Low Cost Recursive Localization scheme for High Density Wireless Sensor Networks

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ABSTRACT

While existing localization approaches mainly focus on enhancing the accuracy, particular attention has recently been given to reducing the localization algorithm implementation costs. To obtain a tradeoff between location accuracy and implementation cost, recursive localization approaches are being pursued as a cost-effective alternative to the more expensive localization approaches. In the recursive approach, localization information increases progressively as new nodes compute their positions and become themselves reference nodes. A strategy is then required to control and maintain the distribution of these new reference nodes. The lack of such a strategy leads, especially in high density networks, to wasted energy, important communication overhead and even impacts the localization accuracy. In this paper, the authors propose an efficient recursive localization approach that reduces the energy consumption, the execution time, and the communication overhead, yet it increases the localization accuracy through an adequate distribution of reference nodes within the network.

KEYWORDS

Accuracy, Cost, Energy Saving, Localization, Localization Overhead, Wireless Sensor Networks

1. INTRODUCTION

Recent technological advances in micro and digital electronics, digital and wireless communication, have made possible the development of low-cost, low-power, multi-functional and highly integrated sensors that are able to communicate in a wireless ad-hoc fashion over short distances (Akyildiz et al., 2002), (Culler et al., 2005). These sensor nodes, typically equipped with processing, sensing, power management and communication capabilities, collaborate to form a Wireless Sensor Network (WSN). The essential objective of WSN is to observe, assemble and process the knowledge of sensor nodes within the network scope (Kaur et al., 2015). Sensed data is typically sent over the network, in a multi-hop manner to a control center either directly or via a base station/sink. The main constraints in such networks are the limited amount of energy and computing resources of the nodes.

With the significant development and deployment of WSNs, associating the sensed data with its physical locations becomes a crucial requirement for different applications such as object tracking, environment monitoring, healthcare, intrusion detection, and habitat monitoring (Gu et al., 2009). Location estimation also supports core network services such as: routing, topology control, coverage, boundary detection and clustering (Lui et al., 2010).

The simplest method to localize a sensor node is to equip it with a Global Positioning System (GPS). However, its high cost and increased energy consumption makes it difficult to install in every

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node (Belghith et al., 2008), (Belghith et al., 2009). To overcome this weakness, other approaches, called collaborative localization algorithms, were proposed (Niculescu et al., 2001), (Oliveira et al., 2009), (Ding et al., 2012), (Gui et al., 2015), (Li et al., 2015), (Ahmadi et al., 2016). They rely on the idea that sensor nodes with unknown coordinates (un-localized nodes) are guided by one or more sensor nodes with known coordinates (either from GPS or by direct manual placement) for position estimation. The latter are called anchors or beacons. Based on the received information, the un-localized sensor nodes can compute their coordinates using distance measuring techniques (ranging techniques) (Mao et al., 2007).

Localization approaches can be classified into non-cooperative localization, and cooperative localization protocols. In non-cooperative localization protocols, every un-localized node needs to communicate with multiple anchors (one-hop communication), which requires either a high density of anchors or a long-range anchor transmission. However, in cooperative localization, un-localized nodes not only make measurements with anchors, but also they perform measurements with other localized nodes and cooperate to estimate their own positions. The cooperative localization approaches are being pursued as a cost-effective alternative to the more expensive non-cooperative approaches. The latter require a high pre-deployment cost (hardware cost, and high number of anchors). On the other hand, cooperative schemes require few anchors and explore the collaboration between nodes to enhance the localization (position) accuracy.

Nevertheless, in such cooperative approaches, additional operational costs should be highlighted and investigated such as the amount of required communication overhead (signaling traffic) to exchange location data, the power consumption required to complete node localization, the time taken for the convergence of the localization algorithm, and resources (storage and computing) required to compute the positions of the different nodes within the network.

Despite the importance of these additional operational costs that may negatively impact the network performances, they remain unexplored. In fact, most of the WSN localization approaches mainly focus rather on checking the localizability of a network and/or how to localize as many nodes as possible with high accuracy given a static and/or mobile set of anchors and distance measurements without considering the execution cost (individual cost, per node or the whole network localization cost) of the considered localization approach. These costs amount to how expensive it is to carry out the localization, and it is often motivated by realistic application requirements.

Recently, several works have proved the effectiveness of a multi-objective inspection and evaluation of localization algorithms to enhance the WSN performances. Authors in (Halder et al., 2016), (Klogo et al., 2013) and (Allen et al., 2009) pointed out some factors that influence a localization technique and presented an overview on new challenges and metrics to be carried out in future research. For example, a localization scheme which can reduce the energy consumption and minimizes the communication overhead is likely to be desirable if maximizing the network lifetime is a primary deployment goal. In this paper, we revisit the Recursive Position Estimation (RPE) cooperative localization technique (Albowicz et al., 2001) and propose novel ways to optimize the aforementioned costs. RPE makes full use of the connectivity of the network, and requires few anchors with the obvious advantages of simple localization method and easy realization. However, it sacrifices energy, time and accuracy especially for networks with high density of nodes. To address these issues, this work aims to improve the functioning of RPE. Our contribution here is to provide suitably accurate results (relative to RPE) in a simple and decentralized way, with low communication overhead and time latency, whilst requiring few number of anchors, and allowing incremental addition of nodes to serve and act as additional anchors.
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