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Cluster-Based Two-Step Target Localization with Incremental Cooperation

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***Abstract*—Target localization is one of the momentous research subjects in wireless sensor networks (WSNs). Several methods have been initiated so far for the aim of target (e.g. sniper) localization using the acoustic signals produced, such as muzzle blast and shock wave in WSNs. One of the preeminent available methods is maximum likelihood estimation (MLE) algorithm, using time difference of arrival (TDOA) of the target signal received at sensor nodes. Although the MLE algorithm is asymptotically optimum and obtains high level of accuracy in comparison with other methods, nevertheless, using MLE has two major challenges. Firstly, the crucial need of this method to begin with a proper initial guess, and secondly, the possibility of not converging to a global minimum. Moreover, employing WSNs constrains the amount of power consumption that is practically possible. In this paper, to overcome the aforementioned obstacles, a two-step algorithm is proposed which in first step, a fast spherical interpolation (SI) method is utilized to prepare an appropriate initial guess for the MLE algorithm. In the second step, a clustering-based network is described to attain less power consumption across the WSN. Furthermore, to increase the probability of convergence, a cooperative incremental cluster-based estimation strategy is proposed. In addition, major issues that can affect the performance of the proposed method are investigated. Simulation results prove the capability of this method and support the claims.**

***Index Terms*—Source localization; target localization; location estimation; wireless sensor networks.**

I. Introduction

Wireless sensor networks (WSNs) have gained worldwide attention in recent years. They are generally inexpensive compared to traditional sensors, and have little power consumptions in which battery is the main power supply. These sensor nodes can sense, measure, and gather information from the environment around, and perform some local decision processes as well. WSNs have been extensively used in wide variety of decisive and critical applications [1]. Evidently, utilizing wireless sensor nodes for localization purposes make them easily deployable, and opting for low-cost nodes fabricates more economical situations [2]. In recent years, location estimation in wireless networks has attracted great interests from researchers in the field of signal processing and wireless communications. Location estimation is also desired in local environments to provide positioning, tracking, and navigation services for people with special needs, such as fire fighters and soldiers during their missions, as well as elderly people and patients under special care [3]. For instance, sniper localization is an important concern in urban warfare. For this purpose, an array of acoustic sensors, microphones or piezoelectric pressure sensors, is deployed to detect and process supersonic shock waves and muzzle blasts produced by the gunshot [4]. The measured acoustic data are further processed using source localization techniques in order to estimate the location of the shooter [5]. Two acoustical phenomena associated with the gun fire will be exploited to determine the shooter's position: the muzzle blast and the shock wave. The principle task is to detect and time stamp the phenomena as they reach the distributed microphones over an area of interest, and let the shooter's position be estimated by, in a sense, the most likely point, considering the microphone locations and detection times. Acoustic or sound localization can be accomplished by utilizing the observed differences in the acoustic signals received at different observation points, such as angle of arrival (AOA), time of arrival (TOA), time difference of arrival (TDOA), received signal strength (RSS) or steered response power (SRP), to estimate the direction and actual location of the sound source. [5], [6]. In [7], WSN is used for sensor localization in outdoors, yet the average achievable accuracy is limited to 7m. The approach given in [8] has achieved 1.5-2m accuracy in location estimation, however, it essentially requires tight proper calibration. In [9], a maximum likelihood estimator for RSS while considering the noise is derived. It reports 1.8m median error while the maximum error to be around 4.2m. In essence, to achieve stronger performance and higher localization accuracy, more anchor nodes as well as more data points are generally required.

In this paper, we focus on target localization using wireless sensor networks. Initially, we propose to deploy the distributed individual sensor nodes in a cluster-based network and then a two-step source localization process is conducted at each cluster. For this aim, the time difference of arrival(TDOA) values are determined using the generalized cross-correlation (GCC) strategy. Afterwards, the TDOA values are utilized by a hybrid spherical interpolation (SI) to be a proper initial guess for the maximum likelihood (ML) estimation method [5]. Furthermore, a modified incremental-based algorithm for

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