Positioning Accuracy of Commercial Bluetooth Low Energy Beacon

by Ali Khumaidi

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***Abstract*—This research presents the positioning accuracy of various commercially available BLE(Bluetooth Low Energy) beacon devices. Accurate data is obtained from beacon devices for indoor positioning taken from various mobile devices with BLE support. We utilize RSSI data to determine distances without any filter in order to present raw performance of the devices. The average result is not too deviate by various kinds of bluetooth beacons being tested. Compared to other related work, our data show nearly similar result. Our result shows various accuracy from 0.07 meters and up to 7.81 meters.**

***Index Terms*—Bluetooth low energy, bluetooth beacon, indoor positioning**

I. Introduction

To face the challenge of microlocation in the indoor scope, the iBeacon protocol can be used as one of the challengers. Using BLE (Bluetooth Low Energy) beacon-based proximity sensing technology, iBeacon can provide location information accurately in indoor spaces [1].This BLE-based technology can allow the determination of microlocation in an ubiquitous manner [2].

Bluetooth beacon devices with iBeacon protocol have been produced by various companies. The diversity and the availability of these devices commercially, on the one hand provides an option for consumers to choose a device according to their needs and available budget. However on the other hand, various devices from different manufacturers may cause a variety of device performance. This may impact the accuracy of the data from BLE beacons.

Bluetooth technology utilized by BLE beacon carried out using optimized power [3]. This technology has been deployed in many dense environment for various usage [4]. One example for commercial usage shows the device feature and capability for shopping activity [5], and also another example for monitoring activity [6]. In the use for location and position at the indoor environment, several research has shown the capability of beacon devices. One research shows Location Fingerprinting With Bluetooth Low Energy Beacons usage in a building, and proven its superiority against wi-fi technology for positioning purpose in term of accuracy [7]. Deployment of multiple beacon also enhance it's performance in indoor positioning system [8]. Despite all of that example, accurate distance estimation still pose challenges, due to unstable signals of BLE beacon more research needs to be done in order to achieve more improved result [4].

Our research aims to evaluate the effectiveness of this bluetooth beacon for microlocation usage. We are testing various beacon devices that can be obtained commercially. We believe that this study is important for wide audiences, especially engineers who deploy beacons, as well for various service providers that support beacon-based microlocation services. We highlight our experimental results to show the accuracy of these bluetooth beacon devices for ubiquitous use.

II. Related Work

Previous research has shown various advantages of using beacons in position and distance information. The survey on the ubiquitous location determination system [2] shows that challenge faced during that time (2001) was around indoor positioning. In a more recent survey on microlocation technology [9], bluetooth beacon shows several advantages which is small size, energy efficiency and low cost of deployment.

The accuracy of the bluetooth beacons has been tested in various researches. In one comparison with other radio frequencies, namely wi-fi [10], bluetooth beacons have an accuracy of less than 2.5 m 95% of the time compared to less than 8.5m 95% of the time for the Wi-Fi Network. Another study also presents the accuracy value of the use of beacons in a scenario on a museum building [9], and it shows good results. However the test scenario involves only beacons from one manufacturer and tested just with one smartphone as a receiver. Detailed analysis of the position accuracy with beacons has also been done [8]. In that research, the author using bluetooth beacons only from two commercial brands and also tested with two smartphones device, which beg some question about capability for various kind of many devices, especially when deployed in real life application.

III. Experiments Method and Scenario

We conduct BLE beacon devices accuracy testing with various kinds of BLE beacon and smartphones from many manufacturer. We have tested five BLE beacons from different companies brands, namely Cubeacon, Bytereal, Nordic, Wellcore, Nyvida. All of our beacons are set to the default factory settings, which means there is no custom user calibration involved in BLE parameter. We measured the accuracy of distances on 23 smartphones owned by our class student as a test subject. Each smartphone devices is placed at a distance from each beacons at 1 meter, 5 meters and 10 meters with an interval of 2 minutes for each distance point. The entire measured distance is stored in a log file that shows variations

