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BLUETOOTH LOW ENERGY (BLE) FOR TRACKING AND DATA ANALYTICS TOWARDS MICE HYBRID VISITORS IN THE NEW NORMAL COVID-19 ERA

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Abstract

MICE (Meeting, Incentive, Conference, Exhibition) has shown a significant promise in its industry growth by virtue of its usage in some Indonesia's big events, such as the 2018 G20 Summit held in Bali. MICE is important for seeing the visitors at a different angle, such as having an insight on the most visited booth of the event, how long the visitors spend time in one booth, and so on. The need of an application on this research for tracking visitors will be high especially during this Covid-19 pandemic. Therefore, to support the Indonesia economy recovery for years to come, especially on the MICE, a visitor tracking application is developed and tested. The purpose of this research is to develop algorithm for measuring the distance between visitors and the visitor density of a certain area in real time. This algorithm is implemented in the MICE event's visitor mobile tracking application which uses Internet of Things (IoT) and Big Data Analytics as their foundation to embrace the new normal. The six BLE Beacons were tested by a testing app developed using a Javascript framework called React Native. The app is used to capture the packet broadcasted by the Beacons. The app uses a third-party library developed by Kontakt.io. In conclusion, among 6 beacons have been tested, Digoo Bytereal iBeacon BLE 4.0 and DS Beacon V1.0 are the most versatile and will be used in the next experiments.

Keywords: Hybrid MICE industry; Bluetooth Beacon; visitor tracking; big data analytics.
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1. INTRODUCTION

Indonesia is highly considered by the MICE tourism market as an attractive destination, for example in 2021, Indonesia will host the U-21 world cup and also one of the MotoGP series for the first time. It proofs the world community trust to carry out MICE activities in Indonesia (Ministry of Trade, Republic of Indonesia, 2011). The MICE industry is an activity that needs to be developed in terms of government regulations, event organizers and locations, as well as academic concepts so the MICE industry can run well (Buathong & Lai, 2017). With the Covid-19 pandemic, ICT technology has also become indispensable for the sustainability of MICE activities in Indonesia (Disimulation, 2020). One of the Internet of Things (IoT)-based ICT research related to MICE is the study of one of the sensors, Smart Beacon, which is implemented into MICE activities using big data technology. Research conducted by Kim et.al. (2016) also monitors the movement and interaction of visitors during the event. However, this research has not solved the problem of social distancing in real time. Therefore, the main research problem is measuring the distance and density level of a certain location in real time. Currently, the use of Beacon sensors with Bluetooth Low Energy (BLE) signals can be measured using the Received Signal Strength Indication (RSSI) method. However, this RSSI method needs to be developed to support measurements quickly and in real time.

This research has a specific goal to develop an algorithm for measuring distance, density, and coordinates/location of visitors using BLE signals in real time. This is to support the implementation of tracking visitor movements and density levels in a venue so the social distancing can be recognized in real time. In the following year, it is necessary to prepare big data infrastructure to support the growing amount of data (scalable) and continue data analysis process of data obtained including Beacon sensor data, event management system data, and data from the event's social media using data mining techniques. The results of the data analysis will be visualized so it can be useful for the event organizers in making decisions. The urgency of this research during the Covid-19 pandemic is the movement of visitors is very important in preparing new normal arrangement in the MICE industry in the future. The event organizers can also find out number of visitors in real time so that it can be adjusted to the maximum capacity of the venue in order to comply with local government regulations.

2. RELATED WORKS

Although not much has been done, hybrid MICE events have been studied by Hamm et.al. (2018). In this study, Hamm defines hybrid MICE as combination of activities carried out with physical presence (face to face) and online using certain technologies to improve the visitor experience in attending the MICE event. The focus of this research is determining coordinate points, the distance between coordinates obtained in real time to support visitor tracking. Our previous research, tracking visitors using a QR-Code, was quite disturbing for visitors because visitors need to scan the QR-Code every time they are in a certain location (Wilbert, et.al., 2017). To improve the research, we then proceed with studying IoT technology by using Beacons for tracking visitors with BLE technology which is implemented at the Museum (Widjaja, et.al., 2019).

Several methods have been carried out by other researchers in measuring distance, such as using the Received Signal Strength Indication (RSSI) method. Zhuan, et.al. (2016) used a Polynomial Regression Model (PRM), Finger Printing (FP) and Extended Kalman Filtering (EKF) to determine location in a smartphone-based closed room using a BLE Beacon. Furthermore, Huh and Seo (2017) used a range-average algorithm using RSSI to determine the location in a closed room. RSSI results are still less accurate because they have a fairly high error rate, therefore Li et.al. (2018) used the RSSI real-time correction method using Bluetooth that is connected to a cloud server in a closed room. Because this Hybrid MICE activity can be carried out in a closed or open room, in this first year, the RSSI method for BLE will be used in combination with several other methods, namely with the addition of Global Positioning System (GPS) technology and also Near Field Communication (NFC). GPS technology combined with BLE Beacons will be very suitable for MICE activities in open spaces, while NFC combined with BLE Beacons can be used both in open and closed spaces requiring a closer distance. Therefore, the state of the art of this research is to combine several algorithms that can be used in several existing technologies (BLE Beacon, WIFI router, GPS, and NFC) to get more accurate coordinates and distance points so they can be implemented for social distancing purposes in real time. This combination has also been used by Cheng, et.al. (2016) to create a guide system for a location, both open and closed. As a continuation of social distancing, the density level in a room will also be measured using the Wasserstein interpolation method (Danis & Cemgil, 2017) by calculating the distance between visitors as a whole.

