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Optimization of Wireless Sensor Networks using PPSS Algorithm

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ABSTRACT—In the development of various large-scale sensor systems, a particularly challenging problem is how to dynamically organize the sensors into a wireless communication network and route sensed information from the field sensors to a target system. The prime motivation of our work is to balance the inherent trade-off between the resource consumption and the accuracy of the target tracking in wireless sensor networks. Toward this objective, the study goes through a new energy-efficient dynamic optimization-based sleep scheduling and target prediction technique for large-scale sensor networks. We present a **probability-based prediction and optimization-based sleep scheduling protocol** (PPSS) to improve energy efficiency of proactive wake up. A cluster-based scheme is exploited for optimization-based sleep scheduling. At every sampling instant, only one cluster of sensors that located in the proximity of the target is activated, whereas the other sensors are inactive. To activate the most appropriate cluster, we propose a non myopic rule, which is based on not only the target state prediction but also its future tendency. Finally, the effectiveness of the proposed approach is evaluated and compared with the state-of-the-art protocols in terms of tracking accuracy, inter node communication, and computation complexity
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Index Terms—Energy efficiency, target prediction, sleep scheduling, target tracking, sensor networks.

In a large-scale sensor network, hundreds or thousands of tiny sensor nodes are randomly deployed into a monitoring field to gather data. The complexity of computation and communication increases with the number of active sensor nodes tracking the target. The amount of energy used in the network is proportional to the number of active sensor nodes. It is best for sensor nodes to be arranged into collaborative m groups. Group collaboration should be limited to a tracking area around the target so that the communication and computation will be independent of the size of the network. Multiple nodes surrounding the target may collaborate and gather information. The tracking accuracy and performance is limited to the information in those sensors. In a large-scale sensor network, it is important to locate the target with high accuracy while consuming the least amount of energy. Some of the existing studies have focused on energy efficient methods to track mobile targets. Our objective is to propose a simple routing metric that is composed of the energy expenditure and battery power of a node. Therefore, the cluster activation phase has a great importance not only in minimizing energy consumption but also improve the optimized tracking accuracy.

1. INTRODUCTION

A wireless sensor network is a collection of nodes ―sensors‖ organized into a cooperative network. The nodes communicate wirelessly and often self-organize after being deployed in an ad-hoc fashion.

It consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring etc…

The WSN is built of nodes from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

2. LITERATURE SURVEY

The tradeoffs involved in the energy-efficient localization and tracking of mobile targets by a wireless sensor network. This work focuses on building a framework for evaluating the fundamental performance of tracking strategies in which only a small portion of the network is activated at any point in time. We first compare naive network operation with random activation and selective activation. In these strategies the gains in energy-savings come at the expense of increased uncertainty in the location of the target [4], resulting in reduced quality of tracking. We show that selective activation with a good prediction algorithm is a dominating strategy that can yield orders-of-magnitude energy savings with negligible difference in tracking quality. We then consider duty-cycled activation and show that it offers a flexible and dynamic tradeoff between energy expenditure and tracking error when used in conjunction with selective activation.

There is an emerging trend towards the use of sophisticated wireless networks of unattended sensor devices for intelligence gathering and environmental monitoring. One \ canonical application of sensor networks that has received considerable attention in the literature is the tracking of a mobile target (point source) by the network. In a tracking scenario, information obtained from nodes far away from the region of activity is of little or no use. For a typical sensor network with a large number of nodes, a major portion of these falls in the above category. In addition, if the nodes are densely deployed information obtained from some sensors close to the region of activity might be redundant. An obvious way to save energy is to switch on only a subset of the sensor nodes. We discuss in this paper various possible activation strategies: [1] naive activation, randomized activation [3] selective activation based on trajectory prediction and [4] duty-cycled activation. In these sensor activation strategies, energy savings come at the expense of a reduction in the quality of tracking. In other words, relying on the information provided by a small subset of the sensor nodes results in an increased uncertainty in the sensed location of the mobile. In this paper we study the energy-quality tradeoffs involved by building a model to quantify both the energy expenditure and the quality of tracking. Also for a particular strategy, we study the impact of the following: a) deployed/activated density of sensors b) their sensing range c) capabilities of activated and un-activated nodes d) the target's mobility model.

