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Energy Efficient Multiple Target Prediction and Sleep Scheduling in WSNs

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Abstract:
Wireless sensor networks are composed of a large number of sensor nodes, which are powered by portable power sources. Scheduling sensor activities is an effective way to prolong the lifetime of wireless sensor networks (WSNs). If the sensor remains active 24/7 its energy will be depleted completely at some point and that sensor will not be taking part in monitoring or it will not function. It will be difficult to check and replace those sensors whose battery is drained. In this paper a Multiple Target Prediction and Sleep Scheduling mechanism (MTPS) is proposed to improve energy efficiency and to detect multiple targets in WSNs. MTPS selects the nodes to awaken, reduces their active time and also activate the boundary nodes to detect and track multiple mobile targets. The efficiency of MTPS mechanism is evaluated with simulation based experiments, In the existing work Probability-based Prediction and Sleep Scheduling mechanism (PPSS) is used. PPSS method precisely selects the nodes to awaken and reduces their active time. PPSS has a limitation of detecting only single target. Simulation based results reveal that MTPS yields better performance compared with PPSS.

Key words*: Target Prediction, Sleep Scheduling, Multiple target Tracking*

1. Introduction

A wireless sensor network (WSN) is a network of transceivers, microcontrollers, sensors, power sources and user interface devices with at least two nodes communicating by means of wireless transmissions. 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 typically capable of sensing, computing, and communication. The applications of WSNs can be found in diverse areas such as military (e.g., battlefield surveillance), environmental protection (e.g., habitat monitoring), healthcare (e.g., tele monitoring of human physiological data), and home automation[1].A sensor node in WSNs usually consists of a microcontroller, memories, a radio transceiver, and sensing devices. All of these components get power from portable power sources such as batteries. Among the many diverse application domains of WSNs, tracking a mobile target (e.g.,an animal, human being or a vehicle) is one of the most significant ones. Tracking usually has more stringent performance requirements than detection, target detection studies discrete detection events at certain times and positions [2,3] i.e., it will succeed as long as there exists a single sensor node that can detect the target; however, a target tracking system is often required to ensure continuous monitoring and estimate the trajectory[4]. Regardless of these applications, extending the network lifetime is a critical issue in WSNs. This is because the sensors are battery-powered and generally difficult to be recharged So another challenging tasks in the field of WSNs is controlling the power consumption of batteries and prolonging their life time. This paper aims both the energy conservation and multiple target tracking in WSNs..

In WSNs, idle listening is a major source of energy waste in target tracking applications. To reduce the energy consumption during idle listening, Sensor nodes are put into sleep state for most of the time, and only wake them up periodically. Sometimes, 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 [5].One effective way to prolong the network lifetime is to schedule sensors wake-up activities. In WSNs, sensors commonly have two operation modes, i.e., active mode and sleep mode. A sensor in active mode can perform its monitoring task and therefore needs to consume a relatively large amount of energy. On the contrary, a sensor in sleep mode does not perform the sensing task and consumes little energy. Therefore, by appropriately scheduling sensors to be in low-energy sleep mode and waking them up when necessary, the network lifetime can be prolonged. In the literature, various efforts have been made on optimizing the wake-up scheduling in WSNs.

The Multiple Target Prediction and Sleep scheduling mechanism (MTPS) helps improve the efficiency of proactive wake up and enhance the energy efficiency with limited loss on the tracking performance. With a target prediction scheme, MTPS predicts a target's location, describes the probabilities with which target moves and also activates the boundary nodes for multiple target detection .Then, based on the prediction results, MTPS increases energy efficiency by reducing the number of awakened nodes and schedule sleep pattern to shorten active time of proactive nodes. In addition, we design distributed algorithms for MTPS that can run on individual nodes. This will improve the scalability of MTPS for large-scale WSNs. Thus MTPS aims at improving the overall performance on energy efficiency and tracking performance using sleep scheduling.

