Inferring Device Identities Through BLE signal strengths

CSE 534 Fall 2020 Course Project

Problem Statement

- Given an arrangement of BLE enabled devices, identify which signal belongs to which device by estimating the distances to each device
- The arrangement may be obtained by different methods such as image capture in the case of pedestrians at a crossing or customers at a store or through assigning seat numbers to devices belonging to people seated at a stadium.

Theoretical Formulation -> Assumes scanners can detect exact distances
Given a collection of n beacons on a plane what is the minimum number of scanners needed to uniquely identify each beacon

Variation -> How many extra scanners are required when each beacon is also capable of scanning

In both, the worst case requires at least O(n) scanners (very sparsely distributed beacons)
This formulation is not of much practical use however, because scanners are pretty inaccurate
Certain modifications, however might be useful.

Governing Equation

$$RSSI = -10n \log_{10} \left(\frac{D}{D_0} \right) + C_0$$

RSSI = Received Signal Strength Indicator in dBm

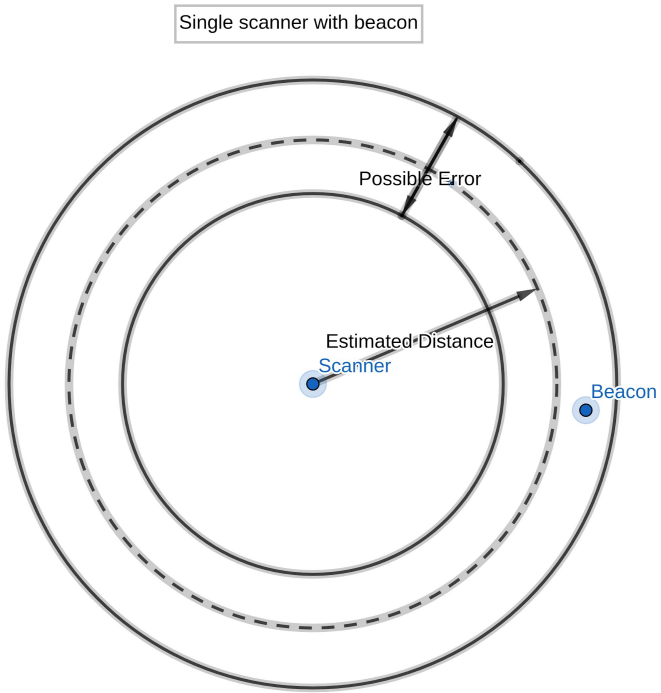
D_0 = Reference Distance

C_0 = Value of RSSI at distance D_0

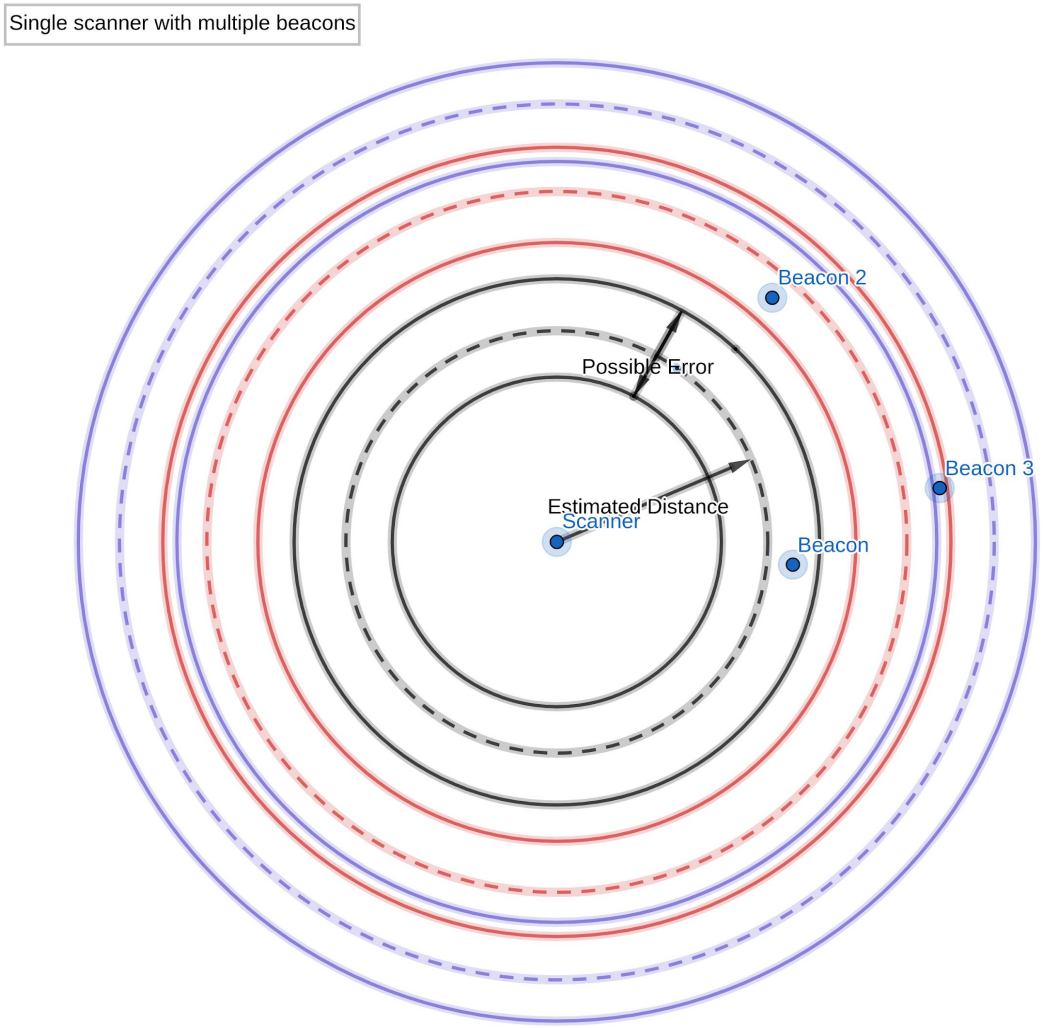
n = Path-loss exponent

We select a reference distance D_0 of 1m and calibrate the devices to calculate n and C_0 using the measured RSSI values

