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A Novel Approach on Covid-19 Contact Tracing – Utilization of Low Calibrated Transmission Power & Signal Captures in BLE

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Abstract

Covid-19 pandemic has compelled countries to conduct contact tracing vigorously in order to curb the highly infectious virus from further spread. In this context, Bluetooth Low Energy (BLE) has been broadly used, utilizing Received Signal Strength Indicator (RSSI) for Close Contact Identification (CCI). However, many of the available solutions are not able to adhere to the guidelines provided by Centers for Disease Control (CDC) and Prevention which are: (1) Distance requirement of within 6-feet (~2 meters) and (2) Minimum 15-minutes duration for CCI. In providing some closure to the gap, we proposed a novel approach of utilizing: (1) Low calibrated transmission power (Tx) and (2) Number of signal captures. Our proposed approach is to lowly calibrate Tx so that when distance is at 2 meters between users, number signal capture gets lower as the chipset's smallest RSSI sensitivity value has been reached. In this paper, complete experimentation for Proof of Concept (POC) and Pilot test conducted are demonstrated. Results obtained shows that the accuracy for POC utilizing signal captures for 2±0.3 m distance is at: (1) 71.43% for 5 users and (2) 70.69% for 9 users. While so, accuracy for the Pilot test when considering CCI on individual case-basis is at 95% for 5 users.

Keywords:

Bluetooth Low Energy;
Contact Tracing; Covid-19;
Transmission Power;
Signal Capture.

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1- Introduction

One of the latest and ongoing threat to the world's public health is the Covid-19 pandemic that has emerged back in December 2019, with its first detection in Wuhan City, Hubei Province of China [1]. Without taking much time, World Health Organization (WHO) Emergency Committee announced the state of emergency on January 30th 2020, as there were growing numbers of cases in China and other parts of the world [2]. The pandemic is very severe that it affects not only public health but many different components of life globally including education, entertainment, tourism, businesses and manufacturing [3]. While so, only some of the infected patients display sign of symptoms while the rest are asymptomatic making it more dangerous and harder to be contained [4].

Thus, governments took measures to curb the spread by using methods such as physical distancing, contact tracing, usage of personal protective equipment (PPE) as well as decontamination and disinfection of contaminated areas [5]. With that being said, contact tracing for Covid-19 scenario becomes one of the most essential tools to control and manage the pandemic as the number of cases keep on escalating from day to day with no signs of stopping. This scenario is illustrated in Figure 1. Thus, countries started to adopt contact tracing rigorously as studies have shown that it is able to curb further virus spread [6]. Nevertheless, each country has its own methods of implementation and choice of technology that makes it ununified in term of execution and accuracy.

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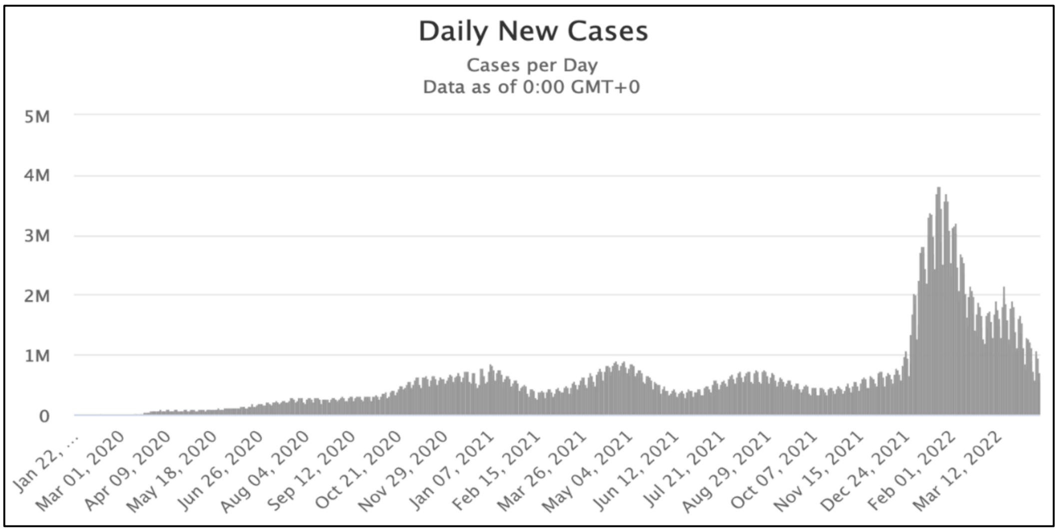