Our efforts are not directed *per se* at proposing new techniques for mobile tracking. Rather the focus is on the evaluation and analysis of general strategies which may be incorporated into a real system. We start with a simple model for tracking and substantiate the intuition that it is possible to obtain orders of magnitude savings in energy while keeping the uncertainty within acceptable limits. We also discuss the extensions of the model to relate closely with real life scenarios. The results in this work are a first step in our attempt to understand the fundamental bounds on the the tracking quality that can be obtained under various energy constraints and sensor models.

Most existing work on sensor networks concentrates on finding efficient ways to forward data from the information source to the data centers, and not much work has been done on collecting local data and generating the data report. This paper studies this issue by proposing techniques to detect and track a mobile target. We introduce the concept of dynamic convoy tree-based collaboration, and formalize it as a multiple objective optimization problem which needs to find a convoy tree sequence with high tree coverage and low energy consumption. We propose an optimal solution which achieves 100% coverage and minimizes the energy consumption under certain ideal situations. Considering the real constraints of a sensor network [5][6], we propose several practical implementations: the conservative scheme and the prediction-based scheme for tree expansion and pruning; the sequential and the localized reconfiguration schemes for tree reconfiguration. Extensive experiments are conducted to compare the practical implementations and the optimal solution. The results show that the prediction-based scheme outperforms the conservative scheme and it can achieve similar coverage and energy consumption to the optimal solution.

The experiments also show that the localized reconfiguration scheme outperforms the sequential reconfiguration scheme when the node density is high, and the trend is reversed when the node density is low. Most existing researches in sensor networks, e.g., the directed diffusion, LEACH, and two-tier data dissemination (TTDD)[4], concentrate on finding efficient ways to forward the data report to the data center, and not much work has been done on how to detect the mobile target and generate robust and reliable reports in an energy efficient way. Recently, Chu et al. studied the problem of tracking a mobile target using an information-driven approach. However, their approach assumed that a single node close to a target can detect the status of the target, and did not consider the collaboration among nodes that can detect the target at the same time. Since sensor nodes deployed in current sensor networks do not have a large sensing distance, or a high level of sensing accuracy and node reliability, Cerpa et al suggested that multiple nodes surrounding the target should collaborate to make the collected information more complete, reliable, and accurate. However, no concrete algorithm was given.

A big challenge of implementing the DCTC framework is how to reconfigure the convoy tree in an energy efficient way as the target moves. To address this problem, we first formalize it as an optimization problem of finding a min-cost convoy tree sequence with high tree coverage, and give an optimal solution (o-DCTC)[5] based on dynamic programming. Considering the constraints of sensor networks, we propose some practical solutions. Specifically, we propose two tree expansion and pruning schemes: the conservative scheme and the prediction- based scheme; and two tree reconfiguration schemes: the sequential reconfiguration and the localized reconfiguration. We also evaluate the performance of the optimal solution and the practical implementations through extensive simulations. Based on the simulation results, when the same reconfiguration scheme is used,[12] the prediction-based scheme outperforms the conservative scheme and it can achieve a similar coverage and energy consumption to the optimal solution. When using the same scheme for tree expansion and pruning, the localized reconfiguration scheme outperforms the sequential reconfiguration scheme when the node density is high, and the trend is reversed when the node density is low.

Wireless sensor networks have inspired tremendous research interest in since the mid-1990s. Advancement in wireless communication and micro electromechanical systems (MEMSs) have enabled the development of low-cost, low power [5], multifunctional, tiny sensor nodes that can sense the environment, perform data processing, and communicate with each other untethered over short distances. A typical wireless sensor network consists of thousands of sensor nodes, deployed either randomly or according to some predefined statistical distribution, over a geographic region of interest. A sensor node by itself has severe resource constraints, such as low battery power, limited signal processing, limited computation and communication capabilities, and a small amount of memory;[7] hence it can sense only a limited portion of the environment. However, when a group of sensor nodes collaborate with each other, they can accomplish a much bigger task efficiently [13]. One of the primary advantages of deploying a wireless sensor network is its low deployment cost and freedom from requiring a messy wired communication backbone, which is often infeasible or economically inconvenient. Wireless sensor networks ensure a wide range of applications, starting from security surveillance in military and battlefields, monitoring previously unobserved environmental phenomena, smart homes and offices, improved healthcare, industrial diagnosis, and many more.

Optimal resource management and assuring reliable QoS are two of the most fundamental requirements in ad hoc wireless sensor networks. Sensor deployment strategies play a very important role in providing better QoS[17], which relates to the issue of how well each point in the sensing field is covered. However, due to severe resource constraints and hostile environmental conditions, it is nontrivial to design an efficient deployment strategy that would minimize cost, reduce computation, minimize node-to-node communication, and provide a high degree of area coverage, while at the same time maintaining a globally connected network is nontrivial.

