Human Body Influence on Bluetooth COVID-19 Contact Tracing Using RSSI Measurement

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Abstract:
Contact tracing has been around for centuries to control disease outbreaks. However, the process of tracking individuals who may have come in contact with an infectious virus is long and arduous. With the spread of COVID-19, the piPACT program was created to research the feasibility of bluetooth contact tracing. The program intends to use the Bluetooth Received Signal Strength Indication (RSSI) to track whether individuals had been too close with an infected individual for too long. This project focused on the human body effect on the reliability of the RSSI signal when people carry devices such as cell phones. The findings show that the human body impacts the RSSI strength and as a result, the design of Bluetooth COVID-19 contact tracing needs to take this into account.

Keywords:
COVID-19, obstruction, RSSI, bluetooth contact tracing, human body obstruction, Raspberry Pi

I. Introduction

A. Project Description

COVID-19 is an airborne virus that can be transmitted between individuals through coughing, sneezing, and talking [4]. The virus can hang in the air or land on other people or surfaces. To mitigate the spread, contact tracing is needed so infected or exposed individuals can be quarantined rather than the entire population quarantined. However, the current process is incomplete, cumbersome, and slow. To address this, the piPACT program was initiated to create an algorithm based on the strength of the Bluetooth Received Signal Strength Indication (RSSI). The ultimate goal for Bluetooth contract tracing is to detect a reliable threshold of data to determine whether a person is too close for too long. This project is conducted to determine how external factors impact the effectiveness of RSSI. Its goal is to test how the human body impacts the Bluetooth (RSSI) values and simulates real world situations including the signal coming from the back pocket, front pocket, and on a flat surface clear of any obstruction.

B. Background Information

Bluetooth low energy (BLE) is a form of low energy communication where devices periodically send short packets of data [1]. BLE differs from bluetooth by using less power and connecting to a maximum of 20 different devices simultaneously. BLE Beacons send low energy signals at a given range and are commonly used in marketing and targeted ads. However, devices can utilize BLE signals where they broadcast and scan for signals and determine if an individual is too close for too long based on the Bluetooth Received Signal Strength Indication (RSSI). RSSI is measured in dBm and ranges from 0 to -120 [5]. The closer the values are to 0, the stronger the signal. For this experiment, one raspberry pi's is used as a beacon and the other one as a receiver which scans for Bluetooth signals.

II. Hypothesis

The objective of this study is to investigate the effect of the presence of the human body on the strength of RSSI. The hypothesis is that the human body has no interference with bluetooth contact tracing, meaning the strength of the RSSI stays the same if the beacon is carried in the front or back of a person compared to on a flat surface without the presence of a person immediately nearby. This is relevant to piPACT because the goal of PACT is to use the RSSI signal strength to determine whether people are too close to each other. If the RSSI changes based on where the device is placed rather than solely from the distance between people, RSSI could give inaccurate results for contact tracing.

III. Experiments and Data Collections

A. Plan and Execution

To research how the human body affects the RSSI signal, the Pis were placed both on the ground with no human interference, carried by a person in front of the body or behind the body. When conducting the experiment, two persons hold the Pis facing each other within a certain distance to generate the RSSI signal data. This was repeated at 1.5 meters, 2.5 meters, and 3.5 meters for approximately 500 data points each inside a single-family house. Initially, the Pis were placed in pockets. However, the Pis heated very quickly and at many times shut off. The Pis were changed to be handheld in front of the body or behind the body. The Pis were all in the same orientation with the top of each Pi facing each other. When changing from behind to in front of the person, the Pi's were always at the same distance but the person was moved so the Pis were apart at the same distance for each variation.

B. Data Relevance

The Pis on a flat surface scenario serves as the control for the comparison of other scenarios where there are obstructions. Distance is the control variable to see if effects of the human body depend on the distance between the devices. Lastly, the Pi's were held behind the individuals to simulate the beacon behind the individual in the back pocket.

C. Experiment Results

Fig. 1 summarizes the results of the experiment with the means of the RSSI value under various scenarios including putting both Pis on the ground, behind a person, and in front of a person. Fig. 2-4 shows the RSSI value distribution under various scenarios such as on the ground with a person, in front of a person, or behind the back of a person.