Figure 1. Daily Covid-19 New Cases from January 22nd until March 12th 2022

CDC in this case, has provided two rules to be followed in order to be identified as CCI for an effective and unified implementation. They are distance of less than 6-feet with a minimum period of 15-minutes with one another [7]. From the scenario stated, two main information are needed in order to identity one as a close contact and they are: (1) Distance and (2) Duration. In obtaining these items, it is only possible with the usage of smart technologies and BLE has been accepted as one of the most promising among others in existence for contact tracing [8]. Even with only two information that are required, not many contact tracing solutions are able to obtain them accurately, especially for the distance estimation. First of all, it is because big segment of BLE-based solutions are utilizing RSSI solely for distance estimation towards CCI [9], which makes it quite unreliable as the nature of RSSI is volatile. Elements such as physical obstruction, angle of arrival (AOA) and movements will affect the RSSI value substantially making the accuracy for contact tracing to be low. While so, obtaining the information on the duration of close contact is not an easy task as well.

Secondly, many of the contact tracing solutions in combating the pandemic are utilizing venue-based tracing rather than close contact tracing, which makes it unable to adhere to CDC's guidelines. Venue-based tracing in general, is used to identify groups or individuals that have been at an outbreak location at a particular time with distance dimensions between users being unutilized. For this type of tracing, technologies such as QR code and Global Positioning System (GPS) are being implemented. These proximity technologies are able to identify the whereabout of the people at a location but does not possess the ability to measure effectively the distance between individuals. Malaysia's MySejahtera for example, initially adopts only QR code for contact tracing [10] with no ability for distance estimation nor mechanism for duration of close contact. Similarly, Columbia's CoronApp [11] and India's Aarogya Setu [12] are utilizing venue-based tracing as well using GPS technology that carries the same setbacks, Figure 2 shows the difference between venue-based tracing and close contact tracing. Last but not least, many of BLE-based contact tracing solutions are adopting Bluetooth's connected mode, which are only able to handle up to 7 users practically [13, 14]. Therefore, when there are more than 7 users in vicinity, these BLE-based connected mode solutions will cease to work effectively producing many errors. Thus, in overcoming this critical issue, we proposed a novel approach of utilizing low calibrated Tx using nRF52832, which is a BLE chipset, as a wearable in this study. The approach is illustrated in Figure 3. The theory behind our proposed approach is that, the usage of low Tx will make the signal generated to be weak producing low RSSI (big negative in value) as shown in Figure 3.