Challenges also arise because topological information about a sensing field is rarely available and such information may change over time in the presence of obstacles. Many wireless sensor network applications require one to perform certain functions that can be measured in terms of area coverage. In these applications, it is necessary to define precise measures of efficient coverage that will impact overall system performance.

Historically, three types of coverage have been defined by Gage:

1. Blanket coverage — to achieve a static arrangement of sensor nodes that maximizes the detection rate of targets appearing in the sensing field

2. Barrier coverage — to achieve a static arrangement of sensor nodes that minimizes the probability of undetected penetration through the barrier

3. Sweep coverage — to move a number of sensor nodes across a sensing field, such that it addresses a specified balance between maximizing the detection rate and minimizing the number of missed detections per unit area

Wireless Sensor Networks (WSNs) provide a valuable capability to autonomously monitor remote activities. Their limited resources challenge WSN medium access control (MAC) layer designers to adequately support network services while conserving limited battery power. This paper presents an energy adaptive WSN MAC protocol[6], Gateway MAC (GMAC), which implements a new cluster-centric paradigm to effectively distribute cluster energy resources and extend network lifetime. G-MAC's centralized cluster management function offers significant energy savings by leveraging the advantages of both contention and contention-free protocols. A centralized gateway node collects all transmission requirements during a contention period and then schedules their distributions during a reservation-based, contention-free period. With minimal overhead, the gateway duties are efficiently rotated based upon available resources to distribute the increased network management energy requirements among all of the nodes.

The G-MAC protocol's innovative architecture is motivated by the necessity for resource-challenged WSN mote sensor platforms to minimize the time radios spend in both the idle and the receive modes. Research shows that wireless platform transceivers expend a significant amount of energy receiving on an idle channel, and many of the WSN mote platform radios expend more energy in receive than in transmit mode. G-MAC provides effective network control mechanisms to maximize sleep durations[7], minimize idle listening, and limit the amount of cluster control traffic overhead. G-MAC dynamically rotates point coordination duties among all the nodes to distribute the management energy costs, to allow other nodes to sleep longer, and to extend the network's lifetime.

Energy management in sensor networks is crucial to prolong the network lifetime. Though existing sleep scheduling algorithms save energy, they lead to a large increase in end-to-end latency. We propose a new Sleep schedule (Q-MAC) [15] for Query based sensor networks that provide minimum end-to-end latency with energy efficient data transmission. Whenever there is no query, the radios of the nodes sleep more using a static schedule. Whenever a query is initiated, the sleep schedule is changed dynamically.

Based on the destination's location and packet transmission time, we predict the data arrival time and retain the radio of a particular node, which has forwarded the query packet, in the active state until the data packets are forwarded. Since our dynamic schedule alters the active period of the intermediate nodes in advance by predicting the packet arrival time, data is transmitted to the sink with low end-to-end latency. The objectives of our protocol are to [18] minimize the end-to-end latency by alerting the intermediate nodes in advance using the dynamic schedule reduce energy consumption by activating the neighbor nodes only when packets (query and data) are transmitted. Simulation results show that Q-MAC performs better than S-MAC by reducing the latency up to 80% with minimum energy consumption.

In query based sensor networks, the sensors report their results in response to an explicit request from the user. Users input the queries at the sink that describes the data they wish to collect. In a home network, user may send a query for eg. "Whether the gas tank should be refilled or the lights are 'on'". Based on the query for a particular detail, data can be collected from the corresponding subset of nodes in the complete network. The flow of data packets from the sensors to sink can be classified as broadcast, unicast or multicast based on the queries.

3. EXISTING SYSTEM

- The sensor's wireless communication ability facilitates distributed sensing and thus, makes WSNs distributed in nature.
- However, distributed computing algorithms demand more inter-node communication.
- It consumes the more power from the battery.

4.PROPOSED SYSTEM

Our proposed work, present a probability-based target prediction and sleep scheduling protocol (PPSS) 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 kinematics rules and theory of probability, PSS not only predicts a target's next location, but also describes the probabilities with which it moves along all the directions.

4.1 Advantages

- The battery life can be increased.
- It can accommodate new devices at any time
- It can be accessed through a centralized monitor.
- The distance between the two sensor node can be calculated using received signal strength indicator (RSSI)

5. PPSS ROUTING PROTOCOL

PPSS 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. We utilize two approaches to reduce the energy consumption during this proactive wake-up process:

1. Reduce the number of awakened nodes.
2. Schedule their sleep pattern to shorten the active time.

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.

