid],
```

```
for: service)
}
}
}
}
```

A list of Characteristics for each Service will come back in the peripheral didDiscoverCharacteristicsFor callback in CBPeripheralManagerDelegate. Use this to subscribe to the Read Characteristics and to save references to each Characteristic:

```
func peripheral(
    _ peripheral: CBPeripheral,
    didDiscoverCharacteristicsFor service: CBService, error: Error?)

{
    // update local copy of the peripheral connectedPeripheral = peripheral
    connectedPeripheral.delegate = self
    // grab the service
    let serviceIdentifier = service.uuid.uuidString

    if let characteristics = service.characteristics {
        for characteristic in characteristics {
            if characteristic.uuid.uuidString == \commandCharacteristicUuid

            { commandCharacteristic = characteristic
            } else if characteristic.uuid.uuidString == \responseCharacteristicUuid
            {
                responsecharacteristic = characteristic
                connectedPeripheral.setNotifyValue( true,
                    for: characteristic)
            }
        }
    }
}
```

Sending Commands

To write the command, build a byte array based on the defined command data structure, and convert to a Data object. Then write the value using the CBPeripheral.writeValue method:

```
func writeCommand(ledCommandState: UInt8) {  
    if peripheral != nil {  
        // build byte array data structure  
  
        var command = [UInt8](repeating: 0, count: characteristicLength)  
        command[bleCommandDataPosition] = ledCommandState  
        command[bleCommandFooterPosition] = bleCommandFooter  
  
        // convert byte array into Data  
        let value = Data(command)  
        peripheral.writeValue(value, for: commandCharacteristic)  
  
    }  
}
```

Subscribing to and Unsubscribing from Notifications

If the Characteristic can send notifications, the Central can subscribe to notifications or unsubscribe from them by setting the Notification value for that Characteristic

```
// Subscribe to Notifications on a Characteristic peripheral.setNotifyValue(true,  
for: characteristic)  
// Unsubscribe from Notification on a Characteristic  
peripheral.setNotifyValue(false, for: characteristic)
```

Receiving Responses

The peripheral didUpdateValueFor callback will be triggered by the CBPeripheralDelegate when the Peripheral has sent a response. This response can be decoded to determine if the LED turned on or off:

```
func peripheral(  
    _ peripheral: CBPeripheral, d  
idUpdateValueFor characteristic: CBCharacteristic, error: Error?)
```

```
{  
if let value = characteristic.value { let responseValue = [UInt8](value)  
  
// decode message  
let responseType = responseValue[bleResponseFooterPosition] switch  
responseType {  
case bleResponseConfirmationFooter:  
let response = responseValue[bleResponseDataPosition]  
  
if response == bleResponseLedOn { // LED was turned on  
} else {  
// LED was turned off  
}  
default:  
}  
}  
}  
}
```

Putting It All Together

The following code will create a single Activity App with a toggle switch that connects to a Peripheral. Once connected the user can flip the toggle back and fourth, which issues a command to the Peripheral to turn an LED on or off. The switch changes state when the App receives confirmation that the

Create a new project called LedRemote.

Create folders and classes, and XML files to reproduce the following structure (Figure 13-4).

```
LedRemote/
  └── Models/
    └── RemoteLed.swift
  └── Delegates/
    └── AppDelegate.swift
    └── BluePeripheralDelegate.swift
  └── UI/
    └── Main.storyboard
    └── LaunchScreen.storyboard
  └── Controllers/
    └── CharacteristicViewController.swift
  └── Assets.xcassets
  └── Info.plist
  └── Frameworks/
    └── CoreBluetooth.framework
```

Figure 13-4.

Project structure

Frameworks

Import the CoreBluetooth Framework (Figure 13-5).

Linked Frameworks and Libraries	
Name	Status
CoreBluetooth.framework	Required
+	-

Figure 13-5.

CoreBluetooth Framework linked into project

Import the CoreBluetooth APIs in the code header:

import CoreBluetooth

Objects

The BleCommManager turns the Bluetooth radio on and scans for nearby Peripherals.

Example 13-1. Models/RemoteLed.swift

```
import UIKit
import CoreBluetooth
class RemoteLed:NSObject, CBPeripheralDelegate {
// MARK: Peripheral properties

// The Broadcast name of the Perihperal
static let advertisedName = "LedRemote"
// the Service UUID
static let serviceUuid = CBUUID(string: "1815")
// The Characteristic UUID used to write commands to the Peripheral static let
commandCharacteristicUuid = CBUUID(string: "2A56") // The Characteristic
UUID used to write commands to the Peripheral static let
responseCharacteristicUuid = CBUUID(string: "2A57") // the size of the
characteristic
let characteristicLength = 2

// MARK: Command Data Format

// Footer data position
let bleCommandFooterPosition:Int = 1 // Message data position
let bleCommandDataPosition:Int = 0 // Command
let bleCommandFooter:UInt8 = 1
// Turn the LED on
let bleCommandLedOn:UInt8 = 1
// Turn the LED off
let bleCommandLedOff:UInt8 = 2
// MARK: Response Data Format
// Footer data position
let bleResponseFooterPosition:Int = 1 // Message data position
let bleResponseDataPosition:Int = 0 // Error response
let bleResponseErrorFooter = 0
// Confirmation response
let bleResponseConfirmationFooter:UInt8 = 1 // Error Response
static let bleResponseLedError:UInt8 = 0 // Confirmation response
static let bleResponseLedOn:UInt8 = 1 // Command
static let bleResponseLedOff:UInt8 = 2
```

```

// MARK: connected device

// RemoteLedDelegate
var delegate:RemoteLedDelegate!
// connected Peripheral
var peripheral:CBPeripheral!
// connected Characteristic
var commandCharacteristic:CBCharacteristic! var
responseCharacteristic:CBCharacteristic!

/**
Initialize EchoServer with a corresponding Peripheral

- Parameters:
- delegate: The RemoteLEDPeripheral
- peripheral: The discovered Peripheral

*/
init(delegate: RemoteLedDelegate, peripheral: CBPeripheral) { super.init()
self.delegate = delegate
self.peripheral = peripheral
self.peripheral.delegate = self

}

/**
Notify the RemoteLed that the peripheral has been connected */

func connected(peripheral: CBPeripheral) {
self.peripheral = peripheral
self.peripheral.delegate = self
self.peripheral.discoverServices([RemoteLed.serviceUuid])

}

/**
Get a advertised name from an advertisementData packet. This may be different
than the actual Peripheral name */

static func getNameFromAdvertisementData(

```

```

advertisementData: [String : Any]) -> String?
{
// grab thekCBAdvDataLocalName from the advertisementData // to see if
there's an alternate broadcast name
if advertisementData["kCBAdvDataLocalName"] != nil { return
(advertisementData["kCBAdvDataLocalName"] as! String) }
return nil
}

/**
Turn the remote LED on */
func turnLedOn() {

writeCommand(ledCommandState: bleCommandLedOn) }

/**
Turn the remote LED off
*/
func turnLedOff() {

writeCommand(ledCommandState: bleCommandLedOff) }

/**
Write a command to the remote
*/
func writeCommand(ledCommandState: UInt8) {
if peripheral != nil {
var command = [UInt8](repeating: 0, count: characteristicLength)
command[bleCommandDataPosition] = ledCommandState
command[bleCommandFooterPosition] = bleCommandFooter let value =
Data(command)
print("writing value: \(value)")
var writeType = CBCharacteristicWriteType.withResponse if
RemoteLed.isCharacteristic(


isWriteableWithoutResponse: commandCharacteristic) {
writeType = CBCharacteristicWriteType.withoutResponse }
peripheral.writeValue(

```

```

value,
for: commandCharacteristic,
type: writeType)
}

}

/** Check if Characteristic is readable
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is readable */
static func isCharacteristic(
isReadable characteristic: CBCharacteristic) -> Bool {
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.read.rawValue) != 0 {
print("readable")
return true
}
return false
}

/** 
Check if Characteristic is writeable
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is writeable */
static func isCharacteristic(
isWriteable characteristic: CBCharacteristic) -> Bool

{
print("testing if characteristic is writeable")
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.write.rawValue) != 0 ||
(characteristic.properties.rawValue & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0

{
print("characteristic is writeable") return true
}

```

```
}

print("characetiristic is not writeable") return false

}

/***
Check if Characteristic is writeable with response
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is writeable with response */
static func isCharacteristic(
isWriteableWithResponse characteristic: CBCharacteristic) -> Bool {
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.write.rawValue) != 0 {

return true }
return false }

/***
Check if Characteristic is writeable without response
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is writeable without response */
static func isCharacteristic(
isWriteableWithoutResponse characteristic: CBCharacteristic) -> Bool {
if (characteristic.properties.rawValue & \
CBCharacteristicProperties.writeWithoutResponse.rawValue) != 0 {

return true }
return false }

/***
Check if Characteristic is notifiable
- Parameters:
- characteristic: The Characteristic to test
- returns: True if characteristic is notifiable */
static func isCharacteristic(
isNotifiable characteristic: CBCharacteristic) -> Bool {
if (characteristic.properties.rawValue &
```

```

CBCharacteristicProperties.notify.rawValue) != 0 {
    return true }
    return false }

// MARK: CBPeripheralDelegate

/**
Characteristic has been subscribed to or unsubscribed from */

func peripheral(
    _ peripheral: CBPeripheral,
    didUpdateNotificationStateFor characteristic: CBCharacteristic, error: Error?)

{
    print("Notification state updated for: " + "\(characteristic.uuid.uuidString)")
    print("New state: \(characteristic.isNotifying)")

    if let errorMessage = error {
        print("error subscribing to notification: ")
        print(errorMessage.localizedDescription as String)
    }
}

/**
Value downloaded from Characteristic on connected Peripheral */

func peripheral(
    _ peripheral: CBPeripheral,
    didUpdateValueFor characteristic: CBCharacteristic, error: Error?)

