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Optimized Power Aware Target Tracking In Wireless Sensor Network

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Abstract

A surveillance system, which tracks mobile targets, is one of the most important applications of wireless sensor networks. When nodes operate in a PPSS, tracking performance can be improved if the target motion can be predicted and nodes along the trajectory can be proactively awakened. However, this will negatively influence the energy efficiency and constrain the benefits of duty cycling. In this paper, present an Optimized Power Aware target tracking (OPTT) to improve energy efficiency. The OPTT balance energy level of target tracking based on the scheduling strategy of the candidate node. Moreover, it provides adequate target tracking coverage area by reducing the overlapping area based on the energy drain rate of the optimal sensor node and determine the candidate node to be in awake state and other nodes are held in sleep state for efficient target tracking. Evaluate the efficiency of OPTT with simulation-based experiments.

Keywords

Energy efficiency, Candidate node, Sleep scheduling, Target tracking, Sensor networks

I. Introduction

Wireless sensor networks (WSNs) are increasingly being envisioned for collecting data, such as physical or environmental properties, from a geographical region of interest. WSNs are composed of a large number of low-cost sensor nodes, which are powered by portable power sources, e.g., batteries. In many surveillance applications of WSNs, tracking a mobile target (e.g., a human being or a vehicle) is one of the main objectives. Unlike detection that studies discrete detection events , a target tracking system is often required to ensure continuous monitoring, i.e., there always exist nodes that can detect the target along its trajectory (e.g., with low detection delay or high coverage level.

Therefore, the most stringent criterion of target tracking is to track with zero detection delay or 100 percent coverage. Since nodes often run on batteries that are generally difficult to be recharged once deployed, energy efficiency is a critical feature of WSNs for the purpose of extending the network lifetime. However, if energy efficiency is enhanced, the quality of service (QoS) of target tracking is highly likely to be negatively influenced. For example, forcing nodes to sleep may result in missing the passing target and lowering the tracking coverage. Therefore, energy-efficient target tracking should improve the tradeoff between energy efficiency and tracking performance, by improving energy efficiency at the expense of a relatively small loss on tracking performance. For target tracking applications, idle listening is a major source of energy waste. To reduce the energy consumption during idle listening, duty cycling is one of the most commonly used approaches. The idea of duty cycling is to put nodes in the sleep state for most of the time, and only wake them up periodically. In certain cases, the sleep pattern of nodes may also be explicitly scheduled, i.e., forced to sleep or awakened on demand. This is usually called sleep scheduling.

As a compensation for tracking performance loss caused by duty cycling and sleep scheduling, proactive wake up has been studied for awakening nodes proactively to prepare for the approaching target. However, most existing efforts about proactive wake up simply awaken all the neighbor nodes in the area, where the target is expected to arrive, without any differentiation. In fact, it is sometimes unnecessary to awaken all the neighbor nodes. Based on target prediction, it is possible to sleep-schedule nodes precisely, so as to reduce the energy consumption for proactive wake up. For example, if nodes know the exact route of a target, it will be sufficient to awaken those nodes that cover the route during the time when the target is expected to traverse their sensing areas.

In this paper, present an Optimized Power Aware target tracking to improve the efficiency of proactive wake up and enhance the energy efficiency with limited loss on the tracking performance. With a target prediction scheme based on both greedy algorithm and random way point model, OPTT not only predicts a target's next location, but also describes the point with which it moves along all the directions. The OPTT balance energy level of target tracking based on the scheduling strategy of the candidate node. Moreover, it provides adequate target tracking coverage area by reducing the overlapping area based on the energy drain rate of the optimal sensor node and determine the candidate node to be in awake state and other nodes are held in sleep state for efficient target tracking. The state of candidate sensor node is tracked across the WSN. In the similar manner, multiple candidate sensors are identified across different regions of WSN. Successive candidate sensors are replaced as and when predecessor runs out of energy. The awakened node with minimal energy consumption search for target objects prediction. The state of sleep schedule state varies based on the candidate node in due course of target object prediction. Feasible solution is obtained by using a greedy algorithm. The Greedy algorithm finds the first layer of sensors by repetitively selecting a sensor node with largest heuristic value. The power levels of the candidate sensor nodes are measured to find successive candidate nodes. Once the candidate sensor runs out of energy then the highly powered successor is utilized to cover the target identification. Each optimal active sensor computes target's location, velocity and trajectory locally.

