Ad Hoc Networks 24 (2015) 20–28

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

Relational position location in ad-hoc networks

Victor H. Perez-Gonzalez *, David Munoz-Rodriguez, Cesar Vargas-Rosales, Raul Torres-Villegas

Electrical and Computer Engineering Department, Tecnologico de Monterrey, Campus Monterrey, Ave. Eugenio Garza Sada 2501, Monterrey, NL 64849, Mexico

ARTICLE INFO

Article history:
Received 18 February 2014
Received in revised form 16 June 2014
Accepted 25 July 2014
Available online 7 August 2014

Keywords:
Ad hoc wireless sensor network
Cooperative location
Multihop position location techniques

ABSTRACT

Position location usually relies on direct observation to/from conventional landmarks with known positions from/to a Node of Interest (NOI). Nonetheless, in an Ad-Hoc Wireless Sensor Network (AHWSN), nodes are often unable to establish a direct connection with the available Access Points (APs). In such a scenario, neighboring nodes may supply cooperative information to enable inference of the location of a given NOI in a network. In this paper we examine the feasibility of relational techniques in multihop environments to estimate position location. Two novel position estimation techniques are presented: the Relative Proximity Algorithm (RPA) and the Enhanced Relative Proximity Algorithm (ERPA). RPA and ERPA can operate as range-based or as range-free techniques, which makes them both attractive and flexible solutions for position estimation in AHWSNs. The performance of these techniques is characterized and found to be related to the number of cooperating nodes, the number of APs available in the network, and the presence of measurement noise. RPA and ERPA are also compared to several known position location methods reported in the literature, and it is shown that they achieve adequate location estimation accuracy with some advantages in terms of the number of access points required and network traffic overhead.

1. Introduction

Nodes in ad hoc wireless networks are generally equipped with sensors, which gather information about specific events of interest associated to a given location [1]. In addition, nodes are capable of processing and transmitting such information. In order to take full advantage of sensed data, the determination of the position location information of the nodes in the network is essential [2]. This is because they may not occupy a permanent location as they might be subject to intentional or unintentional motion [3]. Therefore, position location algorithms are demanded for a wide variety of applications, such as factory logistics, warehousing, real time surveillance, environmental control and monitoring, among others [4].

Location is always described in relation to a coordinate referential system defined by known conventional landmarks [5]. Nonetheless, direct observation from a given node to known landmarks is unlikely in an Ad-Hoc Wireless Sensor Network (AHWSN) because of limitations in the transmission range of nodes and adverse propagation conditions. Therefore, in AHWSNs, conventional landmarks or Access Points (APs) are reached through the concatenation of consecutive links, defining a multi-hop transmission path. In such a scenario where APs are unable to establish a single-hop connection with most network nodes (thus providing them with only limited reliable information), location must be inferred from the context of several descriptors. These descriptors are often related to population features that characterize the neighborhood of a nearby node [6,7]. Hence, location determination of a node becomes a task that involves the cooperation from several nodes in the network. Therefore, cooperative

* Corresponding author. Tel.: +52 (81) 8358 2000x5414.
E-mail address: vhpg@itesm.mx (V.H. Perez-Gonzalez).

http://dx.doi.org/10.1016/j.adhoc.2014.07.009
1570-8705/

position location methods have been suggested over the last decade for these type of scenarios [5,8].

Although several cooperative location techniques have been recently proposed [9,10], many of them require a preprocessing stage in addition to the location estimation stage. This requirement may have adverse effects on their performance. For instance, the preprocessing stage significantly augments the number of information packets transmitted across the network, increasing traffic overhead. Furthermore, several cooperative location methods present low estimation accuracy even with a large number of APs deployed throughout the network (which also increases the implementation cost of the system) [3]. Therefore, it is necessary to develop low-cost, accurate, and efficient cooperative location algorithms.

