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Large-scale mobile phenomena monitoring with energy-efficiency in wireless sensor networks ☆

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ABSTRACT

In intelligent sensing systems with wireless sensor nodes, energy efficiency is one of the most important research issues. In this paper, we focus on energy efficiency for monitoring a large-scale object such as gas and chemical material diffusion and spread of radioactive contamination and wild fire. For monitoring of a large-scale object, a great number of sensor nodes might be participated in object detection and tracking. Thus, general functions of such huge quantities of sensor nodes like sensing and message exchanging could be sources of energy exhaustion and shorten network lifetime. Therefore, we firstly adopt the sleep/wakeup state switching to restrict active sensor nodes for object tracking. That is, since an object dynamically alter its own shape by wind or geographical condition, we support that only the sensor nodes around the current boundary of the changeable object actively function while the others are on the sleep mode. In addition, we also propose that active nodes are steadily held as a small set of sensor nodes collaborated for detecting and tracking of the current boundary. A variety of computational simulations proves that our proposal is able to provide high energy efficiency as well as to trace accurate boundary shapes.

1. Introduction

Advances in wireless communication and micro-sensor technologies enable to deploy large-scale intelligent sensing systems. Intelligent sensing systems have supported a wide variety of monitoring applications from industrial complexes to smart cities. Event detection and tracking to trace the roaming path of a target object are one of the most typical monitoring applications. Since sensor nodes usually rely on their limited and unattended battery, it is highly important to achieve energy efficiency and thus prolong system lifetime [1–3]. For energy efficiency, sleep/wakeup state switching of sensor nodes is widely used in object tracking studies. It makes only a small set of sensor nodes participate in tracking procedures while the other sensor nodes remain in the sleep mode for energy saving until an object approaches to them. In fact, up to date there are numerous energy-efficient object tracking researches [2–20] using their unique sleep state switching algorithms, and almost researches mainly aim to track small individual objects such as human beings, animals, vehicles, and so on.

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Recently, the research on monitoring for large-scale objects, denoted by continuous objects, such as gas, wildfire, mud flows, bio-chemical material, oil spill, radioactive contamination, etc., is of increasing concern due to dire calamities happening lately like Japan's nuclear disaster and Greek forest fires. Previous studies on continuous object tracking [21–27] focus on monitoring the current boundary of a large-scale object rather than detecting the entire diffused area of it. Even though they merely track the current boundary, a large number of sensor nodes may join in sensing and communicating to determine the current boundary essentially. Accordingly, the studies have proposed their own cost reduction mechanisms to control communicating based on static/dynamic clustering or representative selection. In other words, they do not adopt the state switching paradigm for high energy efficiency in the case of individual object monitoring.

In order to achieve high energy efficiency and prolong the lifetime of energy-constrained sensor systems, sleep/wakeup state switching by which only small sets of sensor nodes on boundaries are activated should be taken into account. Since a continuous object diffuses widely and changes its shape dynamically, previous state switching methods proposed for an individual object considered as a movable point cannot be applied. Accordingly, a novel stat switching method should be designed for continuous object. In addition, although the novel state switching method is adopted to sensor systems, it should be able to provide adequate boundary tracking accuracy as well as be based on light control signaling. This means that we also try to beat previous sensing and communicating mechanisms to detect boundaries.

Therefore, we propose a energy-efficient and accurate monitoring scheme for a continuous object in this paper. Fig. 1 shows the operation and architecture of the proposed scheme. We first introduce a well-balanced boundary node selection algorithm for low control overhead and high accuracy. This is because detection of a boundary of a continuous object, i.e., the current boundary at this moment, would be the basis to determine the next boundary, i.e., the current boundary at the next time. Then, we are able to start explaining our sleep/wakeup state switching algorithm, named a boundary zone based state switching that offer successive activation of a small set of sensor nodes only around boundaries of a continuous object along its diffusion.

For providing high boundary detection accuracy and light control signaling, our boundary detection algorithm focuses on selection of boundary nodes only closest to an actual boundary of a continuous object. Since previous boundary detection schemes merely rely on communication range to select boundary nodes, they select all the sensor nodes within communication range from a boundary as boundary nodes. It means that a boundary shape drawn from too many boundary nodes selected irregularly might not be correct and node density could influence the boundary shape. On the other hand, our scheme evenly chooses the closest sensor nodes to the current boundary by location-aware boundary node selection and explicit representative arrangement among boundary nodes. Due to this

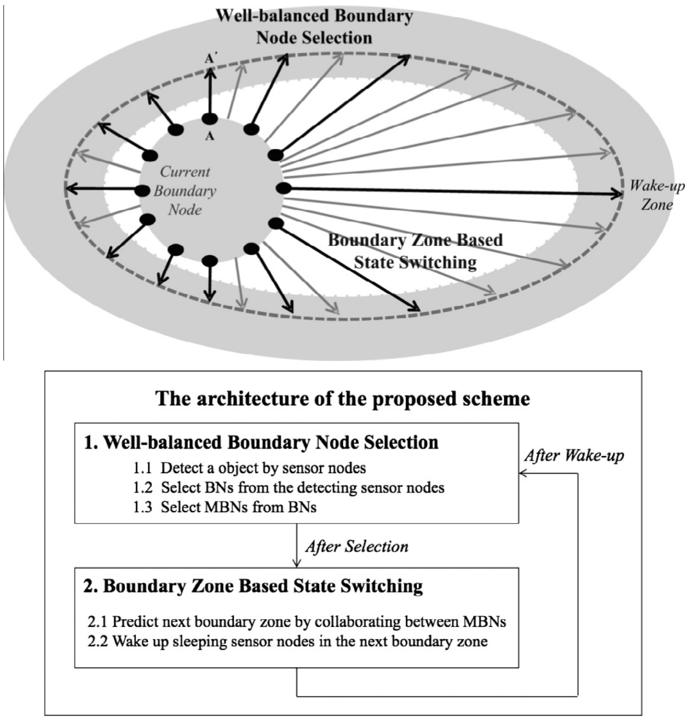

Fig. 1. The operation and architecture of the proposed energy-efficient and accurate monitoring scheme.