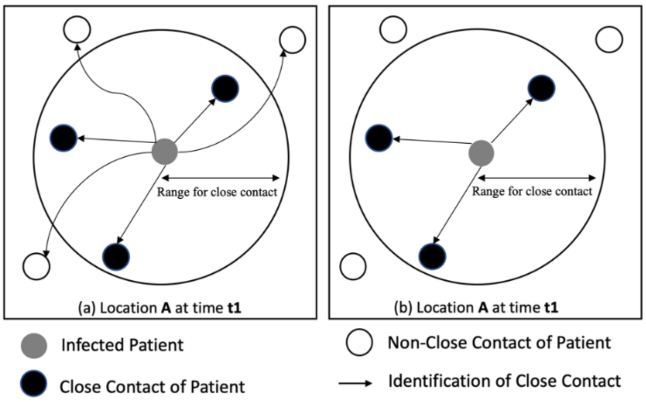

Figure 2. (a) Venue-based tracing; (b) Close contact tracing

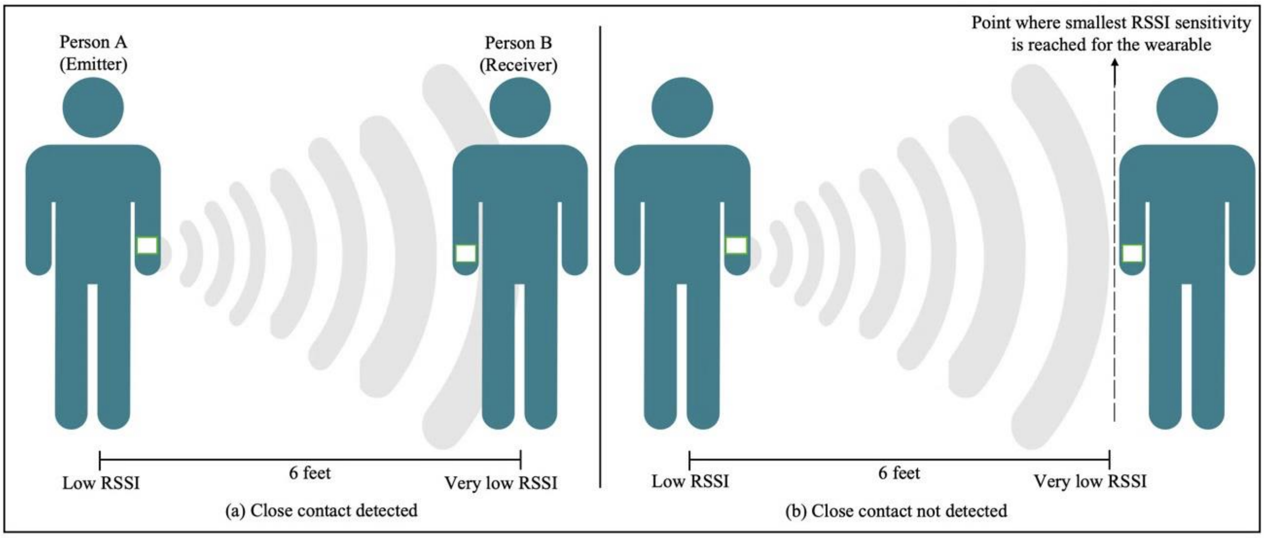

Figure 3. (a) Close contact detected; (b) Close contact not detected

In general, RSSI is the indication of power level that are being received by the antenna in which, it means the bigger the value of RSSI (small negative value), the stronger the signal is [15]. As the signal travels further, it will be weaker that the RSSI value keeps on getting smaller with distance travelled [16, 17]. While at the same time, each BLE chipset possess its own maximum RSSI sensitivity (maximum negative value) that differs from one model to another. When the maximum RSSI sensitivity has been reached, the chipset will not be able to detect incoming signals anymore theoretically. While in practical scenario, it will be the case of lesser number of signals that are being captured on the receiver side. Therefore, utilizing this insight, Tx is calibrated to be low and for the RSSI reaching maximum sensitivity for the wearable at the distance of 2 meters for this Covid-19 pandemic. Thus, when the number of signal detections gets lower than minimum required value that has been obtained from experimentation, there will be no longer CCI making the accuracy to be high. Our proposed approach eliminates the mainstream method of solely using RSSI for distance estimation towards CCI in contact tracing solutions for the pandemic. While so, the approach also eliminates the disadvantages of venue-based tracing while being scalable as advertising mode is being used. RSSI in this approach, will only be utilized as a tool to limit the distance of detection up to 2 meters along with the Tx. Afterwards, it is the number of signal captures that will determine CCI. In this study, we used nRF52832 BLE chipset, which is a versatile Bluetooth 5.2 system on a chip (SoC) for the whole experimentation. It has a maximum sensitivity of -96 dBm with its own central processing unit (CPU) of 64 MHz Arm Cortex-M4 along with flash memory of 256 KB and 128 KB random access memory (RAM) [18]. While so, it is equipped with 4 dBm maximum Tx which is more than enough for this study. Figure 4 shows the layout of nRF52832 chipset. In this study, experimentation is separated into three main stages as shown in Figure 5 below. They are: (1) Tx Set Up to obtain and test for Tx, (2) Proof of Concept (POC) to verify the proposed approach and (3) Pilot Test to test the approach in real-life environment. It should be noted that this approach and experimentation methods can be duplicated using other BLE modules as well.

Figure 4. nRF52832 chipset

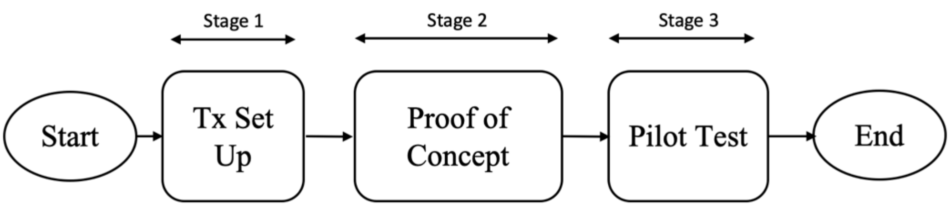

Figure 5. Overall Experimentation Stages

2- Methods

2-1- Experimentation Set Up – Hardware and Software

In setting up the experiment, multiple nRF52832 powered by 5V lithium-ion battery were used with the number of devices vary in each stage. For stage 1, two devices were utilized as the transmitter and iPhone XS with iOS 15.1 (smartphone was put into flight mode) as the receiver using a software to record. Usage of two transmitters is to observe if there exists substantial difference in the experimentation results as it is crucial in this stage to obtain data as accurate as possible in order for the accuracy to be high. For stage 1, the chipset is set to transmit advertising packets every 50 ms while the receiver is set to have scan interval of 5s. Distance measured were for 0m, 1m, and 2m to test for best suitable Tx. The obtained information will be recorded into an Excel sheet containing four crucial information which are: (1) Medium Access Control Address (MAC Address), (2) RSSI value, (3) Date and (4) Time. It should be noted that that this four information will be the only data that are being captured throughout all the experimentation stages and it is being arranged according to latest time. While so, observations size of 100 were used in stage 1 so that it is enough to observe variations (if any) and wearables were elevated to 0.5m to imitate actual wearing on the wrist with line-of-sight (LOS) to the receiver. In other words, conditions were set to be ideal for stage 1. Figure 6 shows the experimentation set up for stage 1 and Table 1 shows the sample of data obtained.

