# EasyFind: A Mobile Crowdsourced Guiding System with Lost Item Finding Based on IoT Technologies

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***Abstract*—This paper designs and implements a mobile crowdsourced guiding system, called EasyFind, using smartphones to guide indoor people and find lost items through Internet of Things (IoT) technologies. In normal time, the EasyFind system can provide the fastest guiding path with the shortest moving time to a destination place based on the density of indoor people in each area. In addition, in emergency time, the EasyFind system can evacuate all people in the shortest total escaping time through modeling spatial and temporal mobilities of indoor people. Furthermore, the EasyFind system can cooperatively find lost items equipped with mobile iBeacon nodes through participatory sensing networks formed by mobile users with smartphones in places with static iBeacon nodes. To precisely localize the lost item, six item localization cases are addressed to reduce the positioning errors with different numbers of smartphones detecting the lost item and different numbers of fixed iBeacon nodes nearby these item-detecting smartphones. An Android-based prototype with static and mobile iBeacon nodes is implemented to verify the feasibility and correctness of our EasyFind system.**

**Keywords:** iBeacon; Internet of Things; Crowdsourced Guiding; Indoor Navigation; Mobile Device.

## I. Introduction

The development of wireless networking technologies and the popularity of mobile Internet devices have made *participatory sensing networks* possible, which can explore the mobility of mobile users, the built-in sensors of smartphones, and the communication diversity of existing infrastructures to achieve pervasive sensing results in a less-expensive and more-efficient manner [1]. Environment, infrastructure, and transportation conditions (e.g., air quality, surrounding noise, traffic flows, crowd congestion, etc.) can be collectively retrieved and contributed using smartphones with multiple built-in sensors, which can form a body of knowledge [2].

Innovative smartphone-based applications and systems have been developed for Automatic Queue Time Estimation [3], Peer-to-Peer Navigation [4], Indoor Floor Plan Construction [5], and Individual-Based Path Planning [6]. On the other hand, Internet of Things (IoT) localization technologies using RFID [7] or iBeacon [8] signals can accurately locate indoor people and rapidly guide them to destination places [9]. In particular, using smartphones with IoT localization devices can efficiently collect the up-to-date locations and distribution of indoor people [10].

In this work, we design and implement a mobile crowdsourced guiding system, called EasyFind, using smartphones to guide indoor people and find lost items through IoT localization technologies. In normal time, the EasyFind system can provide the fastest guiding path with the shortest moving time to a destination place based on the density of indoor people in each area. In addition, in emergency time, the EasyFind system can evacuate all people in the shortest total escaping time on a basis of spatial and temporal mobilities of indoor people.

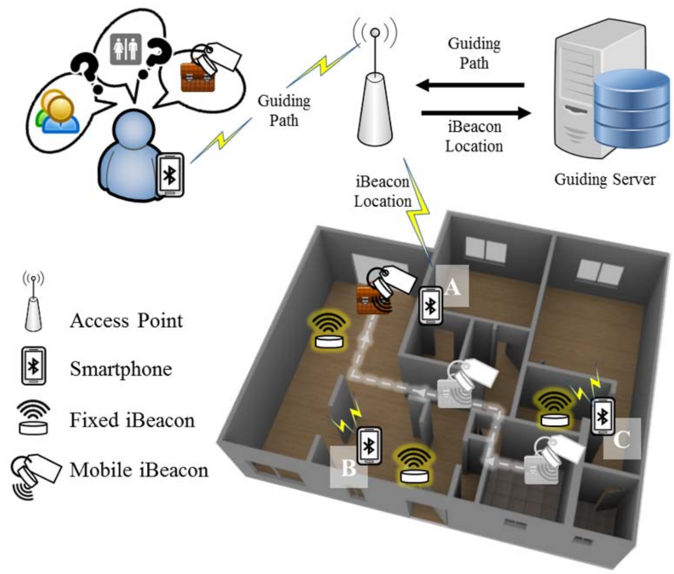


Fig. 1. System architecture of EasyFind.

In particular, the EasyFind system can track lost items equipped with mobile iBeacon nodes in a crowdsourced guiding manner. To precisely localize the lost item, six item localization cases are addressed to reduce the positioning errors with different numbers of smartphones detecting the lost item and different numbers of fixed iBeacon nodes nearby these item-detecting smartphones. An Android-based prototype with static and mobile iBeacon nodes is implemented to verify the feasibility and correctness of our EasyFind system.

