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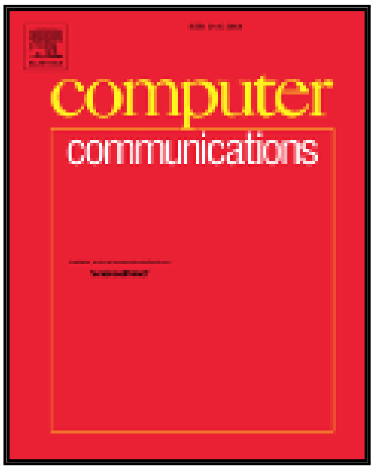

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Noise-aware localization algorithms for wireless sensor networks based on multidimensional scaling and adaptive Kalman filtering

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Abstract

The range-based MDS-MAP (multidimensional scaling-MAP) localization algorithm has been widely applied to the estimation of node position in wireless sensor networks (WSNs). However, the range for the MDS-MAP is often influenced by measurement noise so that there is an error, which will greatly reduce the positioning precision of MDS-MAP. Although the current improved MDS-MAP algorithms, such as MDS-MAP(P) and MDS-MAP(P,R), and the algorithms based on the theory of the rigid graph can obtain higher accuracy compared to the MDS-MAP, they are not suitable for the occasion where there are large errors in distance measurements between most nodes, namely the non-rigid graph. Therefore, Kalman filter (KF) is employed to refine the node coordinates from the MDS-MAP on this occasion, but it requires obtaining accurate noise statistics in advance and cannot adapt to the change of noise statistics. In the real WSN localization scenario with unknown or time-varying noise statistics, the inaccurate statistical parameter of noise will seriously weaken the refinement effect of KF on the MDS-MAP, especially under large noise-statistic bias. In this work, we propose two types of two-stage noise-aware localization algorithms for WSNs based on MDS-MAP and adaptive KF (AKF), i.e. an existing adaptive extended KF and an innovative adaptive unscented KF. The positioning accuracy and the time complexity of the AKF for the proposed algorithms are better than those of the spring relaxation for the rigid-graph based localization and the least square optimization for the improved MDS-MAP in the noisy environment. The results of extensive simulations show that compared with the present algorithms for refining the MDS-MAP, our proposed algorithms can always achieve higher positioning accuracy and lower time complexity regardless of the placement way of node, the shape of network topology, the communication radius of node, the node degree of network, and the deviation of noise statistics.

Keywords: Range-based localization; Multidimensional scaling; Adaptive Kalman filtering; Wireless sensor networks; RSSI

1. Introduction

Wireless sensor networks (WSNs) are a class of ad-hoc networks composed of large numbers of nodes equipped with sensors, microcontrollers and transceivers [1]. At present, the WSN has been widely applied in various fields such as environment monitoring, industry control, health care, and smart home. For many WSN applications, obtaining the location information of nodes is crucial, e.g. network routing, energy management, location service and so on. Therefore, the algorithm for positioning the node in the WSN has been extensively studied.

According to whether requiring measuring the distance between nodes in the process of localization or not, the WSN positioning algorithm is divided into two categories: one is range-based and the other is range-free [2-5]. In the range-based algorithm, the distance or the angle between nodes is needed. The main ranging technology contains time of arrival (TOA), time difference of arrival (TDOA), angel of arrival (AOA), received signal strength indicator (RSSI) [6-9]. The range-free algorithm does not need to know the distance and angle information between nodes, but it is less accurate than the range-based one. The classical range-free localization algorithms are convex position estimation (CPE), centroid, distance vector-hop (DV-Hop), multidimensional scaling-MAP (MDS-MAP) .

The MDS-MAP algorithm can localize a large number of nodes with unknown location in the WSN only using a small number of anchor nodes with known position. This algorithm can not only utilize the link information between nodes to roughly compute the coordinates of the node but also employ the distance information between nodes to precisely calculate the node coordinates. The TOA, TDOA, and AOA ranging technologies require that the node installs additional hardware in order to acquire the distance and angle information, so that these techniques are not suitable for the large-scale WSN with limited cost. Since the RSSI between nodes is very easy to extract from their wireless transceiver, the ranging technology based on the RSSI has been widely applied to the estimation of the distance between nodes in the WSN.

However, the measurement of RSSI is often affected by

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