NB-IoT 기술에서 Multiple Linear Regression Model을 활용하여 OTDOA 기반 포지셔닝 정확도 최적화

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Optimize OTDOA-based Positioning Accuracy by Utilizing Multiple Linear Regression Model under NB-IoT Technology

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● 요 약 ●

NB-IoT(Narrow Band Internet of Things) is an emerging LPWAN(Low Power Wide Area Network) radio technology. NB-IoT has many advantages like low power, low cost, and high coverage. However low bandwidth and low sampling rates also lead to poor positioning accuracy. This paper proposed a solution to optimize positioning accuracy under the OTDOA(Observed Time Difference of Arrival) approach by utilizing MLR(Multiple Linear Regression) models. Through the MLR model to predict the influence degree of weather(temperature, humidity, light intensity and air pressure) on the arrival time of signal transmission to improve the measurement accuracy. The improvement of measurement accuracy can greatly improve IoT applications based on NB-IoT.

키워드: NB-IoT, Multiple Linear Regression Model, LPWAN, OTDOA

I. Introduction

Traditional mobile communication mode is changing from the connection between people and people to between people and things or things and things, and the interconnection of everything is becoming an inevitable trend. IoT technology has penetrated all industries, such as manufacturing, transportation, and health care. The advantages of NB-IoT are in low power, large connection area with low cost, wide-coverage, and these advantages attracted more and more attention in the IoT field. At present, most of NB-IoT-based applications or systems are positioned through GPS module[1-3]. However, this approach consumes a lot of power and does not conform to the low power and low cost features of IoT applications. Therefore, the new version of core specification R14 standard was frozen in August 2017 by 3GPP(3rd Generation Partnership Project), positioning by the OTDOA approach has become an important study direction. OTDOA uses DL(Service Downlink) positioning approach to locate signals based on the time difference between three base stations and mobile terminals. However, due to the broadband of NB-IoT is only 180KHz and the SNR(Signal to Noise Ratios) is quite low, usually below -10 dB, the accuracy of OTDOA positioning has a big margin of error and greatly influenced by natural factors. For the purpose of improving the positioning accuracy of NB-IoT under OTDOA approach. This paper proposed a solution, by utilizing MLR model to optimize the delay estimation loss. This model will predict the influence degree of natural factors (temperature, humidity, light intensity, and air pressure) on the arrival time of signal transmission under the traditional OTDOA approach. We could eliminate the natural impact factor to improve the measurement accuracy.

The remainder of this paper is organized as following. Section 2 describes related work. The experimental method and

experimental process are introduced in section 3 and section 4. The conclusions and future work are described in section 5.

II. Related Works

With the rapid development of the NB-IoT, more and more researches focus on how to improve the accuracy of positioning to achieve the features of low cost and high efficiency by using OTDOA approach. These researches are divided into three categories.

- **Successive interference cancellation**: In paper [4], the author proposed an iterative EM-SIC(Expectation-Maximization based Successive Interference Cancellation) algorithm to joint consideration the estimations of residual FO(Frequency-Offset), fading-channel taps and ToA(time-of-arrival) of the first arrival-path for each of the detected cells. In order to design a low complexity ToA detector, they assume an NB-IoT device working at a low-sampling rate such as 1.92 MHz or lower. In order to improve OTDOA localization performance in multi-path scenarios, in paper [5], the author presented an adaptive SIC-based (Successive Interference Cancellation) TDOA (Time Difference of Arrival) estimator. It is an adaptive-threshold-based TDOA estimator with a previous SIC stage.

- **Fingerprints** : In paper [6], the author proposed a CSI(Channel State Information) amplitude fingerprinting-based localization algorithm in the Narrowband IoT system and optimize a centered algorithm based on CSI propagation model. Especially in fingerprint matching, euclidean distance and time anti-resonance intensity between the target and the reference point are calculated by MDS(Multidimensional Scaling) analysis, and then the KNN(K-Nearest Neighbor algorithm is used to estimate the location. By conjugate gradient method, moreover, they optimize the localization error of triangular centered algorithm and combine the positioning result with MDS and estimated position of KNN to get the final estimated position.