{
    if let value = characteristic.value { print(value.debugDescription)

        print(value.description as String)
        let responseValue = [UInt8](value)

        // decode message
        let responseType = responseValue[bleResponseFooterPosition] switch
            responseType {

```

```

case bleResponseConfirmationFooter:

print("ble device responded")
let response = responseValue[bleResponseDataPosition]
delegate.remoteLed(confirmationReceived: response) default:
print("ble response unknown") }
}

/***
Servicess were discovered on the connected Peripheral */

func peripheral(
    _ peripheral: CBPeripheral,
    didDiscoverServices error: Error?) {

{
print("services discovered")

if error != nil {
print("Discover service Error: \(error)")
} else {
print("Discovered Service")
for service in peripheral.services!{
if service.uuid == RemoteLed.serviceUuid {
self.peripheral.discoverCharacteristics( [
RemoteLed.commandCharacteristicUuid,
RemoteLed.responseCharacteristicUuid ],
for: service)
}
}
print(peripheral.services!)
print("DONE")
}
}
/***
Characteristics were discovered
for a Service on the connected Peripheral
*/

```

```
func peripheral(  
    _ peripheral: CBPeripheral,  
    didDiscoverCharacteristicsFor service: CBService, error: Error?)  
{  
    print("characteristics discovered")  
  
    // grab the service  
    let serviceIdentifier = service.uuid.uuidString  
    print("service: \(serviceIdentifier)")  
  
    if let characteristics = service.characteristics { print("characteristics found: \(characteristics.count)") }  
    for characteristic in characteristics {  
  
        if characteristic.uuid == \  
            RemoteLed.commandCharacteristicUuid {  
            commandCharacteristic = characteristic }  
        else if characteristic.uuid == \  
            RemoteLed.responseCharacteristicUuid {  
            responseCharacteristic = characteristic  
            print(" -> \(characteristic.uuid.uuidString): \(characteristic.properties.rawValue)")  
            if RemoteLed.isCharacteristic(  
                isNotifiable: responseCharacteristic)  
            {  
                self.peripheral.setNotifyValue( true,  
                    for: responseCharacteristic)  
            }  
        }  
    }  
    delegate.remoteLed(connectedToCharacteristics: [ responseCharacteristic,  
        commandCharacteristic  
    ])  
}
```

Delegates

Create an `RemoteLedDelegate` that relays important events from the `RemoteLed`.

Example 13-2. Delegates/RemoteLedDelegate.swift

```

import UIKit
import CoreBluetooth
protocol RemoteLedDelegate {
    /**
     Characteristic was connected on the Remote LED
     - Parameters:
     - characteristic: the connected Characteristic
     */
    func remoteLed(
        connectedToCharacteristics characteristics: [CBCharacteristic])
    /**
     Error received from Remote
     - Parameters
     - messageValue: an error response */
    func remoteLed(errorReceived messageValue: String)
    /**
     Remote command was successful and a response was issued
     - Parameters:
     - ledState: one of RemoteLed.ledOn or RemoteLed.ledOff
     */
    func remoteLed(confirmationReceived ledState: UInt8) }

```

Storyboard

Create the UISwitches, UITextView, and UILabels in the UIView in the Main.storyboard to create the App's user interface (Figure 13-6):

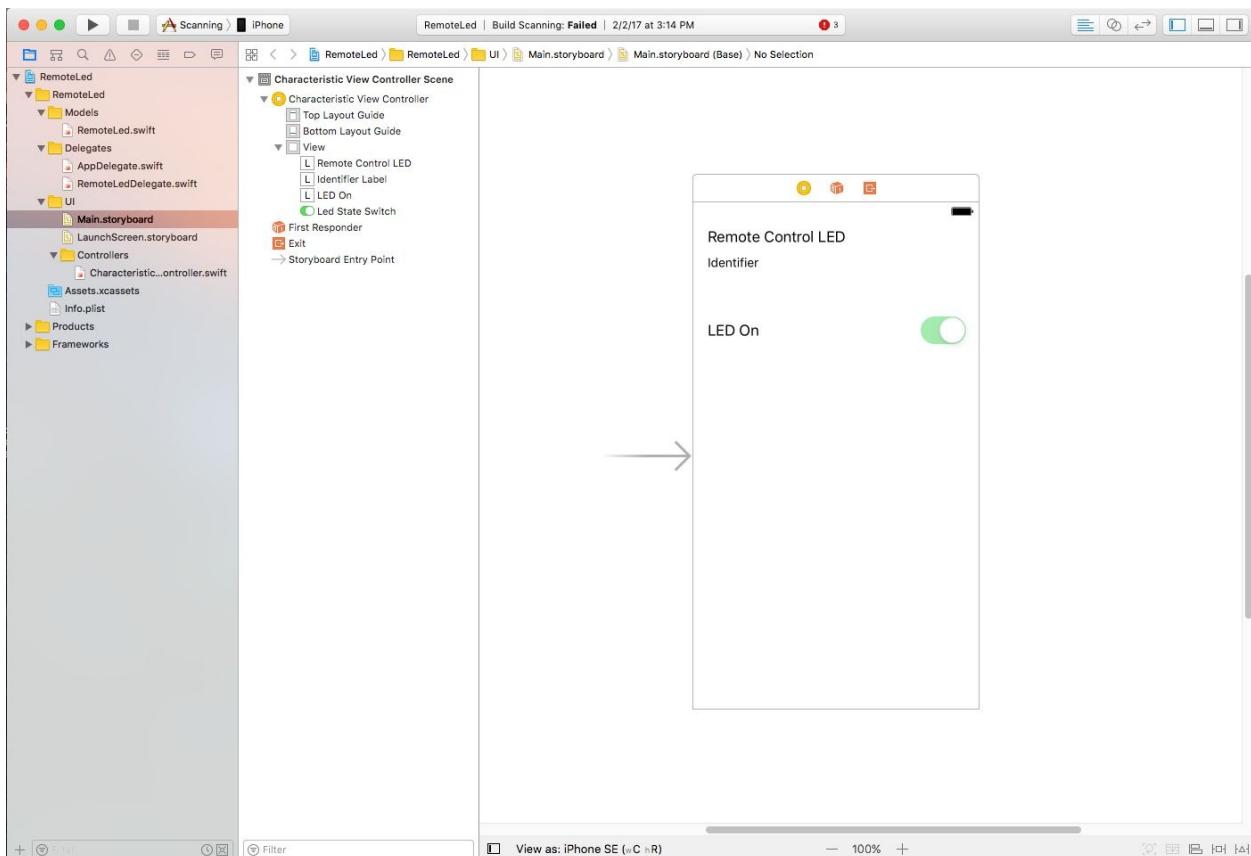


Figure 13-6. Project Storyboard Controllers

The Main activity will have a switch and a label describing what the switch does. When the user toggles the switch, the UIViewController will issue a command to the Peripheral to turn its LED on or off.

Example 13-3. UI/Controllers/CharacteristicViewController.swift

```
import UIKit
import CoreBluetooth
class CharacteristicViewController: UIViewController, \
```

```
CBCentralManagerDelegate, RemoteLedDelegate {
// MARK: UI Components
@IBOutlet weak var identifierLabel: UILabel! @IBOutlet weak var
ledStateSwitch: UISwitch!

// MARK: Bluetooth stuff
// Bluetooth Radio
var centralManager:CBCentralManager!
```

```
// the remote Peripheral var remoteLed:RemoteLed!

/***
View loaded
**/

override func viewDidLoad() {
super.viewDidLoad()
centralManager = CBCentralManager(delegate: self, queue: nil)

}

/***
LED switch toggled
**/

@IBAction func onLedStateSwitchTouchUp(_ sender: UISwitch) { // prevent
user interaction during update
sender.isEnabled = false
if sender.isOn {

print("led switched on")
remoteLed.turnLedOn()

} else {
print("led switched off")
remoteLed.turnLedOff()

}
}
// MARK: RemoteLedDelegate

/***
Characteristic was connected on the Remote LED. Update UI */

func remoteLed(
connectedToCharacteristics characteristics: [CBCharacteristic])
{
ledStateSwitch.isEnabled = true remoteLed.turnLedOn()
}
```

```

/**
Error received from Remote. Update UI
*/

func remoteLed(errorReceived messageValue: String) { // There was a problem.
flip the switch back ledStateSwitch.isOn = !ledStateSwitch.isOn
ledStateSwitch.isEnabled = true

}

/***
Remote command was successful and a response was issued. Update UI */

func remoteLed(confirmationReceived ledState: UInt8) { if ledState ==
RemoteLed.bleResponseLedOn {
print("led turned on")
ledStateSwitch.isOn = true

} else {
print("led turned off")
ledStateSwitch.isOn = false

}
ledStateSwitch.isEnabled = true
}

// MARK: CBCentralManagerDelegate /**
centralManager is called each time a new Peripheral is discovered

- parameters
- central: the CentralManager for this UIView
- peripheral: A discovered Peripheral
- advertisementData: Bluetooth advertisement found with Peripheral
- rssi: the radio signal strength indicator for this Peripheral

*/
func centralManager(
    _ central: CBCentralManager,
    didDiscover peripheral: CBPeripheral,
    advertisementData: [String : Any], rssi RSSI: NSNumber) {

```

```

//print("Discovered \$(peripheral.name)")
print("Discovered \$(peripheral.identifier.uuidString) " + \$(peripheral.name))
remoteLed = RemoteLed(delegate: self, peripheral: peripheral)
// find the advertised name
if let advertisedName = RemoteLed.getNameFromAdvertisementData(
advertisementData: advertisementData)
{
if advertisedName == RemoteLed.advertisedName { print("connecting to
peripheral...") centralManager.connect(peripheral, options: nil) }
}
}

/***
Peripheral connected.

```

- Parameters:
- central: the reference to the central
- peripheral: the connected Peripheral */

```

func centralManager(
    _ central: CBCentralManager, didConnect peripheral: CBPeripheral)

```

```

{
print("Connected Peripheral: \$(peripheral.name)")
remoteLed.connected(peripheral: peripheral)
// Do any additional setup after loading the view.
identifierLabel.text = remoteLed.peripheral.identifier.uuidString

```

```
}
```

```
/***
```

Peripheral disconnected

- Parameters:
- central: the reference to the central
- peripheral: the connected Peripheral

```
*/
```

```

func centralManager(
    _ central: CBCentralManager,
didDisconnectPeripheral peripheral: CBPeripheral, error: Error?)

```

```
{  
// disconnected. Leave print("disconnected")
```

```
}  
/**
```

```
Bluetooth radio state changed
```

- Parameters:

- central: the reference to the central

```
*/
```

```
func centralManagerDidUpdateState(_ central: CBCentralManager) {  
print("Central Manager updated: checking state") switch (central.state) {  
  
case .poweredOn:  
print("bluetooth on")  
centralManager.scanForPeripherals(  
  
withServices: [RemoteLed.serviceUuid], options: nil)  
default:  
print("bluetooth unavailable")  
}  
}  
}
```

The resulting App scan for and connect to a Bluetooth Low Energy Peripheral. Once connected, the user can turn the Peripheral's LED on or off using the switch. When the LED turns on. The switch fully moves when the App receives confirmation from the Peripheral that the LED state has changed (Figure 13-7).

●●●○○ Fido 3G

21:17

蓝牙 100%  ⚡

Remote Control LED

Identifier

LED On



●●●○○ Fido 3G

21:16

蓝牙 100%  ⚡

Remote Control LED

Identifier

LED On



Figure 13-7. App screen showing LED switch in on and off states

Programming the Peripheral

This project shows how to process commands sent from a Central, and respond with status confirmations.

Data Formatting

In order to read and write binary commands to the Peripheral, it and the Central must understand the same messages and formatting. To best emulate a typical Bluetooth device, UInt8 data types are used to represent the binary commands. Regular Integers are used for positions:

```
// MARK: Commands

// Data Positions
let bleCommandFooterPosition = 1; let bleCommandDataPosition = 0;

// Command flag
let bleCommandFooter:UInt8 = 1;

// LED State
let bleCommandLedOn:UInt8 = 1; let bleCommandLedOff:UInt8 = 2;

// MARK: Response

// Data Positions
let bleResponseFooterPosition = 1; let bleResponseDataPosition = 0;

// Response Types
let bleResponseErrorFooter:UInt8 = 0; let
bleResponseConfirmationFooter:UInt8 = 1;

// LED States
let bleResponseLedError:UInt8 = 0; let bleResponseLedOn:UInt8 = 1; let
bleResponseLedOff:UInt8 = 2;
```

Advertising and GATT Profile

The GATT Profile will be set up as a digital input/output under the Automation IO (0x1815) Service, with commands to and responses from the Peripheral on separate Characteristics.

The Peripheral will host a writeable Characteristic on UUID 0x2a56 to receive commands and a read-only, notifiable Characteristic on UUID 0x2a57 to issue responses:

```
// Service UUID
let serviceUuid = CBUUID(string: "00001815-0000-1000-8000-00805f9b34fb")
// Characteristic UUIDs
let commandCharacteristicUuid =
    CBUUID(string: "00002a56-0000-1000-8000-00805f9b34fb") let
    responseCharacteristicUuid =
        CBUUID(string: "00002a57-0000-1000-8000-00805f9b34fb")

// Command Characteristic
var commandCharacteristic:CBMutableCharacteristic!
// Response Characteristic
var responseCharacteristic:CBMutableCharacteristic!
// Create Service
let service = CBMutableService(type: serviceUuid, primary: true)

var rProperties = CBCharacteristicProperties.read
rProperties.formUnion(CBCharacteristicProperties.notify) var rPermissions =
    CBAttributePermissions.writeable
rPermissions.formUnion(CBAttributePermissions.readable)
responseCharacteristic = CBMutableCharacteristic(
    type: responseCharacteristicUuid,
    properties: rProperties,
    value: nil,
    permissions: rPermissions)

let cProperties = CBCharacteristicProperties.write let cPermissions =
    CBAttributePermissions.writeable commandCharacteristic =
        CBMutableCharacteristic(
            type: commandCharacteristicUuid,
            properties: cProperties,
```

```
    value: nil,  
    permissions: cPermissions)  
  
// add Characteristics to Service  
service.characteristics = [ responseCharacteristic, commandCharacteristic ] //  
add Service to Peripheral  
peripheralManager.add(service)
```

It will also advertise as "LedRemote" so as to be discoverable by the corresponding Central.

```
// Advertized name  
let advertisingName = "LedRemote"  
  
// build Advertising Data  
let serviceUuids = [serviceUuid]  
let advertisementData:[String: Any] = [
```

```
CBAdvertisementLocalNameKey: advertisingName,  
CBAdvertisementServiceUUIDsKey: serviceUuids ]  
// start Advertising  
peripheralManager.startAdvertising(advertisementData)
```

Handling Subscriptions and Writes

Once Central initiates a connection, it can subscribe to the response Characteristic (0x2a57), triggering the peripheralManager didSubscribeTo callback. This is used as an opportunity to store a reference to the connected Central:

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager,  
    central: CBCentral,  
    didSubscribeTo characteristic: CBCharacteristic)  
  
{  
    self.central = central  
}
```

When a Central writes data to the command Characteristic (0x2a56), the

RemoteLed will process the command and change the LED state. It will change the value of the response Characteristic (0x2a56) to match the new LED state and send a notification of that change.

```
func peripheralManager(  
    _ peripheral: CBPeripheralManager, didReceiveWrite requests:  
    [CBATTRequest])  
  
{  
    for request in requests {  
        peripheral.respond(to: request, withResult: CBATTError.success) if let value =  
            request.value {  
  
            let bleCommandValue = [UInt8](value)  
            processCommand(bleCommandValue: bleCommandValue) }  
    }  
}
```

The command is processed by reading the footer at position 1 to determine what type of message is being sent. If it is a command, position 0 is inspected to determine the LED state:

```
func processCommand(bleCommandValue: [UInt8]) {  
    if bleCommandValue[bleCommandFooterPosition] == bleCommandFooter {  
        print ("Command found")  
        switch (bleCommandValue[bleCommandDataPosition]) {  
  
            case bleCommandLedOn:  
                print("Turning LED on") setLedState(ledState: true)  
  
            case bleCommandLedOff:  
                print("Turning LED off") setLedState(ledState: false)  
  
            default:  
                print("Unknown command value")  
        }  
    }  
}
```

On iOS, it is possible to turn on the camera flash LED, like this:

```

func remoteLedPeripheral(ledStateChangedTo ledState: Bool) { if let device =
AVCaptureDevice.defaultDevice( withMediaType: AVMediaTypeVideo)
{
if (device.hasTorch) { do {

try device.lockForConfiguration()
try device.setTorchModeOnWithLevel(1.0)
if ledState {

print("Led turned on")
device.torchMode = AVCaptureTorchMode.on ledStateSwitch.setOn(true,
animated: true)

} else {
print("Led turned off")
device.torchMode = AVCaptureTorchMode.off ledStateSwitch.setOn(false,
animated: true)

}

device.unlockForConfiguration()

} catch let error as NSError {
print("problem locking camera: "+error.debugDescription)
}
}
}
}
}

```

Putting It All Together

The following code will create an App that turns the camera flash on and off when a command is received over a writeable Characteristic. A readable Characteristic is used to respond and notify the Connected central of the updated LED state.

Create a new project called RemoteLed with the following project structure (Figure 13-8).

```
📁 RemoteLed/
  📁 Models/
    ⚡ RemoteLedPeripheral.swift
  📁 Delegates/
    ⚡ AppDelegate.swift
    ⚡ RemoteLedPeripheralDelegate.swift
  📁 UI/
    ⚡ Main.storyboard
    ⚡ LaunchScreen.storyboard
  📁 Controllers/
    ⚡ ViewController.swift
    ⚡ Assets.xcassets
    ⚡ Info.plist
  📁 Frameworks/
    ⚡ CoreBluetooth.framework
```

Figure 13-

8. Project structure

Frameworks

Import the CoreBluetooth Framework (Figure 13-9):

Linked Frameworks and Libraries	
Name	Status
(CoreBluetooth.framework)	Required
+	-

Figure 13-9.

CoreBluetooth Framework linked into project

Import the CoreBluetooth APIs in the code header:

```
import CoreBluetooth
```

Models

The RemoteLedPeripheral class will define the GATT Profile for the Peripheral, and will react to read, write, and subscription events:

Example 13-4. Models/RemoteLedPeripheral.swift

```
import UIKit
import CoreBluetooth
class RemoteLedPeripheral : NSObject, CBPeripheralManagerDelegate {
// MARK: Peripheral properties

// Advertized name
let advertisingName = "LedRemote"
// Device identifier
let peripheralIdentifier = "8f68d89b-448c-4b14-aa9a-f8de6d8a4753"

// MARK: GATT Profile

// Service UUID
let serviceUuid = CBUUID(string: "00001815-0000-1000-8000-00805f9b34fb")
// Characteristic UUIDs
let commandCharacteristicUuid =
    CBUUID(string: "00002a56-0000-1000-8000-00805f9b34fb") let
responseCharacteristicUuid =
    CBUUID(string: "00002a57-0000-1000-8000-00805f9b34fb") // Command
Characteristic
var commandCharacteristic:CBMutableCharacteristic!
// Response Characteristic
var responseCharacteristic:CBMutableCharacteristic!
// the size of a Characteristic
let commandCharacteristicLength = 2
let responseCharacteristicLength = 2

// MARK: Commands

// Data Positions
let bleCommandFooterPosition = 1; let bleCommandDataPosition = 0; //
Command flag
let bleCommandFooter:UInt8 = 1; // LED State
let bleCommandLedOn:UInt8 = 1; let bleCommandLedOff:UInt8 = 2;

// MARK: Response
```

```
// Data Positions
let bleResponseFooterPosition = 1; let bleResponseDataPosition = 0; // Response
Types
let bleResponseErrorFooter:UInt8 = 0; let
bleResponseConfirmationFooter:UInt8 = 1; // LED States
let bleResponseLedError:UInt8 = 0;
let bleResponseLedOn:UInt8 = 1;
let bleResponseLedOff:UInt8 = 2
```

```
// MARK: Peripheral State
```

```
// Peripheral Manager
```

```
var peripheralManager:CBPeripheralManager! // Connected Central
var central:CBCentral!
```

```
// delegate
```

```
var delegate:RemoteLedPeripheralDelegate!
```

```
/**
```

```
Initialize BlePeripheral with a corresponding Peripheral
```

- Parameters:

- delegate: The BlePeripheralDelegate
- peripheral: The discovered Peripheral

```
*/
```

```
init(delegate: RemoteLedPeripheralDelegate?) { super.init()
```

```
// empty dispatch queue
```

```
let dispatchQueue:DispatchQueue! = nil
```

```
// Build Advertising options
```

```
let options:[String : Any] = [
```

```
CBPeripheralManagerOptionShowPowerAlertKey: true, // Peripheral unique
identifier
```

```
CBPeripheralManagerOptionRestoreIdentifierKey:
```

```
peripheralIdentifier
```

```
]
```

```
peripheralManager = CBPeripheralManager(
```

```
delegate: self,
```

```

queue: dispatchQueue, options: options)

self.delegate = delegate }

/***
Stop advertising, shut down the Peripheral */

func stop() {
peripheralManager.stopAdvertising()
}

/***
Start Bluetooth Advertising.
This must be after building the GATT profile
*/
func startAdvertising() {
let serviceUuids = [serviceUuid]
let advertisementData:[String: Any] = [
CBAdvertisementLocalNameKey: advertisingName,
CBAdvertisementServiceUUIDsKey: serviceUuids ]
peripheralManager.startAdvertising(advertisementData) }

/***
Build Gatt Profile.
This must be done after Bluetooth Radio has turned on
*/
func buildGattProfile() {
let service = CBMutableService(type: serviceUuid, primary: true) var rProperties
= CBCharacteristicProperties.read
rProperties.formUnion(CBCharacteristicProperties.notify) var rPermissions =
CBAttributePermissions.writeable
rPermissions.formUnion(CBAttributePermissions.readable)
responseCharacteristic = CBMutableCharacteristic(
type: responseCharacteristicUuid,
properties: rProperties,
value: nil,
permissions: rPermissions)
}

