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Dynamic Indoor Localization using Multilateration with RSSI in Wireless Sensor Networks for Transport Logistics

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Abstract

In this paper a novel localization approach in wireless sensor networks (WSNs) with spatial dynamic RSSI-filtering is presented. For the food transportation logistics WSNs could be applied to monitor the environmental parameters, e.g. temperature and humidity, within the container. The sensor nodes are arbitrarily distributed within the palettes. In a narrow and crammed environment like a closed container, it is difficult to achieve a direct positioning with Received Signal Strength Indicator (RSSI) due to the signal damping and reflection. The proposed approach exploits the movement of the sensor node during the loading process to compensate the reflection effect of the electromagnetic wave. In order to achieve a precise distance measurement with RSSI, a spatial dynamic RSSI-filter is applied in this work. The position of the sensor nodes is able to be already determined during the loading, thus neither additional hardware nor a further positioning process is required during the transportation process.

Keywords: Wireless sensor network; dynamic RSSI-filtering, localization; reflection compansition; transport logistics

1. Introduction

Transport logistics plays an increasingly important role in our daily life. The transportation of sensitive food such as fruits and vegetables requires optimal environmental conditions within the container to keep the low quality loss of the freight. The “intelligent container” developed in the University of Bremen combined the RFID technology and WSN for the online monitoring and local decision making system [1,2]. The WSN inside the container consists of a number of anchor nodes (fixed attached with known position) and the unknown nodes arbitrarily distributed within the palettes. The localization of the sensor nodes enables a precise description of the environmental parameter distribution. Due to the simple applicability the integrated Received Signal Strength Indicator (RSSI) is the favorite tool for distance determination in outdoor application [3]. However, it is difficult to achieve a direct

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positioning using RSSI in a narrow and crammed environment like a closed container due to the signal damping and reflection. In [4] the reflection effect of RF signal in an indoor environment was illustrated using a RSSI map. In this paper the proposed approach exploits the straightforward movement of the sensor node during the loading process to compensate the reflection effect. Due to the significant signal strength variation with small movements, the dynamic RSSI filtering is used to reduce the measurement error of the distances. Compare to the previous work [5] using Multilateration with static RSSI measurements the dynamic approach produces higher localization accuracy. The positioning of the sensor node is able to be completed during the loading process, thus neither additional hardware nor a further online localization is required during the entire transportation.

2. Static vs. dynamic RSSI

The basic idea for positioning with RSSI is that the sensor node to be localized stays at a fixed position and measures the received signal strength from different anchor nodes. The experimental results of many works have shown that the RSSI values for a given link vary little over time [5, 6]. However, the RSSI map [4] shows that the RSSI depends significantly on the spatial factor in an indoor environment. Therefore, a dynamic spatial RSSI filter can be used instead of a static temporal RSSI mean to reduce the ranging error. In order to prove it, a simple test is carried out. Two sensor nodes A and B are used as transmitter and receiver, separately. The distance between the two nodes is kept one meter (Fig 1a). For the dynamic RSSI measurement node A moves slowly from the position of 0° to 90° and 1400 RSSI readings are totally taken into account. For the static measurement the angle of 90° is evenly divided into six parts, thus seven positions are obtained. The node A stays at each position for 200 RSSI readings. The results (Fig. 1b) show that the dynamic readings change significantly with small distance difference. But for a fixed sensor node the RSSI values vary barely over time. The static and dynamic RSSI mean value is equal to -38 dBm and -43 dBm, respectively. The reference RSSI value for a distance of one meter is -45 dBm [7]. Therefore, in order to compensate the ranging error, it is better to make a small movement than to wait for a long time at the same position.