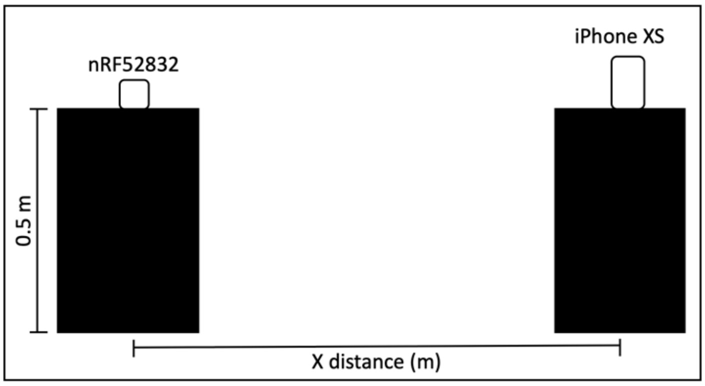

Figure 6. **Stage 1 Experimentation Set Up**

Table 1. **Sample of Captured Data**

No.	Mac	RSSI	Date
1	ac:23:3f:a5:74:34	-58	2022-02-22 08:19:59
2	ac:23:3f:a5:74:34	-58	2022-02-22 08:19:54
3	ac:23:3f:a5:73:bc	-59	2022-02-22 08:19:49
4	ac:23:3f:a5:74:63	-81	2022-02-22 08:19:44
5	ac:23:3f:a5:73:e8	-67	2022-02-22 08:19:39
6	ac:23:3f:a5:74:34	-63	2022-02-22 08:19:33
7	ac:23:3f:a5:74:63	-81	2022-02-22 08:19:27

For POC experimentation in stage 2, it was conducted using multiple devices with the maximum of 9 devices in total comprising 8 transmitters and 1 receiver. The distance experimentation ranges from 1m to 3m with multiple conditions and positions set. This is to test the concept under ideal conditions for multiple real-life scenarios. Similar to stage 1, the devices in stage 2 also were elevated to 0.5 m with varying angles and 15-minutes duration for every distance tested. Different angles will be able to provide information on how the approach will respond for different OAOs. Figure 7 shows the experimentation set up for POC in stage 2. The aim of POC is to determine whether the approach can be verified whether it is working before advancing towards the next stage. As for the scanning interval, it was set at 3 seconds per scan for devices of more than one in order to cater for the increasing number of users.

In stage 3, it is the Pilot test where experimentation was set up in an indoor office environment comprising of 5 users. There are multiple doors and walls in vicinity with the users walking by once in a while. Stage 3 is the most crucial stage as it will determine whether or not the approach can be implemented in real-world scenario. The nRF52832 chipsets were inserted into rubber-type strap and given to the 5 users for the duration of 3 hours. Users were asked to record down on a form for every person whom they had contact with for distance within 2-meters and duration of no less than 15-minutes. After the period of 3-hours has ended, wearables were collected and data were analyzed by comparing the data obtained in the wearable and the data from the users' record. Table 2 below shows the summary for the experimentation set up for three stages in this study.

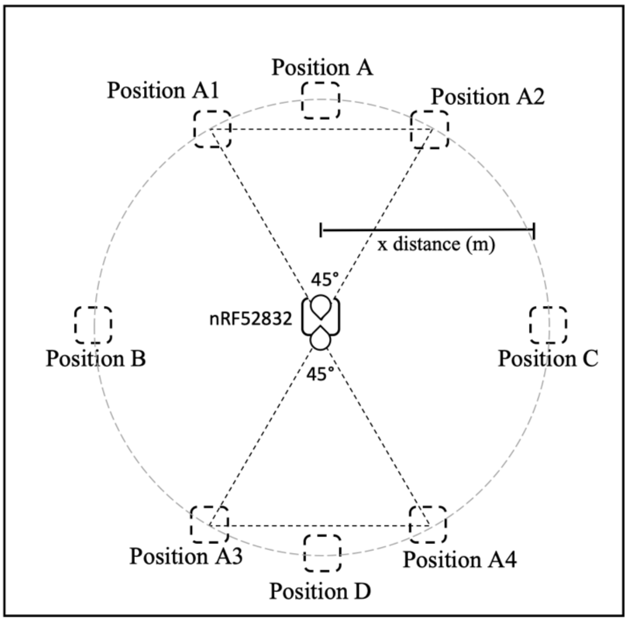

Figure 7. Stage 2 Experimentation Set Up

Table 2. Summary of Experimentations Set Up for Three Stages

Stage	Number of Transmitters	Condition	Scanning Interval	Distance Tested (m)	Elevation
1	One nRF52832 with an iPhone as the receiver	No obstacle - LOS	5s	0, 1, 2	0.5 m
2	1, 4 and 8	Multiple conditions and scenarios	5s, 3s	1, 1.5, 2, 2.1, 2.2, 2.3, 2.5, 3	0.5 m
3	4	Office setting	3s	Various	Various