```

```

let cProperties = CBCharacteristicProperties.write let cPermissions =
CBAttributePermissions.writeable commandCharacteristic =
CBMutableCharacteristic(
    type: commandCharacteristicUuid,
    properties: cProperties,
    value: nil,
    permissions: cPermissions)

service.characteristics = [
    responseCharacteristic,
    commandCharacteristic
]

peripheralManager.add(service)
}

/**
Make sense of the incoming byte array as a command
*/
func processCommand(bleCommandValue: [UInt8]) {
    if bleCommandValue[bleCommandFooterPosition] == bleCommandFooter {
        print ("Command found")
        switch (bleCommandValue[bleCommandDataPosition]) { case
            bleCommandLedOn:

                print("Turning LED on")
                setLedState(ledState: true)
            case bleCommandLedOff:
                print("Turning LED off")
                setLedState(ledState: false)
            default:
                print("Unknown command value")
            }
        }
    /**
    Turn Camera Flash on as an LED

```

- Parameters:

```
- ledState: *true* for on, *false* for off
*/
func setLedState(ledState: Bool) {
if ledState {
sendBleResponse(ledState: bleResponseLedOn)

} else {
sendBleResponse(ledState: bleResponseLedOff)
}
delegate?.remoteLedPeripheral?(ledStateChangedTo: ledState) }
```

```
/**
```

```
Send a formatted response out via a Bluetooth Characteristic
```

```
- Parameters
- ledState: one of bleResponseLedOn or bleResponseLedOff */
```

```
func sendBleResponse(ledState: UInt8) {
var responseArray = [UInt8](
repeating: 0,
count: responseCharacteristicLength)
```

```
responseArray[bleResponseFooterPosition] = \ bleResponseConfirmationFooter
responseArray[bleResponseDataPosition] = ledState
let value = Data(bytes: responseArray)
responseCharacteristic.value = value
peripheralManager.updateValue(
value,
for: responseCharacteristic,
onSubscribedCentrals: nil)
// MARK: CBPeripheralManagerDelegate
```

```
/**
```

```
Peripheral will become active
```

```
*/
```

```
func peripheralManager(
_peripheral: CBPeripheralManager, willRestoreState dict: [String : Any])
```

```
{  
print("restoring peripheral state")  
}  
  
/**/  
Peripheral added a new Service  
*/  
  
func peripheralManager(  
    _ peripheral: CBPeripheralManager, didAdd service: CBService,  
    error: Error?)  
  
{  
print("added service to peripheral") if error != nil {  
  
    print(error.debugDescription) }  
}  
  
/**/  
Peripheral started advertising  
*/  
  
func peripheralManagerDidStartAdvertising( _ peripheral:  
    CBPeripheralManager, error: Error?)  
  
{  
if error != nil {  
    print ("Error advertising peripheral")  
  
    print(error.debugDescription) }  
self.peripheralManager = peripheral  
  
delegate?.remoteLedPeripheral?(startedAdvertising: error) }  
  
/**/  
Connected Central requested to read from a Characteristic */  
  
func peripheralManager(  
    _ peripheral: CBPeripheralManager,  
    didReceiveRead request: CBATTRequest)
```

```

{
let characteristic = request.characteristic
if (characteristic.uuid == responseCharacteristic.uuid) {

if let value = characteristic.value {
//let stringValue = String(data: value, encoding: .utf8)! if request.offset >
value.count {

peripheralManager.respond(
to: request,
withResult: CBATTError.invalidOffset)

return
}
let range = Range(uncheckedBounds: (
lower: request.offset,
upper: value.count - request.offset))
request.value = value.subdata(in: range)
peripheral.respond(
to: request,
withResult: CBATTError.success)
}
}
}
}

```

```

/** Connected Central requested to write to a Characteristic */

func peripheralManager(
_peripheral: CBPeripheralManager,
didReceiveWrite requests: [CBATTRequest])

{
for request in requests {
peripheral.respond(to: request, withResult: CBATTError.success) print("new
request")
if let value = request.value {

let bleCommandValue = [UInt8](value)
processCommand(bleCommandValue: bleCommandValue) }

```

```
}

}

/***
Connected Central subscribed to a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    central: CBCentral,
    didSubscribeTo characteristic: CBCharacteristic)

{

self.central = central
}

/***
Connected Central unsubscribed from a Characteristic */

func peripheralManager(
    _ peripheral: CBPeripheralManager,
    central: CBCentral,
    didUnsubscribeFrom characteristic: CBCharacteristic)

{

self.central = central }
/***
Peripheral is about to notify subscribers of changes to a Characteristic
*/
func peripheralManagerIsReady(
    toUpdateSubscribers peripheral: CBPeripheralManager)

{
print("Peripheral about to update subscribers")
}

/***
Bluetooth Radio state changed
*/
func peripheralManagerDidUpdateState( _ peripheral: CBPeripheralManager)
```

```

{
peripheralManager = peripheral
switch peripheral.state {
case CBManagerState.poweredOn:
buildGattProfile()
startAdvertising()
default: break
}
delegate?.remoteLedPeripheral?(stateChanged: peripheral.state)

} }

```

Delegates

The RemoteLedPeripheralDelegate will relay important events and state changes from the RemoteLedPeripheral, such as changes in the Advertising state and changes in the LED state:

Example 13-5. Delegates/RemoteLedPeripheralDelegate.swift

```

import UIKit
import CoreBluetooth
@objc protocol RemoteLedPeripheralDelegate : class {
/**
RemoteLed State Changed

- Parameters:
- rssi: the RSSI
- blePeripheral: the BlePeripheral

*/
@objc optional func remoteLedPeripheral( stateChanged state:
CBManagerState)
/**
RemoteLed statrted advertising

- Parameters:
- error: the error message, if any */

@objc optional func remoteLedPeripheral( startedAdvertising error: Error?)
/**
```

LED turned on or off

- Parameters:
- ledState: *true* for on, *false* for off */

@objc optional func remoteLedPeripheral(ledStateChangedTo ledState: Bool)

Storyboard

Create the UISwitches, UITextView, and UILabels in the UIView in the Main.storyboard to create the App's user interface (Figure 13-10).

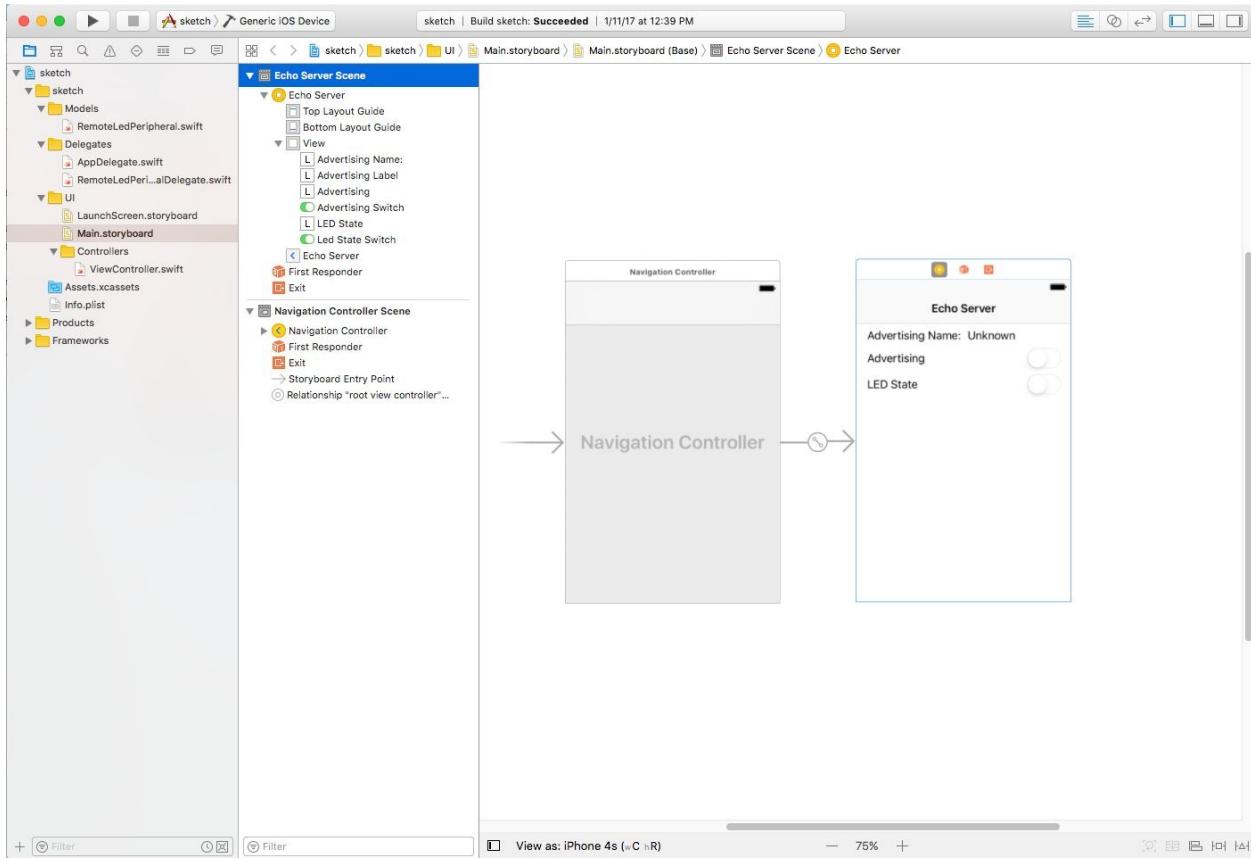


Figure 13-10. Project Storyboard Controllers

The View will display the advertising state and LED state with UISwitches, and will turn the camera flash on and off in response to the incoming LED state:

Example 13-6. UI/Controllers/ViewController.swift

```
import UIKit
import CoreBluetooth import AVFoundation

class ViewController: UIViewController, RemoteLedPeripheralDelegate {

    // MARK: UI Elements
    @IBOutlet weak var advertisingLabel: UILabel! @IBOutlet weak var
    advertisingSwitch: UISwitch! @IBOutlet weak var ledStateSwitch: UISwitch!

    // MARK: BlePeripheral
    // BlePeripheral
    var remoteLed:RemoteLedPeripheral!

    /**

```

```

UIView loaded
*/
override func viewDidLoad() { super.viewDidLoad()
}

/***
View appeared. Start the Peripheral
*/
override func viewDidAppear(_ animated: Bool) { remoteLed =
RemoteLedPeripheral(delegate: self) advertisingLabel.text =
remoteLed.advertisingName

}

/***
View will appear. Stop transmitting random data */
override func viewWillDisappear(_ animated: Bool) { remoteLed.stop()

/*
View disappeared. Stop advertising
*/
override func viewDidDisappear(_ animated: Bool) {
advertisingSwitch.setOn(false, animated: true)
}

// MARK: BlePeripheralDelegate
/**
RemoteLed state changed

- Parameters:
- state: the CBManagerState representing the new state */

func remoteLedPeripheral(stateChanged state: CBManagerState) { switch (state)
{
case CBManagerState.poweredOn:

```

```
print("Bluetooth on")
case CBManagerState.poweredOff:
print("Bluetooth off")
default:
print("Bluetooth not ready yet...")
}
}
```

```
/***
RemoteLed statrted adertising
```

- Parameters:
 - error: the error message, if any
- ```
*/
```

```
func remoteLedPeripheral(startedAdvertising error: Error?) { if error != nil {
```

```
print("Problem starting advertising: " + error.debugDescription)
```

```
} else {
print("adertising started")
advertisingSwitch.setOn(true, animated: true)
```

```
}
```

```
***/
Led State Changed
```

- Parameters:
  - stringValue: the value read from the Charactersitic
  - characteristic: the Characteristic that was written to
- ```
*/
```

```
func remoteLedPeripheral(ledStateChangedTo ledState: Bool) { if let device =
```

```
AVCaptureDevice.defaultDevice(
```

```
withMediaType: AVMediaTypeVideo)
```

```
{
```

```
if (device.hasTorch) { do {
try device.lockForConfiguration()
try device.setTorchModeOnWithLevel(1.0)
```

```
if ledState {  
    print("Led turned on")  
    device.torchMode = AVCaptureTorchMode.on ledStateSwitch.setOn(true,  
    animated: true) } else {  
    print("Led turned off")  
    device.torchMode = AVCaptureTorchMode.off ledStateSwitch.setOn(false,  
    animated: true) }  
    device.unlockForConfiguration()  
} catch let error as NSError {  
    print("problem locking camera: "+error.debugDescription) }  
}  
}
```

The resulting App can turn the camera flash on and off in response to commands from a connected Central. When the command is processed, a response is sent through the response Characteristic (Figure 13-11).

●●●●● Fido 3G

14:20

蓝牙 100%  ⚡

Bluetooth Peripheral

Advertising Name: LedRemote

Advertising



LED State



●●●○ Fido 3G

14:21

蓝牙 100%  ⚡

Bluetooth Peripheral

Advertising Name: LedRemote

Advertising



LED State



Figure 13-11. App screen showing LED in on and off states

Example code

The code for this chapter is available online
at: <https://github.com/BluetoothLowEnergyIniOSSwift/Chapter13>

Appendix

For reference, the following are properties of the Bluetooth Low Energy network and hardware.

Range 100 m (330 ft)

Data Rate 1M bit/s

Application Throughput 0.27 Mbit/s

Security

128-bit AES with Counter Mode CBC-MAC and application layer user defined
(BEWARE: this encryption has vulnerabilities)

Robustness

Adaptive Frequency Hopping, Lazy Acknowledgement, 24-bit CRC, 32-bit Message Integrity Check

Range 100 m (330 ft)

Data Rate 1M bit/s

Application Throughput 0.27 Mbit/s

Security

Peak Current Consumption

Byte-Order in Broadcast

Range

Data Rate

Application Throughput

Security

128-bit AES with Counter Mode CBC-MAC and application layer user defined
(BEWARE: this encryption has vulnerabilities)

< 15 mA

Big Endian (most significant bit at end)

100 m (330 ft)

1M bit/s

0.27 Mbit/s

128-bit AES with Counter Mode CBC-MAC and application layer user defined
(BEWARE: this encryption has vulnerabilities)

Source: Wikipedia: Bluetooth_Low_Energy Retrieved from
https://en.wikipedia.org/wiki/Bluetooth_low_energy

Appendix II: UUID Format

Bluetooth Low Energy has tight space requirements. Therefore it is preferred to transmit 16-bit UUIDs instead of 32-bit UUIDs. UUIDs can be converted between 16-bit and 32-bit with the standard Bluetooth Low Energy UUID format:

Table II-1. 16-bit to 32-bit UUID Conversion Standard

UUID Format **uuid16** **Resulting uuid32** 00000000-0000-1000-8000-00805f9b34fb 0x2A56 00002A56-0000-1000-8000-00805f9b34fb

Appendix III: Minimal Recommended GATT

As a best practice, it is good to host a standard set of Services and Characteristics in a Peripheral's GATT Profile. These Characteristics allow connected Centrals to get the make and model number of the device, and the battery level if the Peripheral is battery-powered:

Table III-1. Minimal GATT Profile

GATT Type Name Data Type UUID

Service Device Information Service 0x180a

Characteristic Device Name char array 0x2a00

Characteristic Model Number char array 0x2a24

Characteristic Serial Number char array 0x2a04

Service Battery Level 0x180f

Characteristic Battery Level integer 0x2a19

Appendix IV: Reserved GATT Services

Services act as a container for Characteristics or other Services, providing a tree-like structure for organizing Bluetooth I/O.

These Services UUIDs have been reserved for special contexts, such as Device Information (0x180A) Which may contain Characteristics that communicate information about the Peripheral's name, version number, or settings.

Note: All Bluetooth Peripherals should have a Battery Service (0x180F) Service containing a Battery Level (0x2A19) Characteristic.

Table IV-1. Reserved GATT Services

Specification Name	UUID	Specification Type
Alert Notification Service	0x1811	org.bluetooth.service.alert_notification
Automation IO	0x1815	org.bluetooth.service.automation_io
Battery Service	0x180F	org.bluetooth.service.battery_service
Blood Pressure	0x1810	org.bluetooth.service.blood_pressure
Body Composition	0x181B	org.bluetooth.service.body_composition
Bond Management	0x181E	org.bluetooth.service.bond_management
Continuous Glucose Monitoring		
	0x181F	org.bluetooth.service.continuous_glucose_monitoring Current Time Service
	0x1805	org.bluetooth.service.current_time
Cycling Power	0x1818	org.bluetooth.service.cycling_power
Cycling Speed and Cadence	0x1816	org.bluetooth.service.cycling_speed_and_cadence
Device Information	0x180A	org.bluetooth.service.device_information
Environmental Sensing	0x181A	org.bluetooth.service.environmental_sensing
Generic Access	0x1800	org.bluetooth.service.generic_access
Generic Attribute	0x1801	org.bluetooth.service.generic_attribute
Glucose	0x1808	org.bluetooth.service.glucose
Health Thermometer	0x1809	org.bluetooth.service.health_thermometer
Heart Rate	0x180D	org.bluetooth.service.heart_rate
HTTP Proxy	0x1823	org.bluetooth.service.http_proxy
Human Interface Device	0x1812	org.bluetooth.service.human_interface_device

Immediate Alert 0x1802 org.bluetooth.service.immediate_alert
Indoor Positioning 0x1821 org.bluetooth.service.indoor_positioning
Internet Protocol Support 0x1820
org.bluetooth.service.internet_protocol_support Link Loss 0x1803
org.bluetooth.service.link_loss
Location and Navigation 0x1819 org.bluetooth.service.location_and_navigation
Next DST Change Service 0x1807 org.bluetooth.service.next_dst_change
Object Transfer 0x1825 org.bluetooth.service.object_transfer
Phone Alert Status Service 0x180E org.bluetooth.service.phone_alert_status
Pulse Oximeter 0x1822 org.bluetooth.service.pulse_oximeter
Reference Time Update Service
0x1806 org.bluetooth.service.reference_time_update
Running Speed and Cadence 0x1814
org.bluetooth.service.running_speed_and_cadence
Scan Parameters 0x1813 org.bluetooth.service.scan_parameters
Transport Discovery 0x1824 org.bluetooth.service.transport_discovery
Tx Power 0x1804 org.bluetooth.service.tx_power
User Data 0x181C org.bluetooth.service.user_data
Weight Scale 0x181D org.bluetooth.service.weight_scale

Source: Bluetooth SIG: GATT Services Retrieved from
<https://www.bluetooth.com/specifications/gatt/services>

Appendix V: Reserved GATT Characteristics

Characteristics act a data port that can be read from or written to.

These Characteristic UUIDs have been reserved for specific types of data, such as Device Name (0x2A00) which may read the Peripheral's current battery level.

Note: All Bluetooth Peripherals should have a Battery Level (0x2A19)

Characteristic, contained inside a Battery Service (0x180F) Service.

Table V-1. Reserved GATT Characteristics

Specification	Name	UUID	Specification	Type
---------------	------	------	---------------	------

Aerobic Heart Rate Lower Limit

0x2A7E org.bluetooth.characteristic.aerobic_heart_rate_lower_limit

Aerobic Heart Rate Upper Limit

0x2A84 org.bluetooth.characteristic.aerobic_heart_rate_upper_limit

Aerobic Threshold 0x2A7F org.bluetooth.characteristic.aerobic_threshold

Age 0x2A80 org.bluetooth.characteristic.age

Aggregate 0x2A5A org.bluetooth.characteristic.aggregate

Alert Category ID 0x2A43 org.bluetooth.characteristic.alert_category_id

Alert Category ID Bit Mask 0x2A42

org.bluetooth.characteristic.alert_category_id_bit_mask

Alert Level 0x2A06 org.bluetooth.characteristic.alert_level

Alert Notification Control Point

0x2A44 org.bluetooth.characteristic.alert_notification_control_point Alert Status

0x2A3F org.bluetooth.characteristic.alert_status

Altitude 0x2AB3 org.bluetooth.characteristic.altitude

Anaerobic Heart Rate Lower Limit

0x2A81 org.bluetooth.characteristic.anaerobic_heart_rate_lower_limit

Anaerobic Heart Rate Upper Limit

0x2A82 org.bluetooth.characteristic.anaerobic_heart_rate_upper_limit

Anaerobic Threshold 0x2A83 org.bluetooth.characteristic.anaerobic_threshold

Analog 0x2A58 org.bluetooth.characteristic.analog

Apparent Wind Direction 0x2A73

org.bluetooth.characteristic.apparent_wind_direction

Apparent Wind Speed 0x2A72 org.bluetooth.characteristic.apparent_wind_speed

Appearance 0x2A01 org.bluetooth.characteristic.gap.appearance

Barometric Pressure Trend

0x2AA3 org.bluetooth.characteristic.barometric_pressure_trend

Battery Level 0x2A19 org.bluetooth.characteristic.battery_level

Blood Pressure Feature 0x2A49
org.bluetooth.characteristic.blood_pressure_feature
Blood Pressure Measurement 0x2A35
org.bluetooth.characteristic.blood_pressure_measurement
Body Composition Feature
0x2A9B org.bluetooth.characteristic.body_composition_feature
Body Composition Measurement 0x2A9C
org.bluetooth.characteristic.body_composition_measurement
Body Sensor Location 0x2A38
org.bluetooth.characteristic.body_sensor_location Bond Management Control Point 0x2AA4 org.bluetooth.characteristic.bond_management_control_point
Bond Management Feature
0x2AA5 org.bluetooth.characteristic.bond_management_feature
Boot Keyboard Input Report
0x2A22 org.bluetooth.characteristic.boot_keyboard_input_report
Boot Keyboard Output Report
Boot Mouse Input Report
Central Address Resolution
0x2A32 org.bluetooth.characteristic.boot_keyboard_output_report
0x2A33 org.bluetooth.characteristic.boot_mouse_input_report