## II. System Design

Fig. 1 shows the system architecture of EasyFind. Static and dynamic IoT localization devices (i.e., fixed and mobile iBeacon nodes) are deployed in the indoor space and equipped on the target items, respectively. Wireless Internet access through Wi-Fi access points/LTE base stations are connected by indoor people using smartphones with Bluetooth Low Energy (BLE) scanning to fixed and mobile iBeacon nodes. Through the deployment of fixed iBeacon nodes, the iBeacon signals received by smartphones can be used to detect the current positions of mobile users. The iBeacon ID with the

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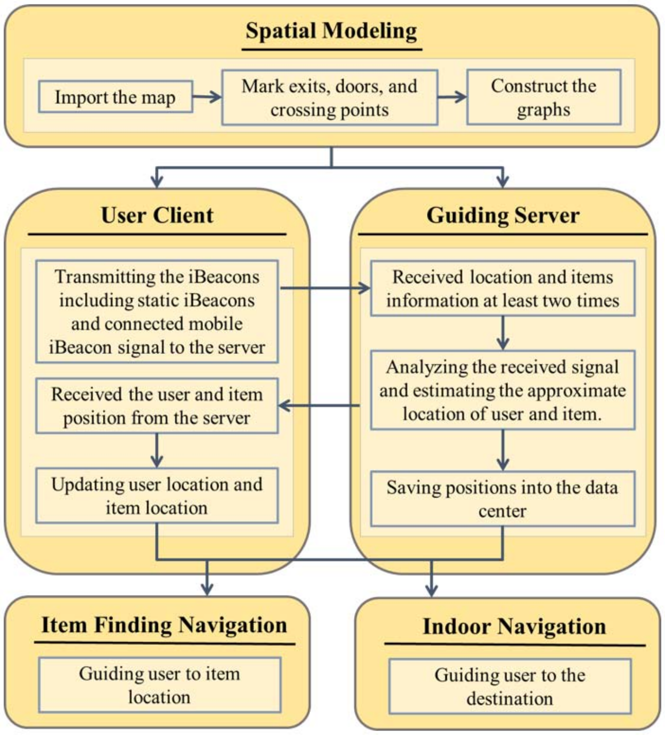


Fig. 2. Operation flow of EasyFind.

strongest signal strength is mapped to the deployed position in the deployment database of fixed iBeacon nodes for determining the up-to-date location. In particular, the smartphones of mobile users keep sending the mapped positions to the EasyFind guiding server for indoor destination guiding and lost item finding.

Through the equipment of mobile iBeacon nodes, the iBeacon ID associated with a specific item can be used to detect and track the iBeacon-equipped item in a crowdsourced manner. Once the iBeacon-equipped item is lost/stolen, the iBeacon signals (broadcasted by the associated mobile iBeacon node) of the lost item can be received by nearby smartphones and then sent to the EasyFind guiding server with the current locations (mapped from the nearest fixed iBeacon nodes) of these item-detecting smartpones. Thus, the owner/finder of the lost item can be properly guided to its up-to-date location. Therefore, the lost item can be cooperatively found through participatory sensing networks formed by mobile users with smartphones and places/items with iBeacon nodes.

Fig. 2 shows the operation flow of EasyFind for indoor destination guiding and lost item finding. For planning navigation paths and tracking item trajectories, a graph $G = (V, E)$ is constructed based on the blueprint map of indoor spaces in the spatial modeling. Three different vertices in $V$ are door, exit, and crossing vertices and their weights are the numbers of people that can pass through per second (i.e., the capacities of doors, exits, and crossing points). For multi-floor buildings, the dedicated edges between different floors are added for stairs in $G$ and weighted by their capacities.

Based on our previous work [11], the fastest speed and adaptive ordering schemes are designed to minimize the total

