

Near Field Distance Awareness Algorithm using Bluetooth for Device Sociality Service

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Abstract—The use of Device-to-Device (D2D) communication in various networks is expected to grow in the coming years. The D2D distance-based device sociality service is affected by distance awareness between the D2D devices. Thus, the wireless distance awareness between smart devices should be accomplished easily, accurately, and immediately. When smart devices are used in the distance-based distance sociality service, the smart device needs to know the distance to other smart devices in order to aware the space sociality. Several methods, such as receive signal strength indication (RSSI), time of arrival (ToA), and time difference of arrival (TDoA), can be used to aware the distance between D2D devices. Among these methods, the RSSI system can aware the D2D distance easily and inexpensively because most smart devices can estimate the received signal strength. However, estimating the distance using a RSSI is difficult due to inaccuracies. We conducted a preliminary test to discover the relationship between the actual distance and a Bluetooth RSSI under near field environment. Through the results of this test, we realize that the near field distance is hard to be classified due to the inaccuracy of Bluetooth RSSI. Therefore, in this paper, the near field distance awareness algorithm is proposed to reduce measurement errors by alleviating fluctuations in a Bluetooth signal. To evaluate the effectiveness of the proposed algorithm, the distance awareness is compared using different filtering algorithms, such as, a low-pass filter (LPF), a Kalman filter, and a particle filter under a meeting room environment. The proposed algorithm showed the best results in terms of the coefficient of determination, standard deviation, and measurement range.

Keywords— Near field awareness, Device to Device (D2D), Distance awareness, Filtering algorithm, Wireless signal

I. INTRODUCTION

The distance-based device sociality service means that the device sociality service is dependent with distance between smart devices. Device sociality describes social relationship between network-equipped objects. Similar to socialization process of human beings, devices may accumulate social relationship from their interactions. Social interactions such as sharing data and resources can be monitored and analyzed to identify the relationship between the devices. With the derived device sociality, devices can discover trustable objects to securely exchange services and resources [1]. The smart devices within same space have a space sociality. The devices nearby are classified to several regions according to the

distance between smart devices. The Near field communication (NFC) region is about within 10 cm, wireless body area network (WBAN) region is about within 1~2 m, wireless personal area network (WPAN) region is about within 10 m, and wireless local area network (WLAN) region is about within 100 m. For each region, different distance-based device sociality services can be applied. The privacy service can be activated between D2D devices in NFC and WBAN regions, the group service can be activated between D2D devices in WPAN region, and the public service can be activated between D2D devices in WLAN region [2].

To support distance-based device sociality services between smart devices, the distance awareness between smart devices should be performed easily and accurately. Several methods, such as the received signal strength indication (RSSI), time of arrival (ToA) [3], and time difference of arrival (TDoA) [4]-[7], have been used to estimate the distance between smart devices. The ToA and TDoA need precisely synchronized devices and extra hardware increasing the cost, respectively. Because an RSSI uses the received signal strength from another device, the distance estimation can be performed easily and inexpensively [8]-[10]. However, the RSSI is an inaccuracy method because of noises, obstacles [11]. Nevertheless, RSSI can become the most used technology of distance estimation due to its low cost [12]. These reasons, we propose the near field distance awareness algorithm using Bluetooth RSSI to increase the accuracy of the distance awareness. To evaluate the effectiveness of the proposed algorithm, a near field distance awareness is compared using different filtering algorithms. Experimental results show that the proposed algorithm showed the best results.

The outline of this paper is as follows. Section II we describe the near field distance awareness algorithm using Bluetooth RSSI, and the experimental results are then provided in section III. Finally, some concluding remarks are given in section IV.

II. THE NEAR FIELD DISTANCE AWARENESS ALGORITHM USING BLUETOOTH RSSI

The Bluetooth RSSI is used to measure the distance between smart devices because it is widely used in a lot of mobile devices nowadays. To see the inaccuracy of near field distance using Bluetooth RSSI, we tested the relationship

between distance and Bluetooth RSSI in a meeting room environment.

A. Relationship between Near Field Distance and Bluetooth RSSI

A tablet PC was used to measure the Bluetooth RSSI from a notebook PC in a meeting room environment as shown Fig. 1. A total of 200 samples were measured from 0 to 30 cm at 5 cm intervals. The result of this test is shown Fig. 2. The average RSSI values from 0 to 30 cm are -32.47, -33.70, -35.12, -37.09, -37.81, -39.02, and -39.72 dBm, respectively. The standard deviation (SD) values are 1.11, 5.08, 4.74, 4.86, 1.07, 5.08, and 0.99 dBm, respectively. The measurement range (MR) values, which are the difference between maximum and minimum value at each distance, are 5, 73, 68, 70, 7, 76, and 4 dBm. The mean values of the standard deviation and measurement range are 3.3 and 43.29 dBm, respectively. As shown the result, it is hard to classify the near field distance between devices when RSSI raw data is used. Thus, for classifying the near field distance, the filtering algorithm should be used to reduce the measurement error.