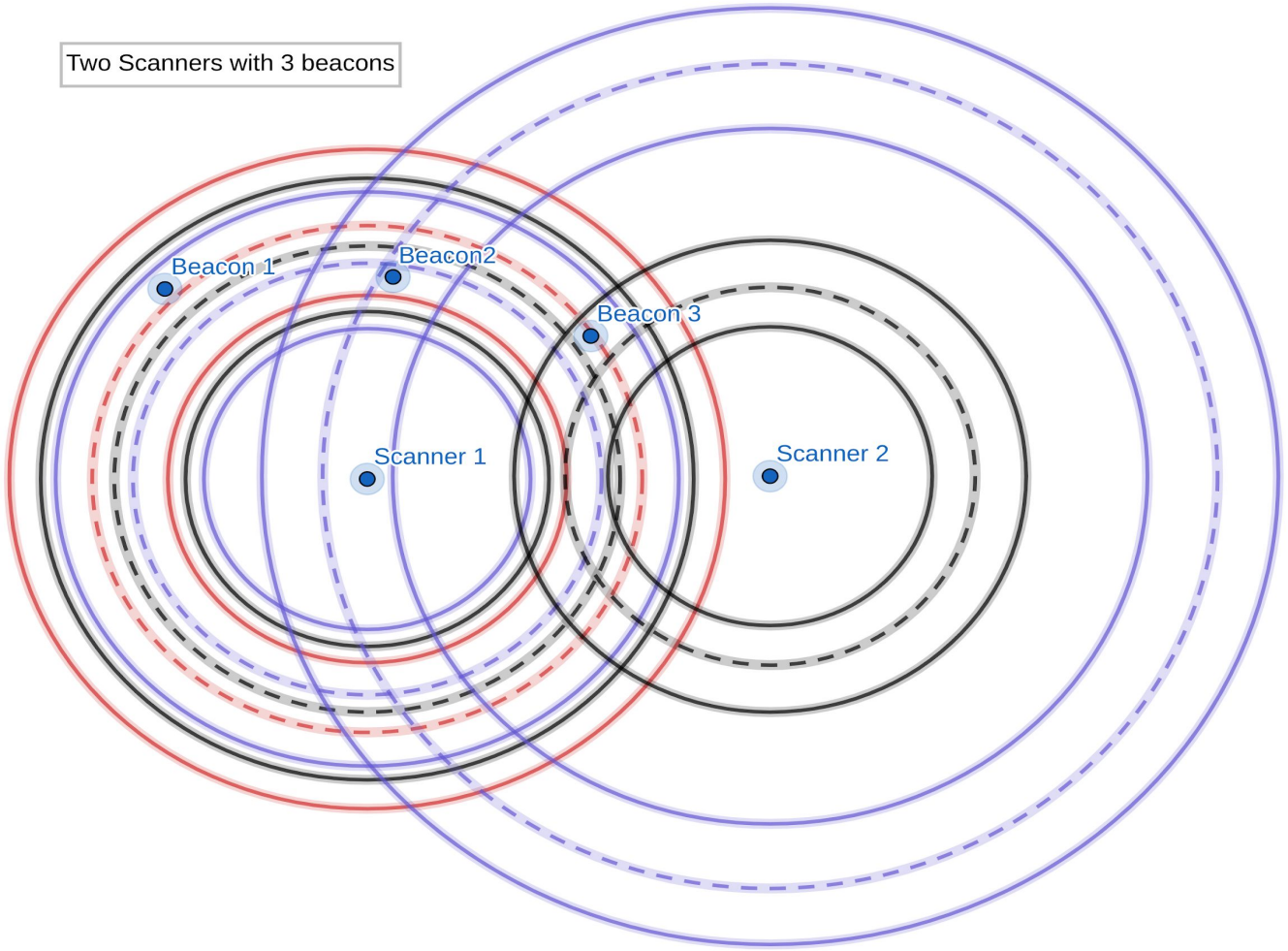
Geometric Formulation



Geometric Formulation (Contd)



Geometric Formulation (Contd)

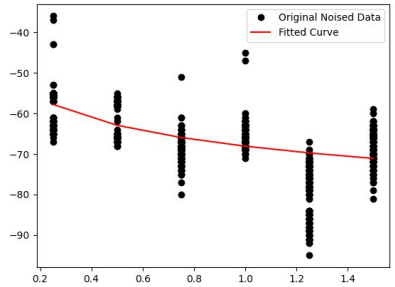
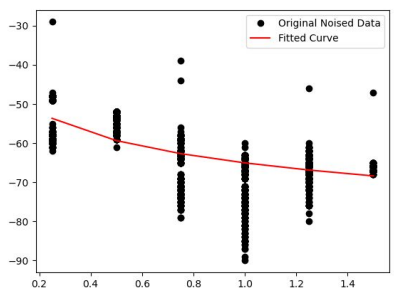
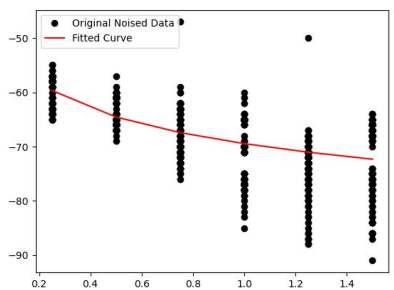


Experiment Setup

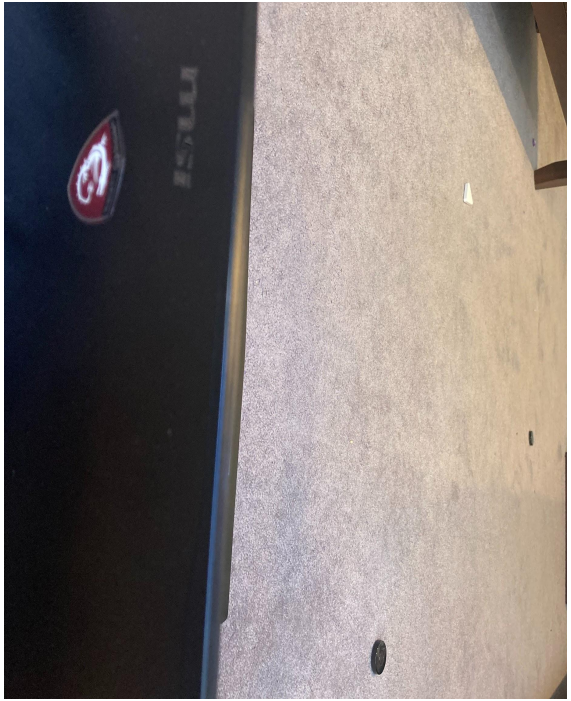
- In this case we attempt to identify three devices placed in front of a laptop (MSI GE6Q2 6F running Ubuntu Focal Fossa) by estimating their distances from the laptop using the strengths of their bluetooth signals
- The devices used were 2 Blue Charm BC037S-iBeacons (Beacon 1 and 2) and 1 FeasyBeacon Mini (Beacon 3)
- The devices were calibrated using samples taken at distances D={0.25m, 0.50m, 0.75m, 1.0m, 1.25m, 1.5m} and these calibrations were later used to estimate distances
- Each sample was obtained over 2 minutes using 100ms intervals giving around 900 measurements per sample for the Blue Charm Beacons and around 500 measurements per sample for the FeasyBeacon