- **Machine learning**: In paper [7], the author explores the generalization and feature extraction abilities of neural networks to tackle the aforementioned challenges. And this paper puts forward a method of using the RSTD(Reference Signal Time Difference) Measurement calculation results as commonly adopted in the OTDOA scheme instead of real-time measurement of signal strength will have the better positioning performance.

Among the above thoughts, their methods are mostly physics-based interference cancellation adapter which may be have extra cost, or using deep learning method to estimate location. Accordingly, we proposed a method that using MLR model to predict weather influence factor (temperature, humidity, light intensity air pressure and so on) to reduce the error of positioning.

III. Proposed Scheme

3.1 Observed Time Difference of Arrival Approach

The OTDOA positioning method determines UE (User Equipment) location by detecting the time difference between the arrival of signals from three different base stations. Figure 1 illustrates the OTDOA-based positioning method. Assume that the coordinate of terminal UE is (x, y), the position coordinate of the base station i is (xi, yi) and the time to send signals is Ti. More than two hyperbolic equations need to be established to determine UE position, the intersection point of the two hyperbolas is the two-dimensional position coordinate of UE. As shown in Figure 1, the UE measures three TOA's relative to the UE internal time base, t1,t2 and t3 and gets the gray part, where is the general range of UE. The time for UE to receive the signals is as the system of formula(1) shows.

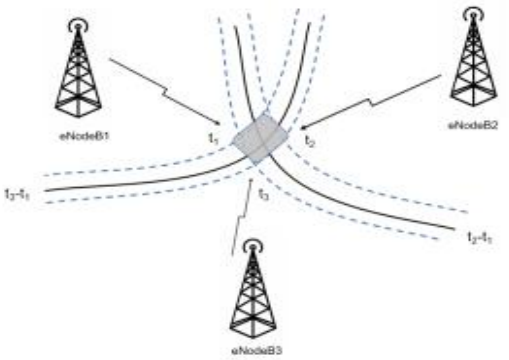

Fig. 1. The OTDOA-based Positioning Approach

$$t_2 - t_1 = (T_2 - T_1) + \frac{\sqrt{(x-x_2)^2+(y-y_2)^2} - \sqrt{(x-x_1)^2+(y-y_1)^2}}{c}$$
$$t_3 - t_1 = (T_3 - T_1) + \frac{\sqrt{(x-x_3)^2+(y-y_3)^2} - \sqrt{(x-x_1)^2+(y-y_1)^2}}{c}$$
(1)

3.2 Multiple Linear Regression Model

A phenomenon is usually associated with multiple factors, and it is more effective to predict or estimate dependent variables

by the optimal combination of multiple independent variables. In regression analysis, if there are two or more independent variables, it is called multiple regression. The general form of a multiple linear regression model is as formula (2) shows.

$$y = \beta_0 + \beta_1 * x_1 + \beta_2 * x_2 + \ldots + \beta_n * x_n + E \quad (2)$$

In this paper, we put forward several factors like temperature, humidity, light intensity and pressure. We assume the value of each factor and put these factors into formula (2). x1 represents that the temperature is 25 degrees, x2 represents that the humidity is 60%, x3 represents that the light intensity is 100lux and x4 represents that the pressure is 1000hPa. Thus, the formula becomes:

$$y = \beta_0 + \beta_1 * 25^\circ + \beta_2 * 60\% + \beta_3 * 100lux + \beta_4 1000hPa + E \quad (3)$$

As mentioned above, going through a lot of sets of data, we can figure out the value of each β. And the value of beta is the weather impact degree of each factor. Through the influence factors obtained by the model, we can infer the influence degree of UE on the signal transmission distance under the prevailing weather conditions, and then calculate the influence distance.

