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Design and Implementation for Indoor Navigation System Using LoRa

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***Abstract*: Navigation system help users access unfamiliar environments. Current technological advancements enable users to encapsulate these systems in handheld devices, which effectively increases the popularity of navigation systems and the number of users. Internet of Things (IoT) is a new period of computing technology. Applications of IoT in different fields such as health, farming, industrial internet and so on. In indoor environments, lack of Global Positioning System (GPS) signals and line of sight makes navigation more challenging compared to outdoor environments. Indoor Positioning System (IPS) enable locating the position of objects or people within buildings. In this paper major aim is to design an indoor navigation design using LoRa technology. LoRa is a long-range, low power wireless technology platform. For indoor localization, many techniques are employed, among these techniques RSSI (Received Signal Strength Indicator) fingerprinting provides several favourable features for indoor environments. RSSI is one of the most widely used method as it is cost-effective and easily implemented. RSSI indicators from the different LoRa nodes are collected to create fingerprint database. LoRa network has been created using LoRa modules, Arduino Uno and LoRa receiver for creating localization system for indoor positioning. Nevertheless, RSSI performance is limited by indoor noise. K-nearest neighbor (KNN) filtering algorithm is an accurate filter algorithm that can enhance RSSI performance in indoors. KNN is one of the most popularly used algorithms for indoor positioning systems. Based on the RSSI indicators the users can locate the estimated position.**

***Keywords*: Indoor Localization, Global Positioning System (GPS), Indoor Positioning System (IPS), Received Signal Strength Indicator (RSSI), K-Nearest Neighbor (KNN), LoRa (Long Range).**

1. Introduction

Location of a user or a device is of extreme importance. Wireless positioning approaches in Low Power Wide Area Network (LPWAN) have become a significant issue because of the increasing growth of Internet of Things (IoT) applications and location-based services, which involve billions of devices and gateways. In case of outdoor technology, Global Positioning System (GPS) signal is widely used to determine the position of user. However, in case of indoor environments this GPS technology fails to deliver. GPS signal is weak to travel in terms in terms and location found out is not precise. Additionally, GPS receivers are too expensive to be included in many IoT devices and are power-hungry, which significantly reduces battery life. Since many location-based services are available indoors, where GPS does not operate, it does not offer an integrated indoor solution. Hence, there was a need to develop an alternative technique, for indoor localization. Over the years various technologies like Bluetooth, ZigBee, Wi-Fi etc are researched to find the best possible technology suited for indoor localization. These technologies were compared using the performance parameters like cost, coverage, accuracy and power consumption. Compare to all these technologies, LoRa found to be more accessible and feasible technology. LoRa technology which is one of the communication technologies has been introduced as an alternative for these existing wireless communication technologies. LoRa is one of the long-range, low power wireless communication for low-power objects. LoRa technology is used in indoor localization or indoor navigation system by using Received Signal Strength Indicator (RSSI) fingerprinting. RSSI fingerprinting is the most popular method of localization because of its high accuracy compared to other methods. In order to achieve positioning, indoor fingerprint positioning technology primarily uses signal fingerprinting, which compares the measured signal strength at the user's location to the received signal strength of every location.

2. Literature Survey

The use of LoRa communication technology in healthcare services has been studied. The paper provides the solution regarding the health-related issues when elderly people living alone at home may fall and become unconscious. They can't call for help and it can cast them their lives and LoRa analysis at an affordable price and analysis of people's tracking area. It provides frequency and bandwidth details for various countries. It provides frequency and bandwidth details for various countries. It provides frequency and bandwidth details for various countries. It demonstrates that LoRa is flexible in operation and should be based with applied conditions [1].

The growth of several Internet of Things-based applications, including indoor localization, which can determine the precise location of people or object, has become a key element of smart homes. For indoor navigation, a number of wireless

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technologies have been deployed, including Wi-Fi, Bluetooth Low Energy (BLE), RFID, and LoRa. Additionally, studies have demonstrated that LoRa can be used for localization. The efficiency of the LoRa ranges is examined first. Then, tests are carried out to show that LoRa can deliver precise and accurate indoor localization. Without the use of any filtering of any kind, the results demonstrate that LoRa-based indoor localization is more precise than line-of-sight scenario [2].

