Group 6 Assignment 3

1. Group Members

Davindran	A0167009E
Low Jun Wei	A0168303J
Shanon Seet	A0172753B

2. Introduction

The objective of this report is to observe and measure the effects of the following factors on Received Signal Strength Indicator (RSSI): distance, different obstacles, and other factors such as surrounding Bluetooth signals and orientation of the receiver/transmitter. Based on our measurements, we will then discuss the suitability of RSSI as a proxy for distance.

3. Measurements and Discussion

3.1. RSSI and Distance

Results

This task was carried out in one of the corridors in SoC. Each set of measurements were taken by averaging the RSSI and loss ratio at the receiver over 10 seconds at a frequency of 4Hz, for a total of 40 samples. We collected 3 sets of data per 5m interval with varying placements of the receiver, always ensuring that the transmitter and receiver remained within line-of-sight.

The results obtained are shown below.

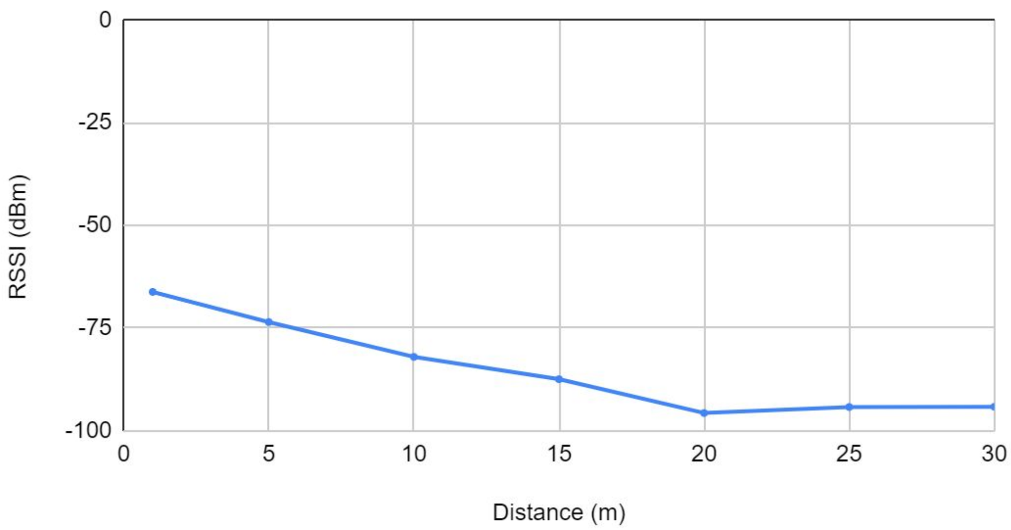

Fig. 1.1. Graph of signal strength (RSSI) over distances ranging from 1 to 30m

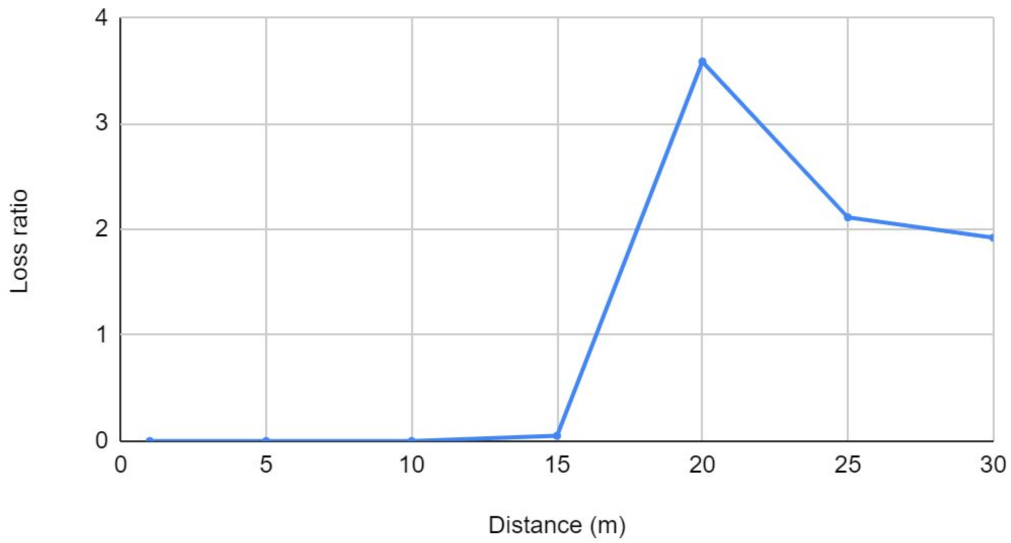

Fig. 1.2. Graph of packet-loss ratio over distances ranging from 1 to 30m

<u>Discussion</u>

A negative correlation can be seen when plotting the distance between the receiver and transmitter, and the RSSI. The packet loss ratio also increases with distance.