The efficiency of MTPS is evaluated with simulation-based experiments. The simulation-based experimental studies shows that compared to Probability based sleep scheduling protocol (PPSS) [6], MTPS introduces an improvement of 25% - 50% on energy efficiency and target prediction.

This paper makes the following contributions:

- Design of a target prediction method based on probability[6]. Multiple Target Prediction and Sleep Scheduling (MTPS) precisely selects the nodes to awaken and reduces their active time also detects multiple targets.
- The proposed distributed algorithms of MTPS, which run on individual nodes, make MTPS scalable for large-scale WSNs.
- MTPS make the boundary nodes in active mode which helps to detect the entry of multiple targets.

2. Related Works

Energy efficiency is a critical feature of wireless sensor networks (WSNs), because sensor nodes run on batteries that are generally difficult to recharge once deployed [1]. Many approaches have been explored to enhance energy efficiency, such as sleep scheduling [7], coverage or topology optimizing [8], and radio transmission power control [9].

For target tracking-one of the most important WSN application types- energy efficiency needs to be considered in various forms and shapes, such as idle listening[10], trajectory estimation[10], and data propagation. Target tracking was studied as a series of continuous localization operations in many existing efforts [11], [12]. The 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. Particle filtering-Two particle filters , Completely distributed particle filter and Vector space based Particle Filter (i.e., VPF and CDPF) to improve the energy efficiency and facilitate the application of particle filters in sensor networks. VPF reduces the problem size of particle filtering by reducing the number of particles, and CDPF provides a completely distributed implementation of PFs. Both methods enhance energy efficiency significantly, by simplifying the computation and reducing the communication cost respectively.[13] Although sleep scheduling and target tracking have been well studied in the past, only a few efforts [14], [9] investigated them in an integrated manner. In [14], 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 [9], 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. If it is able to predict the probability by which the mobile target moves ,we can make the sensors along that direction to be active and putting rest of the sensors in sleep mode, thus can save more energy in WSNs. Despite the energy conservation, forcing nodes to sleep will probably result in target missing, thereby impairing the tracking performance. As one of the sleep scheduling approaches, proactive wake-up has been studied for awakening nodes proactively to prepare for the approaching target. However, most existing reports about proactive wake-up simply awaken all the neighbor nodes in the area that 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 only and can save comparatively more energy than the existing work, this can be achieved by creating a Local Active Environment and sleep scheduling. for eg., a wireless sensor which detects the mobile target will create a Local active environment, i.e., by awakening the neighbor sensors or next hop sensors and sensors in the routing table to send the information about the target to the base station, putting the remaining sensors to sleep mode using method called probability based prediction and sleep scheduling (PPSS). PPSS not only predicts a target’s next location, but also describes the probabilities with which it moves along all the directions. [6]. By this way the sensors that are close to mobile target will predict the direction in which mobile target moves and creates a Local Active Environment dynamically each time the target moves. Thus the energy efficiency is increased to a great extent compared to the Existing works which maximizes the network lifetime.[6].

3. Design Overview

This section introduces system models and assumptions, and overview the design of MTPS mechanism.

3.1. System Models and Assumptions

Consider a homogeneous, static sensor network in a two-dimensional plane, with sensor nodes randomly and uniformly deployed. There is a single sink node, to which all the nodes report their detection and assume that every node is aware of its own location , and is able to determine a target's position at detection (either by sensing or by calculating., [15]). In addition we assume that the sensor nodes are locally time synchronized using the RBS protocol .

3.2. Proposed MTPS Method

The existing PPSS method detects single target only. In order to detect the multiple number of mobile targets we have to enhance the PPSS concept of local active environment and sleep scheduling with boundary selection nodes ie, in the existing concept when a mobile target enters the field region or surveillance region the first sensor that detects the mobile target will create local active environment putting the remaining sensors to sleep mode, the limitation here is if another mobile target enters the surveillance region the sensors that are in sleep mode cannot detect the target , to overcome this we are synchronizing this local active environment with boundary selection nodes in which the sensors along the boundary of the field region are allowed to remain active, since the mobile target can enter the field region only through the boundaries ,By activating the boundary selective nodes we can detect multiple number of mobile targets entering the surveillance region from different direction and once the mobile target is detected it will be informed to the base station. MTPS method is design to detect and track multiple targets by activating the sensor nodes along the boundaries.