3- Analysis and Results

3-1- Stage 1 – Tx Set Up

After several testing and consideration, Tx was chosen and calibrated at -8dBm due several reasons. First, the value makes the device to be reaching its maximum RSSI sensitivity of -96dBm at 2 meters as shown in Table .

Table 3. Results from Stage 1 Experimentation

Device Number, (*n*)	Condition	Distance, (m in meters)	Observations	Max RSSI Value, ($RSSI_{max}$)	Min RSSI Value, ($RSSI_{min}$)	Average RSSI Value, ($RSSI_{avg}$)
1	No obstacle - LOS	0	100	-39	-33	-35
2				-37	-32	-35
1		1		-78	-66	-71
2				-75	-70	-72
1		2		-90	-77	-83
2				-86	-78	-82

Although the RSSIavg value is not exactly at the chipset's maximum level at 2 meters, it is done deliberately to offset potential errors due physical obstacles as well as different AOAs and elevations that may be observed during real-life implementations in the upcoming stages. Table 3 shows the results obtained from stage 1 experimentation

From Table 3, it shows that there is not much of difference for the results obtained from the two devices. With only 1dBm difference in the average value, it is safe to say that experiment has been successful and Tx has been calibrated successfully for nRF52832 for this study. While so, the difference in the RSSImax and RSSImin has the maximum value of 4dBm for distance of 2 meters which is small enough to be noticeable. With the results from Table 2, Tx is set at -8dBm with the RSSI reaching towards -83dBm at distance of 2 meters.

3-2- Stage 2 – Proof of Concept

As mentioned in the previous section, stage 2 utilizes number of successful scans in considering for CCI for 15-

minutes period. Thus, towards analyzing the results for CCI and accuracy calculation, there are several important Equations and variables that needs to be considered. First is the number of scans needed under ideal condition, n_{sn}, which is calculated using Equation 1, where t_s scanning interval and n_d is number of devices or transmitters. Number of scans needed is important in analyzing as it gives overview on what the number of successful signal scans should be obtained under ideal conditions. Lesser than the calculated value means there are obstructions or error somewhere along the experimentation.

$$n_{sn} = \frac{\frac{60\,(s) x\, 15\,(minutes)}{t_s}}{n_d} = \frac{900}{t_s n_d} \tag{1}$$

Next is the number of minimum scans needed, n_{min}, which is used to determine the smallest value needed in order to be considered for potential close contact. In determining n_{min}, considerations taken that the value should be chosen from one of the smallest number of signals detected for distance less than 2 meters from POC experimentation. While so, the value should not be too small that there can be many false positives. With that being said, n_{minv} is the value that is determined by n_{min} for CCI calculation shown in Equation 2, where n_{dtc} is the number of signals detected from experimentation. The value from n_{minv} will determine whether a particular incident can be a potential close contact or not.

$$n_{minv} = (1,0);\ \text{“1” if } n_{dtc} \geq n_{min},\ \text{“0” if } n_{dtc} < n_{min} \tag{2}$$

In BLE-based contact tracing, there are five main factors that have been identified that can affect the number of successful signal scans and they are: (1) Scan Interval, t_s (2) AOA from users, (3) Physical obstruction from surroundings, (4) Passerby scenario and (5) Multiple devices in vicinity. For item 1, it is a variable that can be set and change according to a situation needs. As for item 2, AOA does not have much of an effect as the distance limitation is set to be small. This scenario can be observed from the results obtained for stage 2 experimentation in Table 4. Similar reasoning also applies to item 3 where experiment was conducted with 2-inch wooden door obstruction and CCI was not counted as the number of minimum scans required is lower. What this indicates is that, obstruction also does not have much of an effect using our proposed approach. As for item 4, it is being addressed using time segmentation of 15-minutes duration as shown in Figure 8.