Our previous research on big data infrastructure, one of which is the use of Hypervisor for education industry (Syahlie, et.al., 2014) and the use of Hadoop for performance optimization on servers (Christian, et.al, 2017). Several Natural Language Processing (NLP) methods are used to process free text from visitors on social media comments and from feedback on MICE activities. The processed free text is focused on Bahasa Indonesia. The NLP developed will go towards sentiment analysis to see how this MICE activity is discussed on various existing social media so the MICE activity organizers can evaluate it better in the coming years. Wijaya, et.al. (2013) used several algorithms, namely Support Vector Machine (SVM), Naïve Bayes and Decision tree for sentiment analysis. The same method is also used to process the data in this study. Data from social media will be retrieved using tools such as RapidMiner, which will then be used as a training set. Preprocessing is carried out to eliminate less important words such as in, to, and so on, which are then analyzed with several machine learning algorithms, such as Support Vector. Machine (SVM), Naïve Bayes and Decision tree for sentiment analysis.

3. METHOD

The methodology that will be used in this research is method for determining coordinates, distance and density in a MICE event. This method is implemented in the development of a visitor tracking mobile application. Specific research on event management has started since 2018, starting with event management using a QR-Code and tour guide application development using Beacon sensor to improve the visitor experience in an event. This research will focus on determining coordinates, distance and density of MICE visitors in the context of social distancing in real time to support new normal activities. It is done based on Internet of Things (IoT) technology. By using BLE Beacon technology, the mobile application will be convenient to use by the visitors. This concept is called unobtrusive visitor tracking. Unlike previous research using a QR-Code, where visitors are required to scan the QR-Code at every location/booth they visit. The several stages conducted in this research as follow:

1. Trial with several types of BLE Beacon sensors using several methods to determine coordinates, distance and density of a room, both closed and open, namely: Received Signal Strength Indication (RSSI), Polynomial Regression Model (PRM), Finger Printing (FP) and Extended Kalman Filtering (EKF). The BLE Beacon sensors that will be used are the RadBeacon chip, HM-10 Bluetooth Beacon, Shenzhen Minew Bluetooth Beacon, Aruba Beacon and Estimote Beacon.
2. Development of concept proof from the results of the BLE Beacon trial into the creation of a mobile application starting with the analysis and design system of the application to the integration of the method of determining coordinates, distances and density into the application.
3. Test the mobile app with partners and some users to get feedback.

The research started with testing and experimenting using RFID reader, RFID labels, and RFID cards to see how well the RFID reader detects nearby RFID labels and RFID cards, as a way of measuring distance, density, and coordinates/location of visitors. We use one CT-i808 RFID reader, ten UHF Alien H3 RFID labels, and ten Alien H3 UHF ISO cards in this research. However, this method has been paused as our research and analysis showed that RFID signals are easily interrupted by any object or person blocking the RFID label/card from the RFID reader. This situation caused any RFID labels or RFID cards be undetectable by the RFID reader itself. Therefore, we have decided to focus on the use of Beacon sensors with Bluetooth Low Energy (BLE), as the signals generated from the Beacon

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sensors itself are not easily interrupted. To determine which Beacon is more suitable for the research, six different types of Beacons were tested and compared. The six types of Beacons were:

1. BLE Beacon with Motion sensor accelerometer sensor push button IoT iBeacon. (KBeacon)
2. IBeacons Type bluetooth 4.0 Module NRF51822 Chipset IBeacon. (Digoo Blue)
3. FEASYCOM Mini Bluetooth 5.0 Proximity Low Energy Beacon with Eddystone, iBeacon and AltBeacon,Android & iOS Programmable. (Feasycom)
4. Radius Networks RadBeacon Dot - Proximity Beacon with Eddystone, iBeacon and AltBeacon Technology. (RadBeacon)
5. Digoo Product Bytereal iBeacon BLE 4.0 Near Field Orientation Modul 9y. (Digoo Cube)
6. DS Beacon V1.0. (DS Beacon)

The six BLE Beacons were tested by a testing app developed using a Javascript framework called React Native. The app is used to capture the packet broadcasted by the Beacons. The app uses a third-party library developed by Kontakt.io, an industry that specializes in indoor location services and BLE Beacons (MIT License, 2020). The library was used to parse the Beacon packets and wrap them into a JSON object that contains information about the Beacon as shown in Fig. 1. The parsed value of the Beacon packet is an array of JSON objects. The JSON object attributes are:

