Computers and Electrical Engineering xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Computers and Electrical Engineering

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

A dynamic lookahead tree based tracking algorithm for wireless sensor networks using particle filtering technique ☆

Aysegul Alaybeyoglu [a,*], Aylin Kantarci [b], Kayhan Erciyes [c]

[a] Department of Computer Engineering, Celal Bayar University, Manisa, Turkey
[b] Department of Computer Engineering, Ege University, Izmir, Turkey
[c] Department of Computer Engineering, Izmir University, Izmir, Turkey

ARTICLE INFO

Article history:
Available online xxxx

ABSTRACT

In this study, five different algorithms are provided for tracking targets that move very fast in wireless sensor networks. The first algorithm is static and clusters are formed initially at the time of network deployment. In the second algorithm, clusters that have members at one hop distance from the cluster head are provided dynamically. In the third algorithm, clustered trees where members of a cluster may be more than one hop distance from the cluster head are provided dynamically. In the fourth, algorithm lookahead trees are formed along the predicted trajectory of the target dynamically. Linear, Kalman and particle filtering techniques are used to predict the target's next state. The algorithms are compared for linear and nonlinear motions of the target against tracking accuracy, energy consumption and missing ratio parameters. Simulation results show that, for all cases, better performance results are obtained in the dynamic lookahead tree based tracking approach.

1. Introduction

Many detection, data association and location methods are proposed in order to track the target [1,2]. Wireless sensor networks provide high quality and reliable observations, accurate and timely signal processing capabilities and hence high performance for target tracking systems [3]. On the other hand, the use of sensor networks for target tracking applications brings some challenges such as limited energy supply and communication bandwidth [3]. In order to overcome these challenges, target tracking applications employ clustering techniques. In clustering techniques, nodes are either classified as cluster members or cluster heads. While the role of cluster head is to collect the data from its member nodes and send this data to the sink, the role of a cluster member is to sense the environment and send the sensed data to its cluster head [4]. Cluster based target tracking algorithms can be generally grouped as static [5–8] and dynamic [9–11] approaches. In static approaches, the clusters and the backbone infrastructure are built at the time of network deployment and the attributes of each cluster, such as the size of a cluster, the area it covers, and the members it possesses, are static [3]. On the other hand, in dynamic approaches, the clusters are constructed dynamically when the event occurs and there is not any restriction on the properties of clusters.

The number of nodes sensing the target in a cluster is important because if there are not enough number of nodes to sense, the position of the target cannot be calculated. This situation is called target miss and in order to decrease target miss ratios, spanning tree based algorithms are used [7,8,10,11]. Enlarging the cluster size by this way can increase the number of

☆ Reviews processed and recommended for publication to Editor-in-Chief by Guest Editor Dr. Catalin Lacatus.

* Corresponding author. Tel.: +90 31465557489.
E-mail addresses: aysegul.alaybeyoglu@cbu.edu.tr (A. Alaybeyoglu), aylin.kantarci@ege.edu.tr (A. Kantarci), kayhan.erciyes@izmir.edu.tr (K. Erciyes).

0045-7906/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compeleceng.2013.06.014

nodes involved in target detection and can decrease the probability of target misses. Also there can be some cases in which the target moves at above expected speeds and hence it can pass by a group of nodes very fast without being detected [6,11].

In order to decrease target miss ratio, prediction techniques can be used [12–15]. The simplest prediction approach is linear prediction which assumes the target will continue along the same direction with the same speed. In case the target changes its kinematics, linear prediction produces erroneous results, reducing the prediction accuracy. Prediction techniques based on Kalman Filtering (KF) and Particle Filtering (PF) which adapt to variable target dynamics enable better predictions by increasing prediction accuracy [16].

Due to the high probability of target miss, existing tracking studies contain many complicated recovery mechanisms for target missing conditions [5]. These recovery mechanisms consume significant energy to detect the target again. In this study, instead of using these complicated recovery mechanisms, it is proposed to awake nodes and form lookahead clusters along the predicted trajectory of the target to decrease the probability of missing the target. The performances of existing tracking approaches and the proposed algorithm are compared for linear and nonlinear mobility models. Unlike many target tracking studies which consider only targets with normal speeds, evaluations are made also for targets with more dynamic motion characteristics. Another contribution is that a new tracking algorithm, namely Dynamic Lookahead Spanning Tree Algorithm (DLSTA) is proposed. All of the algorithms described in this paper are simulated under ns-2 environment and are compared in terms of different parameters.

This paper is organized as follows: In Section 2, background information on the focused algorithms and prediction techniques are presented. The DLSTA algorithm is explained in Section 3. Performance evaluations obtained from simulations are presented in Section 4. Finally, discussions are given in Section 5 and Conclusions are drawn in Section 6.

2. Background

In this section, the existing tracking approaches which are compared with DLSTA are summarized and the prediction techniques are briefly mentioned.

2.1. Tracking algorithms

2.1.1. Generic Static Cluster Based Target Tracking Algorithm (GSCTA)

In GSCTA [17], clusters are formed statically at the time of network deployment so that all the member nodes and their related leader nodes could be defined before the tracking algorithm is executed. In this approach, current active cluster head warns the cluster head closest to the future location of the target about the approaching target. When the cluster head receives this information, it wakes up its members of cluster and makes them ready to detect the moving target. Although this cluster ready infrastructure brings simplicity into target tracking, the restrictions on memberships can cause some problems in fault tolerance. Since the nodes in different clusters will not be able to cooperate with each other, they will not know about each other's observed data. Secondly, when a predetermined leader node consumes its energy, the nodes in its cluster will not be able to calculate the location of the target although they detect the target.

2.1.2. Generic Dynamic Cluster Based Target Tracking Algorithm (GDCTA)

In GDCTA [17], clusters are formed dynamically as the events occur in the network area. In this approach, current active leader node sends a warning message to the node closest to the target's predicted future location. The node receiving this message, becomes the new leader node and forms its cluster dynamically with its one hop neighbors. This approach does not impose any restrictions on memberships. For example, a node can be a member of different clusters at different times which makes this approach more advantageous for the minimization of localization errors.

2.1.3. Generic Dynamic Spanning Tree Based Target Tracking Algorithm (GDSTA)

Localization techniques require three nonlinear nodes to calculate the position of the target. In GDCTA, when the nodes in a cluster are aligned linearly or fewer nodes than three fall into a cluster, localization process does not work. To eliminate this problem, more nodes should be included in a cluster. This can be achieved with tracking algorithms based on spanning trees [10]. In this approach, spanning trees are formed dynamically as the events occur in the network area. Current active root node sends a warning message to the node closest to the target's predicted location. The node receiving this warning message, becomes the new root node and forms its spanning tree to become ready to detect the target.

2.1.4. Dynamic Lookahead Cluster Based Target Tracking Algorithm (DLCTA)

As the target increases its speed, the probability of missing that target also increases. Awakening the nodes in the predicted trajectory in advance may help to decrease the target misses. For this reason, DLCTA [18] which predicts the future k locations of the target and awakes the corresponding leader nodes is designed. So that the nodes along the trajectory self organize to form the clusters to collect data related to the target in advance and thus reduce the target misses. The number of clusters to be formed varies in accordance with the target's speed for energy efficiency considerations. As the speed increases, the number of clusters to be formed will also increase.