IV. Experimental Process

By using the MLR model mentioned above, we can obtain an impact factor. The traditional OTDOA positioning method was used to obtain the positioning range, and then the impact factor was subtracted to obtain a new positioning range. The desired effect is shown in Figure 2. The gray part is the original OTDOA positioning range, and the yellow part is the new positioning range obtained by removing the impact factor.

1. **Data collection and MLR model training**: We need to measure the influencing factors (temperature, humidity, light intensity and air pressure), and then to train an MLR model, and figuring out the weight between these influencing factors and distance.
2. **Error optimization**: Setting the parameters under NB-IOT network by NS-3 to simulation. And then the previous step distance error was subtracted to obtain a more accurate distance range.
3. **Experimental result comparison and analysis**: We will compare and analyze the positioning accuracy with the traditional OTDOA positioning method and the method mentioned in this paper.

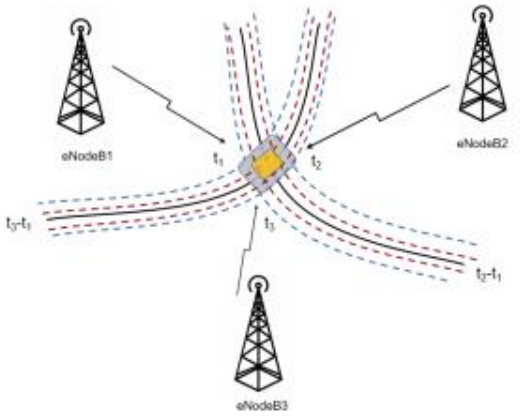

Fig. 2. The Proposed Schema based on MLR Model

V. Conclusions

We propose an MLR-based model to optimize the performance of OTDOA positioning by utilizing NB-IoT. In future research, We will obtain real data through experiments and use more models to reduce errors. We will adopt more sensors to collect more influence factor data. The results obtained will be simulated and compared using tools such as NS-3.

REFERENCES

[1] S. Chen, C. Yang, J. Li and F. R. Yu, "Full Lifecycle Infrastructure Management System for Smart Cities: A Narrow Band IoT-Based Platform," in IEEE Internet of Things Journal, vol. 6, no. 5, pp. 8818-8825, Oct. 2019, doi: 10.1109/JIOT.2019.2923810.

[2] Z. Wang, F. Wang, H. Liu, Z. Qian and Z. Bi, "Design of Human Health Monitoring System Based on NB-IoT," 2019 IEEE 3rd Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC), Chongqing, China, 2019, pp. 6-9, doi: 10.1109/IMCEC46724.2019.8983915.

[3] M. Praveen and V. Harini, "NB-IOT based smart car parking system," 2019 International Conference on Smart Structures and Systems (ICSSS), Chennai, India, 2019, pp. 1-5, doi: 10.1109/ICSSS.2019.8882847.

[4] S. Hu, A. Berg, X. Li and F. Rusek, "Improving the Performance of OTDOA Based Positioning in NB-IoT Systems," GLOBECOM 2017 - 2017 IEEE Global Communications Conference, Singapore, 2017, pp. 1-7, doi: 10.1109/GLOCOM.2017.8254510.

[5] I. Sobron, I. Landa, I. Eizmendi and M. Velez, "Adaptive TDOA Estimation for Positioning in NB-IoT," 2019 IEEE International Conference on Electrical Engineering and Photonics (EExPolytech), St. Petersburg, Russia, 2019, pp. 149-152, doi: 10.1109/EExPolytech.2019.8906855.

[6] Q. Song, S. Guo, X. Liu and Y. Yang, "CSI Amplitude Fingerprinting-Based NB-IoT Indoor Localization," in IEEE Internet of Things Journal, vol. 5, no. 3, pp. 1494-1504, June 2018, doi: 10.1109/JIOT.2017.2782479.

[7] G. Pan, T. Wang, X. Jiang and S. zhang, "Deep Learning based OTDOA Positioning for NB-IoT Communication Systems," 10 Apr 2020.