1. Accuracy: An estimated distance by the library between the Beacon and the mobile phone.
2. Address: The Mac Address of the BLE Beacon. It is a unique identifier to be used as a network address.
3. BatteryPower: An estimate of the BLE Beacon battery power.
4. UUID (Universally Unique Identifier): 32 hexadecimal digits, split into 5 groups and separated by hyphens used to distinguish the BLE Beacon.
5. Major and Minor values: Assigned numbers to identify the BLE Beacon with greater accuracy than just UUID.
6. RSSI (Received Signal Strength Indication): The measurement of the power received from a signal. It is used to indicate signal strength coming from the Beacon. The closer it is to positive value, the closer the signal source is.
7. Name: The Beacon type.
8. Proximity: The approximate distance of the source.

```
beaconsDidUpdate ▼(2) [{…}, {…}]
    ▼0:
        accuracy: 2.246586021115714
        address: "E2:65:B2:73:D5:51"
        batteryPower: -1
        firmwareVersion: "-1"
        isShuffled: false
        major: 10035
        minor: 56498
        name: "WGX_iBeacon"
        proximity: "NEAR"
        rssi: -66
        txPower: -59
        uniqueId: null
        uuid: "fda50693-a4e2-4fb1-afcf-c6eb07647825"
      ▶__proto__: Object
    ▶1: {isShuffled: false, uniqueId: null, txPower: -59, address: "D0:55:6A:2A:C3:F1", name: "WGX_iBeacon", …}
     length: 2
    ▶__proto__: Array(0)
▶{minor: -1, secureUuid: "null", major: -1, uuid: "f7826da6-4fa2-4e98-8024-bc5b71e0893e", identifier: "Everywhere"}
```


FIGURE 1. KONTAKT.IO LIBRARY PACKET

Source: MIT LICENSE, 2020

The smartphone used during testing procedure was a Xiaomi Redmi Note 7 android smartphone with an Android version 10 QKQ1.190910.002, Bluetooth V5, 4GB RAM, and Octa-core Max 2.20GHz CPU, as shown in Fig. 2. The main information required to calculate distance between the mobile phone and the Beacon are the RSSI and the Mac Address of the BLE Beacon. Furthermore, the library also includes a function that shows estimated distance between the mobile phone and the BLE Beacon. Below are the parameters that can be set in the app:

1. TxPower : The measured power of the Beacon or the RSSI value of the Beacon when it is 1m range to the receiving devices.
2. Environmental Factor: A path loss exponent constant that depends on the environmental factor. It ranges from 2-4. This parameter is used to set the sensitivity of the Beacon. The higher the value, the more sensitive it becomes. Therefore, the denser the area, the better it is to increase the value of the environmental factor constant.
3. Test count: The amount of tests will be conducted (1 test = 30 second).
4. Beacon mac address: The mac address of the Beacon being tested.

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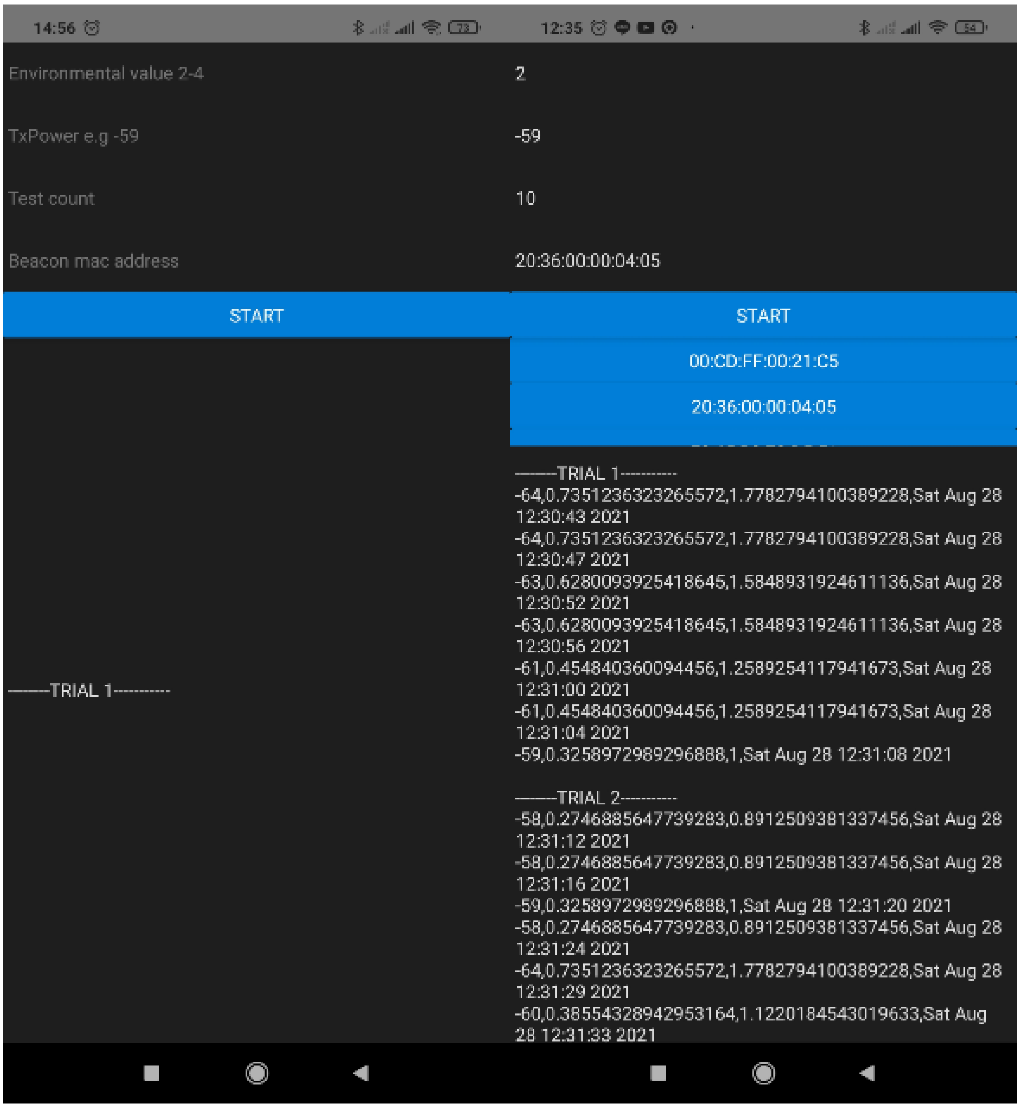