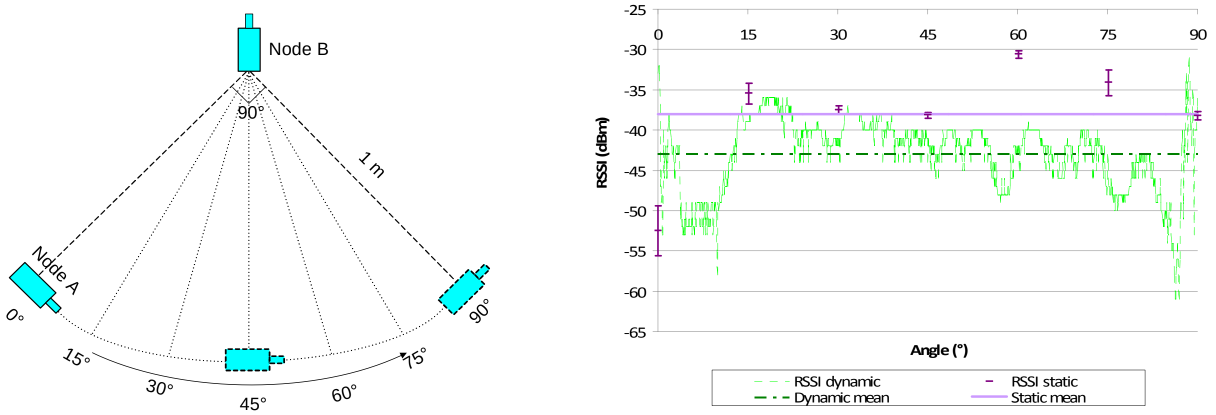

Fig. 1 Comparison test of static and dynamic RSSI measurement a) test setting b) test results

3. Implementation of dynamic RSSI during loading process

Since the pallet accompanying sensor nodes make a simple straightforward movement during the loading process before transportation, the dynamic spatial RSSI filter is suitable to be applied for this application. In the implementation test we added a simple spatial RSSI filter in the RSSI-Demo protocol to collect the unfiltered and filtered RSSI values from the anchor nodes simultaneously. Using the both RSSI readings the position of the moving sensor node is calculated and compared.

3.1. Test setting

The practical test is carried out in an empty TEU (Twenty-foot-Equivalent-Unit, $6058 \times 2488 \times 2591\,mm^3$) truck (Fig 2a). The telosb sensor nodes by Company Crossbow are used for this test. Twenty anchor nodes are attached to the wall of the truck in upper and lower layers. In this test only the lower layer is used, i.e. the distance measurement and localization are two-dimensional. The freight with the accompanying sensor node is pushed straightforward into the container along the x-axe (Fig 2b). The sensor node receives the RSSI-value from ten anchor nodes. The frequency of the packet sending is 16 packets/S.

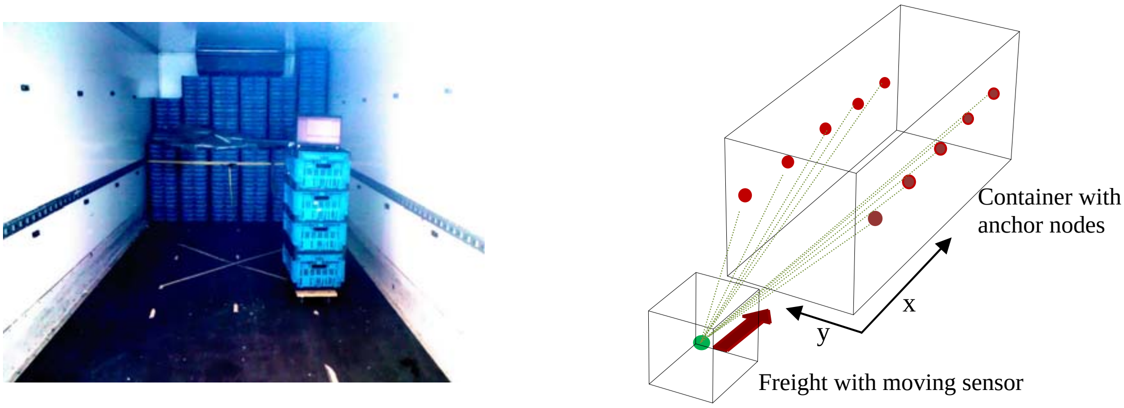

Fig. 2 Test setting a) Inside of the test container b) Loading of goods into the container

3.2. Test results

The dynamic RSSI filter calculates the mean value of every 20 RSSI readings. The direct RSSI records and the filtered ones from a single anchor node are illustrated in Fig. 3a. The unfiltered RSSI values show that the receiver node collects during the movement always the signal with the extreme fluctuating strength. The spatial filter smoothes the outliers and the filtered RSSI show if the receiver moves to or departs from an anchor. With more anchors in a row (Fig. 3b) the movement of the receiver is able to be estimated. Figure 3b shows that the moving sensor has past the anchor sensor 4. Using these RSSI curves simple cell based localization can also be achieved.