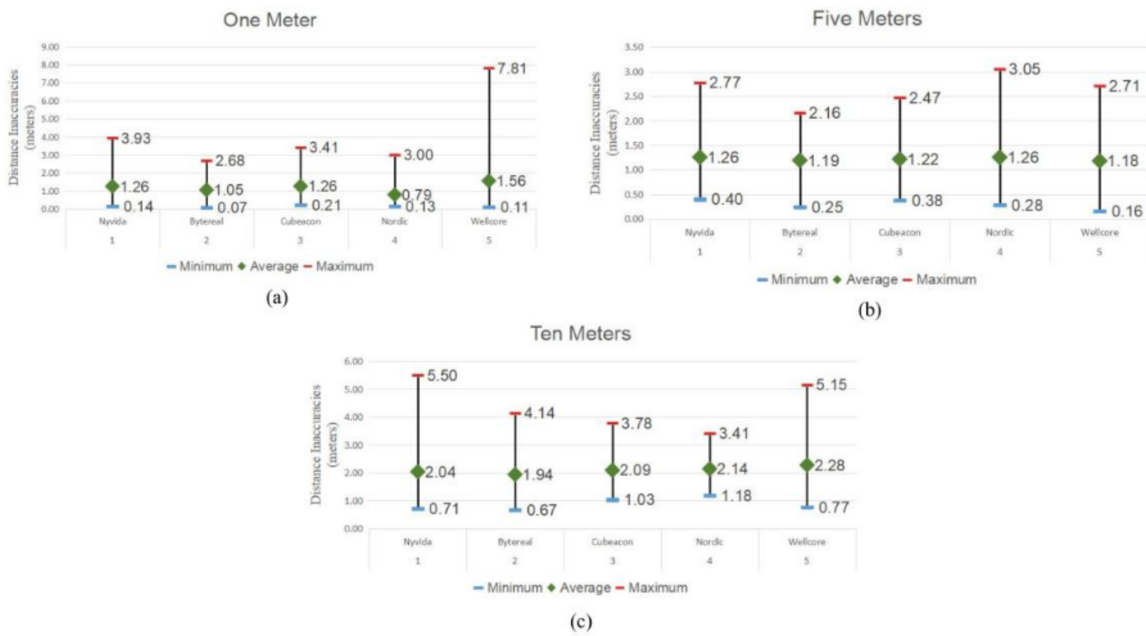

Fig. 1. Result of the experiment at (a)one meter, (b)five meters, (c)ten meters

in the accuracy performance of each beacon devices and smartphone devices.

$$D = 10^{\left(\frac{TxPower - RSSI}{10n}\right)} \tag{1}$$

In order to get distance data from the BLE beacon, we use RSSI(Received Signal Strength Indication) reading from our test subject. We used equation 1 [6]to convert the distance (D) based on received RSSI value. TxPower is the signal strength at a one meter distance, while n is the value of exponential path loss. We do not apply any filter, so the distance value are purely based on device performance.

IV. Results and Discussion

The results of the experiments shows in figure 1 and 2. Figure 1 show the compilation of the accuracy results of the distance readings for each beacons from distance point at 1 meter, 5 meters and 10 meters. the value in the figure, indicates the average value of the inaccuracies in distance reading from the entire test subject(our students smartphones) as well as the maximum and minimum inaccuracies that have occurred. During 2 minutes distance read by the entire smartphones, the accuracy variation that occur is quite diverse. Reading at a time can be quite accurate with only 0.07 meters inaccuracy, but it can also miss really far up to 7.81 meters. At certain device, the average value obtained is quite satisfactory. The average value of one beacon reaches 0.79 meters at 1 meter measurement. The highest inaccuracy is found in the reading of one of the beacon at a measurement of 10 meters, which averages at 2.28 meters. Figure 2 shows some interesting result, while graphs of average and minimum accuracy values have a tendency to rise along with the increase in measurement distance, but the maximum inaccuracy value is at the best value in a 5 meter measurement.

The data we collected shows that the accuracy of distance measurements can vary due to devices heterogeneity. Compared to other researches [8], BLE beacon have an accuracy of less than 2.5 m error similar to our result. Those data however is obtained from two smartphone devices, while our experiment employ more devices. Another study also presents the accuracy value of the use of beacons in a scenario on a museum building [9], and it shows good results. However the test scenario involves only beacons from one manufacturer and tested just with one smartphone as a receiver. The data shows comparison of measured estimated distance from distance up to 5 meters and the error at that distance is within 3 meters. Our data also shows a maximum value of errors at 3.05 meters for the 5 meters measurement at certain BLE beacon, while other BLE beacon we used shows a maximum value of errors at 2.16 meters.

V. Conclusion

In this paper, we shows the performance of bluetooth beacon devices that vary in accuracy when used in distance measurements by various smartphone devices. This result shows the average accuracy that is not too deviate by various kinds of bluetooth beacons being tested. The accuracy of the beacons we get varies from the highest accuracy with 0.07 meters at