FIGURE 2. TESTING APPLICATION

Source: The Authors

After a test, an output of CSV formatted data will be produced as shown in Fig.3. The test can be repeated automatically depending on the test count parameter. Respectively, the columns of the CSV data are stated below:

1. RSSI.
2. Estimated distance using the Kontakt.io library.
3. Estimated distance using the IOT and Electronics formula.
4. Current date and time to calculate time interval after every test.

A	B	C	D	E
RSSI	Kontakt.io	IOT and Electronics Formula	Date	
Trial 1				
-54	0.412494	0.562341	Sat Jun 5 15:54:53 2021	
-51	0.232907	0.398107	Sat Jun 5 15:54:56 2021	
-53	0.342167	0.501187	Sat Jun 5 15:54:59 2021	
-51	0.232907	0.398107	Sat Jun 5 15:55:04 2021	
-51	0.232907	0.398107	Sat Jun 5 15:55:07 2021	
-53	0.342167	0.501187	Sat Jun 5 15:55:10 2021	
-58	0.842868	0.891251	Sat Jun 5 15:55:13 2021	
-59	1.01076	1	Sat Jun 5 15:55:16 2021	
-58	0.842868	0.891251	Sat Jun 5 15:55:19 2021	
Trial 2				
-57	0.708318	0.794328	Sat Jun 5 15:55:41 2021	
-56	0.593417	0.707946	Sat Jun 5 15:55:45 2021	
-55	0.495572	0.630957	Sat Jun 5 15:55:48 2021	
-56	0.593417	0.707946	Sat Jun 5 15:55:51 2021	
-56	0.593417	0.707946	Sat Jun 5 15:55:54 2021	
-58	0.842868	0.891251	Sat Jun 5 15:55:57 2021	
-56	0.593417	0.707946	Sat Jun 5 15:56:01 2021	
-57	0.708318	0.794328	Sat Jun 5 15:56:04 2021	
-57	0.708318	0.794328	Sat Jun 5 15:56:07 2021	
Trial 3				
-54	0.412494	0.562341	Sat Jun 5 15:56:28 2021	
-56	0.593417	0.707946	Sat Jun 5 15:56:32 2021	
-52	0.282822	0.446684	Sat Jun 5 15:56:35 2021	
-52	0.282822	0.446684	Sat Jun 5 15:56:38 2021	
-58	0.842868	0.891251	Sat Jun 5 15:56:41 2021	
-56	0.593417	0.707946	Sat Jun 5 15:56:44 2021	
-58	0.842868	0.891251	Sat Jun 5 15:56:47 2021	
-56	0.593417	0.707946	Sat Jun 5 15:56:50 2021	
-54	0.412494	0.562341	Sat Jun 5 15:56:54 2021	
-57	0.708318	0.794328	Sat Jun 5 15:56:57 2021	

FIGURE 3. CSV FORMATTED DATA

Source: The Authors

For calculating the distance, the app uses a function from the Kontakt.io library and a formula from IOT and Electronics as we are trying to find the most suitable formula/function to be used (iotbymukund, 2016).

$$Distance = 10^{\left(\frac{Measured\ Power\ -\ RSSI}{10\ \cdot\ Environmental\ Factor}\right)} \quad \text{(eq.1)}$$

Equation 1 shows the following parameters:

1. Measured Power: A read only calibrated constant that indicates the expected RSSI when it is 1m in range to receiving devices.
2. RSSI: Received Signal Strength Indicator, which shows signal strength generated by each Beacon. The signal strength depends on the distance and the broadcasting power.
3. Environmental Factor: A path loss exponent constant that depends on the environmental factor. It ranges from 2-4. This parameter is used to set sensitivity of the Beacon. The higher the value, the

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more sensitive it becomes. Therefore, the denser the area, the better it is to increase the value of the environmental factor constant.

4. RESULT AND ANALYSIS

Each Beacon type was tested with the React JavaScript testing app containing a library/formula from Kontakt.io using a Xiaomi Redmi Note 7 android smartphone in indoor environment. The testing procedure started by marking the floor by multiples of 100cm to 500cm, and each Beacon type is tested 10 times at each distance for 30 seconds each. Every data packet received by each Beacon contains data of RSSI, calculation result from Kontakt.io library calculation result from IOT and Electronics formula, and time the data packet is received by the application (MIT License, 2020). The data received by the application is then recorded into a spreadsheet and is later compared by variance, standard deviation, average RSSI, average distance result calculated using Kontakt.io library and IOT and Electronics formula, and average number of packets received from each Beacon.