In this paper, we examine the applicability of simple cooperative relational information for position location in multihop environments. Different proximity measurements (i.e., range-based and range-free) are suggested to be used in the determination of the position of a node. Position location estimation is carried out employing two novel methods, the Relative Proximity Algorithm (RPA) and the Enhanced Relative Proximity Algorithm (ERPA), where in principle the estimation is based on the amount of neighboring nodes surrounding the Node of Interest (NOI) to be located. Performance results of both techniques are presented for several scenarios. Nevertheless, position location estimation may be affected by measuring errors and even by routing techniques [11]. Therefore, the effect of composed proximity error on relational position location is analyzed. In addition, in order to further highlight their advantages, the performance of the proposed methods is compared to that of other position location techniques reported in the literature in scenarios where measurement noise, node density, and available APs are varied.

The remainder of the paper is organized as follows: Section 2 provides a brief summary of position location methods for multihop networks. Section 3 describes RPA, a novel, basic and simple position location technique based on the concept of proximity. In Section 4 ERPA, an enhanced version of the RPA, is presented. ERPA provides important performance advantages over previously published position location systems. Such a comparison is presented in Section 5, where both proposed algorithms are evaluated through computational modeling. Finally, Section 6 contains the conclusions of this work.

2. Related work

The Global Positioning System (GPS) can be regarded as the most widely employed position location system in the world [12]. Nonetheless, in some particular environments (e.g., AHWSNs), GPS presents important drawbacks, for instance: deployment cost, service availability, and estimation accuracy [13–15]. Therefore, cooperative and collaborative algorithms have been developed over the past decade to solve the position location estimation problem in AHWSNs [9,16–18]. In this section, we briefly review some of the best-known and more recent localization schemes for multihop networks available in the literature, although the review is not exhaustive, it does present important algorithms from the point of view of their relation to the methods proposed in this paper. In Section 5, some of those algorithms will serve as a benchmark for the performance evaluation of RPA and ERPA.

In [19], the DV-Hop method was presented, which is perhaps the simplest available approach to follow in order to estimate the position of a NOI. It consists of two stages: a preprocessing stage and an estimation stage. In the preprocessing stage, employing shortest path routing, every node (including the APs) calculates its distance in hops (or links) to every AP available in the network. Since APs are assumed to know their own positions, they will have the information of the Euclidian distance between themselves. Therefore, employing the Euclidian distance and the hop count, APs are able to estimate the ‘‘average hop-length’’ factor, which is broadcasted to the network. Then, in the estimation stage, the NOI estimates its distance to each AP by multiplying the hop count in the path joining it to each AP times the average hop-length factor. Finally, a simple triangulation process can be employed to estimate the position location of the NOI. Recently, in [20], the DV-Hop estimation accuracy was enhanced through the use of a linear programming approach for minimization of the hop-length factor. Their results suggest an estimation accuracy improvement of roughly 20% (in comparison with the standard DV-Hop approach) for high node density scenarios. Nonetheless, its estimation accuracy cannot be further improved, not even increasing the number of APs or the communication range of the nodes.

One of the most important issues in every positioning or localization algorithm is the number of reference nodes that are needed to obtain accurate results. In [21] the localization problem is presented as an optimization formulation where the number of reference nodes is to be minimized. The authors use greedy algorithms and trilateration methods in their formulation. In addition to the required amount of available reference nodes, another important issue is the deployment (distribution) of the reference nodes in AHWSNs. In [22], it is recommended that the reference nodes be deployed in a circle that surrounds the entire sensor network as it minimizes position estimation error. The paper considers the case of very-large-areas AHWSNs, such as those employed for environment monitoring, surveillance, and tracking applications. Furthermore, Ref. [22] also presents the most important proposed improvements for the original DV-Hop algorithm, which is used as a reference algorithm for comparison purposes in the results. The localization algorithm proposed in [22] is named Hybrid DV-Hop (HDV-HOP) because it exploits DV-Hop advantages and the minimization of energy consumption, flooding of messages and number of reference nodes needed for localization. Moreover, the authors had also shown that depending on the scenario and the algorithm considered, an increased number of reference nodes does not always leads to a smaller localization error.

Also in [19], the authors presented the range-based version of DV-Hop, which was called DV-Distance. This alternative follows the same approach described in the previous paragraph with just slight changes in the process.