A Room-Based Localization System Using Wireless Triggers and Pattern Matching Techniques

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***Abstract*— With the increasing number of LBS applications in the mobile computing, location tracking has been attracted much attention recently. In outdoor environments, GPS already provides a satisfactory solution for location tracking. However, a globally usable solution is still missing in indoor environments. This paper proposes a room-based localization system using wireless triggers and pattern-matching approaches in wireless sensor networks (WSNs). When users require determining their locations, this system identifies the users' logical areas and estimates their locations. For logical area identification, several devices called wireless triggers are deployed at entrances or boundaries of logical areas. The logical area of user's location will be identified by the transitions of received wireless triggers. This system then uses this area and the received signal strength (RSS) to estimate the user's location. Experimental results show that the proposed system performs better than the existing method in indoor environment.**

Keywords: Location-Based Service, Location Tracking, Pattern-Matching Localization, Wireless Sensor Network.

I. INTRODUCTION

Location-based services (LBS) [3], [6] have become essential applications in mobile computing. At the iTunes App Store, thousands of LBS applications are available for download and they all rely on location estimation algorithms to provide services. In outdoor environments, GPS already provides a satisfactory localization solution, but it can not be used in indoor environments. Much research has been dedicated to wireless positioning systems (WPS) based on Radio Frequency (RF) signals for indoor localizations. These systems can be classified into five categories: AoA-based [7], ToA-based [1], TDoA-based [9], path-loss [10], and pattern-matching [2], [8], [4], [5] techniques. This paper focuses on pattern-matching techniques [2] since they can provide meter-level accuracy in complex indoor environments.

In indoor environments, identifying users' logical areas, such as rooms and corridors, is more meaningful than providing precise locations specified by coordinate information. Hence, our primary goal is to correctly estimate the rooms in which users are located. This paper proposes a room-based indoor localization system using wireless triggers and pattern-matching approaches in wireless sensor networks (WSNs). To improve the accuracy, this paper introduces a new hardware, called the wireless trigger, which is deployed at the entrances or boundaries of logical areas. With the help of wireless triggers, the proposed system can identify the event of the logical area transition and determine the user's logical area. It then uses this area and the received signal strength (RSS) to estimate the user's location.

The rest of this paper is organized as follows. Section II gives some preliminaries. Section III describes the system architecture. Experimental results are presented in Section IV. Conclusions are presented in Section V.

II. PRELIMINARIES

The pattern-matching localization system in this paper consists of two phases: training and positioning phases. During the training phase, we are given a set of beacons (routes) $\mathcal{B} = \{b_1, b_2, \ldots, b_m\}$ and a set of training locations $\mathcal{L} = \{\ell_1, \ell_2, \ldots, \ell_n\}$. This system then measures the RSS generated at each training location $\ell_i \in \mathcal{L}$ to create a *feature vector* $\boldsymbol{v}_i = [v_{(i,1)}, v_{(i,2)}, \ldots, v_{(i,m)}]$ for ℓ_i, where $v_{(i,j)} \in \mathbb{R}$ is the average RSS. Then, the matrix $\mathcal{V} = [\boldsymbol{v}_1, \boldsymbol{v}_2, \ldots, \boldsymbol{v}_n]$ is called the *radio map* and used as the basis of positioning results.

During the positioning phase, this system will measure the RSS vector $\boldsymbol{s} = [s_1, s_2, \ldots, s_m]$ at the current location and compare s with each feature vector in $\mathcal{V}$. In particular, for each $v_{(i,j)} \in \mathcal{V}$, we define a distance function $h(\cdot)$ for the corresponding training location ℓ_i as [2]

$$h(\ell_i) = \|\boldsymbol{s}, \boldsymbol{v}_i\| = \sqrt{\sum_{j=1}^{n}(s_j - v_{i,j})^2}.$$

The user is then considered at location ℓ_i if $h(\ell_i)$ returns the smallest value.

III. SYSTEM MODEL AND HARDWARES

A. System Model

Our goal is to identify the logical areas and estimate the locations of users. To achieve this goal, this system uses a server and four devices in a sensing field: badges, routers, a coordinator, and triggers. The localization server is used to run the location estimation algorithm. The badge which is a

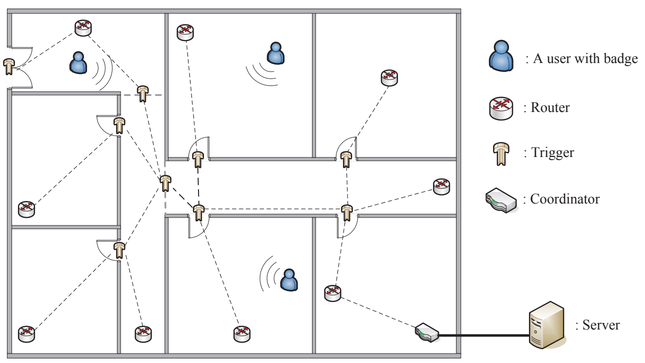


Fig. 1. The environment of room-based localization system.

