Bluetooth Signal Strength Interference From External Factors

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Abstract

Bluetooth enabled devices have the capability to send advertisements which can be scanned and stored on other Bluetooth enabled devices, such as a smartphones and computers. This technology has the ability to contact individuals who have potentially been exposed to someone who has been diagnosed with COVID-19. In this project, Bluetooth signal monitoring was used to track signal strength through various materials and structures at defined distances, with the goal to determine if RSSI signal strength can be used to predict distance. This was done by measuring RSSI signal strength through various materials at one-foot intervals over twenty feet. As this experiment was conducted in a controlled environment, further research is needed to determine the effects other factors.

Keywords — Obstructions, reflections, material, Bluetooth, COVID-19, contact tracing, signal strength

I. INTRODUCTION

A. Project Description

This experiment addresses the variability in signal strength as it passes through different materials at varying distances. In this study, the materials used were common materials found in clothing and bags which would carry cellphones, laptops, and other Bluetooth devices. The goal is to use Bluetooth signals to facilitate Private Automated Contact Tracing in real-world scenarios in order to reduce the spread of COVID-19. This study addresses this goal by concluding that certain signal strengths, regardless of the material tested, indicate that a person has had close contact (within 6ft) of a person who has been diagnosed with COVID-19. This experiment was carried out by advertizing and scanning on two model 4B Raspberry Pi's for two minutes at one foot intervals within a twenty foot range. For each trial, there was a different covering over the stationary Raspberry Pi in order to simulate a device being put in a pocket or other portable enclosure.

Further testing included measuring RSSI signal strength in the same manner through interior walls as well as in the presence of nearby walls.

B. Background Information

Bluetooth enabled devices advertise their presence by sending signals to one another, "chirps", and receive chirps from nearby devices. Each device has a unique ID which gets recorded when a chirp is received. Devices are able to store these chirps for extended periods of time, anonymously logging the devices that it has come in contact with. This technology alerts individuals who may have been in close proximity to an infected person without revealing the identity of either party.

II. HYPOTHESIS

This experiment studied the transmittance of Bluetooth signals through various everyday materials that people use to carry their devices over defined distances up to twenty feet. This study hypothesized that signals passing through materials will decrease in strength, and therefore different thresholds would be necessary to determine if a person has been in close contact (defined as six feet) with COVID-19, dependent on the material used to carry or obstruct the Bluetooth device. The aspect of the hypothesis that required the most investigation was obtaining the precise relationship between the diminished signal strength and the material of the obstacle.

III. EXPERIMENTS AND DATA COLLECTIONS

TABLE I. EXPERIMENT OVERVIEW

Experiment Name	**Hypothesis**	**Reason**	**Repetitions**
No barrier	Control	Empirical quantification of signal strength	19
Denim Jeans (Cotton)	Effect of obstruction	Empirical quantification of signal strength	19
Handbag (Polyester & PVC)	Effect of obstruction	Empirical quantification of signal strength	19
Backpack	Effect of obstruction	Empirical quantification of signal strength	19
Wallet (Cotton & Polyester)	Effect of obstruction	Empirical quantification of signal	19

Experiment Name	Hypothesis	Reason	Repetitions
		strength	
Wallet (Cotton, Polyester, RFID Blocker)	Effect of obstruction	Empirical quantification of signal strength	19
Wall (2-½ inch Gypsum, 2x4 pine studs)	Effect of obstruction	Empirical quantification of signal strength	9
No Wall	Effect of reflection	Empirical quantification of signal strength	9

A. Plan and Execution

This experiment was conducted in a controlled environment by sending Bluetooth signals from one Raspberry Pi to another over fixed distances and time intervals. For each material, the stationary Raspberry Pi was fitted with the material and laid in a fixed position at the twenty-foot mark along a straight line. Meanwhile, the other Raspberry Pi was kept uncovered, and was laid at one-foot increments along the straight line between one and twenty feet away from the stationary Raspberry Pi. No other obstacles were present between the two Raspberry Pi's. While the stationary Raspberry Pi advertised, the mobile Raspberry Pi scanned for two minutes at each foot increment. This was intended to increase controllability as it reduced the allowance for external noise in the data and prevented the polling interval from being an external factor. The setting of the experiment was in a house, the rooms did not have perfect symmetry (the ceilings were two-story).