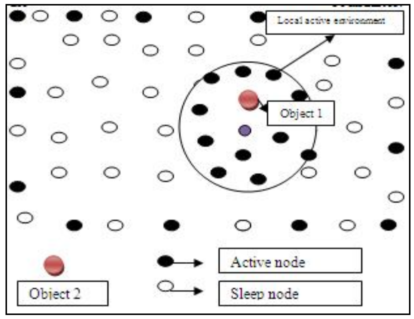

Figure 1: Proposed multiple target detection Architecture

3.2.1. Target Prediction and Local Active Environment

All the sensors communicate with each other and update the routing information. Once object is detected creates a Local Active environment predicts the Target movement and sends the information to base station Typical techniques for target prediction include kinematics-based prediction [9], dynamics based prediction [16], and Bayesian estimation methods [17]. 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 .The target prediction scheme consists of the Current state calculation ,kinematics – based prediction and probability based prediction. In fact, most of past work about target prediction uses kinematics rules as the foundation, even for those that use Bayesian estimation methods. Minimal contour tracking Algorithm (MCTA) reduces energy consumption for tracking mobile targets in wireless sensor networks by letting a minimum number of sensor nodes participate in communication. MCTA algorithm presented in [9] is just an example of kinematics-based prediction. Another example of the kinematics-based prediction is the Prediction-based Energy Saving scheme (PES). It only uses simple models to predict a specific location without considering the detailed moving probabilities.

In this paper probability based prediction is used . if we can able to predict the probability by which the Mobile target moves, make the sensors along that direction to be active and putting rest of the sensors in sleep mode and can save comparatively more energy in WSNs. This can be achieved by creating a Local Active Environment and sleep scheduling. for eg., a wireless sensor which detects the mobile target will create a Local active environment i.e., by awakening the neighbor sensors or next hop sensors and sensors in the routing table to send the information about the target to the base station, putting the remaining sensors to sleep mode. By this way the sensors that are close to mobile target will predict the direction in which mobile target moves and creates a Local Active Environment dynamically each time the target moves. Thus the energy efficiency is increased to great extent extend compared to the Existing works which maximizes the network lifetime.[6]

3.2.2. Sleep Scheduling

Once Target is detected an Awake region is created in the sensor network and based on the prediction results assigns Sleep scheduling to individual sensors at synchronized time. MTPS selects some of the neighbor nodes 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. An alarm node's responsibility here is to broadcast an alarm message on detecting a target. In fact an awake region is only a virtual concept. No functions are built upon this concept, except for the selection of awakened nodes. Fig 2 shows sleep scheduling based on target prediction

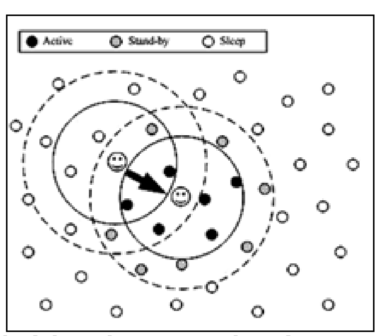

Figure 2: Scheduling sleep pattern based on Target prediction

3.2.3. Multiple Target Detection

Creating a local active environment with boundary selection nodes in which the selected nodes along the boundary of the field region are activated , thus the mobile target that arrives from different directions are detected, once it detects the moving object along the boundaries, it will start sending the information to the base station.

4. Performance Evaluation

This section presents the simulation environment. The simulation was conducted in an environment developed in network simulator, and the MTPS was compared to PPSS[6] and EFT(Energy Efficient Target Tracking) mechanism like TPSS(Target Prediction and Sleep Scheduling).