Figure 1. The relationship test between near field distance and Bluetooth RSSI in a meeting room environment.

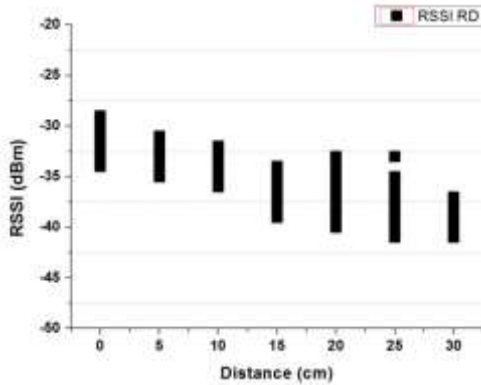


Figure 2. The relationship result between near field distance and Bluetooth RSSI in a meeting room environment.

B. Near Field Distance Awareness Algorithm

The near field distance algorithm is consisted of two steps for real time because the proposed algorithm is based on an average values. In the first step, a low-pass filter (LPF) is used until the k -th RSSI is received, as shown in Eq. 1.

$$\bar{R}_n = \alpha R_{n-1} + (1 - \alpha) R_n \quad (1)$$

where n is the number of data instances, α is a constant value larger than 0 and smaller than 1, R_n is the n -th RSSI measurement value, and $\bar{R}_n$ is the consequence of the n -th initial filtering.

When the k -th RSSI is received, the filtered RSSI values are calculated and passed to the second step to filtered RSSI values. The filtering method of the second step is shown below, as seen in Fig. 3. First of all, the average from 1 to k is calculated. And then, the first filtered RSSI value is set to the average RSSI value. The difference value between the measured RSSI value and the average RSSI value is calculated, and the ratio value is then measured using these values. If the ratio value is small, small RSSI measurement errors will occur. The correction value is measured using the ratio value and correction constant. If the constant value is small, the measurement error is further increased, and the change becomes more sensitive. The calibrated value is measured using the average value, the difference value, and the correction value to reduce measurement errors. The filtered RSSI value is measured using the recursive mechanism with the calibrated value to eliminate the high frequency. The parameters are updated to filter the next RSSI value.

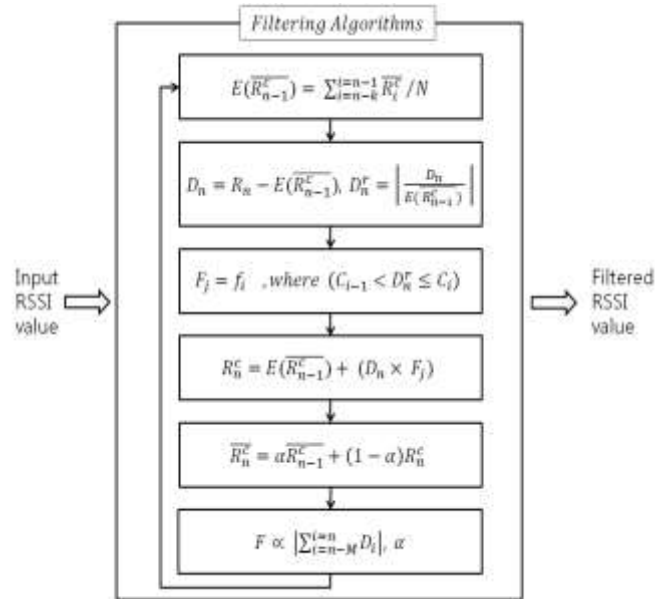


Figure 3. The near field distance awareness algorithm

III. EXPERIMENTAL RESULTS

To see the effectiveness of near field distance awareness algorithm, distance estimations using raw RSSI, LPF, Kalman filter, particle filter, and proposed algorithm data from the meeting room are compared. The Bluetooth RSSI values were

measured from 0 to 30 cm. The polynomial regression (order 2) is used to estimate the distance as shown in Fig. 4.

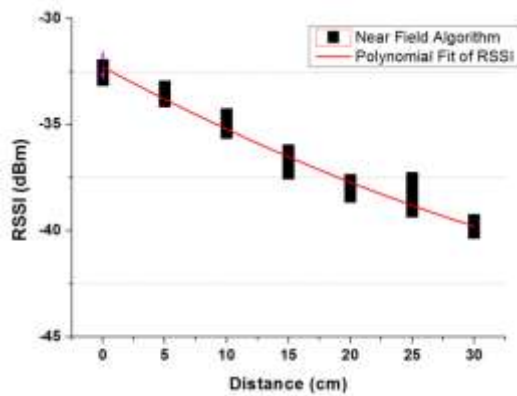


Figure 4. The regression result of the near field distance awareness algorithm

The results of the comparison test in the meeting room environment are shown in Table 1. The R-square value of the raw RSSI, LPF, Kalman filter, particle filter, and EC-LPF data is 0.303, 0.795, 0.812, 0.903, and 0.985, respectively. The R-square value of the proposed filtered data is the best R-square value.

