4_Paper TSSA 2020

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Automatic Asset Location Determination for Warehouse Management System Based on Wi-Fi Signal Strength

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***Abstract*—Warehouse Management System of a company which has the main objective of controlling the processes that occur in the warehouse starting from the shipping, receiving, put-away, movement and picking processes. Determining the location of stored assets is one important aspect to help speed up the process of storing and removing goods from the warehouse. In this study we use WI-FI technology in determining the position of the item in the warehouse. This technology is chosen besides being cheaper and can be placed either in an open space or in a closed space. Is an alternative technology to GPS technology that fails if it enters a closed space. Although the implementation of this method is the cheapest it does not really produce good accuracy. The RSSI measurement tends to fluctuate according to the environment because of the multipath fading. This position determination will apply the Internet of thing technology because the position reporting is carried out automatically by the assets themselves and recorded via the internet network to the warehouse management system server. In this way, the position of assets can be up-to-date and can be searched precisely from anywhere.**

Keywords*—*Wi-Fi, Warehouse Management System, Signal Strength

I. Introduction

Warehouse Management System is a management information system designed to support warehousing management that is used to manage and control processes that occur in the supply chain [5]. This system has the main objective of controlling the processes that occur in the warehouse as a whole starting from the shipping, receiving, putaway, movement and picking processes.

The following are the advantages of a warehouse management system, namely:

1. Make it easy for warehouse managers to provide information on the availability of an item to the production or delivery planning department so that the availability of goods remains at a safe level.
2. The placement of goods is determined by the system to facilitate storage, collection and calculation of stock items.
3. Reducing the lead time from storage and delivery of goods.
4. The availability of various information regarding item descriptions and warehouse features can facilitate analysis to develop a more efficient warehouse use strategy.

Determining the location of an item in the warehousing system is the perfection of a warehousing system. One important part of warehousing management is determining the location for storing goods in the warehouse. Determination of the storage location for incoming goods and/or moving goods should be updated so that when the goods are released, they will know the exact location of the goods to be released. This system itself can be done manually or electronically by utilizing Radio Frequency, Wi-Fi LAN, Barcode Scanner, and Email technology in its application.

For large, movable items. Determination of a new location should be done precisely when the goods/vehicle are moved to a new location. Of course this requires officers who do with high dedication to report after changing the location of the goods in the warehouse. To reduce the errors of the officers, changes to the location recording are carried out independently by moving goods through a tag device embedded in the item that will actively report their new position to the system database. This term is known as node self-localization.

WPS or Wi-Fi Positioning System to determine the position of an item electronically. Each asset that will be stored will be tagged in the form of a Wi-Fi card as an item marker. This Wi-Fi technology is an alternative technology for determining the location of an item where GPS technology will fail if the warehouse is in a closed place.

Self-localization nodes can be broadly categorized into range-free and range-based methods. Range-free is a method for calculating the position of a node by using the distance between the transmitter node and the receiving node. The methods are centroid, DV-hop and conjecture geometry. Other node independent locations are range-based which includes several techniques: (i) received signal strength

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indicator (RSSI), (ii) angle of arrival (AoA), (iii) time of arrival (ToA), and (iv) time of difference in arrival (TDoA). The advantages of node self-localization are cost-effective, fast to use and low power consumption. Although the standalone node localization method is highly accurate, additional hardware is required [1].

II. Wi-Fi Technology

A. Wi-Fi position System

Wi-Fi is a technology that utilizes electronic equipment to exchange data wirelessly (using radio waves) over a computer network. The Wi-Fi Alliance defines Wi-Fi as "any wireless local area network (WLAN) product based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard.

A location determination system using Wi-Fi (WPS, WiPS or WFPS) is a geolocation system that uses the characteristics of nearby Wi-Fi hotspots and other wireless access points to locate devices. This method can be used both outdoors and indoors. Wi-Fi positioning is already used in many projects.

B. Signal Strength Base

There are many methods for measuring position, one of which is signal strength based. The technique of determining the location using RSSI (Received Signal Strength Indication) is based on measuring the signal strength of the client device to several different access points, then this information is combined and calculated to determine the distance between the client device and the access point using the trilateration technique (sometimes called multilateration).

This method although one of the cheapest and easiest methods to implement, its drawback is that it does not provide very good accuracy, as RSSI measurements tend to fluctuate according to environmental changes or multipath fading [2].

Wi-Fi signal distance is affected by:

a. Output Power, The output power is measured in mW (milliwatts). The FCC regulates the Wi-Fi output power up to a maximum of 1 watt (1000mW) in the US. Access points with higher output power can broadcast Wi-Fi over a larger area. For example a router with an output power of 200mW will be able to broadcast Wi-Fi twice as far as a router with an output power of 100mW,

b. WI-FI antenna, All Wi-Fi devices use at least one antenna to broadcast the signal. Some devices have antennas that are internal to the unit and others have external antennas, and some antennas will amplify the transmit power.

c. WI-FI Technology, Wireless radio 'N' capable of transmitting at a longer distance than previous Wi-fi generations (g, b, a).

d. Environmental Impact, Regardless of device specifications and features, actual Wi-Fi coverage will depend on construction, layout and interference interference.