In the same manner, signal strength was afterwards measured in a different location, through no barrier, and through a standard interior wall.

B. Data Relevance

Through analysis, it was determined that the wearable materials tested, though they had some significant effect at short distances, were less significant at distances greater than five feet. This supported the hypothesis that materials will reduce the Bluetooth signal strength, and therefore, a higher tolerance is necessary in order to make a general conclusion that two devices have been in close proximity, regardless of the materials tested. Each test was conducted to determine the effect of the specific material on signal strength across distance.

In the second location, the same pattern held true.

IV. Analysis and Algorithms

A. Description

For each material, the average RSSI value at each distance was calculated and a plot of RSSI values versus distance was created using Python. These graphs were all superimposed onto a single plot. Then, in order to see the variance of the RSSI values at a single distance for any given material, a plot was created for every RSSI value at six feet over the entire two-minute capture. This plot was recreated with a moving average. As it was found that there was high fluctuation in these plots, the maximum RSSI value for each material at each distance was also plotted in the same manner as the first graph. From this final graph, there was an evident trend showing that there was a steep decrease in signal strength over the first three feet, and a continuous, less-steep trend after five feet. Upon further analysis, it was determined that all signals with an RSSI strength of negative sixty-nine or less would be considered in a high-risk range.

B. Results and Examples

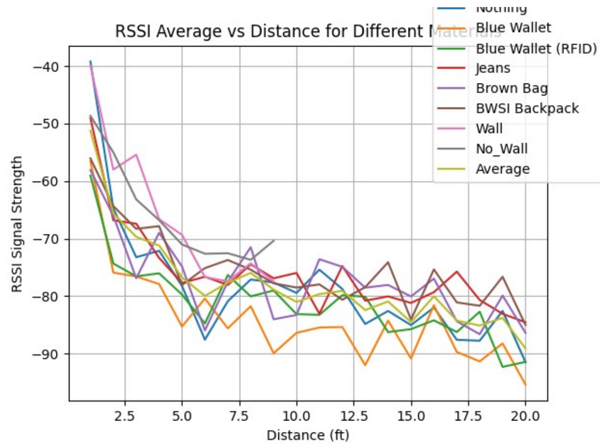

Fig. 1 RSSI Average vs Distance for Different Materials

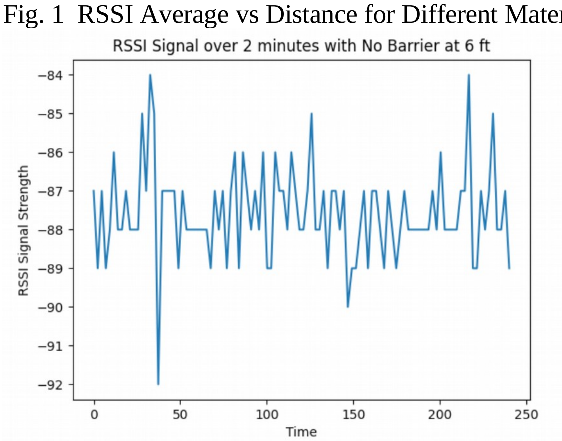

Fig. 2 RSSI Signal over 2 Minutes with No Barrier at 6 ft

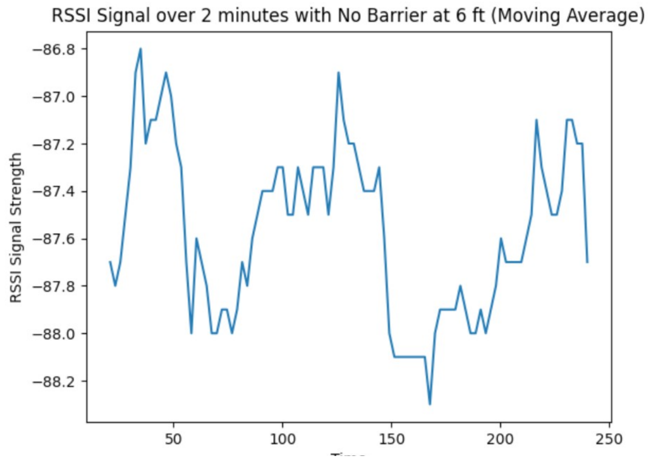

Fig. 3 RSSI Signal over 2 Minutes with No Barrier at 6 ft (Moving Average)