The optimal powered candidate nodes are identified based on high coverage target prediction, lower energy drain rate with the ability to predict more number of targets. Some of the advantages of the proposed Optimized Power aware Target Tracking (OPTT) scheme include power aware optimized sleep scheduling strategy for candidate sensor nodes, better energy performance tradeoff with reduced overhead cost. The performance constraints are imposed based on balanced energy consumption for target tracking. Simulations are conducted to measure the efficiency level of energy, applied to different number of sensor nodes for a specified coverage area to prove the effectiveness of the proposed method.

The rest of the paper is organized as follows: Related work is discussed in Section 2. In Section 3, we introduce system models, our assumptions, and overview the protocol design. Conclusion in Section 4, In Section 5, we specify future enhancement.

II. Related Works

Energy efficiency has been extensively studied either independently or jointly with other features. In, the authors proposed, analyzed, and evaluated the energy consumption models in WSNs with probabilistic distance distributions to optimize grid size and minimize energy consumption accurately. An experimental effort based on real implementation is conducted for energy conservation in. In, Sengul et al. explored the energy-latency, reliability tradeoff for broadcast in WSNs by presenting a new protocol called PBBF. In, the authors proposed a distributed, scalable, and localized multipath search protocol to discover multiple node-disjoint paths between the sink and source nodes, in which energy was considered as a constraint so that the design is feasible for the limited resources of WSNs.

As one of the most important applications of WSNs, target tracking was widely studied from many perspectives.

- First, tracking was studied as a series of continuous localization operations in many existing efforts.
- Second, target tracking was sometimes considered as a dynamic state estimation problem on the trajectory, and Bayesian estimation methods, e.g., particle filtering, were used to obtain optimal or approximately optimal solutions.
- Third, in some cases, target tracking was considered as an objective application when corresponding performance metrics, e.g., energy efficiency or real-time feature, were the focus.
- Fourth, a few efforts were conducted based on real implementation, and emphasized the actual measurement for a tracking application.
- Finally, a few target tracking efforts did not explicitly distinguish tracking from similar efforts, such as detection and classification.

Although sleep scheduling and target tracking have been well studied in the past, only a few efforts investigated them in an integrated manner. In, the authors utilize a “circle-based scheme” (Circle) to schedule the sleep pattern of neighbor nodes simply based on their distances from the target. In such a legacy Circle scheme, all the nodes in a circle follow the same sleep pattern, without distinguishing among various directions and distances. In, Jeong et al. present the MCTA algorithm to enhance energy efficiency by solely reducing the number of awakened nodes. MCTA depends on kinematics to predict the contour of tracking areas, which are usually much smaller than the circles of Circle scheme. However, MCTA keeps all the nodes in the contour active without any differentiated sleep scheduling.

Typical target prediction methods include kinematics based prediction, dynamics-based prediction, and Bayesian estimation methods. Kinematics and dynamics are two branches of the classical mechanics. Kinematics describes the motion of objects without considering the circumstances that cause the motion, while dynamics studies the relationship between the object motion and its causes. In fact, most of past work about target prediction uses kinematics rules as the foundation, even for those that use Bayesian estimation methods.MCTA algorithm presented in is just an example of kinematics-based prediction.

Another example is the Prediction- based Energy Saving scheme (PES) introduced. It only uses simple models to predict a specific location without considering the detailed moving probabilities. In, Taqi et al. discussed a dynamics-based prediction protocol named as A-YAP. They leveraged the physics research results on the yaw rate and the side force. However, these results depend on the target mass, which requires the surveillance system to recognize the target with target classification techniques.

In many cases, target classification is difficult especially when the real-time tracking constraint is applied. Moreover, A-YAP also predicts an exact location that the target is probably moving to, instead of considering all the possibilities. Bayesian estimation methods estimate the target state by incorporating new measures to modify the prior states as well as predict the posterior ones. For example, information-driven sensor querying (IDSQ) optimizes the sensor selection to maximize the information gain while minimizing the communication and resource usage.