The resulting distance will depend on the transmit power sent from the access point.

The calculation of the RSSI range statistical model is as follows.

$$P(d) = P_0 - 10n_p \log\frac{d}{d_0}, \quad (1)$$

where $P(d)$ is the RSSI value at distance d; n_p is a path loss factor that ranges from 2 to 4; P_0 is the RSSI value at the distance d_0 (dBm). Taken $d_0 = 1$, $P_0 = 40$. The relationship of distance and RSSI signal in Fig. 1.

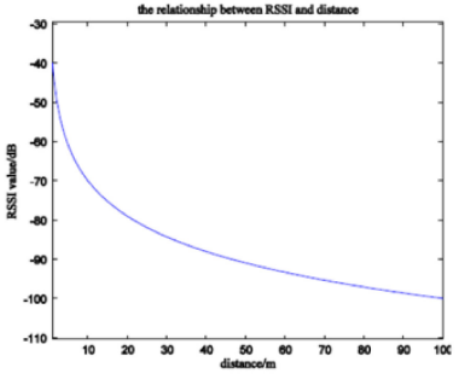

Fig. 1. Relationship between RSSI and distance [12]

III. Proposed Design of Automatic Asset Location Determination System

In designing the system for determining the location of goods in the warehousing system, several steps will be taken. First, the warehouse building will be equipped with several WAPs (wireless access points) that cover the entire warehouse area. These access points will be connected to the warehousing system. Second, every item that will be stored in this warehouse will be equipped with an IoT device as a tag that has been associated with the item data in the warehousing management system.

Fig. 2. Device Tag IoT

Fig. 3. WAP (wireless access point) location

The IoT tag device will read the WAP signal strength periodically and send it to the server via the closest WAP connection. The server will process the data received and convert it to the coordinates of the location of the assets to be stored in the database. This process of identifying your own position will keep your positioning up to date. Users will have this location data if access to this warehousing system is from anywhere.

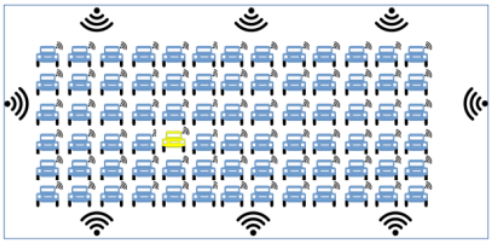

Fig. 4. Tag self-identification position

This self-identification system will make sure the position of the goods will be known. If the asset position changes, the records in the data base will automatically change without the need for any entry from the employee/officer.

A. Software Application

The software application system can be described in the following diagram.

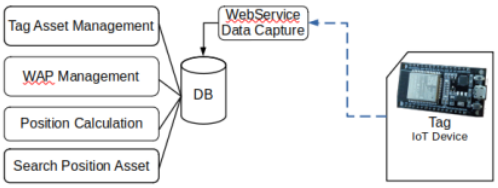

Fig. 5. Software Aplication

A tag in the form of an IoT device will be placed on the item to be stored. This Tag (IoT device) will actively send data for the purpose of calculating the location of this item to the database wirelessly. This device will scan the amount of Wi-Fi signal that can be received and sort by the amount of signal strength.

On the server side, several modules that must be developed as part of the application system are:

1. Webservice data capture
2. Tag Asset Management
3. WAP Management
4. Estimated Calculation
5. Searching Position Asset

B. Hardware Tag

As an active tag, we use a single board microcontroller NodeMCU ESP32 from Espressif Systems with a dual core 32-bit processor with built-in 2.4 GHz Wi-Fi (802.11 b/g/n, 802.11 n, up to 150 Mbps), Bluetooth and BLE (Bluetooth Low Energy) with 4MByte flash memory and 520KByte RAM.

Fig. 6. NodeMCU ESP32

TABLE I. WI-FI CHARACTERISTICS ESP32 [6]

Parameter	Condition	Min	Typical	Max	Unit
Operating freq. range	-	2412	-	2484	MHz
Output Impedance	-	-	-	-	Ω
TX power	11n, MCS7	12	13	14	dBm
	11b mode	18.5	19.5	20.5	dBm
Sensitivity	11b, 1 Mbps	-	-98	-	dBm
	11b, 11 Mbps	-	-88	-	dBm
	11g, 6 Mbps	-	-93	-	dBm
	11g, 54 Mbps	-	-75	-	dBm
	11n, HT20, MCS0	-	-93	-	dBm
	11n, HT20, MCS7	-	-73	-	dBm
	11n, HT40, MCS0	-	-90	-	dBm
	11n, HT40, MCS7	-	-90	-	dBm
Adjacent channel rejection	11g, 6 Mbps	-	27	-	dB
	11g, 54 Mbps	-	13	-	dB
	11n, HT20, MCS0	-	27	-	dB
	11n, HT20, MCS7	-	12	-	dB

C. Program

Software is carried out on an active tag in the form of an IoT device that is attached to the item. The program will scan for RSSI signals from several access points (AP) it receives and then ranks it based on the signal strength received. All signal strength data will be sent to the server to be calculated into the coordinates of the asset location. Fig. 7.