0x2AA6
org.bluetooth.characteristic.gap.central_address_resolution_su pport

CGM Feature 0x2AA8 org.bluetooth.characteristic.cgm_feature
CGM Measurement 0x2AA7 org.bluetooth.characteristic.cgm_measurement
CGM Session Run Time
0x2AAB org.bluetooth.characteristic.cgm_session_run_time
CGM Session Start Time
0x2AAA org.bluetooth.characteristic.cgm_session_start_time
CGM Specific Ops Control Point 0x2AAC
org.bluetooth.characteristic.cgm_specific_ops_control_point
CGM Status 0x2AA9 org.bluetooth.characteristic.cgm_status
CSC Feature 0x2A5C org.bluetooth.characteristic.csc_feature
CSC Measurement 0x2A5B org.bluetooth.characteristic.csc_measurement
Current Time 0x2A2B org.bluetooth.characteristic.current_time
Cycling Power Control Point

0x2A66 org.bluetooth.characteristic.cycling_power_control_point Cycling

Power Feature

0x2A65 org.bluetooth.characteristic.cycling_power_feature

Cycling Power Measurement 0x2A63

org.bluetooth.characteristic.cycling_power_measurement

Cycling Power Vector 0x2A64

org.bluetooth.characteristic.cycling_power_vector

Database Change Increment

0x2A99 org.bluetooth.characteristic.database_change_increment

Date of Birth 0x2A85 org.bluetooth.characteristic.date_of_birth

Date of Threshold Assessment 0x2A86

org.bluetooth.characteristic.date_of_threshold_assessment

Date Time 0x2A08 org.bluetooth.characteristic.date_time

Day Date Time 0x2A0A org.bluetooth.characteristic.day_date_time

Day of Week 0x2A09 org.bluetooth.characteristic.day_of_week

Descriptor Value Changed

0x2A7D org.bluetooth.characteristic.descriptor_value_changed

Device Name 0x2A00 org.bluetooth.characteristic.gap.device_name

Dew Point 0x2A7B org.bluetooth.characteristic.dew_point

Digital 0x2A56 org.bluetooth.characteristic.digital

DST Offset 0x2A0D org.bluetooth.characteristic.dst_offset

Elevation 0x2A6C org.bluetooth.characteristic.elevation

Email Address 0x2A87 org.bluetooth.characteristic.email_address Exact Time

256 0x2A0C org.bluetooth.characteristic.exact_time_256

Fat Burn Heart Rate Lower Limit

0x2A88 org.bluetooth.characteristic.fat_burn_heart_rate_lower_limit

Fat Burn Heart Rate Upper Limit

0x2A89 org.bluetooth.characteristic.fat_burn_heart_rate_upper_limit

Firmware Revision String

0x2A26 org.bluetooth.characteristic.firmware_revision_string

First Name 0x2A8A org.bluetooth.characteristic.first_name

Five Zone Heart Rate Limits

0x2A8B org.bluetooth.characteristic.five_zone_heart_rate_limits

Floor Number 0x2AB2 org.bluetooth.characteristic.floor_number

Gender 0x2A8C org.bluetooth.characteristic.gender

Glucose Feature 0x2A51 org.bluetooth.characteristic.glucose_feature

Glucose Measurement 0x2A18

org.bluetooth.characteristic.glucose_measurement

Glucose Measurement Context

0x2A34 org.bluetooth.characteristic.glucose_measurement_context

Gust Factor 0x2A74 org.bluetooth.characteristic.gust_factor

Hardware Revision String

0x2A27 org.bluetooth.characteristic.hardware_revision_string

Heart Rate Control Point

0x2A39 org.bluetooth.characteristic.heart_rate_control_point

Heart Rate Max 0x2A8D org.bluetooth.characteristic.heart_rate_max

Heart Rate Measurement

0x2A37 org.bluetooth.characteristic.heart_rate_measurement Heat Index

0x2A7A org.bluetooth.characteristic.heat_index

Height 0x2A8E org.bluetooth.characteristic.height

HID Control Point 0x2A4C org.bluetooth.characteristic.hid_control_point

HID Information 0x2A4A org.bluetooth.characteristic.hid_information

Hip Circumference 0x2A8F org.bluetooth.characteristic.hip_circumference

HTTP Control Point 0x2ABA org.bluetooth.characteristic.http_control_point

HTTP Entity Body 0x2AB9 org.bluetooth.characteristic.http_entity_body

HTTP Headers 0x2AB7 org.bluetooth.characteristic.http_headers

HTTP Status Code 0x2AB8 org.bluetooth.characteristic.http_status_code

HTTPS Security 0x2ABB org.bluetooth.characteristic.https_security

Humidity 0x2A6F org.bluetooth.characteristic.humidity

IEEE 11073-20601 Regulatory

Certification Data List

Indoor Positioning Configuration

Intermediate Cuff Pressure

Intermediate

Temperature

0x2A2A

org.bluetooth.characteristic.ieee_11073-20601_regulatory_cert
ification_data_list

0x2AAD org.bluetooth.characteristic.indoor_positioning_configuration

0x2A36 org.bluetooth.characteristic.intermediate_cuff_pressure

0x2A1E org.bluetooth.characteristic.intermediate_temperature

Irradiance 0x2A77 org.bluetooth.characteristic.irradiance Language 0x2AA2
org.bluetooth.characteristic.language

Last Name 0x2A90 org.bluetooth.characteristic.last_name

Latitude 0x2AAE org.bluetooth.characteristic.latitude
LN Control Point 0x2A6B org.bluetooth.characteristic.ln_control_point
LN Feature 0x2A6A org.bluetooth.characteristic.ln_feature
Local East Coordinate 0x2AB1
org.bluetooth.characteristic.local_east_coordinate
Local North 0x2AB0 org.bluetooth.characteristic.local_north_coordinateCoordinate
Local Time Information 0x2A0F
org.bluetooth.characteristic.local_time_information
Location and Speed 0x2A67 org.bluetooth.characteristic.location_and_speed
Location Name 0x2AB5 org.bluetooth.characteristic.location_name
Longitude 0x2AAF org.bluetooth.characteristic.longitude
Magnetic Declination 0x2A2C org.bluetooth.characteristic.magnetic_declination
Magnetic Flux Density 0x2AA0
org.bluetooth.characteristic.magnetic_flux_density_2D-_{2D}
Magnetic Flux Density 0x2AA1
org.bluetooth.characteristic.magnetic_flux_density_3D-_{3D}
Manufacturer Name 0x2A29
org.bluetooth.characteristic.manufacturer_name_stringString
Maximum
org.bluetooth.characteristic.maximum_recommended_heart_raRecommended Heart
0x2A91 teRate
Measurement Interval 0x2A21
org.bluetooth.characteristic.measurement_interval
Model Number String 0x2A24
org.bluetooth.characteristic.model_number_string
Navigation 0x2A68 org.bluetooth.characteristic.navigation
New Alert 0x2A46 org.bluetooth.characteristic.new_alert
Object Action Control Point
0x2AC5 org.bluetooth.characteristic.object_action_control_point
Object Changed 0x2AC8 org.bluetooth.characteristic.object_changed
Object First-Created 0x2AC1 org.bluetooth.characteristic.object_first_created
Object ID 0x2AC3 org.bluetooth.characteristic.object_id
Object Last-Modified 0x2AC2 org.bluetooth.characteristic.object_last_modified
Object List Control Point
0x2AC6 org.bluetooth.characteristic.object_list_control_point
Object List Filter 0x2AC7 org.bluetooth.characteristic.object_list_filter
Object Name 0x2ABE org.bluetooth.characteristic.object_name
Object Properties 0x2AC4 org.bluetooth.characteristic.object_properties

Object Size 0x2AC0 org.bluetooth.characteristic.object_size
Object Type 0x2ABF org.bluetooth.characteristic.object_type
OTS Feature 0x2ABD org.bluetooth.characteristic.ots_feature

Peripheral Preferred Connection
Parameters

Peripheral Privacy Flag
PLX Continuous Measurement

0x2A04
org.bluetooth.characteristic.gap.peripheral_preferred_connection_parameters

0x2A02 org.bluetooth.characteristic.gap.peripheral_privacy_flag
0x2A5F org.bluetooth.characteristic.plx_continuous_measurement
PLX Features 0x2A60 org.bluetooth.characteristic.plx_features
PLX Spot-Check Measurement 0x2A5E
org.bluetooth.characteristic.plx_spot_check_measurement
PnP ID 0x2A50 org.bluetooth.characteristic.pnp_id
Pollen Concentration 0x2A75 org.bluetooth.characteristic.pollen_concentration
Position Quality 0x2A69 org.bluetooth.characteristic.position_quality
Pressure 0x2A6D org.bluetooth.characteristic.pressure
Protocol Mode 0x2A4E org.bluetooth.characteristic.protocol_mode
Rainfall 0x2A78 org.bluetooth.characteristic.rainfall
Reconnection Address 0x2A03
org.bluetooth.characteristic.gap.reconnection_address
Record Access Control Point
0x2A52 org.bluetooth.characteristic.record_access_control_point
Reference Time Information 0x2A14
org.bluetooth.characteristic.reference_time_information
Report 0x2A4D org.bluetooth.characteristic.report
Report Map 0x2A4B org.bluetooth.characteristic.report_map Resolvable Private
0x2AC9 org.bluetooth.characteristic.resolvable_private_address_only Address Only
Resting Heart Rate 0x2A92 org.bluetooth.characteristic.resting_heart_rate
Ringer Control Point 0x2A40 org.bluetooth.characteristic.ringer_control_point
Ringer Setting 0x2A41 org.bluetooth.characteristic.ringer_setting
RSC Feature 0x2A54 org.bluetooth.characteristic.rsc_feature
RSC Measurement 0x2A53 org.bluetooth.characteristic.rsc_measurement
SC Control Point 0x2A55 org.bluetooth.characteristic.sc_control_point

Scan Interval Window 0x2A4F

org.bluetooth.characteristic.scan_interval_window

Scan Refresh 0x2A31 org.bluetooth.characteristic.scan_refresh

Sensor Location 0x2A5D org.bluetooth.characteristic.sensor_location

Serial Number String 0x2A25 org.bluetooth.characteristic.serial_number_string

Service Changed 0x2A05 org.bluetooth.characteristic.gatt.service_changed

Software Revision 0x2A28 org.bluetooth.characteristic.software_revision_stringString