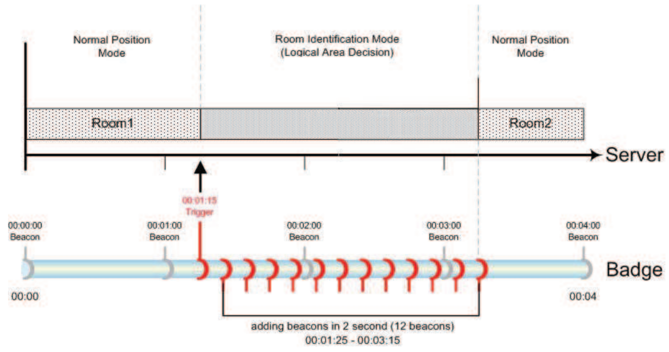


Fig. 2. An example of the events received at a badge side and server side.

personal device carried by users of this system, broadcasts packets periodically. The router is the basic node in the WSN. This node can measure RSS from the badge and send it to the coordinator. The coordinator plays the role of a gateway. It collects all the packets from the badges and routers and transmits them to the localization server via Ethernet. The trigger which is often set on the top of a door and emits the signal downward is capable of wakening up users' badge devices in a limited range. It also plays the role of a router. The environment of this system is shown in Fig. 1.

The location estimation algorithm includes two phases: *normal positioning* and *room identification* phases. During the normal positioning phase, the system uses a general pattern matching method (refer to Section II) to determine the user's location. The region of this localization area will be restricted to a logical area. When a badge passes through the sensing area of a wireless trigger, a trigger event will occur. This event then transfers the normal positioning phase into the room identification phase. During the room identification phase, the transmitting rate of the badge will be increased. The system obtains the logical areas connected to the wireless trigger. It then collects several RSS in a short period of time and uses the pattern matching method to determine the user's locations. Finally, the system adopts a simple voting strategy to determine the current logical area. After identifying the logical area, the system transfers the room identification phase into the normal positioning phase and sets the localization area in the new logical area. An example of the events received at the badge and the server is shown in Fig. 2.

B. Hardwares

This paper uses Fontal's FT-6300 iTracer Easy Kit to develop the system. It's based on the Jennic JN5121 with 16MHz 32-bit RISC CPU, 96kB RAM and 64kB ROM. The Jennic JN5121 includes 4-input 12-bit ADC, 2 11-bit DAC, one temperature sensor, two application timer/counters, three system timers, two UARTs, 21 GPIO, 5 SPI port to select and 2-wire serial interface. The special design of FT-6300 is trigger. The node with trigger can transmit a 40KHz signal and receive it. The details are described as following.

- Badge: The badge is a personal device as shown in Fig. 3. It actively and periodically broadcasts packets.

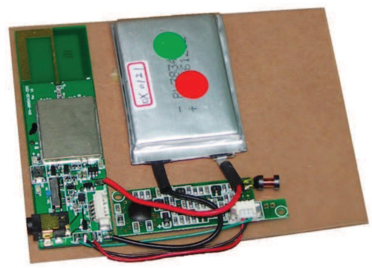


Fig. 3. A badge.

- Router: Routers are basic nodes in this system. A router receives packets from badges or other routers and sends packets to coordinator through a path. The router device is shown in Fig. 4.

Fig. 4. A router.

- Coordinator: The coordinator is the most important device in the network. In routing algorithm, it calculates and assigns address to build a mesh routing network. It also plays the role of a gateway. It collects all packets from badges and routers and sends them to server from RS-232 or Ethernet. The coordinator device is shown in Fig. 5.

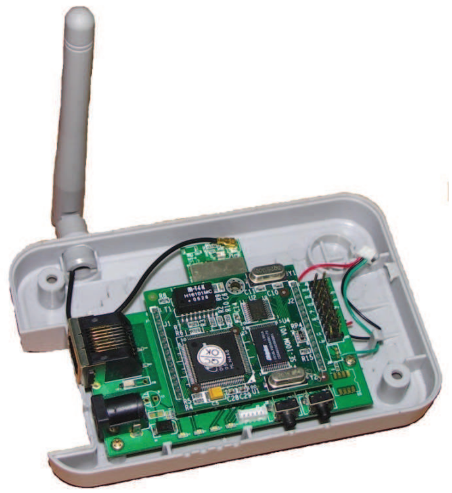


Fig. 5. A coordinator.