4.1. Simulation Setup

This study used ns-2 as the network simulator and conducted numerous simulations to evaluate the performance. All sensor nodes are randomly scattered with a uniform distribution. The location of the sink is stationary.

- Packet delivery ratio: The ratio of the number of delivered data packets to the destination. This illustrates the level of delivered data to the destination.

$$\text{Packet delivery ratio} = \frac{\sum \text{Number of packets received}}{\sum \text{Number of packets send}}$$

- Average energy consumption: measures the rate of energy consumption.
- Throughput: Means the rate of successful target prediction.

4.2. Simulation Results

4.2.1. Throughput

Fig.2 show the comparison three mechanism in terms of throughput Compared to existing TPSS and PPSS mechanism MTPS produces more throughput .Throughput means the rate of successful target prediction. As the time increases throughput also increases. The graph shows that the proposed method achieves better throughput than the existing approaches.

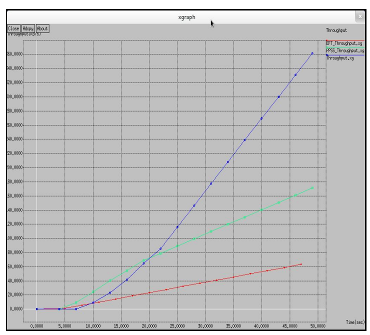

Figure 3: Comparison of MTPS with TPSS And PPSS mechanism in terms of throughput

4.2.2. Packet Delivery Ratio

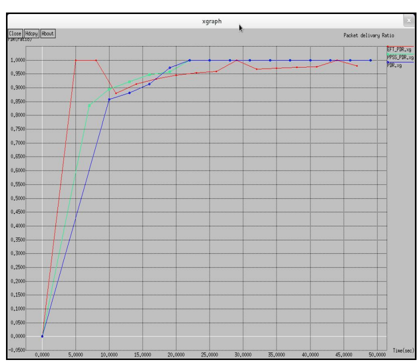

Figure 4: Comparison of MTPS with TPSS and PPSS in terms Packet Delivery Ratio

Fig. 4. Shows the Comparison of MTPS with TPSS and PPSS in terms Packet Delivery Ratio. Packet Delivery Ratio defines the level of delivered data to the destination. The graph shows that the proposed method achieves better packet delivery ratio than the existing approaches.

4.2.3. Average Energy Consumption

Fig.4 provides a comparison of the energy consumption results of existing and the proposed methods. From the figure it is clear that the proposed MTPS mechanism consumes less energy. As the proposed method reduces the number of awaken nodes, it consumes less energy compared to the existing approaches. Thus, the lifetime of the sensor network will increase.

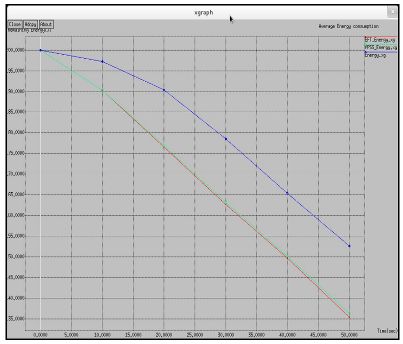

Figure 5: Comparison of PPSS, EFT and MTPS in terms energy consumption

5.Conclusion

This paper has proposed a multiple target prediction and sleep scheduling mechanism to provide energy-efficient multiple target tracking in wireless sensor networks. Here a local active environment with Boundary Selection node in which the sensors along the boundary of the field region is activated, thus the mobile targets that come from different directions can be detected. Once it detects the Moving object along the boundaries, it will start sending the information about the mobile target to the base station, This approach is a solution for solving the problem in the existing PPSS mechanism that can able to detect only a single target, so we are enhancing the proposed concept to detect multiple target along with improved power efficiency. Simulation results confirm that the proposed concept achieves a better packet delivery ratio, energy consumption, and throughput than the PPSS mechanism.

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