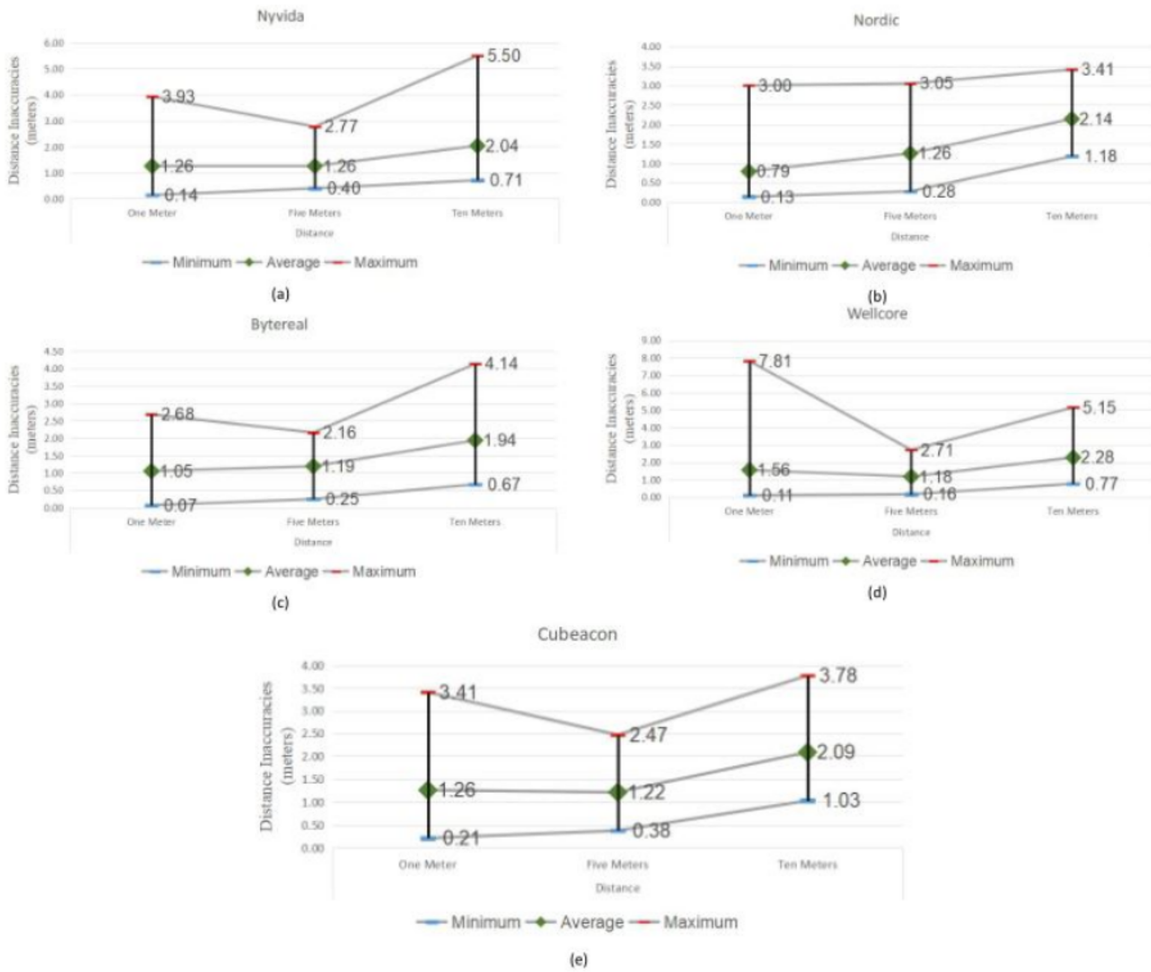

Fig. 2. Result of the experiment for each beacon: (a)Nyvida, (b)Nordic, (c)Bytereal, (d)Wellcore, (e)Cubeacon

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Our current study presented in this paper is limited to the use of bluetooth beacons as device to obtain distance data. Our work in the future will extend this bluetooth beacons device to use to determine indoor location information. We plan to create a bluetooth beacon network in a building using various devices from many manufacturers to observe the impact of location information generated from these beacons.

ACKNOWLEDGMENT

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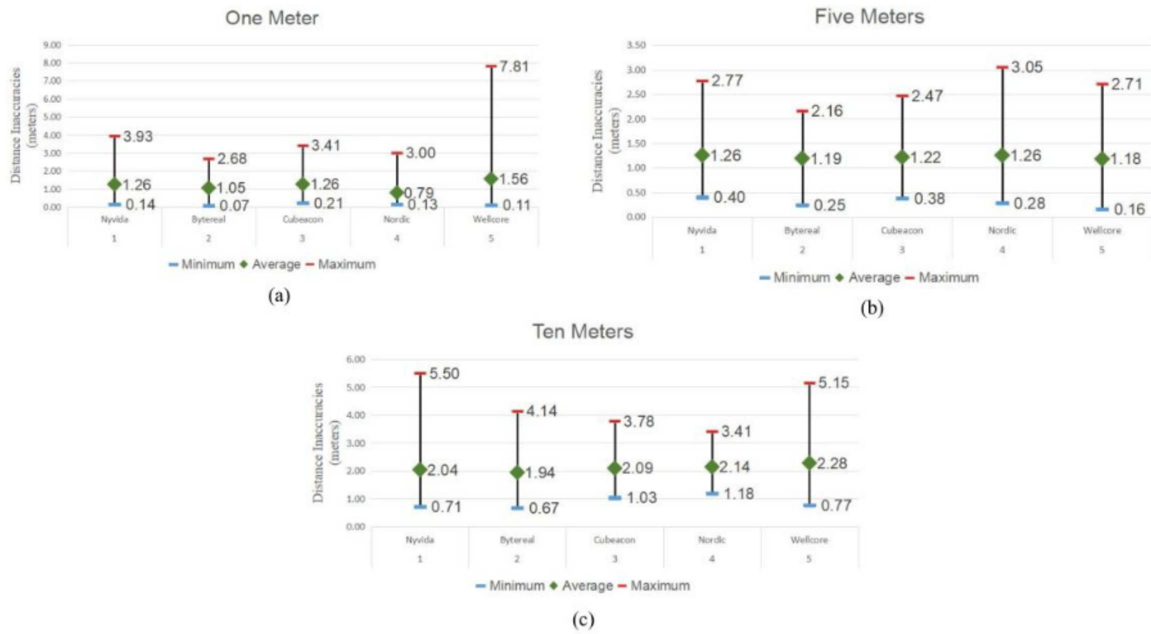