Calibration

The calibration parameters C_0 and n were calculated from the measurements taken from each device by fitting a curve to the RSSI path loss equation. The results are tabulated below

Beacon	Beacon 1	Beacon 2	Beacon 3
n	1.71175143	1.89106888	1.62841785
C_0	-68.083807	-65.039038	-69.448262
Curve Fit			

Setup 1

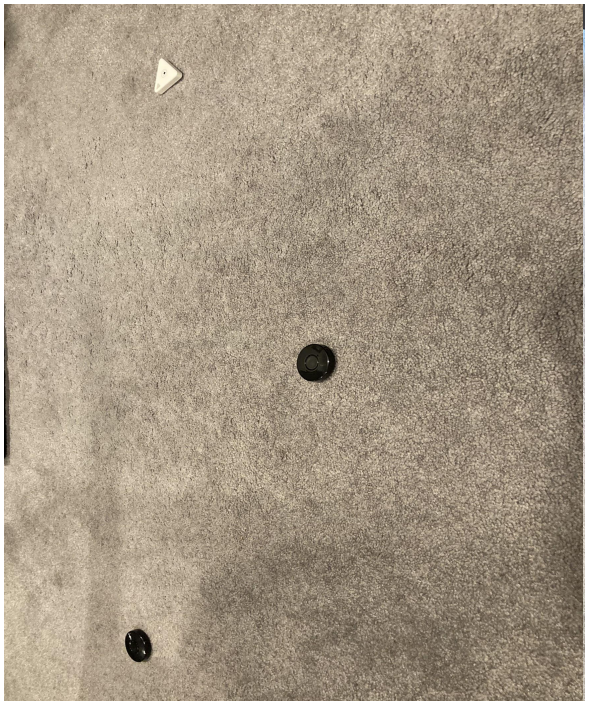


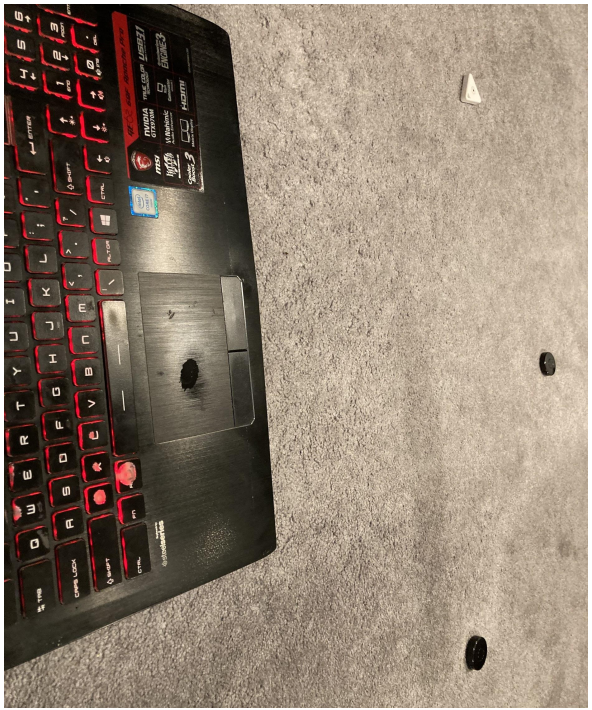
Beacon	Actual Distance	Estimated Distance (Error %)	Physical Order	Order Based On estimated distance
Beacon 1	36cm	14.732 cm (59%)	1	1
Beacon 2	135cm	141.805 cm (5%)	3	3
Beacon 3	76cm	101.450 cm (33%)	2	2

Setup 2

Beacon	Actual Distance	Estimated Distance (Error %)	Physical Order	Order Based On estimated distance
Beacon 1	62cm	62.747 cm (1%)	2	2
Beacon 2	86cm	77.569 cm (9.8%)	3	3
Beacon 3	20cm	59.659 cm (198%)	1	1

