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LOCATING OBJECTS IN WAREHOUSES USING BLE BEACONS AND MACHINE LEARNING

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Abstract— Warehouse management plays a pivotal role to boost the entire supply chain. To increase productivity, enterprises are focusing on different object localization approaches to achieve better accuracy amid high interferences. This helps to reduce the overall time for order taking & perform effective stock management. For this purpose, we propose a cost-effective system to achieve better accuracy for locating objects in indoor spaces with the help of BLE beacons. BLE is the term used for the Bluetooth wireless standard for low power consumption. BLE beacons are used as technology enablers because BLE supports all the major mobile smart devices and tablets. The measurement is performed using Received Signal Strength Indication (RSSI). Also, improved the location accuracy with the help of machine learning algorithms & utilizing neighborhood beacons for real- world use cases of warehouse management. The target object & neighborhood beacons provide the raw data to the system & the mobile device acts as a receiver. Our results show that the proposed work provides high accuracy for finding resources, taking orders & improving the overall stock process in management.

I INTRODUCTION

Object localization in indoor space has paramount importance considering the number of use cases for IoT applications and business advantages. In warehouses, it is crucial to cut the operational cost [1] and improve the productivity of the costly order taking process. The slow process for taking stock & picking the orders lead to delay in the delivery of the order to the customer. In real-life scenarios, placing the objects causally due to heavy load makes the overall management complicated. As most of the warehouses are indoor, the Global Positioning System (GPS) is not very useful as it can't penetrate the walls of the building. The approaches like image based and wireless signal based were discussed & implemented by researchers. Among these, Receive Signal Strength Indication (RSSI) based wireless localization has been used in millions of applications across the world. [2] There are many different approaches to achieve localization like triangulation finger priniting.The wireless technologies consist of RFID, Wi-Fi & BLE. Wi-Fi basedsystems require complex deployment & additional techniques. [4] RFID based systems can only sense the target resources when they are in range of the RFID scanner and installation is complex with high hardware costs. Bluetooth Low Energy (BLE) has more scan time as compared to traditional Bluetooth and has influenced many developers as a technology enabler for indoor apps. Moreover, it is supported by most of the current hardware available in the smart devices in the market. The key advantages of BLE devices are: power saving, light weight, small size and low cost. It uses data structure with different hierarchy for information storage and advertises the signals consisting of services and characteristics for communicating with other devices. Let's go through three main techniques for RSSI BLE localization. PROXIMITY

The proximity method helps to find the target object location w.r.t known object location. The broadcaster beacon sends a signal to the smart object and the beacon location or identification of the symbolic cell provides the target location in indoor premises. If the RSSI values are stronger than the threshold, then the target object is marked in the proximityarea and labelled as localized. Proximity clears mean it is either nearby or close enough to the requestor.

RANGE

In the range-based algorithm like a trilateration, the distance between beacons and smart objects can be calculated using a propagation model (PM). It determines the location of the point measuring the distance with the help of geometrical figures like circle, rectangle and spheres.

FINGERPRINTING

This method is called offline data training and always is the first step for any positioning system based on fingerprinting. This allows us to create a map between a blueprint and the actual objects and display them over the blueprint based on the real-time positioning. The RSSI value determines the receiving capability of the device from the transmitter. As it works, higher the RSSI, stronger the signal & vice versa. As per research, BLE beacons use 3 channels for

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advertisement (channel 37, 38 & 39). Figure 1 shows the 3 channel RSSI advertising values for the same distance. They have different measurements in terms of accuracy due to channel gain and multi- path effect and can be seen by Figure.1. Smartphones are used as signal receivers/transmitters. To the best of knowledge, few studies have used BLE beacons like iBeacon, Eddystone, AltBeacon & GeoBeacon in warehouses. Despite the improvements in the technology sector for warehouse management solutions, few challenges still exist

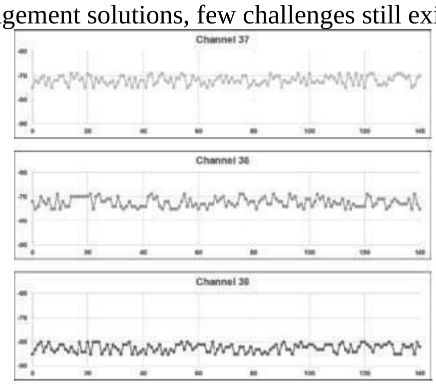

Fig 1: Primary channel advertising data

1. Locate the item in very fast time so as to improve theoperation time.
2. Accurately find the target resource despite numerousinterferences inside the warehouses
3. Deploy the solution in the warehouses so as to reduce theoverall system cost.