In theory, signal strength is inversely proportional to distance^alpha, depending on the surrounding environment. However, one can see that the curve obtained in our measurements does not fully follow an exponential curve. There are several possible reasons for this:

1. There was a variation of surroundings over the distance we conducted the experiment. Some portions along the corridor had an open area extending to the sides, while other portions were enclosed between walls. The varying shape of the environment and presence of various objects affect the amount of signal reflection along different parts of the corridor.
2. There was movement of people around the corridor, although we always made sure that the transmitter and receiver had a clear line-of-sight between them. This would also affect signal reflection due to signal absorption by the obstructing human bodies, since the walls of the corridor would reflect signals better than people as shown in section 3.2.
3. The presence of other signals around the transmitter and receiver would affect the RSSI. The experiment was conducted in a public area with no control over the consistency of interfering signals. As the transmitter and receiver moved across the corridor, they would approach or move away from the access points placed around SoC, as well as other signals such as stationary Bluetooth signals from phones belonging to other students. As shown in section 3.3, the presence of other signals can greatly affect RSSI.

3.2. RSSI and Obstacles

Results

This task was carried out by placing the transmitter and receiver 1m apart, with different obstacles placed in the center of them. Each of the measurements were taken by averaging the RSSI and loss ratio at the receiver over 10 seconds, or over 40 samples taken at a rate of 4Hz.

The measurements of RSSI received by the receiver are shown below.

	RSSI 1	RSSI 2	RSSI 3	Avg RSSI
Table	-45.600	-47.300	-46.300	-46.400
Pillar	-59.825	-60.200	-60.350	-60.125
2 Humans	-71.150	-70.850	-65.400	-69.133
2 Laptop Screens	-59.575	-67.550	-64.359	-63.828
Glass Door	-47.425	-46.525	-42.300	-45.417
Sweater	-67.000	-64.150	-55.675	-62.275

Table 1. Table of RSSI measured across different obstacles

Discussion

Based on our results, we can arrange the obstacles from least to most effective in blocking the signal: glass door, table, pillar, sweater, 2 laptop screens, and 2 humans.

Generally, it can be observed that human bodies and electronic devices such as laptop screens were most effective in blocking the received signal.

The specific material of the obstacles determined its interaction with the signals. Generally, the material through which a signal is transmitting affects the signal by means of absorption, reflection, and refraction. Materials with less densely packed molecules are better at absorbing and refracting waves. For human bodies, once the signal permeated the skin, the water content and tissue also affected the absorption and refraction of the waves. For a glass door with more densely packed molecules, there was much less absorption and refraction of the signal and hence it was less effective in blocking the signal.

We acknowledge that several other factors could have affected the measured RSSI:

1. The texture and shape of the obstacle could affect the signal reflection. For example, the pillar we chose was circular, which would scatter the signal in a different manner than if we had measured the RSSI using a rectangular pillar.
2. The surrounding environment of the obstacle could affect the strength of the reflected signal received at the receiver. For example, in our measurement of RSSI across the table surface could have been affected by the presence of other tables beside it acting as reflection surfaces. This is opposed to our measurement of RSSI across 2 humans, which was done in a relatively open area.

3. The transmission medium could have played a part in affecting RSSI, such as the air having differing humidity levels. Although we do not have conclusive evidence from our experiments of how various transmission mediums affect RSSI, it is worth mentioning.

3.3. RSSI and Other Factors

We considered 2 other factors that could affect RSSI: signal interference, and the orientation of the transmitter and receiver. Based on these 2 factors, we conducted 2 experiments to measure the effects of these factors on RSSI.

The following experiments were carried out by placing the transmitter and receiver 0.70m from each other. Each of the following measurements were taken by averaging the RSSI at the receiver over 10 seconds, or over 40 samples taken at a rate of 4Hz.

Factor 1: Signal Interference

In this experiment, we compared the difference between RSSI when the Bluetooth on our phone and laptops were turned on (for a total of 6 devices) and placed directly next to the transmitter and receiver, and RSSI when our devices were on airplane mode and there were no transmitting devices in close proximity of the transmitter and receiver.

The measurements of RSSI received by the receiver are shown below.