The table 1 shows average value of RSSI received from 10 trials of testing, in which every trial takes up 30 seconds. The data is processed to calculate accuracy of the RSSI value. The expected RSSI value received is -59 when the distance between the Beacon and the phone is 100 cm.

TABLE 1. AVERAGE VALUE OF RSSI

	Average Value of RSSI of 10 Trials					
distance in cm	RadBeacon Dot	iBeacon NRF51822	Byetereal iBeacon	FSC-BP103B	CC2640 R2F	iBeacon NRF52832 DS-Beacon
100	-61.45945946	-58.33333333	-58.31914894	-84.26027397	-69.53521127	-58.30555556
200	-69.58108108	-65.15909091	-64.03191489	-82.015625	-73.3015873	-65.97222222
300	-73.17808219	-70.87628866	-68.32978723	-87.73584906	-74.65671642	-69.85507246
400	-76.01369863	-73.12903226	-69.18085106	-87.12765957	-75	-71.91304348
500	-82.20547945	-73.72631579	-77.98947368	-86.05555556	-75.38571429	-73

Source: The Authors

The table 2 shows percent error of the RSSI value with a distance of 100 cm from the mobile phone. Sorted BLE Beacon names in terms of percentage error of RSSI accuracy from the lowest to the highest respectively: iBeacon NRF51822, Bytereal iBeacon, iBeacon NRF 52832 DS-Beacon, RadBeacon Dot, CC2640 R2F, FSC-BP103B.

TABLE 2. PERCENTAGE ERROR OF RSSI ACCURACY

Percentage Error of RSSI Accuracy (unit in percent)					
RadBeacon Dot	iBeacon NRF51822	Bytereal iBeacon	FSC-BP103B	K Beacon	iBeacon NRF52832 DS-Beacon
4.168575356	1.129943508	1.153984847	42.81402368	17.85629029	1.177024475

Source: The Authors

The table 3 shows the ranking based on signal stability. Sorted BLE Beacon names from the highest RSSI stability to the lowest RSSI stability: iBeacon NRF52832 DS-Beacon, Bytereal iBeacon, RadBeacon Dot, FSC-BP103B, CC2640R2F, iBeacon NRF51822.

TABLE 3. RANKING IN TERMS OF SIGNAL STABILITY

Ranking in terms of signal stability	100 cm	200 cm	300 cm	400 cm	500 cm
1	iBeacon NRF52832 DS-Beacon	Bytereal iBeacon	iBeacon NRF52832 DS-Beacon	iBeacon NRF52832 DS-Beacon	Byelereal iBeacon
2	RadBeacon Dot	RadBeacon Dot	Byelereal iBeacon	FSC-BP103B	iBeacon NRF52832 DS-Beacon
3	Byelereal iBeacon	iBeacon NRF52832 DS-Beacon	FSC-BP103B	RadBeacon Dot	FSC-BP103B
4	FSC-BP103B	FSC-BP103B	RadBeacon Dot	Byelereal iBeacon	CC2640 R2F
5	iBeacon NRF51822	CC2640 R2F	CC2640 R2F	CC2640 R2F	RadBeacon Dot
6	CC2640 R2F	iBeacon NRF51822	iBeacon NRF51822	iBeacon NRF51822	iBeacon NRF51822

Source: The Authors

The table 4 and 5 shows average distance calculated by using distance calculation formula by IOT and Electronics (Table 4) and by Kontakt.io (Table 5). The environmental factor constant of the IOT and Electronics formula was set to 2 because the testing environment was not dense. In other words, the testing environment had minimal objects and people in the vicinity. The delta shows the difference between actual distance of the Beacon and distance calculated by using the formula. The percent error method was implemented to measure percentage error of the actual distance and the estimated distance.

TABLE 4. AVERAGE DISTANCE CALCULATED USING IOT AND ELECTRONICS FORMULA

Average Distance Calculated Using IOT and Electronics Formula (Environmental Factor = 2)						
distance in cm	RadBeacon Dot	iBeacon NRF51822	Bytereal iBeacon	FSC-BP103B	CC2640 R2F	iBeacon NRF52832 DS-Beacon
100	122.552873	101.8187333	97.84775098	1992.154213	79.43282347	92.97281417
delta 100 cm	22.552873	1.8187333	-2.15224902	1892.154213	-20.56717653	-7.02718583
200	226.9183905	288.6922966	181.1779	1543.660541	622.5946236	234.7058147
delta 200 cm	26.9183905	88.6922966	-18.8221	1343.660541	422.5946236	34.7058147
300	586.8698288	492.4387268	310.5654191	2879.494636	696.8208039	365.7629352
delta 300 cm	286.8698288	192.4387268	10.5654191	2579.494636	396.8208039	65.7629352
400	781.0330466	629.1295355	355.5323116	2724.816204	736.4045	456.4355794
delta 400 cm	381.0330466	229.1295355	-44.4676884	2324.816204	336.4045	56.4355794
500	1705.089858	751.44646	959.3531933	2500.039405	767.3271489	527.474323
delta 500 cm	1205.089858	251.44646	459.3531933	2000.039405	267.3271489	27.474323
average delta	384.4927994	152.7051504	80.895315	2028.033	280.51598	35.47029329

