Analysis of Distributed Algorithms with Adjustable Sensing Ranges and Placement Strategies for Improving the Lifetime of Heterogeneous WSNs

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Abstract—This paper contemplates on distributed algorithms for scheduling and adjustable range with different deployment strategies. The problem of lifetime enhancement of wireless sensor networks is dealt with the adjustment of transmission or sensing range of the sensor nodes with various sensor placement strategies. The analysis includes maximization of lifetime using heterogeneous deterministic energy efficient protocol with adjustable sensing range (HADEEPS) and heterogeneous load balancing protocol with adjustable sensing range (HALBPS) for different mode of sensors arrangement in a field. The lifetime of a network is highly dependent on the nodes arrangement that in turn affects energy consumption in WSNs.

Keywords: Sensing Range, Energy Efficiency, Lifetime, HADEEPS, Heterogeneous WSNs, Deployment.

I. INTRODUCTION

Wireless sensor networks (WSN) consist of tiny devices equipped with sensing hardware, processing, transceivers and storage resources and batteries. However, wireless sensor networks are deployed in open and indiscreet environment. The collected information is sent through wireless links using multiple hops to a sink or controller, which can use it locally or further, transmits to other networks through a gateway. A node in sensor network consists of CPU, memory, battery, and transceiver. The CPU performs data processing, memory stores data, battery provides energy, and the transceiver receives and sends data. The nodes can be stationary or mobile, location-aware or location-unaware, homogeneous or heterogeneous. The nodes in sensor networks can be individually addressable or group-addressable in which the aggregated data is communicated. There are two types of WSN first, homogeneous WSN and second, heterogeneous WSN. We have chosen heterogeneous WSN for our survey because there are following advantages of heterogeneous WSN:

1. Prolonging network lifetime
2. Improving reliability of data transmission.
3. Decreasing latency of data transportation.

Early study on wireless sensor networks mainly focused on technologies based on the homogeneous wireless sensor network in which all nodes have same system resource. However, heterogeneous wireless sensor network is becoming more and more popular recently. One of the important issues in sensor networks is power supply that is constrained by battery size, which normally cannot be enhanced. Thus, optimal use of the sensor energy has a great impact on the network lifetime [1]. This can be done either scheduling the sensor nodes to alternate between active and sleep mode or adjusting their sensing range [3]. Power saving mechanism can be classified into two general ways: adjusting the transmission or sensing range and scheduling the sensor nodes to alternate between active and sleep mode [4, 5, 6 and 7].

A. Heterogeneous WSN

A heterogeneous wireless sensor network (WSN) consists of several different types of sensor nodes (SNs). It supports various applications like event detection, localization, and monitoring a target. In a network with thousands of nodes, this is a very complex task. A heterogeneous node consists of complex processor and memory in order to perform sophisticated tasks compared to a normal node. A heterogeneous node has high bandwidth and long distant transceiver for proving reliable transmission [8]. A heterogeneous network consists of three types of nodes depending on their energy levels and we may name them as normal, advance, and super nodes [9,10].
B. Comparison between Heterogeneous WSN and Homogeneous WSN

In homogeneous networks, all the sensor nodes are indistinguishable in terms of battery energy and hardware complexity. In heterogeneous network, all nodes in the network share the same functionality where as in heterogeneous network all the nodes treated differently. Heterogeneous sensors more realistic in terms of their sensing and communication capabilities in order to improve network reliability and extend network lifetime [14]. Also, an even if the sensor is equipped with the identical hardware but differs in sensing and communication models. During manufacturing stage, two sensors may not use the same platform and similar physical properties. This constraint focuses on heterogeneity at the designing stage, when sensors are intended to have non identical capabilities to meet the specific needs of sensing applications. In the heterogeneous wireless sensor network, the average energy utilization for forwarding a packet from nodes to the sink will be much less than the energy consumed in homogeneous sensor network [15].

II DISTRIBUTED ALGORITHMS

A. HALBPS

It relates to adjustable sensing range [16], deployment strategy and node heterogeneity. The HALBP is used to keep as many sensors alive as possible using load balancing method and try to let them die simultaneously. Here aliveness is different from activeness. Initially, each sensor broadcast its battery level and covered targets to its neighbors. It then stays in the deciding state with its maximum sensing range for finding sensor cover schedules. Each sensor will change its state as per following rules:

- When a sensor is in the deciding state with range r, it will change its state to -
  - Active state with sensing range r, if there is a target with given range r which is not covered by any other active or deciding sensors.
  - Deciding State, if all covered targets at range r are covered by either active or deciding sensors with a prominent monitoring time. In that case, it decreases its sensing range to the next furthest away target.
  - Idle state, if the sensor decreases its transmission range to zero.