Table 4. Stage 2 Experimental Results

Number of Devices, n_d	Condition	Position	Actual Distance, d_a	Scan Interval, t_s	Number of Scans Needed n_{sn} = (900)/ $t_s n_d$	Number of Detection, n_{dtc}	Signal Detection (n_{dtc} / 180) x 100	False Detection	Number of min. Scans Needed, n_{min}	Total Detections	Commentaries	Accuracy
1	No obstacle – LOS, Zero angle	Position A	1	5s	180	180	100%		150 (considering distance of **2m**)		For one transmitter, it is still possible to use n_{dtc} effectively for close contact identification	((19)/(19+4)) x 100 = **82.61%**
			1.5			179	99.44%					
			2			150	83.33%					
			2.1			158		87.78%				
			2.2			135		75.00%				
			2.3			108		60.00%				
			2.5			127		70.56%				
			3			117		65.00%				
	No obstacle – LOS, -22.5° angle from horizontal	Position A1	1			180	100%					
			2			180						
	No obstacle – LOS, 22.5° angle from horizontal	Position A2	1			179	99.44%					
			2			178	98.89%					
	No obstacle – LOS, -90° angle from horizontal	Position B	1			180	100%					
			1.5									
			2			179	99.44%					
			2.1			143		79.44%				
			2.2			131		25.56%				
			2.3			113		62.78%				
			2.5			120		66.67%				
			3			107		59.44%				

	No obstacle – LOS, 90° angle from horizontal	Position C	1			175	97.22%					
			1.5			160	88.89%					
			2			172	95.56%					
			2.1			145		80.56%				
			2.2			130		72.22%				
			2.3			110		61.11%				
			2.5			107		59.44%				
			3			101		56.11%				
	No obstacle – LOS, 180° angle from horizontal	Position D	1			177	98.33%					
			1.5			179	99.44%					
			2			179						
			2.1			152		84.44%				
			2.2			121		67.22%				
			2.3			124		68.89%				
			2.5			119		66.11%				
			3			120		66.67%				
	2-inch wooden door	Zero angle	1			169	93.89%					
			1.5			172	95.56%					
			2			160	88.89%					
			2.1			158		87.78%				
			2.2			153		85.00%				
			2.3			144		80.00%				
			2.5			130		72.22%				
			3			122		67.78%				
n_d	**Condition**	**Position**	d_a	t_s	n_{sn}	n_{dtc}	((n_{dtc} / 75 x 100)		n_{min}			
4	No obstacle – LOS, Multiple Angles, 4 Devices in vicinity	A	1	3s	75	82	100%		57 (considering distance of **2 ±0.3m**)	268	As n_d increases, it can no longer reliable to solely rely on n_{dtc} to determine close contact as shown by the red color boxes	(20 / (24 + 8)) x 100 = **71.43%**
		B				69	92%					
		C				39	52%					
		D				78	100%					
		A	1.5			70	93.33%			261		
		B				57	76%					
		C				64	89.33%					
		D				70	93.33%					
		A	2			74	98.67%			266		
		B				62	82.67%					
		C				62	82.67%					
		D				68	90.67%					
		A	2.1			75		100%		272		
		B				53		70.67%				
		C				69		92%				
		D				75		100%				
		A	2.2			65		86.67%		269		
		B				66		88%				
		C				80		100%				
		D				58		77.33%				
		A	2.3			50		66.67%		260		
		B				85		100%				
		C				32		42.67%				
		D				93		100%				
		A	2.5			47		62.67%		253		
		B				16		21.33%				
		C				95		100%				
		D				95		100%				
		A	3			59		78.67%		242		
		B				31		41.33%				
		C				55		73.33%				
		D				97		100%				
n_d	**Condition**	**Position**	d_a	t_s	n_{sn}	n_{dtc}	((n_{dtc} / 37 x 100)		n_{min}			
8	No obstacle – LOS, Multiple Angles, 8 Devices in vicinity	A	1	3s	37	42	100%		30 (considering distance of 2	286	As can be observed from	((41)/(48+10)) x 100 = **70.69%**
		B				37	100%					
		C				31	83.78%					
		D				43	100%					
		A1				33	89.19%					
		A2				33	89.19%					
		A3				31	83.78%					

		A4				36	97.30%					
		A	1.5			40	100%			291		
		B				32	86.49%					
		C				45	100%					
		D				37	100%					
		A1				30	81.08%					
		A2				33	89.19%					
		A3				34	91.89%					
		A4				40	100%					
		A	2			42	100%			289		
		B				26	70.27%					
		C				15	40.54%					
		D				32	86.49%					
		A1				36	97.30%					
		A2				47	100%					
		A3				44	100%					
		A4				47	100%					
		A	2.1			39		100%		281		
		B				23		62.16%				
		C				43		100%				
		D				35		94.59%				
		A1				30		81.08%				
		A2				46		100%				
		A3				32		86.49%				
		A4				33		89.19%				
		A	2.2			49		100%		278		
		B				5		13.51%				
		C				9		24.32%				
		D				46		100%				
		A1				51		100%				
		A2				57		100%				
		A3				31		83.78%				
		A4				30		81.08%				
		A	2.3			44		100%		282		
		B				30		81.08%				
		C				0		0%				
		D				43		100%				
		A1				38		100%				
		A2				26		70.27%				
		A3				55		100%				
		A4				46		100%				
		A	2.5			50		100%		271		
		B				4		10.81%				
		C				0		0%				
		D				53		100%				
		A1				42		100%				
		A2				32		86.49%				
		A3				45		100%				
		A4				45		100%				
		A	3			16		43.24%		265		
		B				0		0%				
		C				4		10.81%				
		D				92		100%				
		A1				41		100%				
		A2				49		100%				
		A3				56		100%				
		A4				7		18.92%				
								Average Accuracy			74.91%	

