An Enhanced DV-Hop Localization Algorithm for Wireless Sensor Networks

Shrawan Kumar, School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi, India
D. K. Lobiyal, School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi, India

ABSTRACT

Obtaining precise location of sensor nodes at low energy consumption, less hardware requirement, and little computation is a challenging task. As one of the well-known range-free localization algorithm, DV-Hop can be simply implemented in wireless sensor networks, but it provides poor localization accuracy. Therefore, in this paper, the authors propose an enhanced DV-Hop localization algorithm that provides good localization accuracy without requiring additional hardware and communication messages in the network. The first two steps of proposed algorithm are similar to the respective steps of the DV-Hop algorithm. In the third step, they first separate error terms (correction factors) of the estimated distance between unknown node and anchor node. The authors then minimize these error terms by using linear programming to obtain better location accuracy. Furthermore, they enhance location accuracy of nodes by introducing weight matrix in the objective function of linear programming problem formulation. Simulation results show that the performance of proposed algorithm is superior to DV-Hop algorithm and DV-Hop–based algorithms in all considered scenarios.

Keywords: Correction Factor, DV-Hop, Linear Programming, Localization, Localization Error, Wireless Sensor Networks

1. INTRODUCTION

Wireless sensor network (WSN) is composed of a large number of sensor nodes that are connected to each other via wireless links. These sensor nodes have the capability of sensing, computing, and wireless communication (HwaLiao, Shih, & Lee, 2008). Current promising technologies require small, cheap, powerful, and multifunctional sensor nodes that communicate in short distances and can form a distributed, multi-hop, and self-organized network by wireless communication (Xiao-gang, Li-fang, & San-yang, 2010). Powerful functions and low energy cost renders application of WSNs in different domains suitable, such as target tracking (Lee & Cha, 2007), inspecting the environment and forecasting, remote

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controlling of dangerous region, reconnaissance (Xiao-gang & Chen-xi, 2010), routing (Chilamkurti, Zeadally, Vasilakos, & Sharma, 2011; Yu, Govindan, & Estrin, 2001), and so forth. In all these applications, location of event is required because without knowing the physical location of event, information related to the event is meaningless. This makes location estimation (localization) a crucial issue in WSNs (Broxton, Lifton, & Paradiso, 2005). Designing a practical algorithm for location estimation under constraints such as limited power of sensor, low computational cost, and various other factors is a challenging task (Liu & Yang, 2011; Patwari, Ash, Kyperountas, Hero III, Moses, & Correal, 2005). Estimating the location by attaching global positioning system (GPS) to each sensor nodes is the simplest way (Hofmann-Wellenhof, Lichtenegger, & Collins, 1993). The use of GPS in each sensor nodes makes network expensive, and GPS-equipped sensor node consumes more energy, which is a constraint of WSNs. These factors make GPS is infeasible for localization in WSNs (Lee, Chung, & Kim, 2011). As a result, there is a need for suitable and efficient (less expensive, energy efficient, scalable, and robust) localization algorithms (Lee, Wicke, Kusy, & Guibas, 2008).

Recently, many localization algorithms for WSNs have been proposed. These have been divided into two categories: range-based (Grid & Estrin, 2001) and range-free (He, Huang, Blum, Stankovic, & Abdelzaher, 2003). Range-based approaches require absolute point-to-point distance or orientation information between neighbor nodes (Gao & Lei, 2010). Measurement of absolute point-to-point distance or orientation requires extra hardware, which makes it expensive. On the other hand, range-free approaches do not require distance or angle information. Therefore, they do not use additional hardware, which makes it more cost-effective and simpler alternative over range-based approaches. Normally, range-free schemes provide lesser accurate results than range-based approaches (Savvides, Han, & Srivastava, 2001). Its cost-effectiveness, simplicity, and applicability have motivated many researchers to improve its localization accuracy (Li, 2006).

Some classic range-free algorithms are Approximate Point-In Triangle Test (APIT) (He, Huang, Blum, Stankovic, & Abdelzaher, 2003), Distance Vector-hop (DV-Hop) (Niculescu & Nath, 2001), Centroid (Srdjan, Maher, & Jean-Pierre, 2001), Amorphous (Nagpal, 1999), and so forth. DV-Hop is one of the most popular range-free localization algorithm. In DV-Hop, the location of normal sensor nodes (unknown nodes) is estimated with the help of some anchor nodes (nodes equipped with GPS). Major drawback of the DV-Hop algorithm is the poor distance estimation between nodes, which is the cause of its poor localization accuracy.

Numerous improvements of DV-hop algorithm have been proposed to improve location accuracy (Chen, Sezaki, Deng, & CheungSo, 2008a & 2008b; Chen, Wang, & Zhou, 2010; Chen & Zhang, 2012; Hou, Zhou, & Liu, 2010; Li, 2011; Niu, Zhang, Xu, Huo, & Gao, 2007; Wu & Gao, 2011). These improvements will be discussed later in the article.

Some improvements to the DV-Hop algorithm are also based on range-based techniques, such as received signal strength indicator (RSSI). In Tian, Zhang, Liu, Sun, and Wang (2007), the distance between nodes is estimated by using RSSI to reduce the ranging error, but Benkic, Malajner, Planinsic, and Cucej (2008) shows that RSSI is not an appropriate distance measurement in a noisy environment. The accuracy using RSSI is not only highly sensitive to multipath, fading, and other sources of interference but it also requires additional hardware.

In this paper, we focus only on the range-free algorithm, DV-Hop, and propose an enhanced DV-Hop localization algorithm for WSNs. Throughout the paper we call it by EDV-Hop. This proposed method improves location accuracy without increasing hardware cost and communication messages in the network. In the proposed algorithm, the error in the estimated distance between unknown node and anchor node is minimized by using linear programming. Simulation results show that the performance of our proposed algorithm is superior to
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