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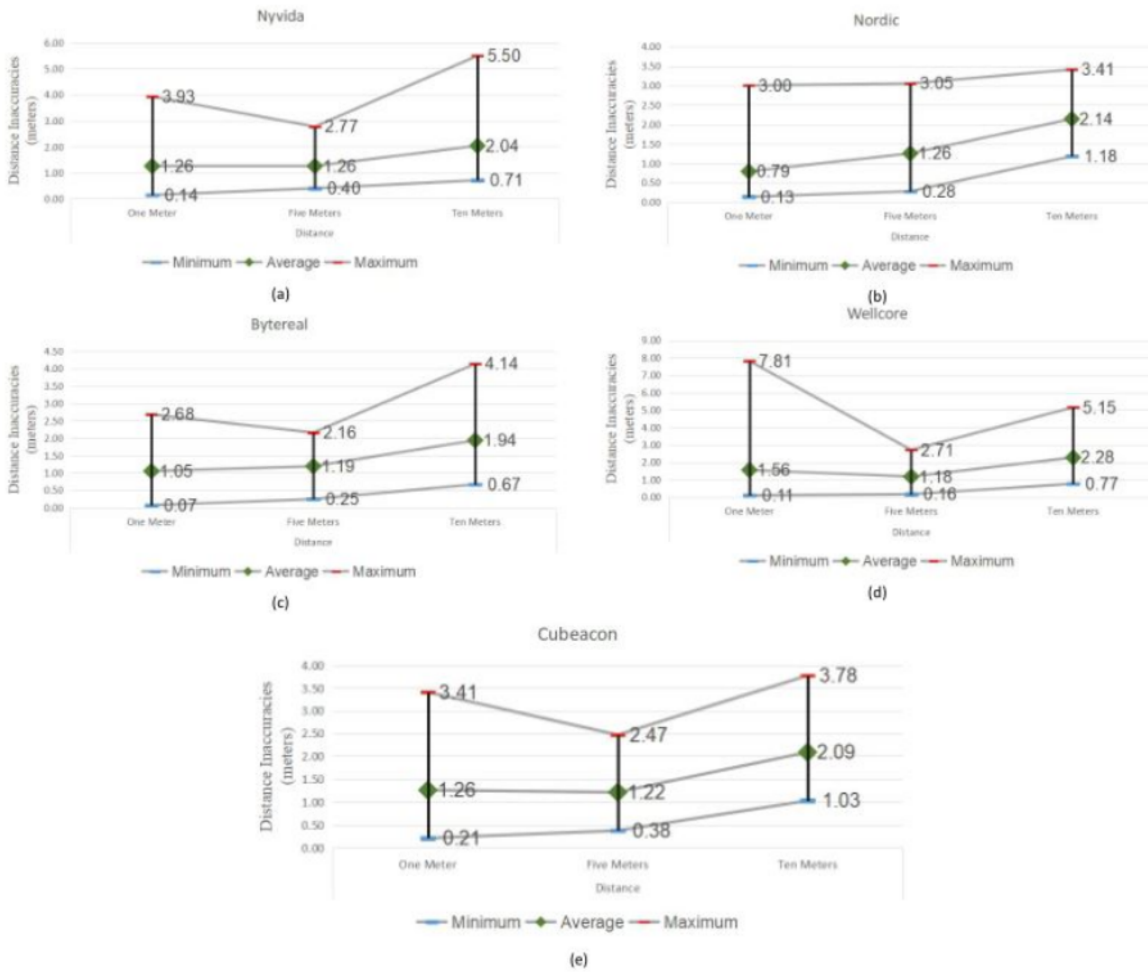

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