To resolve these challenges, the proposed work uses Eddystone BLE beacons for transmitting rich and strong data to the system. The beacons are attached to the target objects and act as the signal emitters whereas the mobile device using mobile app act as receivers. The system aims to provide a cost effective solution for warehouse management. This paper is considered a short paper for which the research is still under development and it predicts preliminary outputs. The proposed work mainly aims at reducing the error in accuracy & providing a cost-effective solution. It uses three advertising channels data as an input. Experimental results were generated to measure the location accuracy in warehouses for target items. Our overall contribution in the field of object localization for industrial warehouses is presented follows:

1. Adaptive Machine learning model trained to detect the surrounding changes
2. Target & neighborhood beacons were used to provide more raw data
3. Machine learning regression model were used for predicting location based on environmental factors using confidence scale
4. The smartphone motion sensor data was utilized forimprovised location

II. DESIGN AND IMPLEMENTATION

Locating Object in warehouses

The warehouse has randomly placed raw materials, which is one of the biggest factors affecting the supply of materials over time. As the materials are not distinguishable from outside, the process takes a longer time to find the appropriate object. This not only affects the business delivery but also decreases.

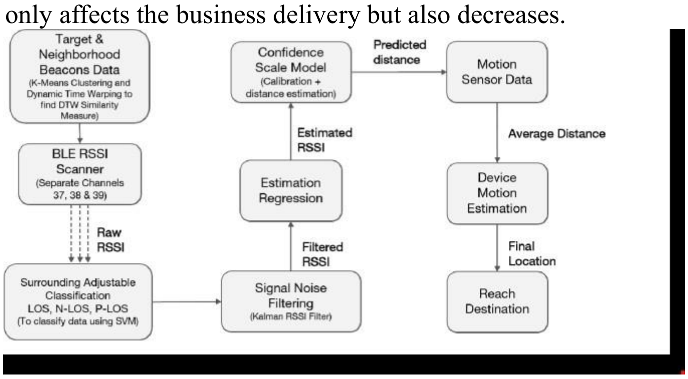

Fig 2: Schematic Diagram of object localization in warehouses

Figure 2 describes the overall architecture of Eddystone beacon based object localization solution. The system consists of various components to collect, process & analyze data to find the location of the target item. The raw data is collected

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from target beacon & neighborhood beacons. This data is collected from advertising channels. The environment is classified using a supervised machine learning algorithm depending upon the data received from the transmitters. Depending upon the environment, supervised machine learning regression model is used. The received data is then filtered using Chebyshev algorithm. The received value is then checked with the confidence scale model which compares the values against the model using calibration measurements for RSSI & actual distances. At the end, the device motion sensor present on worker's handset is used with calculated distance to provide the final distance to the target object. The beacon are attached to the raw materials act as signal emitters. A beacon is a very small wireless hardware device which is based on BLE. It continuously transmits the signal which other nearby devices can scan. The signal is a radio signal made of numbers & letters transmitted over a short / regular interval. Beacon has measured broadcasting power, which varies based on the different vendors and size. Considering the scenario where a worker wants to identify the location of the raw material i.e. target object to be used, the worker shall send a request to find the warehouse target material through an Android mobile app. This mobile app is built using native Android framework using Java & has support till

Android 11. The app then scans all the stationsand waits for the response. The scanning provides the results in the form of RSSI & UUID which are then converted into the actual distances using algorithms. All the processing & calculations happen over the server. All the machine learning algorithms are built in python & deployed on the server. Oncethe final location is received, it is showcased to the worker in the mobile app. The raw material target beacon has a unique code for identification. This code is then scanned using a mobile app & providesall the relevant information about the raw material like type, serial, price, quantityetc.