Sport Type for Aerobic

org.bluetooth.characteristic.sport_type_for_aerobic_and_an aerobic and Anaerobic 0x2A93

obic_thresholdsThresholds

Supported New Alert 0x2A47

org.bluetooth.characteristic.supported_new_alert_categoryCategory

Supported Unread 0x2A48

org.bluetooth.characteristic.supported_unread_alert_categoryAlert Category

System ID 0x2A23 org.bluetooth.characteristic.system_id

TDS Control Point 0x2ABC org.bluetooth.characteristic.tds_control_point

Temperature 0x2A6E org.bluetooth.characteristic.temperature

Temperature Measurement 0x2A1C

org.bluetooth.characteristic.temperature_measurement

Temperature Type 0x2A1D org.bluetooth.characteristic.temperature_type

Three Zone Heart Rate Limits 0x2A94

org.bluetooth.characteristic.three_zone_heart_rate_limits

Time Accuracy 0x2A12 org.bluetooth.characteristic.time_accuracy

Time Source 0x2A13 org.bluetooth.characteristic.time_source

Time Update Control Point

0x2A16 org.bluetooth.characteristic.time_update_control_point

Time Update State 0x2A17 org.bluetooth.characteristic.time_update_state

Time with DST 0x2A11 org.bluetooth.characteristic.time_with_dst

Time Zone 0x2A0E org.bluetooth.characteristic.time_zone

True Wind Direction 0x2A71 org.bluetooth.characteristic.true_wind_direction

True Wind Speed 0x2A70 org.bluetooth.characteristic.true_wind_speed

Two Zone Heart Rate Limit

0x2A95 org.bluetooth.characteristic.two_zone_heart_rate_limit

Tx Power Level 0x2A07 org.bluetooth.characteristic.tx_power_level

Uncertainty 0x2AB4 org.bluetooth.characteristic.uncertainty

Unread Alert Status 0x2A45 org.bluetooth.characteristic.unread_alert_status

URI 0x2AB6 org.bluetooth.characteristic.uri

User Control Point 0x2A9F org.bluetooth.characteristic.user_control_point

User Index 0x2A9A org.bluetooth.characteristic.user_index
UV Index 0x2A76 org.bluetooth.characteristic.uv_index
VO2 Max 0x2A96 org.bluetooth.characteristic.vo2_max
Waist Circumference 0x2A97 org.bluetooth.characteristic.waist_circumference
Weight 0x2A98 org.bluetooth.characteristic.weight
Weight Measurement 0x2A9D org.bluetooth.characteristic.weight_measurement
Weight Scale Feature 0x2A9E org.bluetooth.characteristic.weight_scale_feature
Wind Chill 0x2A79 org.bluetooth.characteristic.wind_chill

Source: Bluetooth SIG: GATT Characteristics Retrieved from
<https://www.bluetooth.com/specifications/gatt/characteristics>

Appendix VI: GATT Descriptors

The following GATT Descriptor UUIDs have been reserved for specific uses.

GATT Descriptors describe features within a Characteristic that can be altered, for instance, the Client Characteristic Configuration (0x2902) which can be flagged to allow a connected Central to subscribe to notifications on a Characteristic.

Table VI-1. Reserved GATT Descriptors

Specification Name	UUID	Specification Type
Characteristic Aggregate Format	0x2905	
org.bluetooth.descriptor.gatt.characteristic_aggregate_format		
Characteristic Extended Properties	0x2900	org.bluetooth.descriptor.gatt.characteristic_extended_properties
Characteristic Presentation Format	0x2904	org.bluetooth.descriptor.gatt.characteristic_presentation_format
Characteristic User Description	0x2901	org.bluetooth.descriptor.gatt.characteristic_user_description
Client Characteristic Configuration	0x2902	org.bluetooth.descriptor.gatt.client_characteristic_configuration
Environmental Sensing Configuration	0x290B	org.bluetooth.descriptor.es_configuration
Environmental Sensing Measurement	0x290C	org.bluetooth.descriptor.es_measurement
Environmental Sensing Trigger Setting	0x290D	org.bluetooth.descriptor.es_trigger_setting
External Report Reference	0x2907	org.bluetooth.descriptor.external_report_reference
	0x2909	Number of Digitals org.bluetooth.descriptor.number_of_digits
Report Reference	0x2908	org.bluetooth.descriptor.report_reference
Server Characteristic Configuration	0x2903	org.bluetooth.descriptor.gatt.server_characteristic_configuration
Time Trigger Setting	0x290E	org.bluetooth.descriptor.time_trigger_setting
Valid Range	0x2906	org.bluetooth.descriptor.valid_range

Value Trigger Setting 0x290A org.bluetooth.descriptor.value_trigger_setting

Source: Bluetooth SIG: GATT Descriptors Retrieved from
<https://www.bluetooth.com/specifications/gatt/descriptors>

Appendix VII: Company Identifiers

The following companies have specific Manufacturer Identifiers, which identify Bluetooth devices in the Generic Access Profile (GAP). Peripherals with no specific manufacturer use ID 65535 (0xffff). All other IDs are reserved, even if not yet assigned.

This is a non-exhaustive list of companies. A full list and updated can be found on the Bluetooth SIG website.

Table VII-1. Company Identifiers

Decimal Hexadecimal Company

- 0 0x0000 Ericsson Technology Licensing
- 1 0x0001 Nokia Mobile Phones
- 2 0x0002 Intel Corp.
- 3 0x0003 IBM Corp.
- 4 0x0004 Toshiba Corp.
- 5 0x0005 3Com
- 6 0x0006 Microsoft

- 7 0x0007 Lucent
- 8 0x0008 Motorola

- 13 0x000D Texas Instruments Inc.
- 19 0x0013 Atmel Corporation
- 29 0x001D Qualcomm
- 36 0x0024 Alcatel
- 37 0x0025 NXP Semiconductors (formerly Philips Semiconductors)
- 60 0x003C BlackBerry Limited (formerly Research In Motion)
- 76 0x004C Apple, Inc.
- 86 0x0056 Sony Ericsson Mobile Communications
- 89 0x0059 Nordic Semiconductor ASA
- 92 0x005C Belkin International, Inc.
- 93 0x005D Realtek Semiconductor Corporation
- 101 0x0065 Hewlett-Packard Company
- 104 0x0068 General Motors
- 117 0x0075 Samsung Electronics Co. Ltd.
- 120 0x0078 Nike, Inc.
- 135 0x0087 Garmin International, Inc.

138 0x008A Jawbone
184 0x00B8 Qualcomm Innovation Center, Inc. (QuIC)
215 0x00D7 Qualcomm Technologies, Inc.
216 0x00D8 Qualcomm Connected Experiences, Inc.
220 0x00DC Procter & Gamble
224 0x00E0 Google
359 0x0167 Bayer HealthCare
367 0x016F Podo Labs, Inc
369 0x0171 Amazon Fulfillment Service
387 0x0183 Walt Disney
398 0x018E Fitbit, Inc.
425 0x01A9 Canon Inc.
427 0x01AB Facebook, Inc. 474 0x01DA Logitech International SA
558 0x022E Siemens AG
605 0x025D Lexmark International Inc.
637 0x027D HUAWEI Technologies Co., Ltd. ()
720 0x02D0 3M
876 0x036C Zipcar
897 0x0381 Sharp Corporation
921 0x0399 Nikon Corporation
1117 0x045D Boston Scientific Corporation
65535 0xFFFF No Device ID

Source : Bluetooth SIG: Company Identifiers Retrieved from
<https://www.bluetooth.com/specifications/assigned-numbers/company-identifiers>

Glossary

The following is a list of Bluetooth Low Energy terms and their meanings.

Attribute - An unit of a GATT Profile which can be accessed by a Central, such as a Service or a Characteristic.

Beacon - A Bluetooth Low Energy Peripheral which continually Broadcasts so that Centrals can discern their location from information gleaned from the properties of the broadcast.

Bluetooth Low Energy (BLE) - A low power, short range wireless protocol used on micro electronics.

Broadcast - A feature of Bluetooth Low Energy where a Peripheral outputs a name and other specific data about a itself

Central - A Bluetooth Low Energy device that can connect to several Peripherals.

Channel - A finely-tuned radio frequency used for Broadcasting or data transmission.

Characteristic - A port or data endpoint where data can be read or written.

Descriptor - A feature of a Characteristic that allows for some sort of data interaction, such as Read, Write, or Notify.

E0 - The encryption algorithm built into Bluetooth Low Energy.

Generic Attribute (GATT) Profile - A list of Services and Characteristics which are unique to a Peripheral and describe how data is served from the Peripheral. GATT profiles are hosted by a Peripheral

iBeacon - An Apple compatible Beacon which allows a Central to download a specific packet of data to inform the Central of its absolute location and other properties.

Notify - An operation where a Peripheral alerts a Central of a change in data.

Peripheral - A Bluetooth Low Energy device that can connect to a single Central. Peripherals host a Generic Attribute (GATT) profile.

Read - An operation where a Central downloads data from a Characteristic.

Scan - The process of a Central searching for Broadcasting Peripherals.

Scan Response - A feature of Bluetooth Low Energy which allows Centrals to download a small packet of data without connecting.

Service - A container structure used to organize data endpoints. Services are

hosted by a Peripheral.

Universally Unique Identifier (UUID) - A long, randomly generated alphanumeric string that is unique regardless of where it's used. UUIDs are designed to avoid name collisions that may happen when countless programs are interacting with each other.

Write - An operation where a Central alters data on a Characteristic. (This page intentionally left blank)

About the Author



essential truth that defines a company. Tony's infinite curiosity compels him to want to open up and learn about everything he touches, and his excitement compels him to share what he learns with others.

He has two true passions: branding and inventing.

His passion for branding led him to start a company that did branding and marketing in 4 countries for firms such as Apple, Intel, and Sony BMG. He loves weaving the elements of design, writing, product, and strategy into an

His passion for inventing led him to start a company that uses brain imaging to quantify meditation and to predict seizures, a company acquired \$1.5m in funding and was incubated in San Francisco where he currently resides.

Those same passions have led him on some adventures as well, including living in a Greek monastery with orthodox monks and to tagging along with a gypsy in Spain to learn to play flamenco guitar.

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About this Book

This book is a practical guide to programming Bluetooth Low Energy for iPhone and iPad.

In this book, you will learn the basics of how to program an iOS device to communicate with any Central or Peripheral device over Bluetooth Low Energy. Each chapter of the book builds on the previous one, culminating in three projects:

- A Beacon and Scanner
- A Echo Server and Client
- A Remote Controlled Device

Through the course of the book you will learn important concepts that relate to:

- How Bluetooth Low Energy works
- How data is sent and received
- Common paradigms for handling data

Skill Level

This book is excellent for anyone who has basic or advanced knowledge of iOS programming in SWIFT.