LoRa for maritime weather communication and for light weighted boats has been described. As marine communication is difficult because of adverse transmission conditions and the absence of a pre-provided support infrastructure [3].

The use of LoRa technology as a Wide Area Network (WAN) for meteorological monitoring in agricultural fields has been addressed. The paper expresses its major motivation to test the feasibility of LoRa based LPWAN technology and for providing a flexible for agricultural fields in the future. It indicates that LoRa operates in an unlicensed band less than 1GHz for long-range wireless connectivity [4].

A Wi-Fi based RSSI ensemble method for indoor localization is provided. The Dempster-Shafer theory of belief functions was used by the authors to determine the weights of four different classifiers in the ensemble decision. Mean and standard deviation, coupled with RSSI Wi-Fi, were introduced as the features to increase the classifiers accuracy. The results show that the method achieves a 2-meter localization error and a localization accuracy of about 98 percent. Even though mean and standard deviation were included, the model did not take into account the temporal autocorrelation presents in the RSSI Wi-Fi signal, which improved localization. [5].

3. RSSI Fingerprinting

One of the most popular features for indoor localization is the Received Signal Strength Indicator (RSSI). The main tenet of the measurement method is that it figures out how much power is transmitted from an access point to a user device or vice versa. Since RF waves attenuate according to the inverse square law, it is possible to estimate the distance by comparing the intensities of the transmitted and received signals. Presumably, additional data can be collected as the number of devices rises. Therefore, the accuracy might be improved if precise RSSI values are obtained. This has a negative impact on the system. The level of signal interference would increase as the number of devices increased. The distance between the two devices should be calculated with errors in mind. In fact, the main issue with wireless localization systems is that range measurements frequently contain errors. Even though RSSI is the least complicated and expensive method, it does not provide the highest level of accuracy. Using RSSI-based localization, filtering is important to reduce noise and raise system accuracy.

4. KNN Algorithm

K-nearest Neighbor is one of the most popular algorithms for indoor positioning systems. To solve problems with classification and regression, supervised machine learning might employ the KNN method. To estimate the location, the database's separation between patterns and reference patterns is utilised. A number of formulas, including the Manhattan distance and the Euclidean distance, can be used to calculate distances. It averages the positions of the identical k patterns and selects the best matching fingerprints based on their distance. Before that, the reference points connected to these k fingerprints are used to calculate the estimated position. KNN algorithm based on Euclidean Distance to find the nearest point. The positioning distance between stored RSSI value (i^{th}) and online collected RSSI value (j^{th}) at reference point is given by,

$$D_j = \sum_{i=1}^{m} \sqrt{\left(\mathrm{RSSI}_{i_{\mathrm{online}}} - \mathrm{RSSI}_{i_{\mathrm{offline}}}\right)^2}$$

5. System Design

RSSI fingerprinting is the most popular method of localization because of its high accuracy It usually consists of two phases- offline phase and online phase as shown in figure 1. For each predefine location, RSSI values are collected during the offline phase. The samples of data are kept in database. The online phase is a testing phase where the latitude and longitude of the testing locations are unknown but the RSSI values are known. These testing locations can be estimated and the location inaccuracy reduced by using KNN algorithm.

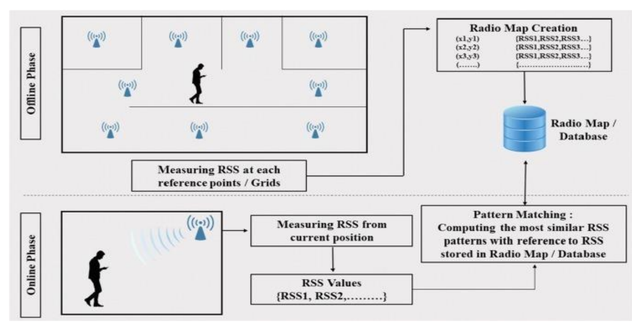

Fig. 1. RSSI fingerprinting based indoor positioning system

In an online phase, as the user moves around the indoor environment when the user is closer to an access point, it records the receive signal strength value at the access point. At the localization, the fingerprint matching of from the online phase and the offline phase takes place. After this matching algorithm is completed if the fingerprint of the online phase and the offline phase are matched then the position of the user is estimated.