B. HADEEPS

First we select the sink and hill targets. Sink targets [17] where lifetime of sensor for monitoring target is poorer. The hill target is identified by the energy accumulated from different sensors that can monitor it and has maximum energy. There is one sensor-in-charge for each target besides that sensor monitoring it. The maximum lifetime of a target is defined in terms of sensor lifetime. It is the sum of the sensors’ lifetime, which covers that target. To determine the in-charge sensor of a target, following rules should be followed:

- For the sink target, the sensor covering it with the highest lifetime and the sink being the poorest target is considered as the in-charge of that target.
- For the hill target, among the sensors covering the hill and the poorest target has the largest lifetime. Then that sensor is considered as the in-charge of that target. If there are several such sensors, the richest one is the in-charge. The in-charge sensor remains active and others are in sleep mode.

In order to find the sensor cover schedule, each sensor primarily send its battery and targets covered to its neighboring sensors in its range and then it stays in the deciding state with its maximum sensing range. The sensor in deciding state with sensing given range r, it changes its state to:

- Active state whenever the sensor with sensing range r and there is a farthest away target at range less than or equal to r which is not covered by any other active or deciding sensors.
- Idle state, whenever the sensor, not in-charge of any target except those earlier covered by the active sensors, switches itself to idle state. The sensors make decision become active or idle state and stay in that state for a specified period of time, called trundle time. When the energy of an active sensor goes below a threshold, it informs neighboring sensors and then goes to the deciding state with its maximum sensing range. A network will not succeed if there is a target which is not covered by any sensors.

In HADEEPS efforts are made to minimize the energy consumption for the sensor which has low energy and to maximize the energy of high energy sensors. Each sensor decides which is to be the head node by using the maximum lifetime of sensors. After this decision has been made, each sensor decides to get active with range or nodes can also decide to sleep. This process will come to halt when all the sensors takes their decisions.
The lifetime of a network is highly dependent on the nodes arrangement that in turn influence energy consumption in WSNs. There are several arrangements, but the most commonly used are triangle, square, and hexagonal in 2-dimensional region [11-13]. They are generally deployed manually by setting up the nodes in predefined locations to analyze for minimum energy consumption and hence the maximum lifetime of a WSN. A sensor network deployment are generally divided into two groups a dense deployment and a sparse deployment. A sparse deployment would have fewer nodes while a dense deployment has a high number of sensor nodes in the given field of interest. The dense deployment technique is used in circumstances where it is very important for every event to be detected or when it is important to have multiple sensors cover an area. When the costs of the sensors make a dense deployment prohibitive or to achieve maximum coverage using the bare minimum number of sensors the sparse deployments can be used. Initially it is assumed that the sensor nodes are stationary i.e. they stay in the same place where they deployed. New sensor nodes have the ability to rearrange their location after deployment, they are not at a halt and these are known as mobile nodes. [18] .Deployment of sensor nodes in triangular, square, and hexagonal tiles are as follows.

A. Triangle Deployment:
In this arrangement, the sensors are placed at each corner of a unilateral triangle. Each internal node shares 6 triangles at any point. We represent the area of a triangle in terms of the area of the exterior circle. The radius of the exterior circle \( d = \sqrt{r} \), where \( r \) denotes the side length of the unilateral triangle. The area of the network consisting of \( N \) nodes is \( N \sqrt{r^2} = N \sqrt{d^2} \)

![Fig 1.1 Triangular arrangements](image)

B. Square Deployment:
In this deployment, the sensors are placed at each corner of the square. The area covered by the network consisting of \( N \) nodes is given by \( 2Nd^2 \), where \( d \) is the radius of exterior circle.

![Fig 1.2 Square arrangements](image)

C. Hexagon Deployment:
A hexagon is a collection of six unilateral triangles. Each hexagon has 6 corners at which a sensor is deployed. The total area covered by \( N \) nodes is given by \( \sqrt{2} \)

![Fig 1.3 Hexagonal arrangements](image)
The sensors will be deployed unattended and in large numbers, so that it will be difficult to change or recharge batteries in the sensors. Thus, optimal use of the sensor energy has a great impact on the network lifetime. In this paper, the network lifetime has been improved by incorporating heterogeneity in the sensor nodes. Various techniques under adjustable sensing approach have been discussed to improve network life time, deployment cost and stability. We throw a light on HADEEPS and HALBPS approach to enhance the sensor network lifetime with different sensor arrangements. The discussion reveals as density of sensors increases the network lifetime also increases and maximum lifetime of network depends on sum of sensor lifetime.

REFERENCES

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