The average standard deviation ($E(SD) = \sum_{i=0}^7 (SD)_i / 7$) of the raw RSSI, LPF, Kalman filter, particle filter, and proposed filter data is 3.3, 1.1, 1.0, 0.8, and 0.2, respectively. The average standard deviation of the proposed filter data is also the best average of all standard deviations. The average measurement region ($E(MR) = \sum_{i=0}^7 (MR)_i / 7$) of the raw RSSI, LPF, Kalman filter, particle filter, and proposed filter data is 434.3, 9.6, 8.8, 4.0, and 0.9 dBm, respectively. The average measurement region of the proposed filter data is also the best average of the measurement regions. The results of the proposed filter data are the best results for all comparison factors in the meeting room environment.

Table 1 The results of the comparison test

Algorithm	E(MR) (dBm)	E(SD) (dBm)	R ²
Raw data	43.3	3.3	0.303
LPF	9.6	1.1	0.795
Kalman filter	8.8	1.0	0.812
Particle filter	4.0	0.8	0.903
Proposed filter	0.9	0.2	0.985

IV. CONCLUSION

This paper addressed the near field distance characteristics of Bluetooth RSSI, and proposed a new and efficient distance estimation algorithm to aware the near field distance for device sociality service. The proposed algorithm reduces the RSSI fluctuation by reducing the RSSI measurement errors that occur from sensor and system. To evaluate the effectiveness of the near field distance awareness algorithm,

distance estimations using raw RSSI, LPF, Kalman filter, Particle filter, and proposed filter data were compared under a meeting room environment. The experimental results indicate that the proposed filter data are better than those of other methods for all environments tested. Therefore, the near field distance region can be classified more clearly when the proposed algorithm is used.

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REFERENCES

- [1] J.H. Choi, D.O. Kang, J.J. Jung, "Enabling Intelligent Device Communication using Device Sociality," in *Proc. IEEE International Conference on Consumer Electronics Berlin*, Berlin, Germany, Sept. 2015, pp. 507-509.
- [2] Joon-young Jung, Dong-oh Kang, Jang-ho Choi, Chang-seok Bae, "D2D Distance Measurement using Kalman Filter Algorithm for Distance-based Service in an Office Environment," in *Proc. IEEE International Conference on Advanced Communications Technology*, PyeongChang, Korea, Jul. 2015, pp. 221-224.
- [3] S. Schwarzer, M. Vossiek, M. Pichler, and A. Stelzer, "Precise distance measurement with IEEE 802.15.4 (ZigBee) devices," in *Proc. IEEE Radio and Wireless Symposium*, Orlando, USA, Jan. 2008, pp. 779-782.
- [4] N.B. Priyantha, A. K. Miu, H. Balakrishnan, and S. Teller, "The cricket compass for context-aware mobile applications," in *Proc. ACM/IEEE International Conference on Mobile Computing and Networking*, Rome, Italy, Jul. 2001, pp. 1-14.
- [5] A. Savvides, C.C. Han, and M.B. Strivastava, "Dynamic fine-grained localization in ad-hoc networks of sensors," in *Proc. ACM/IEEE International Conference on Mobile Computing and Networking*, Rome, Italy, Jul. 2001, pp. 166-179.
- [6] K. Whitehouse and D. Culler, "Calibration as parameter estimation in sensor networks," in *Proc. Wireless Sensor Networks and Applications*, Atlanta, USA, Sep. 2002, pp. 59-67.
- [7] K. Whitehouse, *The design of calamari: an ad hoc localization system for sensor networks*, Master's thesis, UC Berkeley, Fall 2002.
- [8] A. Awad, T. Frunzke, and F. Dressler, "Adaptive distance estimation and localization in WSN using RSSI measures," in *Proc. Euromicro Conference on Digital System Design Architectures, Methods and Tools*, Lubeck, Germany, Aug. 2007, pp. 471-478.
- [9] S. Feldmann, K. Kyamakya, A. Zapater, and Z. Lue, "An indoor bluetooth-based positioning system: concept, implementation and experimental evaluation," in *Proc. International Conference on Wireless Networks*, Las Vegas, USA, Jun. 2003, pp. 109-113.
- [10] A.S. Paul and E.A. Wan, "RSSI-Based Indoor Localization and Tracking Using Sigma-Point Kalman Smoothers," *IEEE J. Sel. Topics Signal Process.*, vol. 3, no. 5, pp. 860-873, Oct. 2009.
- [11] T. He, C. Huang, B. M. Blum, J. A. Stankovic, and T. Abdelzaher, "Range-free localization schemes for large scale sensor networks," in *Proc. ACM/IEEE International Conference on Mobile Computing and Networking*, San Diego, USA, Sep. 2003, pp. 81-95.
- [12] J. Bachrach and C. Taylor, *Handbook of Sensor Networks: Algorithms and Architectures*, John Wiley & Sons Press: New Jersey, 2005.

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