The enhancement of energy efficiency is not achieved by sleep scheduling, but by minimizing the communication energy. On the contrary, OPTT aims at improving the overall performance on energy efficiency and tracking performance using sleep scheduling. Another example of Bayesian estimation methods is the particle filtering. In, the authors predict the target location using a particle filter, then schedule the sleep patterns of nodes based on the prediction result.

III. Designs Overview

In this section, we introduce system models, our assumptions, and overview the design of OPTT protocol.

A. System Models and Assumptions

Homogeneous, static sensor network, in which sensor nodes work in a duty cycling mode. In each toggling period (TP), a node keeps active for TP_DC, where DC is the duty cycle. Although the active period of neighbor nodes may be different, the communication among them can be guaranteed based on a MAC protocol such as B-MAC .In the active state, a node may detect targets within its sensing radius r, and communicate with other nodes within its communication radius R. We assume that every node is aware of its own location (using GPS or algorithmic strategies such as), and is able to determine a target’s position at detection (either by sensing or by calculating). In addition, we assume that the sensor nodes are locally time synchronized using a protocol such as RBS .In this paper, we consider single target tracking only. In fact, as long as the distance between two targets is more than two times of the communication radius of nodes, the sleep scheduling actions triggered by them will not overlap; thereby they can be handled with single target tracking algorithms.

B. OPTT Design

OPTT is designed based on proactive wake up: when a node (i.e., alarm node) detects a target, it broadcasts an alarm message to proactively awaken its neighbor nodes (i.e., awakened node) to prepare for the approaching target. To enhance energy efficiency, we modify this basic proactive wake-up method to sleep-schedule nodes precisely. Specifically, PPSS selects some of the neighbor nodes (i.e., candidate node) that are likely to detect the target to awaken. On receiving an alarm message, each candidate may individually make the decision on whether or not to be an awakened node, and if yes, when and how long to wake up.

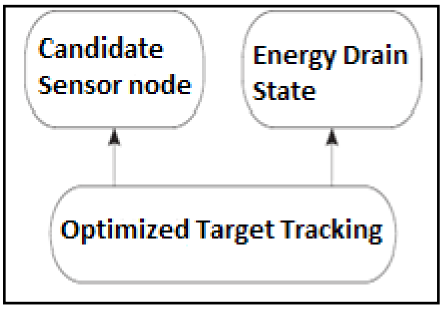

Fig. 1 : OPPTT Design Overview

It utilizes two approaches to reduce the energy consumption during this proactive wake-up process:

1. Select candidate sensor nodes.
2. Schedule their sleep pattern to reduce energy drain state. First, the number of awakened nodes can be reduced significantly, because:

1) Those nodes that the target may have already passed during the sleep delay do not need to be awakened;
2) Nodes that lie on a direction that the target has a low probability of passing by could be chosen to be awakened with a low probability.

For this purpose, we introduce a concept of awake region and a mechanism for computing the scope of an awake region.

Second, the active time of chosen awakened nodes can be curtailed as much as possible, because they could wake up and keep active only when the target is expected to traverse their sensing area.

For this purpose, we present a sleep scheduling protocol, which schedules the sleep patterns of awakened nodes individually according to their distance and direction away from the current motion state of the target. Both of these energy reducing approaches are built upon target prediction results. The OPTT balance energy level of target tracking based on the scheduling strategy of the candidate node. Moreover, it provides adequate target tracking coverage area by reducing the overlapping area based on the energy drain rate of the optimal sensor node and determine the candidate node to be in awake state and other nodes are held in sleep state for efficient target tracking. The state of sleep schedule state varies based on the candidate node in due course of target object prediction. Feasible solution is obtained by using a greedy algorithm.

The Greedy algorithm finds the first layer of sensors by repetitively selecting a sensor node with largest heuristic value. The power levels of the candidate sensor nodes are measured to find successive candidate nodes. Once the candidate sensor runs out of energy then the highly powered successor is utilized to cover the target identification. Each optimal active sensor computes target's location, velocity and trajectory locally. The optimal powered candidate nodes are identified based on high coverage target prediction, lower energy drain rate with the ability to predict more number of targets. Some of the advantages of the proposed Optimized Power aware Target Tracking (OPTT) scheme include power aware optimized sleep scheduling strategy for candidate sensor nodes, better energy performance tradeoff with reduced overhead cost.