- Trigger: The trigger broadcasts a 40kHz signal periodically. It often sets on the top of a door and emits the signal downward. Besides, triggers still do all the works that general routers can do. The trigger device is shown in Fig. 6.

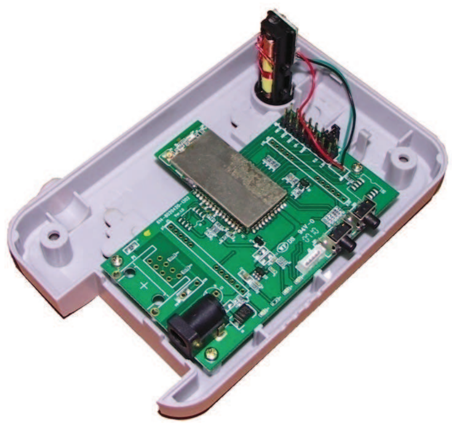


Fig. 6. A trigger.

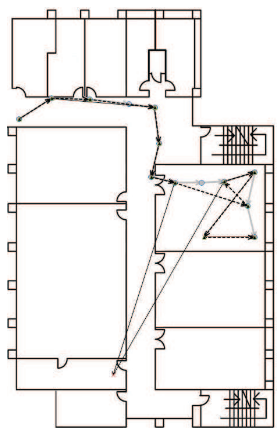
IV. Experimental Results

We verified our results in a campus building. Twenty five routes, ten triggers, and one coordinator are deployed in this environment. Training data were collected from 150 training locations which are separated by 1m. We randomly collected 100 samples from 150 training locations and compared our system with the nearest neighbor in signal space (NNSS) system [2]. Table I shows the average and maximum errors in meters of the NNSS system and the proposed system. The proposed system performs better than the existing method in indoor environment.

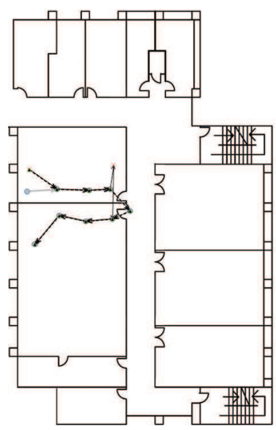
TABLE I
Comparison of average errors (in meters).

	NNSS	Our system
Average errors	3.15	1.98
Maximum errors	8.20	3.11

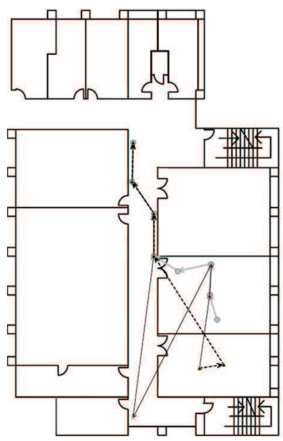
We further design four different moving paths to observe the results as shown in Fig. 7. The gray line is original moving path, the thin line is the results of NNSS and the dotted line is the amended results of our trigger system. Table II shows the hit rate of the logical area using the NNSS system and the proposed system. As can be seen, our system performs better than NNSS.



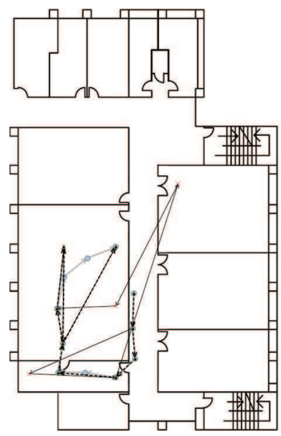
(a) Path1.



(b) Path2.



(c) Path3.



(d) Path4.

Fig. 7. Four paths in the experiment.

TABLE II
COMPARISON OF HIT RATE.

Hit rate	path1	path2	path3	path4
NNSS	84.5%	88.9%	75%	81.8%
Our system	100%	100%	87.3%	94.5%

V. CONCLUSIONS

In conclusion, this paper proposes a room-based localization system using wireless triggers and pattern-matching methods. We introduce a new hardware, called wireless trigger, deployed at entrances or boundaries of logical areas to identify the event of logical area transition and determine the user's logical area. Based on our results, the proposed system performs better than NNSS in indoor environment.

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