Source: The Authors

TABLE 5. AVERAGE DISTANCE CALCULATED USING KONTAKT.IO LIBRARY

Average Distance Calculated Using Kontakt.io Library						
distance in cm	RadBeacon Dot	iBeacon NRF51822	Bytereal iBeacon	FSC-BP103B	CC2640 R2F	iBeacon NRF52832 DS-Beacon
100	12.76626351	96.21955161	92.36616304	242.3376864	394.2316252	29.36415752
delta 100 cm	-87.23373649	-3.78044839	-7.63383696	142.3376864	294.2316252	-70.63584248
200	42.32993514	275.7587886	182.6009288	198.4808395	555.8265209	100.7846868
delta 200 cm	-157.6700649	75.7587886	-17.3990712	-1.5191605	355.8265209	-99.2153132
300	74.99561644	446.0249361	303.3475419	320.5037451	618.6254087	155.3798435
delta 300 cm	-225.0043836	146.0249361	3.3475419	20.5037451	318.6254087	-144.6201565
400	102.3353973	553.6436624	342.8800448	306.1774053	592.780177	189.5621281
delta 400 cm	-297.6646027	153.6436624	-57.1199552	-93.8225947	192.780177	-210.4378719
500	191.2878384	624.3655379	822.5352955	285.2401017	670.0332964	212.8234682
delta 500 cm	-308.7121616	124.3655379	322.5352955	-214.7598983	170.0332964	-287.1765318
average delta	-215.2569898	99.20249532	48.74599481	-29.4520444	266.2994056	-162.4171432

Source: The Authors

Respectively Table 6 and 7 show the percentage error of distance calculated using IOT and Electronics Formula. The bottom row is the average percentage error. The lower the average percentage, the more accurate the result is. Sorted list of BLE Beacon in terms of distance accuracy when calculated using the IOT and Electronics Formula from the highest accuracy to the lowest accuracy: 1) iBeacon NRF52832 DS-Beacon, 2) Bytereal iBeacon, 3) iBeacon NRF51822, 4) RadBeacon Dot, 5) CC2640 R2F, 6) FSC-BP103B. Sorted list of BLE Beacon in terms of distance accuracy when calculated using the Kontakt.io from the highest accuracy to the lowest accuracy: 1) Bytereal iBeacon, 2) iBeacon NRF51822, 3) FSC-BP103B, 4) iBeacon NRF52832 DS-Beacon, 5) RadBeacon Dot, 6) CC2640 R2F.

TABLE 6. PERCENTAGE ERROR OF DISTANCE CALCULATED USING IOT AND ELECTRONICS FORMULA.

	Percentage error of distance calculated using IOT and Electronics Formula (unit in percent)					
Distance	RadBeacon Dot	iBeacon NRF51822	Bytereal iBeacon	FSC-BP103B	CC2640 R2F	iBeacon NRF52832 DS-Beacon
100 cm	22.552873	1.8187333	2.15224902	1892.154213	20.56717653	7.02718583
200 cm	13.45919525	44.3461483	9.41105	671.8302705	211.2973118	17.35290735
300 cm	95.62327627	64.14624227	3.521806367	859.8315453	132.2736013	21.9209784
400 cm	95.25826165	57.28238388	11.1169221	581.204051	84.101125	14.10889485
500 cm	241.0179716	50.289292	91.87063866	400.007881	53.46542978	5.4948646
Average	93.58231555	43.57655995	23.61453323	881.0055922	100.3409289	13.18096621

Source: The Authors

TABLE 7. PERCENTAGE ERROR OF DISTANCE CALCULATED USING KONTAKT.IO LIBRARY

	Percentage error of distance calculated using Kontakt.io (unit in percent)					
Distance	RadBeacon Dot	iBeacon NRF51822	Bytereal iBeacon	FSC-BP103B	CC2640 R2F	iBeacon NRF52832 DS-Beacon
100 cm	87.23373649	3.78044839	7.63383696	142.3376864	294.2316252	70.63584248
200 cm	78.83503243	37.8793943	8.6995356	0.75958025	177.9132605	49.6076566
300 cm	75.00146119	48.6749787	1.1158473	6.8345817	106.2084696	48.20671883
400 cm	74.41615068	38.4109156	14.2799888	23.45564868	48.19504425	52.60946798
500 cm	61.74243232	24.87310758	64.5070591	42.95197966	34.00665928	57.43530636
Average	75.44576262	30.72376891	19.24725355	43.26789534	132.1110117	55.69899845

Source: The Authors

Table 8 shows the average number of packets received in 30 seconds. In other words, it shows the average number of packets received by the mobile app in under 30 seconds. This data is used to measure the signal strength. The higher the number of packets sent, the stronger the signal is. Sorted list of BLE Beacon from the highest signal strength to the lowest signal strength: 1) iBeacon NRF51822, 2) Bytereal iBeacon, 3) iBeacon NRF52832 DS-Beacon, 4) RadBeacon Dot, 5) CC2640 R2F, 6) FSC-BP103B.