A. System Architecture

The system architecture for LoRa base localization is as shown in the figure 2. The system architecture consists of 3 LoRa transmitter, Arduino Uno, LoRa receiver.

Arduino Uno is interfaced with LoRa module. One LoRa module is configured as receiver and other LoRa modules as transmitter. The RSSI values are collected from all LoRa transmitter and it is given to the LoRa receiver. These RSSI values are used to decide the location co-ordinates.

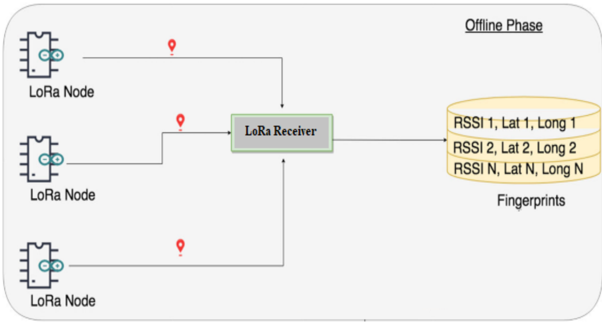

Fig. 2. System architecture of LoRa based localization

B. Hardware Requirements

1) LoRa SX1278

LoRa SX1278 is half duplex SPI communication. The LoRa SX1278 works with the SPI communication protocol and can thus be used with any microcontroller that supports SPI. LoRa SX1278 operates at 433MHz. It is mainly used for Long Range communication. It is also a low-cost transceiver module. It can achieve a sensitivity of over -149dBm in LoRa modulation. The operating voltage that is required to operate is 3.3V.

2) Arduino Uno

Arduino UNO is a microcontroller with a processor platform and a software IDE i.e., Arduino UNO board is programmed with the Arduino software. It has 14 digital input/output pins in which 6 pins are used as PWM outputs and 6 pins are used as analog inputs. It is an open-source microcontroller, due to which it is popular in the embedded world. Arduino UNO is used as controller to the LoRa modules.

3) OLED Display

OLED display module is a white, compact, and precise OLED module that can be connected to any microcontroller through the use of the SPI protocol. It has a 128 x 64 resolution. A thin, multi-layered organic film sandwiched between an anode and a cathode makes up an organic light-emitting diode. OLED technology does not require a backlight, in contrast to LCD technology.

C. Software Requirements

1) Arduino IDE

Arduino IDE (Integrated Development Environment) contains a text editor for a writing a code, message area with buttons for common functions. It runs on windows, Linux. Here it acts as a control unit for the proposed system.

D. Interfacing LoRa with Arduino UNO

The interfacing of LoRa module with Arduino UNO is as shown in figure 3.

Lora modules are available in various frequency range, the most commonly 433MHz, 915MHz and 868MHz are used. In the proposed system LoRa SX1278 has been used. LoRa Sx1278 operates at 433MHz. The microcontroller that is used for the interfacing with LoRa SX1278 is Arduino UNO. LoRa module is interfaced with Arduino UNO because the values from the LoRa module can't be read directly. So, the LoRa module has to be interfaced with Arduino UNO.

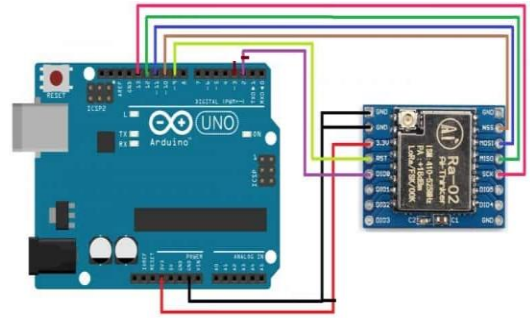

Fig. 3. Interfacing LoRa module with Arduino Uno

The LoRa module consists of 16 pins with 8 pins at either side. Of those 16 pins, six are used by GPIO pins from DIO0 to DIO5 and four are used by GND pins. The module operates in 3.3V and thus the 3.3Vpin on LoRa module is connected to the 3.3V pin of the Arduino board. The LoRa SPI pins are connected to the SPI pins on the LoRa module and Arduino UNO. Connecting wires are used to make the connection between Arduino UNO and LoRa module.