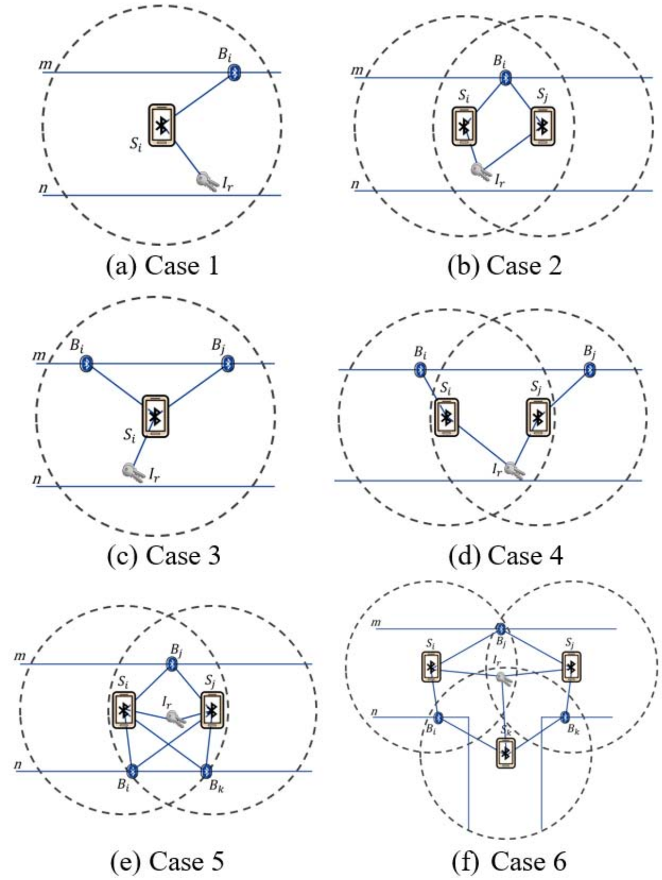


Fig. 3. Item localization cases using different numbers of smartphones and iBeacon nodes.

moving and escaping times in $G$ for indoor navigation and evacuation, respectively. In addition, mobile crowdsourced guiding is further proposed to efficiently find lost items using smartphones with BLE scanning and mobile iBeacon nodes. To localize the lost item $I_r$ more precisely, as shown in Fig. 3, we address six item localization cases to reduce the positioning errors based on different numbers of smartphones (i.e., $S_i$, $S_j$, and $S_k$) detecting $I_r$ and different numbers of fixed iBeacon nodes (i.e., $B_i$, $B_j$, and $B_k$) nearby these item-detecting smartphones.

On the other hand, in the fastest speed navigation, the weight of each edge between two vertices in $E$ is the average moving time of the corresponding corridor transformed from the density of the corridor. In the adaptive ordering evacuation, the spatial and temporal mobilities of mobile users are considered in the evacuation path planning based on their nearest iBeacon positions. In particular, for outdoor destination guiding and lost item finding, GPS locations can be used in EasyFind instead of iBeacon positions as fixed iBeacon nodes are unavailable.

## III. System Implementation

We have developed an Android-based EasyFind system consisting of USBeacon B2010 nodes (i.e., fixed iBeacon nodes), iBeacon iB07-C2450 nodes (i.e., mobile iBeacon nodes), a notebook computer (i.e., guiding server), and smartphones (i.e., client platform), as shown in Fig. 4. USBeacon B2010

Fig. 4. Hardware components of EasyFind.

nodes with 8051 microcontroller [12] are installed in the indoor space and powered by USB chargers on the wall, whereas iBeacon iB07-C2450 nodes with TI CC2541 [13] Bluetooth 4.0 chip are equipped on the wallet and powered by CR2450 coin battery, as shown in Fig. 5.

For supporting the vector-typed and rotatable map, we use the SAILS SDK [14] to implement indoor destination guiding and lost item finding. In the EasyFind App, the indoor map located by the nearest fixed iBeacon node can be displayed on the smartphone touchscreen. Guidance path planning and item trajectory tracking for target place guiding, friend location guiding, emergency evacuation guiding, and lost item finding can be selected and requested in the pull-down menu of the EasyFind App. In particular, the smartphones of mobile users periodically send their mapped iBeacon positions to the EasyFind guiding server and continuously report the detected mobile iBeacon IDs of lost items. The EasyFind guiding server replies the fastest guiding path to the requesting user from his/her current location to a target place, safe exit, or lost item, as shown in Fig. 6.

On the other hand, for desktop demonstration with a limited space (e.g, in a conference hall), we can use several smartphones and iBeacon-equipped items to simulate indoor people moving and lost item tracking in a building to demonstrate our EasyFind system. In addition to equipping on items, a few iBeacon iB07-C2450 nodes (powered by coin battery) can be used as fixed iBeacon nodes to provide location mapping in a small space only with a table, which are placed on the large-size printed copy of an indoor map.

The place and item locations from fixed and mobile iBeacon ID signals can be mapped and detected, respectively, and then the current positions of mobile users and lost items can be displayed on the smartphone touchscreen. During the system demonstration, we can check the mapped/tracked positions on the notebook computer screen and guiding paths on the smartphone touchscreen to verify the correctness of indoor positioning, path planning, and item finding results. Furthermore, the fastest escaping path from the current location to a safe exit can be sent to each smartphone by actively triggering an emergency event.

## IV. Acknowledgments

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Fig. 5. Installation of static and mobile iBeacon nodes.


Fig. 6. System demonstration of EasyFind.

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