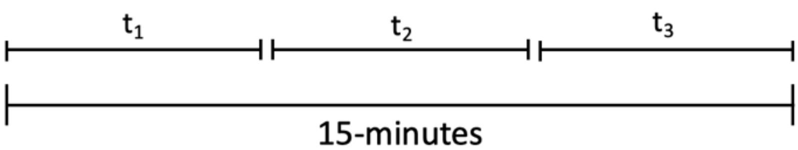

Figure 8. Separation of 15-minutes duration into three-time segments

Separation of 15-minutes duration into three-time segments will enable to eliminate the passerby scenario by ensuring that there is at least one signal scan in each of the time segments to be considered as close contact. What it means is that, it indicates a user has been present with another person throughout the period of 15-minutes. With that being said, towards calculating accuracy for contact tracing using number of signal captures, α, denoted as signal detection in each of t_1, t_2 and t_3 time segments, is given value using Equation 3 as shown. The value α in this case will eliminate the case of passerby scenario.

$\alpha = (1,0)$; "1" if n_{dtc} is present in each of t_1, t_2, t_3, "0": if (3)

n_{dtc} is not present in each of t_1, t_2, t_3.

Thus, to be accepted as close contact or for CCI, it is obtained using Equation 4 as shown below where ntcc is number of true close contact and it is a summation Equation for all the instances.

$$n_{tcc} = \sum_{i=1}^{i+1}(\alpha_i \; x \; n_{minv,i}) \tag{4}$$

Similarly, number of false close contacts formula (false negatives), n_{fcc}, is also the same as Equation 4 that fulfills all the requirement of CCI with an addition that it occurs after the distance exceeds 2 meters. Calculation for n_{fcc} is shown in Equation 5 below.

$$n_{fcc} = \left(\sum_{i=1}^{i+1}(\alpha_i \; x \; n_{minv,i}\right), for \; d > 2 \; meters \tag{5}$$

With all the main formulas listed, accuracy for CCI using signal captures is calculated using Equation 6. All of the Formulas are calculated and presented along with results for stage 2 experimentation as shown in Table 4.

$$General \; Accuracy \; Formula: Accuracy = \frac{True \; Positive}{True \; Positive + True \; Negative} = \frac{n_{tcc}}{n_{acc} + n_{fcc}} \tag{6}$$

From results obtained in Table 4, it shows that n_{dtc} is decreasing as the distance exceeds 2 meters for all the tests conducted. Although there maybe some of the instances that the decrease value is less than the others, however, results shown that the trend is in existance. This in return, proves the validity for the approach used in this study of utilizing low calibrated Tx and number of signal scans for contact tracing. While so, experimentation also shows that physical obstruction does not have much of an effect as n_{dtc} does not differ much from the ones without obstruction. This can be due to the fact that the approach focusses on small distances making potential errors to be small and negligible. Nevertheless, Table 4 also shows that, as n_d increases (more than 4 devices in this case), it is no longer viable to use n_{dtc} solely for CCI as the accuracy starts to drop. This is because, n_{dtc} becomes not too reliable when a device can have the potential to obtain a higher number of n_{dtc} than the other devices. It can be due to some angle difference, smaller range or better elevation. It can be also due to obstruction at one of the devices creating variance in the n_{dtc} obtained. Thus, the sweet spot or a good value for n_{min} as the n_d gets bigger than 8 should remain at 30 successful scans. Another logical reasoning is that, even though the number of users increase, the probability or the chance that a person will be close to other individuals within the range of 2 meters for more than 8 people at one time is quite thin. Nevertheless, an average accuracy of 74.91% for POC utilizing signal scans is good enough considering there are many things that can affect it while solely using n_{tcc} and n_{fcc} for accuracy. The reasoning why taking account of ±0.3m in accuracy calculations is to offset potential errors that may arise. As for the accuracy of real-life application (Pilot test), it will not determine solely by n_{tcc} alone but rather than individual-basis. What it means is that, if there is at least one instance that one user's n_{tcc} has been identified from multiple n_{tcc} from another same user, that person will be considered as close contact even though there may exist some n_{fcc} eliminating false positive errors and making accuracy to be even higher.