TABLE 8. AVERAGE NUMBER OF PACKET RECEIVED IN 30 SECONDS

	Average # of Packet Received in 30 Seconds					
distance in cm	RadBeacon Dot	iBeacon NRF51822	Bytereal iBeacon	FSC-BP103B	CC2640 R2F	iBeacon NRF52832 DS-Beacon
100	7.4	9.3	9.4	7.222222222	6.454545455	7.9
200	7.4	10.4	9.4	6.1	6.3	7.9
300	6.636363636	9.7	9.4	5.888888889	6.7	8
400	7.333333333	9.3	9.2222222	5.222222222	6.272727273	7.9
500	7.3	9.5	9.5	5.888888889	6.363636364	7.9
average	7.213939394	9.64	9.38444444	6.064444444	6.418181818	7.92

Source: The Authors

The main objective of this BLE Beacon comparison is to find the most optimal Beacon for the research. There are several traits to be looked for to find the most optimal Beacon: accuracy, signal stability, and signal strength. From this comparison result, it can be seen that iBeacon NRF51822 and Bytereal iBeacon are the most versatile among all the BLE Beacons we've tested thus far based on their overall performance. Each Beacon's stability and accuracy is compared by variance, standard deviation, average RSSI, average distance result calculated from Kontakt.io and the formula from IOT and Electronics, and average number of packets received from each Beacon. The Beacon sensor that will be used for this research is the one with variance that has least difference between each distance. Based on results from Beacon systems that we've compared and calculated in the spreadsheet, we can conclude that Digoo Bytereal iBeacon BLE 4.0 and DS Beacon V1.0 are the most versatile among all the Beacon systems we've tested thus far.

As shown in the Fig. 4, the BLE Beacon would broadcast a packet which contains RSSI signals that would be received by the mobile application via Bluetooth. The mobile application would send the RSSI, the mac address received from the Beacon, as well as the user id to the backend server where the RSSI and mac address are sent to the MySQL database. If the database query is successful in finding the Beacon by the RSSI and mac address, the Beacon packets would be sorted to find the most positive RSSI value to identify user location with the highest occurrence Beacon. Once the Beacon with the highest occurrence is found, the MySQL database would update the user location. It will then be returned to the mobile app, showing the user his/her location.

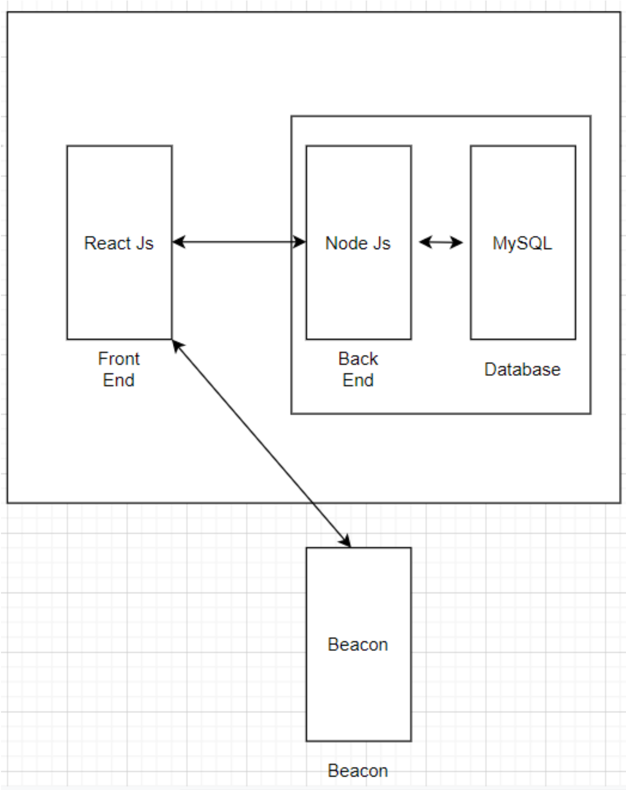

FIGURE 4. ARCHITECTURE DIAGRAM

Source: The Authors

Fig. 5 shows the Activity Diagram how users can use the application, which user types have access to certain features of the app, as well as how the app receives packets from the Beacons. As shown in the Activity Diagram, the user will open the app to either register an account or log in, depending whether the user already has an account or not. If the user does not have an account, the user will have to register his/her data using the "Register" feature which will then be stored into the database. The user can then log in to the app through the “Login” feature, which will then be verified by the app by looking up the user’s email address and password in the database through endpoint in the backend server. Once the user has successfully logged in, the user will be redirected to the main menu, where the user is able to view details of the event, event schedule, and heat map. Some features of the application are only available to Event Admins, these features include “Edit Event Details”, “Edit Event Schedule”, and “Booth Statistics” (which is also accessible by Booth Owners). The application will start receiving packages from the BLE Beacons which will be automatically sent to the backend server every x seconds.The data then will be processed and sent to the database. The mobile app will then fetch the data through an endpoint to the database every *x* seconds to determine the user location which will appear on the app’s Heat Map.