5.1 Advantages

- 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.
- PPSS improves the energy efficiency with an acceptable loss on the tracking performance

6. ARCHITECTURE

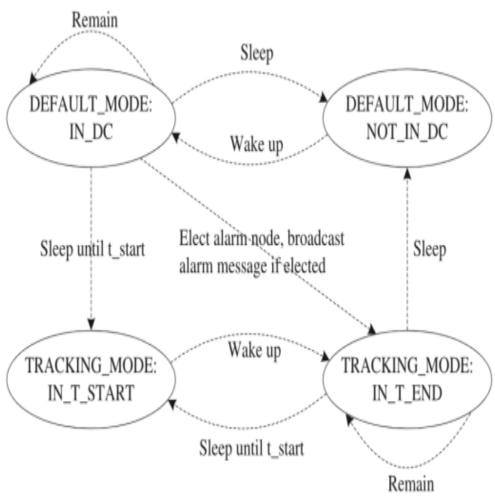

Fig.1. Finite State Machine

In the protocol core module of PPSS, we designed an internal finite state machine consisting of four states as shown in Figure

1. Default mode/IN_DC: active in the default duty cycling mode;
2. Default mode/NOT_IN_DC: sleeping in the default duty cycling mode;
3. Tracking mode/IN_T_START: the sleep pattern is scheduled to sleep until tstart; and

4. Tracking mode/IN_T_END: the sleep pattern is scheduled to keep active until tend.

For each protocol under testing, the experiment was repeated five times. Unlike the simulation, we did the implementation-based

implementation-based experiment under a single deployment only. This is because that compared to the simulation, changing network configuration (e.g., node density) is more difficult in the implementation. For example, the transmission power level of motes' RF radio can only be configured as a series of discrete integer values, i.e., the communication radius cannot be configured to any number. Therefore, simply redeploying nodes in a different density, even in the same topology, may introduce a different connection status of nodes. Comparing the experimental results obtained from these different connection status will be less helpful.

As previously discussed, we evaluate EDP for tracking performance in the implementation, instead of AD used in the simulation.

7. RESULT

Nodes used for simulation is generated in the network animator

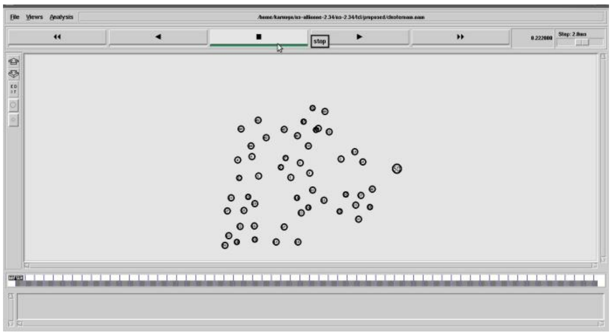

Fig.2. Generation of nodes

This graph shows the performance analysis of end to end delay between sleep-wakeup and ppss

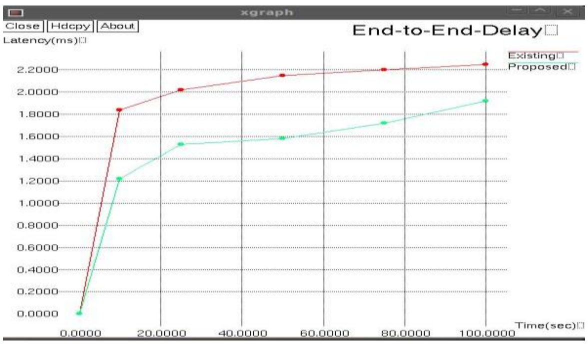

Fig.3. End to End Delay

8. CONCLUSION

Sensor Networks hold a lot of promise in applications where gathering sensing information in remote locations is required. Many factors can influence the energy consumption in wireless sensor networks. Their energy-constrained nature necessitates one to look at more energy efficient design and operation. The concept of sleep scheduling Procedure seems to be very common and effective. Care must be taken to make sure more energy is not consumed by the process of putting a node to sleep and waking it up than would be consumed by leaving the node awake during the time period. The observation is that nodes must sleep most of the time in order to achieve multi-year battery life.

For further study, local data processing and data fusion algorithm, will be added into the designed sensor node for reducing the power consumptions.

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