Setup 3





Beacon	Actual Distance	Estimated Distance	Physical Order	Order Based On estimated distance
Beacon 1	56cm	57.742 cm (3.1%)	3	3
Beacon 2	37cm	26.134 cm (29%)	1	1
Beacon 3	43cm	52.796 cm (23%)	2	2

Setup 4

Beacon	Actual Distance	Estimated Distance	Physical Order	Order Based On estimated distance
Beacon 1	101cm	145.516 cm (44%)	1	1
Beacon 2	124cm	184.634 cm (49%)	3	3
Beacon 3	111cm	164.134 cm (48%)	2	2

Issue!

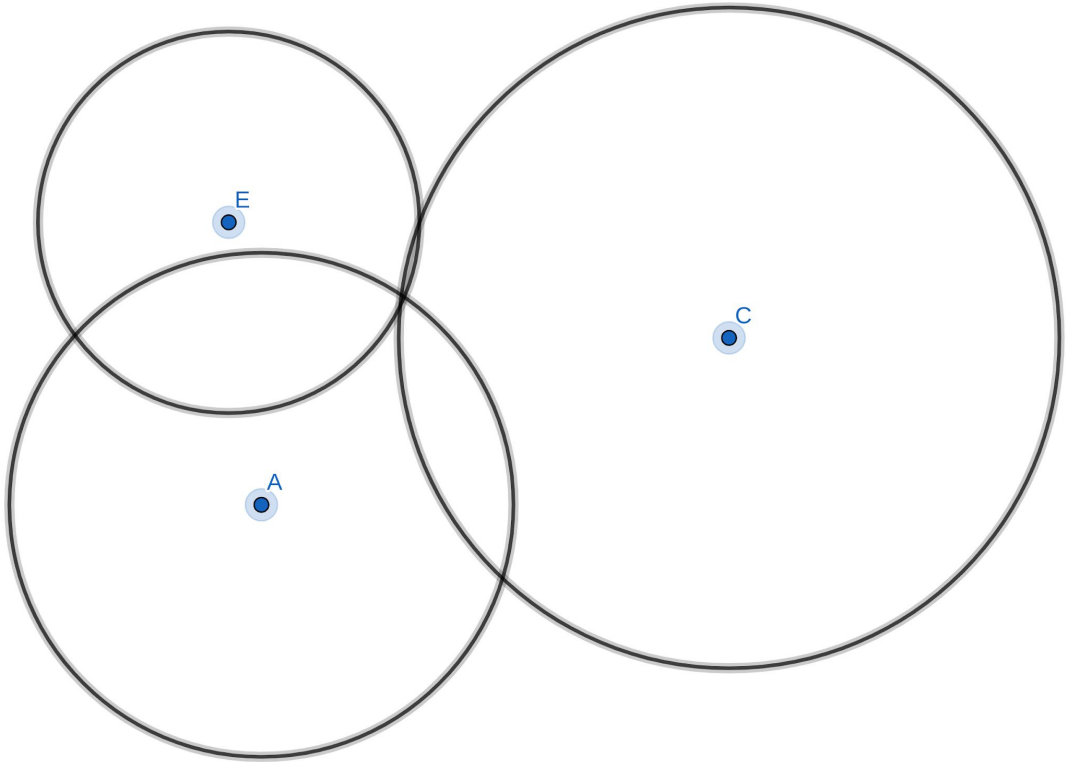
What happens if multiple devices are at the same distance from the scanner?

Solution -> Use more than one scanner placed at different locations to predict positions of devices

Conclusion and Further Work

- The simplified experiments we carried out demonstrate that even in non-perfect environments such as the one this was carried out in (a bedroom with multiple sources of interference including other devices detectable in the neighborhood), despite inaccuracies in exact distance estimation, it is possible to establish relative positions of devices fairly accurately with a single scanner with direct application to situations such as identifying pedestrians at a crossing. These accuracies can be further improved by filtering out noise in the signal.
- In real life applications the devices to be located (likely cellular phones) are capable of both transmitting and receiving signals. This opens up the possibility of using these devices to create a grid of scanners working together (with at least one or more scanners whose absolute position is known) to predict spatial distributions of large crowds (such as identifying which section in a stadium a device is located at using neighboring devices) using triangulation

Theoretical formulation



Notes from questions

Can this be achieved without precallibration?

RSRP as a metric?