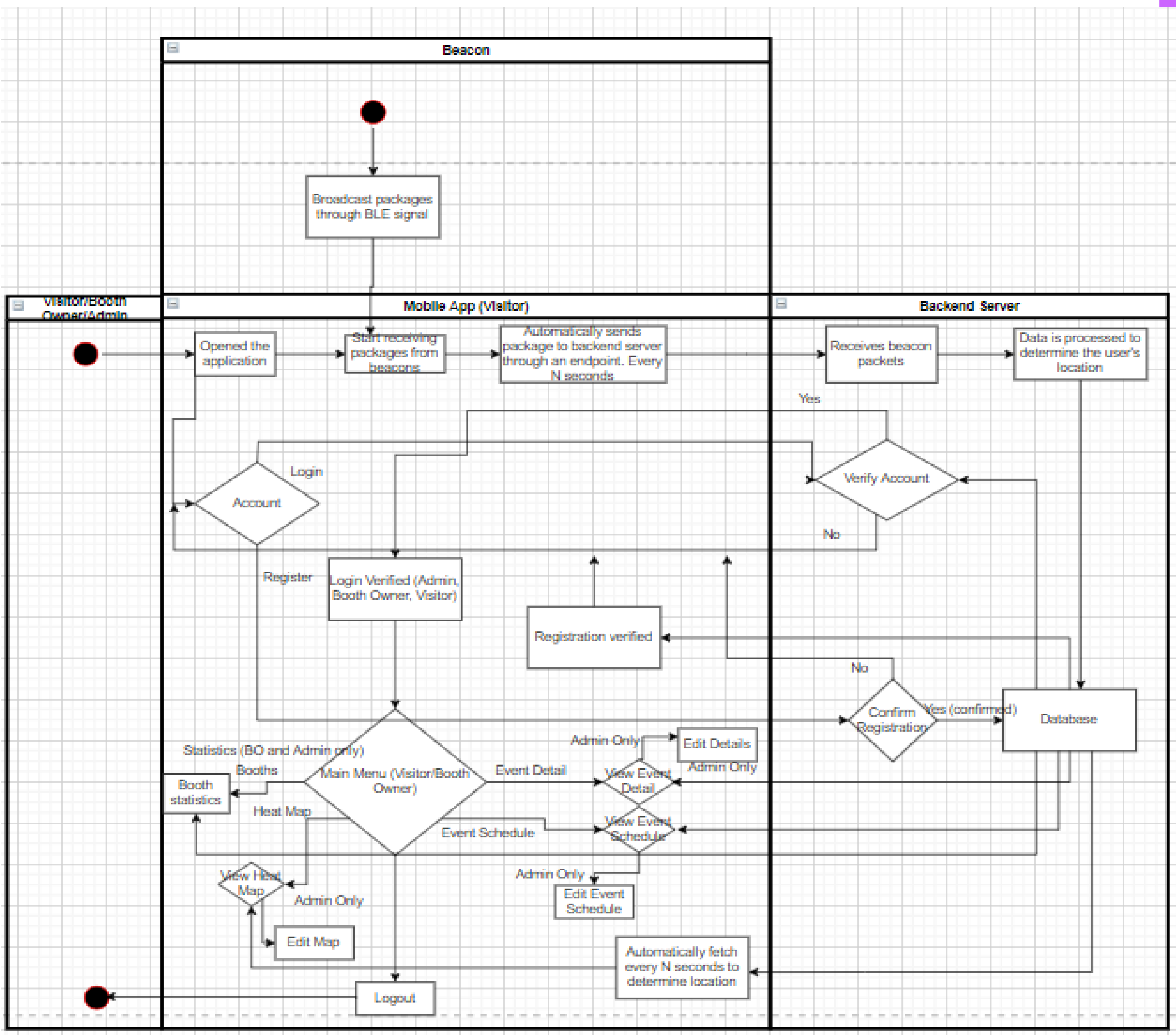

FIGURE 5. ACTIVITY DIAGRAM

Source: The Authors

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5. CONCLUSIONS

The purpose of this research is to enforce social distancing between visitors in local physical MICE events. Based on conducted experiments and analysis, it is shown that Bluetooth low energy Beacon systems are capable in transmitting signals via Bluetooth without any interference. Therefore, it is decided to use Bluetooth low energy Beacon systems in our mobile app. It will enable event administrators to track and figure out location of every person attending a physical MICE event, to notify app users whenever a room has reached or near it's visitor limit, as well as to adapt people to the new normal arrangement. Among 6 beacons have been tested, Digoo Bytereal iBeacon BLE 4.0 and DS Beacon V1.0 are the most versatile and will be used in the next experiments. One of the limitations for this research is that depending on the limited number of BLE Beacon that used in the experiments, including all their features.

For the next research, big data infrastructure will be prepared using cloud technology, including the data warehouse technology as part of the back-end system using Relational Database Management System (RDBMS) or non-RDBMS. Furthermore, data analysis of the coordinates, distances and density of visitors are important to determine the behavior of visitors, so that the sequence points and patterns can be seen in real time. Which is then visualized as a reporting dashboard for the requirement from the event organizer to make decisions.

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