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블루투스를 이용한 실내 영역 결정 방법

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Indoor Zone Detection based on Bluetooth Low Energy

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● Abstract ●

Location awareness is an important capability for mobile-based indoor services. Those indoor services have motivated the implementation of methods that need high computational load cost and complex mechanisms for positioning prediction. These mechanisms, such as opportunistic sensing and machine learning, require more energy consumption to achieve accuracy. In this paper, we propose the Bluetooth Low Energy indoor zone detection (BLEIZOD) technique. This method exploits the concept of proximity zone to reduce the load cost and complexity. Our proposed method implements the received signal strength indicator (RSSI) function more effectively to gain accuracy and reduce energy consumption.

키워드: Indoor zone detection, RSSI, 블루투스(Bluetooth Low Energy)

I. Introduction

The development of wireless technologies influences the advancement of positioning solutions. However, as wireless nodes become smaller and portable, their features become complex. Therefore, this trend requires more energy consumption.

BLE is a short-range low-power wireless technology. This technology gives easy and reliable access to external hardware from every major mobile platform. Therefore, the determination of proximity or distance between nodes becomes, intuitively, necessary.

BLE provides parameters related with distance and location estimation such as RSSI and link quality indicators (LQI). We will study about the former in this paper.

Previous research has focus on understand and improve the accuracy of the distance calculation based on RSSI. For instance, [2] focus on optimizing correlation model between RSSI and distance, while [1], [3] present novel filters for using fingerprints in indoor positioning. However, the concept of proximity sensing and its impact on user experience remains overlooked.

In this paper, we present the design of an indoor zone-detection method base on BLE. This method provides an empirical method, which improves the accuracy by processing the RSSI combined with an active learning to enrich the user experience.

In summary, this paper makes the following contributions:

- We propose BLEIZOD: a BLE indoor zone-detection methodology based on RSSI.
- Propose an empirical definition and architecture for proximity zone-based services.
- Demonstrate feasibility of using proximity information to provide a rich set of indoor services to improve the user experience.

II. Preliminaries

The difference between range and accuracy is one of the challenges of understanding how to build effective proximity-base services with Bluetooth LE devices. This section, describes the advantage and limitation of the actual RSSI.

1. Proximity range and accuracy

There is a profound difference between BLE and GPS. The latter is provides a localization service, while the former provides a proximity service. However, using low power radio BLE's located at known positions within a building and a trilateration method, it is possible to get an accurate location as well, but BLEs are primarily about proximity. Additionally, GPS localization methods are not feasible for indoors scenarios as they require line-of-sight to satellites.

$$I(t_i) = \begin{cases} 1, & if \quad PRR_{t_i} > PRT \\ 0, & if \quad PRR_{t_i} \leq PRT \end{cases}$$

Mobile receiver nodes depend on signal strength to identify if they come in range of a BLE node. This BLE's signal helps to estimate the distance between a mobile node and the BLE node with an accuracy of less than one meter. However, the signal strength is dependable over time, while interference can change with time of day. This means that the measurement of proximity range will be variable for the receiver node's point of view.

Table 1, shows that the closer you are, the more accurate the detection of proximity becomes. Therefore, the main factors that drive accuracy are radio interference and signal strength.

III. The Proposed Scheme

The development of wireless technologies influences the advancement of proximity solutions. As wireless nodes became smaller and stronger, as BLE, the ability of managing network operations and processing information became complex and smart. These properties are particularly useful in person-centered thinking, where wearable devices can discover and interact with other nodes in the same environment without explicit user interventions. Therefore, the proximal object discovering mechanism must be within the average person's sphere influence. For instance, when the user sits in front of the desk its computer may automatically wake up. However, it should not react to other people walking past around.

1. ProximityZoneDefinition

We consider the BLE's proximity zones as centered within concentric circles; the outer boundary is the signal coverage radius.

2. RSSI Measurement

As RSSI value is not exactly the received power, we will proceed to convert it as a normal power in dBm as per the following equation:

$$P = RSSI_{original} + RSSI_{offset}$$

In this equation, P represents the normalized power from a BLE node that will dynamically range from -100 to 0dBm. RSSIoriginal is the value from the reference node and RSSIoffset is the received signal strength at 1 meter distance value that is approximately equal to 50dBm. Additionally we applied a Gaussian filtering to reduce the stochastic volatility of the RSSI.

$$Zone(P, t_0, t_S) = \begin{cases} \text{secure, } if \prod_{t_i} I(t_i) = 1 : \forall t_i \in [t_0, t_0 + t_S - W) \\ \text{in-zone, } if \prod_{t_i} I(t_i) = 0 \text{ and } \sum_{t_i} I(t_i) \geq 1 : \forall t_i \in [t_0, t_0 + t_S - W) \\ \text{out-zone, } if \prod_{t_i} I(t_i) = 0 : \forall t_i \in [t_0, t_0 + t_S - W) \end{cases}$$

Furthermore, we define a reception indicator function based on the packet reception rate (PRR) and the packet reception threshold (PRT) to add consistency over the time. In addition, we assume that the BLE node broadcast at a fixed frequency within some period of time:

$$t_S, \forall t_i \in [t_0, t_0 + t_S - W)$$

3. Zone classification

Demonstrate feasibility of using proximity information we classified three different contiguous zones:

IV. Conclusions

In this paper, we study the proximity zones established by BLE. We propose a methodology based on RSSI sampling and classification techniques that enable us to compute zone boundaries. As future work, we plan to explore the possibility of integrating this methodology into regular mobile devices and expanding its applications. Finally, we believe that, our mechanism has high use value for the zone-based services.

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