Figure 1 Mean of the RSSI Value

Distance - Control Variable	On Ground	Front	Back
1.5 Meters	-62.95	-76.79	-73.07
2.5 Meters	-66.79	-80.60	-84.19
3.5 Meters	-72.46	-76.77	-90.32

Figure 2 RSSI Distribution at 1.5 meters

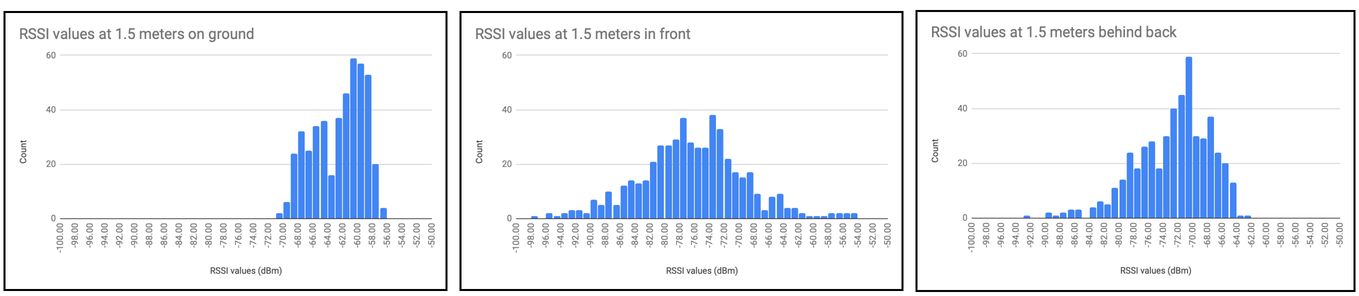


Figure 3 RSSI Distribution at 2.5 meters

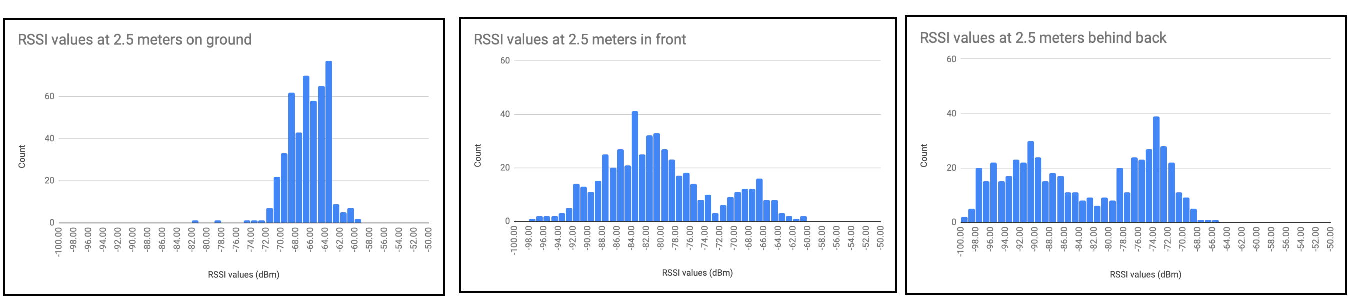
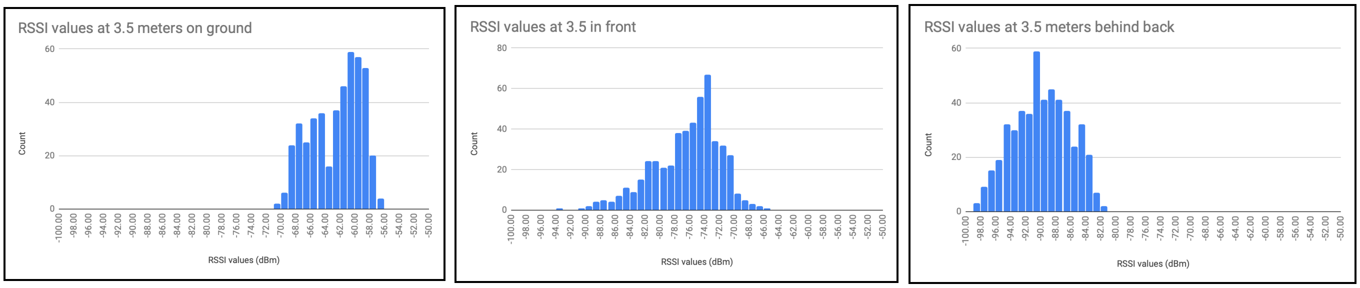