6. Experimental Results

Indoor localization has been implemented using a specific setup that includes LoRa transmitter and LoRa receiver. The hardware setup is as shown in figure 4.

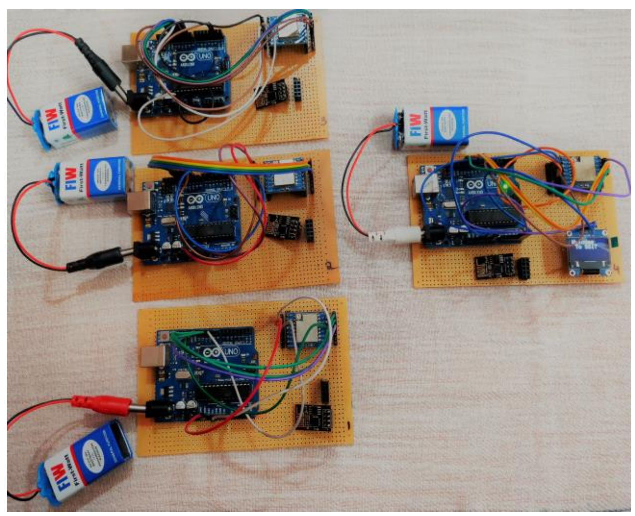

Fig. 4. Hardware setup for proposed system

The LoRa receiver consists of LoRa module interfaced with Arduino Uno, OLED and 9V battery for the power supply. LoRa receiver is as shown in figure 5. For the proposed system, 3 LoRa transmitter are used with consists of Lora module interfaced with Arduino Uno and 9V battery is used for the power supply. These LoRa transmitter are placed at 3 different locations in indoor localization. LoRa transmitter module is as shown in figure 6. When the user moves around in indoor environment as the user reaches near to the location where the LoRa transmitter are placed, RSSI values are displayed on the OLED on the LoRa receiver. From these RSSI values the user can located their estimated position.