3-3- Stage 3 – Pilot Test

Pilot test is the most important part of the experimentation as it is a test whether the approach can be implemented in a real world or not. Analysis done in this part is whether a user has at least one n_{tcc} with another user from multiple number of CCIs. It is a bit different from the stage 2's POC where the analysis solely utilizes n_{tcc} and n_{fcc} in calculating accuracy. This is because, practically, it is important and adequate just to identify one instance of close contact from multiple contacts that may have happened considering short period of time within a day. Nevertheless, the requirement for CCI is still the same as before where it has to fulfill n_{minv} and α for the data obtained from the devices. With that being said, Table 5 shows the results obtained from stage 3 experimentation of 5 users.

Table 5. Stage 3 Experimentation Results

n_d	Receiver ID	Transmitter ID	n_{tcc} from user's record	n_{tcc} from devices	Accuracy
5	34	BC	Yes	Yes	75%
		E8	Yes	No	
		AD	Yes	Yes	
		63	Yes	Yes	
	BC	34	Yes	Yes	100%
		E8	Yes	Yes	
	E8	BC	Yes	Yes	100%
		AD	Yes	Yes	
	AD	E8	Yes	Yes	100%
	63	BC	Yes	Yes	100%
		AD	Yes	Yes	
		34	Yes	Yes	
		E8	Yes	Yes	
				Average Accuracy	*95%*

Table 5 shows that the results have been outstanding with majority of the close contacts being able to be identified using our proposed approach. This stage of experiment proves that the approach can be utilized in real-life application and has the potential for bigger number of users for the public.

4- Discussion

In general, the experimentation set up and results obtained have been adequate and solid to prove our proposed approach for Covid-19 contact tracing. Like any other studies, there are rooms for improvements and directions for future research. One of them is to add a bigger number of devices for the POC and Pilot test in order to find out more insights on the potential of the proposed approach for bigger number of users. Not just that, bigger number of devices also will help to strengthen the logical reasoning as well as the value obtained for what is the best nmin as the number of users gets bigger. It should not be too small that there can be many potential errors and cannot be too big that there are many false positives. A balance should be strike to offset it for optimum accuracy in which it is the value 30 from the experimentation. Not just, improvements also can be made by adding more scenarios and different physical objects to test the approach. With only limited test for physical obstruction, it can be further improved. Nevertheless, the approach is not only suitable for Covid-19 pandemic, but also for future similar outbreaks to come. This is because, the approach is quite versatile that variables such as Tx and scanning interval can be adjusted to suit a situation' needs.

Not just that, at this current stage, the proposed solution is able to conduct first-level of close contact tracing effectively. With a more comprehensive algorithm, it can be further expanded to several levels of close contact utilizing MAC address and the time of close contact. This in return, will further increase its impact and effectiveness in combating the pandemic.

5- Conclusion

Summing up, the study has successfully demonstrated the use of low calibrated Tx and number of signal scans to successfully conduct contact tracing for the Covid-19 pandemic. It should be noted that the approach is duplicable with other BLE chipsets and versatile enough that it can be adjusted for future infectious virus outbreaks to come. Thus, the solution is not limited to Covid-19 pandemic usage only but rather for infectious deceases that transmits in a short duration and space. With average accuracy of 74.91% under POC and 95% for real-life application, it is more than enough to be implemented for any countries towards indoor-type contact tracing for the public. Apart from that, a search for other BLE-based contact tracing literatures were conducted in order to compare the accuracy among the available solutions, however, only very few are able to provide the value. Even if the study is able to, the experimentation part is too vague or weak for the results to be accepted. Anglemyer et al. [19] also has stated that current digital contact tracing solutions is largely still unproven in real-world settings. Thus, to have a comparison between solutions for accuracy and improvements is not yet possible. In this view, our proposed solution can be one of the first that produces results with experimentation conducted up to real-life stage for Covid-19 contact tracing especially utilizing a novel approach. Apart from that, the approach also eliminates the setbacks of RSSI and venue-based tracing while provides scalability for mass implementation. Last but not least, with the data obtained, we believed that the pandemic can be better managed if better contact tracing with high accuracy can be implemented as the close contact identification is accurate making the spread to stop in a short period of time.

6- Declarations

6-1- Author Contributions

Conceptualization, T.O.K.Z. and S.M.; methodology, T.O.K.Z. and K.S.M.A.; software, T.O.K.Z.; validation, S.M., M.T.S.; formal analysis, T.O.K.Z and M.T.S.; investigation, T.O.K.Z.; writing—original draft preparation, T.O.K.Z.; writing—review and editing, S.M.; supervision, S.M.; project administration, K.S.M.A.; All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

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6-4- Acknowledgements

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6-5- Ethical Approval

Not applicable.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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