The performance constraints are imposed based on balanced energy consumption for target tracking. Simulations are conducted to measure the efficiency level of energy, applied to different number of sensor nodes for a specified coverage area to prove the effectiveness of the proposed method.

1. WSN Candidate Sensor Nodes

Candidate sensor node by means of minimal node energy drain rate. State of candidate sensor node is tracked across the WSN surveillance area. As active sensor runs out of energy second candidate sensor made effective to satisfy coverage requirement. Successive candidate sensors are replaced as and when predecessor runs out of energy. If full coverage constraint cannot be satisfied sensors returns out of energy state, selects a new sensor again until finding a new successor cover set. When successfully finds successor cover set move to coverage requirement region as per energy drain rate in newly found cover set.

2. Sleep Scheduler based on Node Energy Drain Rate

Feasible solution is obtained by using a greedy algorithm. Greedy algorithm finds first layer of sensors by repetitively selecting a sensor with largest heuristic value computed. Active state sensor runs out of energy optimal sleeping sensors with largest heuristic value are activated to satisfy coverage requirement. Process is repeated until full coverage constraint cannot be satisfied. Steps to be followed.

1. The greedy algorithm finds the first layer of sensors by repetitively selecting a sensor with the largest heuristic value computed.
2. Once an active sensor runs out of energy, sleeping sensors with the largest heuristic value are activated to satisfy the coverage requirement.
3. This process is repeated until the full coverage constraint cannot be satisfied.
4. Then the pheromone values are initialized as

$$\tau_i = \tau_{ij} = t_0$$

Where τ_i is the pheromone on vertex si of the first construction graph, τ_{ij} is the pheromone on the edge between osi and s_j, t_0 is the network lifetime of the solution found by the greed algorithm.

3. Optimized Power Aware Target Tracking

Power aware target tracking use optimal candidate active sensor sleep scheduler. Each optimal active sensor computes target's location, velocity, trajectory locally. Used successive active candidature sensor nodes to collect target tracking of object being detected.

Here, target tracking does not require time synchronization applied to targets moving in random directions and varied velocities. In WSN deployment each node initializes list of statuses to its candidate sensor neighbors. Node discovers change in target's presence within its sensing range identifies region of sensing range. Target location is estimated as middle point of corresponding region broadcasted to sensor neighbors.

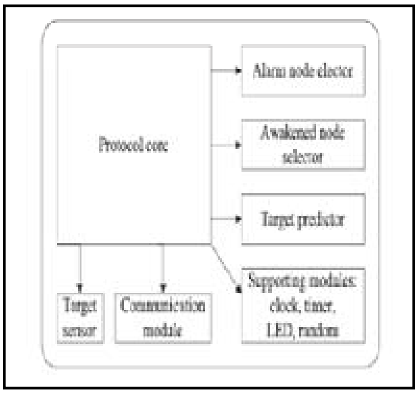

Fig. 2 : Protocol structure

IV. Conclusion

In a duty-cycled sensor network, proactive wake up and sleep scheduling can create a local active environment to provide guarantee for the tracking performance. By effectively limiting the scope of this local active environment (i.e., reducing low value-added nodes that have a low probability of detecting the target), OPTT improves the energy efficiency with an acceptable loss on the tracking performance.

In addition, the design of OPTT protocol shows that it is possible to precisely sleep-schedule nodes without involving much physics. Though the emulation is sometimes unavoidable, our prototype implementation can still provide more real and convincing results than the simulation. For example, besides exposing motes to real environmental noises and unstable links, the implementation itself can verify the rationality of the solutions, and the feasibility of applying them into the constrained resources of actual mote hardware platforms.

V. Future Enhancement

Except for the strengths, OPTT has limitations as well.First, it use random way point methods,i.e,use random selection. Second, the prediction method of PPSS cannot cover special cases such as the target movement with abrupt direction changes. This is the expense that OPTT pays for the energy efficiency enhancement. Given these limitations, further enhancement deals with optimized way point and prediction for abrupt direction changes.

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