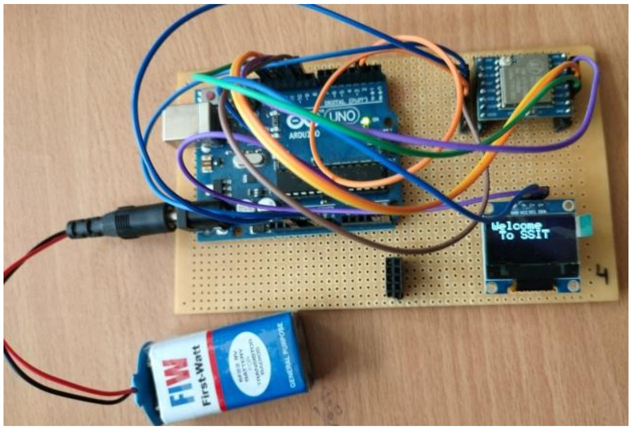

Fig. 5. LoRa receiver module

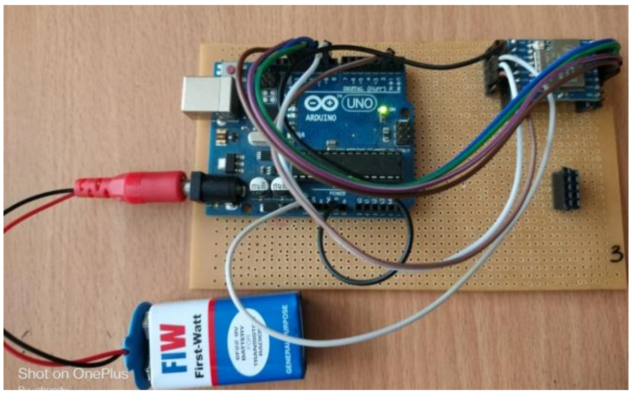

Fig. 6. LoRa transmitter module

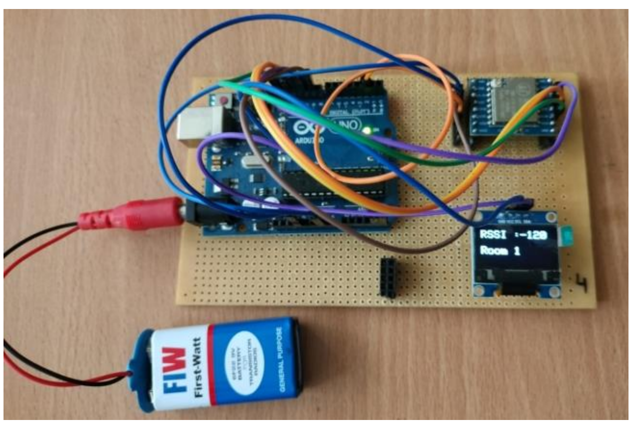

Fig. 7. RSSI value for Room 1

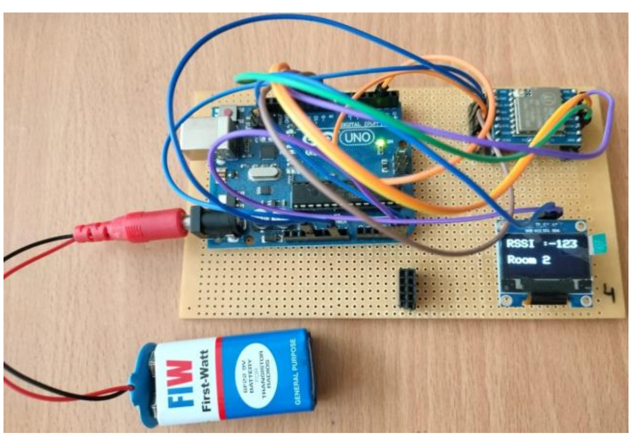

Fig. 8. RSSI Value for Room 2

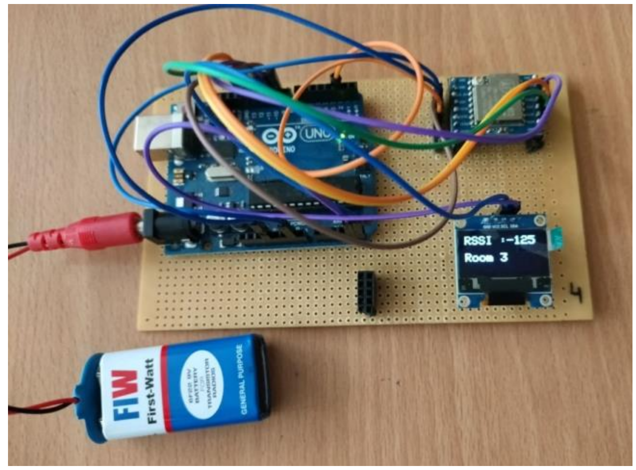

Fig. 9. RSSI value for Room 3

Figure 7, 8, 9 shows the RSSI values for different locations. Figure 7 shows the RSSI value for the transmitter which is placed at Room 1, figure 8 shows the RSSI value for transmitter which is placed at Room 2 and figure 9 shows the RSSI value for the transmitter which is placed at Room 3.

7. Advantages

Advantages for the proposed system are as follows:

- Indoor positioning system helps in aiding navigation inside the buildings.
- Comparing LoRa to other wireless systems, LoRa indoor positioning can ensure a long lifespan for wireless system and is extremely energy-efficient.
- Indoor positioning system is the improved user experience, as many users are already familiar with the usage of positioning systems like Google Maps.

8. Applications

- Hospitals: Indoor Positioning System is useful for guiding people inside the hospital building.
- Supermarkets and Shops: Indoor Positioning System are used to facilitate the shopping experience.
- Industrial applications and logistics: Indoor Positioning System in industry and logistics enables the tracking of goods and employees.
- Travel and transportation: Indoor positioning offers support for travellers at railway stations and airports and guides them to the right place in hassle free.

9. Conclusion

An indoor positioning system is a useful feature that has a variety of applications. LoRa is a feasible technology that can provide connection stability with minimum power consumption. LoRa module is interfaced with Arduino UNO microcontroller. RSSI fingerprinting technique has been used in order to estimate the location. RSSI fingerprinting is one of the most popularly used technique for indoor localization as it provides high accuracy. In order to remove the noise and to provide accuracy KNN algorithm. RSSI values of the estimated position is displayed on OLED. Proposed system results have been verified.

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