Gateway Fingerprinting

As we have seen the way beacon addition & removal communicates with the system. The smart beacons communicate with the gateway / cloud beacons. The gateway beacon is used to gather, access real-time data from smart beacons in the warehouse section and then send to the cloud server. The fingerprinting & calibration is done for the smart beacons. Their actual location is calculated and fed into the system with next to zero-error in the calibration process. Please notethat beacons are calibrated appropriately by placing them in the warehouse. This is illustrated in Figure 3. Gateway beacons keep track of the beacons in the vicinity and help to keep the inventory upto date. Whenever the inventory person wants to request the location of the target item with a beacon attached, the request is sent from the Android app to the server. The server then tries tofind the Gateway which is able to scan the target object and nearest to it. The location is then sent back to the Android device app and the user can proceed towards the item. All the processing ofthe algorithms in the upcoming sections is done on the server side. Please note that Gateway beacons can talk to smart beacons and communicate with cloud server over Wi-Fi.

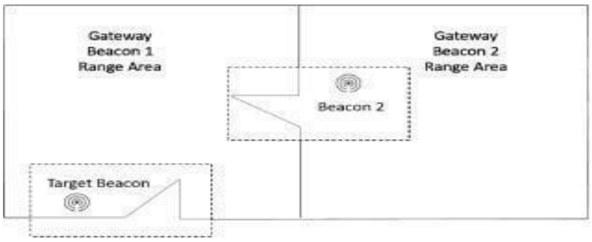

Fig 3: Gateways with smart beacon

Raw RSSI Data Extraction

The raw data is important when we have to work in indoor spaces with interference challenges. BLE uses three different broadcasting channels for advertisement of the data. This is basically done to adapt to the frequency hopping for avoiding interference with other 2.4 GHz signals. The interval in Android OS is 5 seconds for switching to the different channel. The data from three advertising channels (37, 38 and 39) [29] is collected. RSSI measurement is directly dependent on the frequency. Hence, when the frequency is changed to a different channel, RSSI provides different measurements. The data collected for 10 seconds and then using a moving average filter passed to the next layer for processing. Please note that the RSSI values of target & neighborhood beacons are taken for consideration for improving accuracy. Due to external entities which influence the radio waves like interference, absorption or diffraction — RSSI values tend to deviate more frequently. To convert the RSSI measurement to actual distances, we use the Log-distance path loss model [28]. Please note that RSSI is a beacon signal strength which depends on distance and measured power. We use Eq. (1) to calculate the distance from RSSI:

$PL(d) = PL(d_0) + 10n \log(d/d_0)$ where PL (d) is the value of the reference path loss value as per the calculated measurements at a distance d0 and n represents the propagation exponent which is rate for path loss component with the distance.

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Location prediction using ML Algorithms

As the warehouse consists of different routes & interferences, it is important to identify the transmitter & receiver environment during object localization. Our proposed system uses the RSSI trends to estimate target item location. As the data increases, our target item location will become more accurate. Most of the time, the RSSI data changes are due to the surrounding changes which produce inaccurate results. To solve this issue, our system proposes to utilize the surrounding changes & tune the estimated location accordingly. We propose to use a feature vector which includes standardized parameters like mean, variance, skewness, median, and max & min value for our estimation. We tried various different kernels like Random Forest, Decision Tree, SVM with various & linear kernels. For our research, we chose SVM with a linear kernel as per results the decision is based on the mean accuracy % parameter.

III CONCLUSION

This paper proposed an Eddystone beacon based object localization system for real life industrial uses of warehouse management. With this work, locating raw materials present inside the warehouses is very easy and helps to reduce the order picking time significantly from 11 mins to 2.2 mins. The location accuracy observed is under 1.4 meters. Preliminary experimental results show that proposed work demonstrates low cost system, robust and high location accuracy. The results show an average location error of 1.3 m and accuracy 1.4m, which is less than most of the algorithms, proposed using a standard traditional propagation model and systems where only target beacons were used as raw data instead of considering neighborhood beacons. Our ongoing research will focus on making

existing work systems secure with the help of federated learning. The algorithm is tested in the sparse and densely populated places inside the warehouse. Since RSSI fluctuates for different interferences and varies according to the different warehouses, more work can be conducted to improve accuracy. The proposed system can be applied to healthcare domain warehouses where it is critical to provide supply in a quick time due to urgent demands. The research considers the beacons to be stationary. The future research and experimental results will focus on moving objects in the indoor premises. The deployment option can also be explored which can affect the accuracy of the predicted distance when neighborhood beacons are used. Also, compatibility support for Bluetooth 5.0 can be provided which consist of wider coverageand will certainly help for better performance & accuracy.

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