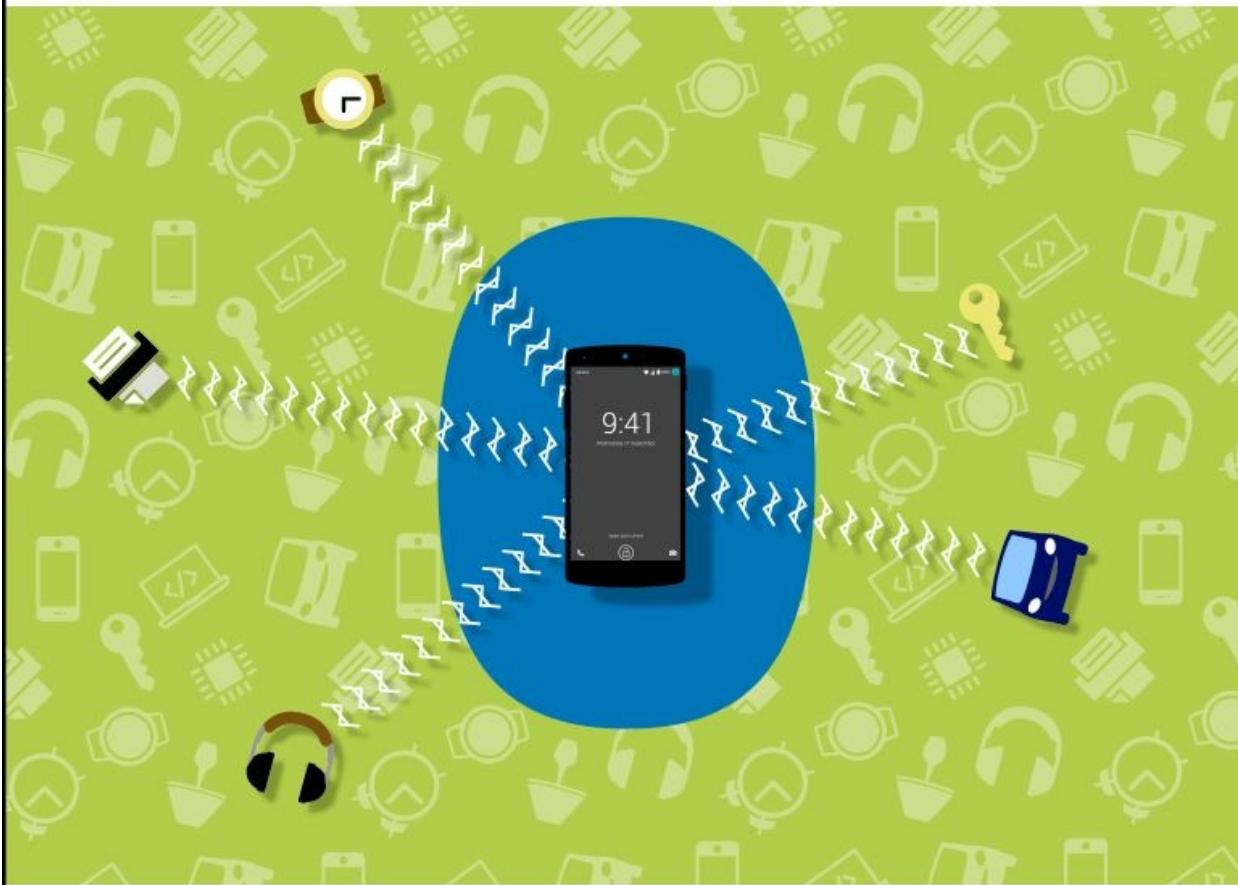
Other Books in this Series

If you are interested in programming other Bluetooth Low Energy Devices, please check out the other books in this series or visit bluetoothlowenergybooks.com:

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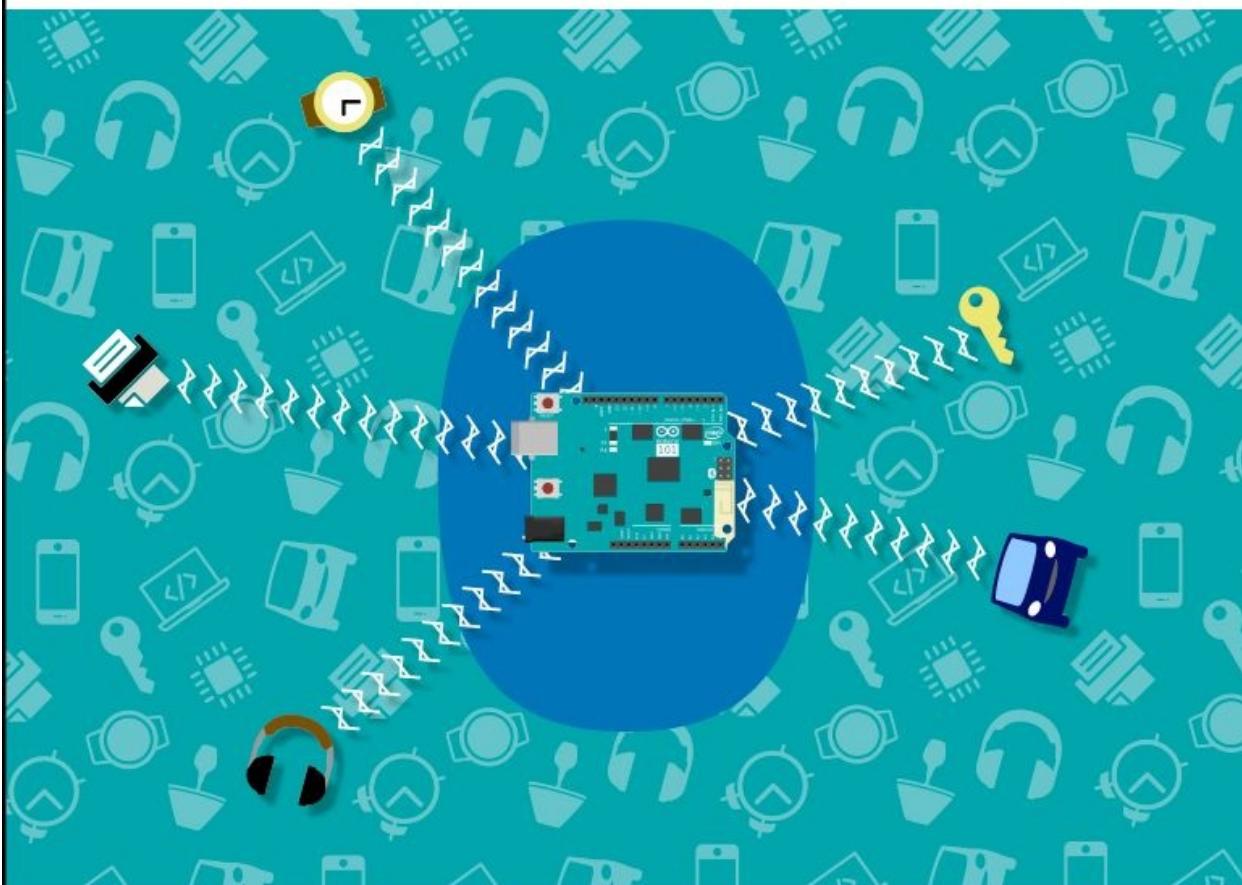
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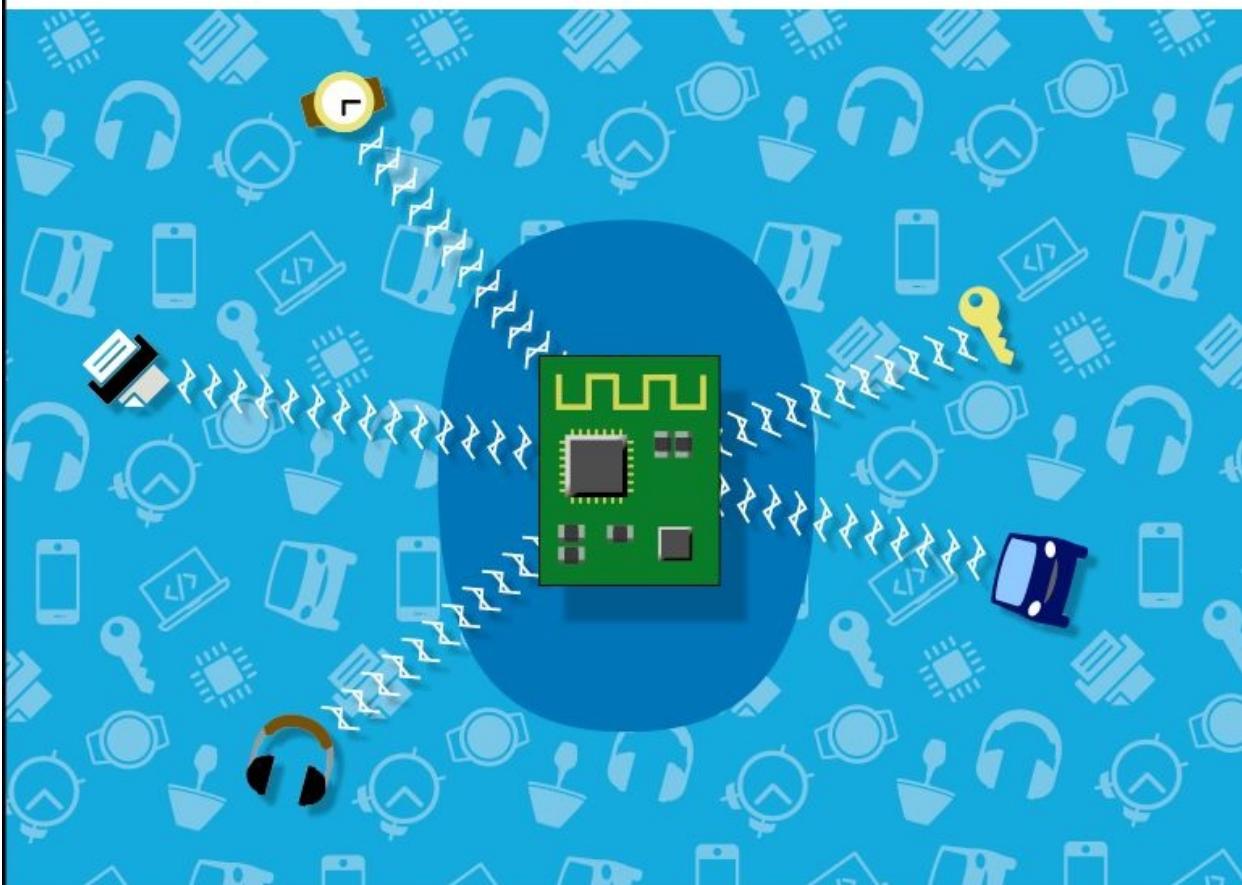
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