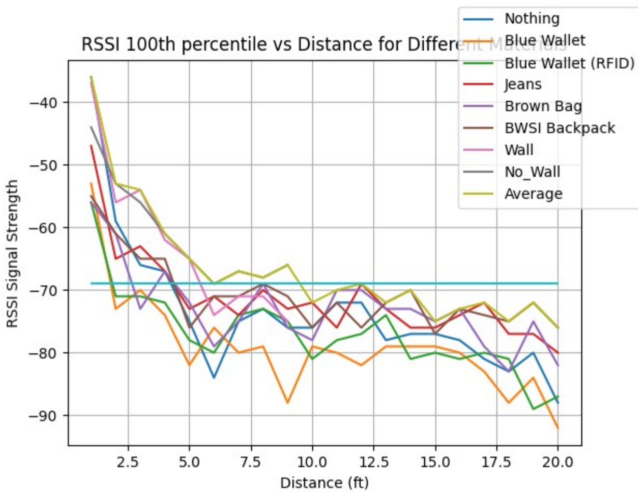

Fig. 4 RSSI Max vs Distance for Different Materials

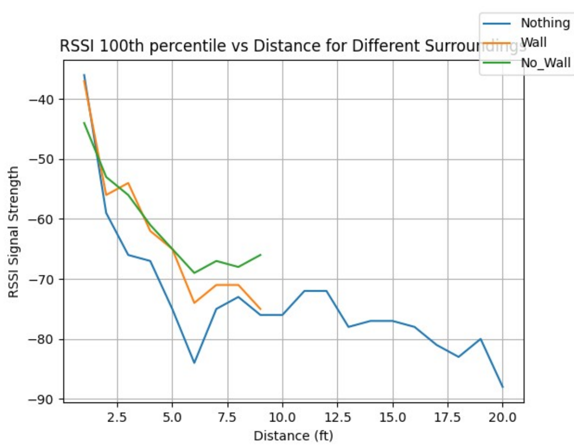

Fig. 5 RSSI 100th percentile vs Distance for Different Surroundings

These charts show how any RSSI values stronger that negative sixty-nine can conclusively be determined as within a six-foot range.

Additionally, chart five shows that there was an amplified effect on the RSSI strength from the nearby walls.

V. Conclusions

A. *Hypothesis Evaluation*

In the end, the hypothesis was indeterminate as a specific correlation to signal strength loss and material was not significant, however, it was determined that the signal strength was affected by the presence of a blocking material. This assessment was made upon the basis that collected data showed a trend where certain materials had a varying greater effect on signal strength than no materials.

B. *Noteworthy Conclusions*

The presence of an obstruction between devices has a dampening effect on the RSSI signal strength which indicates that a higher threshold of negative sixty-nine is necessary in order to conclude that two devices have come into close contact (six-foot range) with one another.

Additionally, a new conclusion could be drawn that nearby walls, and perhaps other objects, could amplify Bluetooth signals through reflections.

C. *General Lessons Learned*

Over the course of this project, I have learned that Bluetooth is a potential way to automate anonymous contact tracing. Throughout my tests, there was not a single signal over sixty-nine when the Raspberry Pi's were more than five feet apart. Therefore, using the common materials tested, if two objects have a signal strength of sixty-nine or stronger, it can be inferred that they have come into a six-foot range of each other. However, the conclusion that nearby objects affect signal strength make Bluetooth contact tracing more of a challenge indoors and in crowded settings.

VI. Next Steps

Given more time and resources, I will be conducting further trials with more materials and non-static subjects and additional surroundings. In addition, I will employ further statistical analysis methods in Python to explore the effects of materials on Bluetooth signals.