	RSSI 1	**RSSI 2**	**RSSI 3**	**Avg RSSI**
Bluetooth On	-46.000	-46.175	-46.650	-46.275
Bluetooth Off	-43.000	-43.000	-43.000	-43.000

Table 2. Table of RSSI measured with Bluetooth of nearby devices on and off

Factor 1: Discussion

Based on our results, we can see that the average RSSI dropped noticeably when Bluetooth signals on surrounding electronic devices were turned on. This shows that nearby signals do pose significant signal interference and weaken the signal strength detected by the receiver. Thus, in order for effective signal transmission, the sender and receiver should be placed sufficiently far away from other transmitting devices in addition to having a clear line-of-sight.

One application of this observation is in choosing the environment when deploying wireless communication devices. If the transmitter or receiver is deployed in an indoor location with other transmitting devices nearby, the signal transmission would be weaker than if the transmitter and receiver were placed in an open area with no devices nearby.

Factor 2: Orientation of Transmitter and Receiver

In this experiment, we compared the difference between RSSI when the receiver and transmitter were placed in different orientations. We defined the top of the debugger pack to be the front-facing side of the SensorTag devices.

The measurements of RSSI received by the receiver are shown below.

	RSSI 1	RSSI 2	RSSI 3	Avg RSSI
Both Facing Each Other	-46.525	-44.525	-44.000	-45.017
Receiver Facing Away	-41.275	-41.100	-40.425	-40.933
Both Facing Away	-36.975	-36.675	-36.250	-36.633
Transmitter Facing Away	-39.475	-39.300	-39.500	-39.425

Table 3. Table of RSSI measured with differing orientations of receiver and transmitter

Factor 2: Discussion

We observed from our results that the orientation of the 2 SensorTag devices noticeably affected our measured RSSI. Since all other factors like distance between sensors, presence of obstacles and interfering signals were held constant during this experiment, we can confidently say that the positioning of the transmitters and receivers on each board is a relevant factor of RSSI. Measured RSSI was the strongest when both the SensorTag devices were facing ‘away’ from each other. Conversely, the RSSI was weakest when they were facing ‘towards’ each other. The results obtained from flipping either board were similar at an average RSSI of -40dBm.

From these readings we are able to conclude that the transmitter and receiver antennae were located at the bottom side of the SensorTag board, hence producing a high RSSI value when placed in an orientation with an unobstructed line-of-sight.

This raises yet another point of consideration when deploying communication devices to achieve the highest possible RSSI. Even at the same distance, the signal strength can be significantly affected by the location and orientation of the antennas. Choosing the correct antenna orientation is an easy way to optimize RSSI.

3.4. RSSI as a Distance Proxy

Based on our experimental results, we observed steady drops in RSSI when incrementing the distance between the transmitter and the receiver up to a maximum of 20m. This observation could have been possible because we ensured that most of the conditions were held constant when taking our readings, with minimal interference from external factors. To replicate similar results, it is essential to first take the signal profile of the environment that the devices will be set up in. As seen in the measurements taken, different obstacles with different placement, densities and materials greatly affect RSSI. Our results also show that the connection starts to drop packets only after 20m and this holds true for all distance readings exceeding 20m, which hints that the connection is stable and consistent up to a maximum distance of 20m. The effectiveness of RSSI as a distance proxy is only valid for static environments with a known signal profile up to a limited range of 20m, making it less than ideal for large scale deployments.

As shown in the report, there are many other confounding factors that affect RSSI value besides distance. For example, a higher RSSI value could either imply that the receiver is closer to the transmitter, or that there are less obstacles between the receiver and transmitter. It might also imply that there is less signal interference in the area, since these are all valid factors contributing to RSSI values.

For mobile wireless devices which have non-static environments, RSSI will be a highly inaccurate distance proxy for several reasons.

Firstly, the device's environment has been shown to play a huge role in influencing RSSI values. In a constantly changing environment, RSSI will fluctuate unpredictably, and will definitely be a poor distance measure.

Also, if the receiver is mobile and the transmitter is fixed, the two will constantly change their relative orientations which will affect its RSSI and therefore its distance measure as shown in section 3.3. For example, if a receiver was moving around the transmitter with a constant radius but with changing orientation, its RSSI will change due to its change in orientation despite the distance remaining constant.

It is possible that a single area in which RSSI is used as a distance proxy is fully mapped out, such that for all known points within the area and all orientations of the receiver, the distance between the transmitter and receiver is recorded. In this manner, RSSI as a distance proxy for a mobile receiver may be acceptable. However, the profile of the surroundings might never be truly static due to the mobility of other transmitting devices. As shown in section 3.3, other transmitting devices moving in and out of range of the receiver will affect its RSSI values, and therefore distance cannot be accurately estimated.