CIS 4930/6930, Spring 2018

Experiment 1: Encounter Tracing using Bluetooth
Due Date: Feb 19 (beginning of class)
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[Note: typically experiments are done in groups, usually the same groups as the project group. One report is to be submitted per group. Several groups can work together especially when more than one device is needed, but will submit different reports (and can refer to and credit one another).]

Introduction

The goal of this experiment is to gain hands-on experience in collecting Bluetooth encounter traces using classic Bluetooth and Low Energy Bluetooth. The experiment consists of two parts: 1- simple trace collection and 2- collecting
encounters scenarios between two specific devices. Three applications are needed: a. Classic Bluetooth Scanner, b. Bluetooth Low Energy (BLE) Advertiser, and c. BLE Scanner.

Both Classic Bluetooth and BLE scanners record the Received Signal Strength Indicator (*RSSI*). *RSSI* has been used for proximity detection and distance estimation, which are required in numerous smart Internet of things (*IoT*) applications. Also, BLE scanner record the TX power that are used by the advertiser.

Encounter Bluetooth Collection Application:

1) Classic Bluetooth:

This is an application for scanning other Bluetooth encounters. The classic Bluetooth scanner will scan for other Bluetooth encounters and will save the following data into a file:

- Time of encounter
- Scanner Bluetooth MAC Address
- Scanned Device Bluetooth MAC Address
- Name of the scanned device
- Received Signal Strength Indicator (*RSSI*)

Example

Time	**Scanner Mac**	**Scanned Device Mac**	**Scanned device Name**	***RSSI***
1478286278	C4:00:60:77:0F:55	F1:90:EX:F5:03:17	SGH-I747	-87

You do not need an advertiser to send a Bluetooth signal. Just turn on the Bluetooth Device. The Device will scan and send its Bluetooth data. Note that the other device MAC is an actual MAC address of the other devices.
The scanned data are saved in the file: ('*EncountersScanner/BluetoothData.txt*')

2) Bluetooth Low Energy (BLE) Applications:

There are two applications: 1- the advertiser: for sending Bluetooth Advertisement, and 2- the scanner for scanning for Bluetooth encounter.

i- Advertising Application:

You can send advertisements using different transmission power: high, medium, low and ultra-low. The advertisement will include the transmission power (*Tx_power*) along with an anonymous MAC address for the device and not the actual device MAC address. However, it will send the device name too.
Note: Before using the advertisement, you can assign a distinguishable name for your device Bluetooth to distinguish it from other advertisements in the scanner.

ii- Scanning Application:

The scanning application has a similar interface as the classic Bluetooth applications, but it scans for BLE advertisements. The scanner will record the following encountered device data:

- Time
- Encountered Device Name (Enc. Name)
- Encountered Device MAC Address (Enc. MAC)
- The transmission power of the received Advertisement(Tx power)
- The Received Signal Strength indicator (RSSI)

Example:

Time	**Enc. Name**	**Enc. Mac**	***Tx_power***	***RSSI***
1482872906	XL1458	43:04:E9:CF:F1:49	1	-52

The information will be saved in ('*AScanningTXLab1/BluetoothData.txt*')

Manual Logging (ground truth!):

Both of the scanners have manual logging to log the time, either for the experiment or for the encounter. For example, start experiment one: Click number one, when you finish click one again. The data will be saved in txt file "record.txt" under the folder generated by the scanner.

Part I: Bluetooth encounter trace collection

This part is to introduce you to the encounter collection for both classic Bluetooth and BLE. Your goal is to compare and contrast the scanning result for both of them.

1. Spend some time (around 10 days) running scanners around the campus.
2. Answer the following questions:
   1) How many encounters have been recorded in each scanner. (plot over time, days, hrs)
   2) How many unique encounters. (plot over time)
   3) What is the average number of scanned records? how many records have been scanned per minutes in each scanner?
   4) What is the max, min, mean of *RSSI* collected by scanners. (plot the distribution)

Part II: Scanning Scenarios for Two specific devices

This part needs two devices and two users to perform the operation. (Several groups can team together if there is need for that). Also, the layout of the place needs to be known. We recommend the computer science hallway. The scenarios is described below:

Scenarios:

- 1st Scenario: Two users walking next to each other.
- 2nd Scenarios: Two users walking in different/opposite directions, but encounter for some time.

When you start the experiment, use a manual log ('1' for example). Then, when you end click it again (to toggle it off). Also, when encountering in the second scenarios (use manual log to click when you encounter and when you end).

Classic Bluetooth Experiment:

The two users have to run the scanner application on each scenario. Filter the scanned data to include the other user device only. Compare the data from each user for each scenario and plot them.

BLE Experiment:

One user runs the advertisement App, the other user will run the *BLE* scanner app. Each scenario has to be run for four times. (one time for each transmission power). Each five minutes, click the advertisement button since the advertisement will stop after five minutes. Also, filter the collected data to include only the device that sent the advertisement. (You
can filter using the device name, and not the MAC address).

Compare the collected data, and plot the received RSSI in each experiment.

Questions:

-Can you deduce the scenario from the collected data? For example, by looking at the encounter data only, can you tell if the users are moving next to each other, or if the users just encounter each other, and for how long?

- How can you use the transmission power and *RSSI* sent in the *BLE* to estimate the encounters between two users?

Part III: Distance Estimation from RSSI

- There are several models that have been used to estimate the distance from the RSSI. In this experiment, place the devices within a specific distance from each other: 0.5m, 1m, …[X]. Plot the RSSI against the distance.
- Select a model [log shadowing model, Android beacon Library, or a regression model]. Compute the Mean Absolute Error of predicted distances.

Part IV: Constructing a Mobility Scenario from scanned RSSI and TX power

Assume *Z*, *X* and *Y* are location points. The distance between X to Z or Y should be more than M meters.

Z---------- *X*----------*Y*

Place the Scanner on X, and use the advertiser to preform the following mobility scenarios.

Scenario 1:
Walk in normal speed from points (*Z* to *Y*), without stopping.

Scenario 2:
In this scenario, stop at *X* for a period of time *P*; Let *P*= *M* minutes. Then, move to *Y*]

- Run the above experiment several times using Classic Bluetooth. Then, run it using the *BLE* using a different *TX_power* setting.

- Explain how you can infer the scenarios using the *RSSI*.
- Is classic Bluetooth or BLE more accurate to construct the scenario? In case of *BLE*, which value of *TX_power* is more accurate for tracking purposes?

Part V: Make your extension to the experiment (extra points)

- Come up with other scenarios, and estimate the encounters' duration between devices.
- Can you come with an algorithm that deduces the scenarios of face-to-face encounters out of Bluetooth encounter data?
- Some real encounters might not be recorded by Bluetooth scanning, can you come up with an algorithm that estimates the encounters that are not reported in the Bluetooth encounter data using the data that collected by the Bluetooth device.