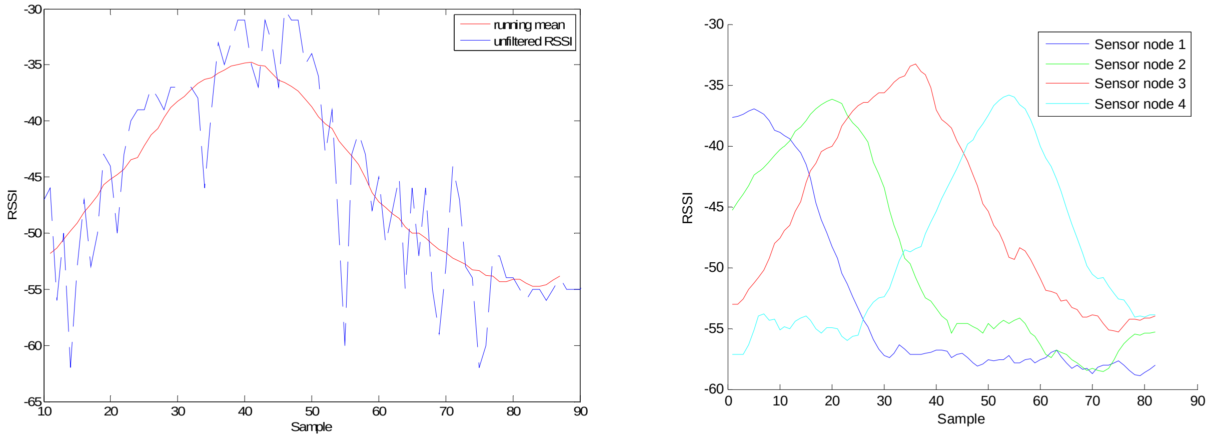

Fig. 3 Test results of the RSSI measurement a) unfiltered and filtered RSSI from single anchor (sensor node 3); b) filtered RSSI from anchors in a row.

The numerical position of the moving sensor node was calculated using Multilateration with the RSSI from ten anchor nodes. The localization results in X- direction with filtered and unfiltered RSSI are compared to each other in Fig. 4. The maximum localization error is about 0.8 m. Compared to the scale of the container (6058×2488 mm^2) and the Euro pallets (1200 $\times$ 800 mm^2) the accuracy reaches the requirement of the application.

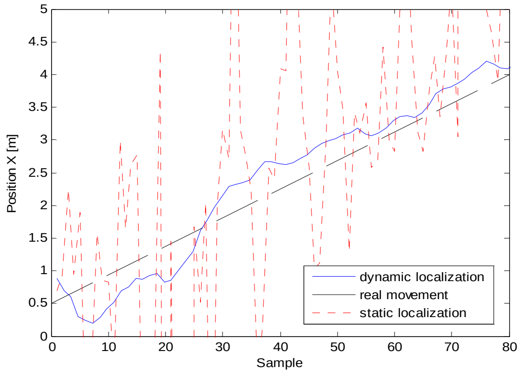

Fig. 4 Localization result with filtered and unfiltered RSSI

4. Conclusion

In this paper a localization approach with a spatial dynamic RSSI filtering is presented. The simple straightforward movements of the pallets accompanying sensor nodes during the loading process were exploited to compensate the reflection effect of the electromagnetic wave and to reduce the localization error. The spatial dynamic RSSI filter is implemented and tested in an empty container and the distance measurement with RSSI is enhanced. Using this approach the maximum localization error in the container has been reduced to 0.8 m.

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