Figure 4 RSSI Distribution at 3.5 meters



IV. Analysis

For each pair of the samples, a T-Test is conducted to test the statistical significance of the means. The null hypothesis is that the means are equal. The confidence level is set at 95% or the critical region is 5%. The alternative hypothesis is that the means are not equal. It is a two-tailed test. If the P-value of the T-Test is less than 2.5% or .025, the null hypothesis should be rejected. The mean, standard deviation, and sample size of each of the samples and the P-value of the T-Test for each pair of the samples are shown in the following figures.

Figure 5. T-Test Result for the 1.5-Meter Scenario

	On-Ground	Front	Back
Mean	-62.95	-76.79	-73.07
Standard Deviation	3.40	7.06	5.02
Sample Size	455.00	511.00	499.00
P-Value of T-Test - Compare On-Ground and Front	0.0000		
P-Value of T-Test - Compare Front and Back		0.0000	
P-Value of T-Test - Compare Back and On-Ground			0.0000

Figure 6. T-Test Result for the 2.5-Meter Scenario

	On-Ground	Front	Back
Mean	-66.79	-80.60	-84.19
Standard Deviation	2.64	7.76	9.21
Sample Size	469.00	507.00	540.00
P-Value of T-Test - Compare On-Ground and Front	0.0000		
P-Value of T-Test - Compare Front and Back		0.0000	
P-Value of T-Test - Compare Back and On-Ground			0.0000

Figure 7. T-Test Result for the 3.5-Meter Scenario

	On-Ground	Front	Back
Mean	-72.46	-76.77	-90.32
Standard Deviation	3.78	4.53	3.76
Sample Size	525.00	509.00	494.00
P-Value of T-Test - Compare On-Ground and Front	0.0000		
P-Value of T-Test - Compare Front and Back		0.0000	
P-Value of T-Test - Compare Back and On-Ground			0.0000

Since all the P-values of the T-Tests are zero, less than the predetermined threshold of 2.5%, there is a significant difference in the means of the data. This indicated the null hypothesis should be rejected since the data readings are strong and not due to chance [3]. This demonstrates that the human body does have an influence on the strength of the RSSI values.

V. Conclusions

A. Hypothesis Evaluation

From the data and analysis, the null hypothesis that human interference does not affect Bluetooth contact tracing is rejected. There is a statistically significant difference between scenarios in terms of the mean of the data, that is, the presence of the human body does influence the strength of RSSI.

B. Noteworthy Conclusions

The presence of the human body between devices creates sufficient ambiguity in RSSI that it cannot reliably be used to determine proximity. At different distances including those within and out 6 feet social distance guideline set by the CDC, the human body alters the RSSI values and bluetooth COVID-19 contact tracing needs to take this into account.

C. General Lessons Learned

The piPACT program is very complex. Based on the experiment, the values vary as seen from the standard deviation in Fig. 5-7 and the histograms in Fig. 2-4. Even without human interference, fluctuations in the values will occur even under the on-the- ground scenario. More studies are needed to evaluate other environmental impacts.

VI. Next steps

Because of the inclusivity of the data, more testing is needed to determine the effect of the human body on the strength of the Bluetooth signal. The next step after that could be to test the sizes of humans: larger or skinnier. This would simulate real world situations in crowded gatherings where COVID spread is rampant such as bars and parties. Additional tests could be conducted out-door to evaluate if the out-door or in-door environment would make a difference with respect to the human body impact on the RSSI strength. Additional research could also be conducted to quantify the extent of the effect of the human body.

References

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