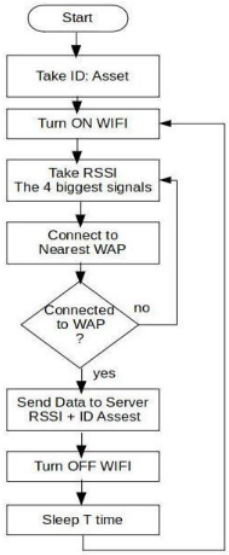

Fig. 7. Flowchart program in device tag

The data sent by the tag device to the server via API in the form of web services. The data sent will be calculated to determine the coordinates of the goods in the warehouse and stored in a database in a warehousing system.

On the server, the data on the signal strength that is caught by the item tag is then processed to obtain the coordinates of the location of the goods. Each signal will be checked whether it comes from the valid existing WAP in the warehouse or not, then the calculation begins by selecting the 3 largest received signals to enter the triliteration calculation Fig. 8.

D. Trilateration Calculation

Trilateration is the process of finding the coordinates of a point based on the distance from that point to at least 3 known coordinates.

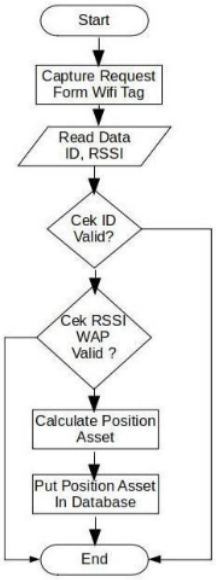

Fig. 8. Flowchart data sinyal proses on server

A simple calculation of the center of the circle is represented by c1, c2 and c3, where P is the point of interest. Meanwhile r1, r2 and r3 are the distances from the center of the circle to point P, see Fig. 9.

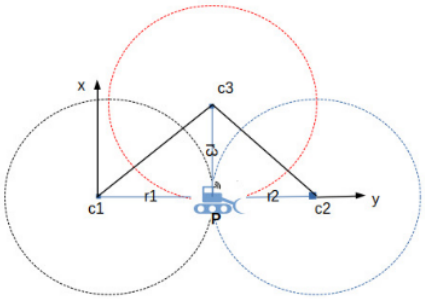

Fig. 9. Triliteration Calculation

if C1(0,0,0), C2(U,0,0) dan C3(V_x,V_y,0) while P(x,y,z) so:

$$r_1^2 = x^2+y^2+z^2$$
$$r_2^2 = (x-U)^2+y^2+z^2$$
$$r_3^2 = (x-V_x)^2+(y-V_y)^2+z^2$$
$$\text{with} \quad V^2 = V_x^2+V_y^2$$

$$x = \frac{r_1^2 - r_2^2 + U^2}{2U}$$
$$y = \frac{r_1^2 - r_3^2 + V^2 - 2V_x x}{2V_y}$$
$$z = \pm\sqrt{r_1^2 - x^2 - y^2}$$

IV. Simulation and Experimental Results

The determination of trilateration will depend on the signal strength and radiation pattern, each access point will have a different power strength depending on its type and class. For that the application must provide a store of signal distribution patterns depending on the type and class.

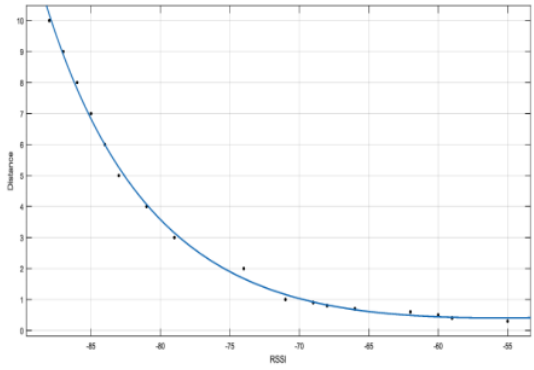

Fig. 10. RSSI vs Distance [6]

As in this experiment, the signal strength emitted by the esp32 device has a signal to distance graph as illustrated in the Fig. 10.

TABLE II. Result the asset position WAPa (5.0), WAPb (0.5), WAPc (5.10)

WAPa	WAPb	WAPc	Location X (m)	Location Y (m)
5	5	5	5	5
5	10	5	12.5	5
7	0	7	0.1	5
10	10	10	5	5
3	3	3	5	5
3.5	9	7.5	9.675	2.8
0.3	0.3	6	3.2045	3.2045
0.4	0.7	3	4.591	4.558
5	0.3	6	1.959	4.45

V. Conclusion

We have implemented a localization system that uses the RSSI trilateration approach in wireless IoT networks. The accuracy of the system position estimation is also evaluated. We conclude that for the proposed system to function there must be at least three reference nodes with known coordinates available. Each reference node must act as a wpa so that the item node position data can be directly stored in the database. The position calculation will be calculated by the server to show the exact position in the warehouse..

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