A Node Scheduling Algorithm in Duty-Cycled Wireless Sensor Networks

Nga Dao Thi*· Rumpa Dasgupta*· Yoon Seokhoon*

*University of Ulsan

E-mail : daothinga.mta@gmail.com, rumpa_0504032@yahoo.com, seokhoonyoon@ulsan.ac.kr

ABSTRACT

In wireless sensor networks (WSNs), due to the very low data rate, the sleeping schedule is usually used to save consumed energy and prolong the lifetime of nodes. However, duty-cycled approach can cause a high end-to-end (E2E) delay. In this paper, we study a node scheduling algorithm in WSNs such that E2E delay meets bounded delay with a given probability. We have applied the probability theory to spot the relationship between E2E delay and node interval. Simulation result illustrates that we can create the network to achieve given delay with prior probability and high energy use efficient as well.

Key words

Wireless sensor network, Duty cycling, Energy efficiency

I. Introduction

Wireless sensor network (WSN) has been widely studied and developed in the variety of areas, such as home monitoring, target detection, health tele-monitoring, and so forth [1]. Although WSN is one type of ad hoc network, but it has limitation of power, computer capacities, and memories. While designing a wireless sensor network, we have to balance two vital requirements, end-to-end delay (E2E) and energy consumption. Sleep/awake schedule is an useful solution to reduce wasted energy since the consumed energy in the idle period is equivalent to energy loss during communication time [2]. However, duty cycling has several drawbacks, that is, degrading E2E delay performance, more control messages exchanged for neighboring nodes, MAC layer handshaking, and big challenges to handle network dynamics [2]. The first weakness becomes more serious in case of applications which require strict delay. We are aware of increasing node interval will lead to higher E2E delay to the data packet. Although how to achieve bounded delay in duty cycled WSN has attracted a lot of attention, the exact relationship between node schedule and E2E delay has not been exposed completely. This limitation can challenge the design of WSN and also the duty cycling. To aim to solve E2E delay limit, there are several solutions in this area. For example, Kim *et al.* [3] tried to maximize the network lifetime while meeting a given E2E delay bound. By repeatedly disseminating nodes' wakeup probability and collecting feedbacks, the sink tunes nodes' wakeup probability until it meets the delay limit. This algorithm will take $O(N)$ for converging, where N is network size. Unlike to this approach, we propose a algorithm of node scheduling based on probability theory to solve with the issue of meeting delay bound in the more efficient way.

II. Network Model

First of all, we will model the network under study. We assume that sensors are deployed in the circle area with radius $R1$ and sink node at the center and divided into a number of groups based on the distance from the nodes to the sink. Figure 1 illustrates how to classify the nodes into groups, where symbol R represents transmission range of a sensor, variable c the distance between two neighbor groups, and variable k is the number of group in the network. We define that a node belongs to group i if it is placed in the area which is outside circle with radius $R(i-1)$ and inside circle with radius $R+c*i$. For example, group 2 is the area which is outside circle with radius $R+c$ and inside circle $R+2c$.

The value of c and k can be variables; however there is a relationship between them:

$$k = \left\lceil \frac{R_1 - R}{c} \right\rceil \quad (1)$$

We can realize that while increasing the value of c, the number of groups declines and vice verse. Choosing the value of c will affect the E2E delay that is shown in section III.

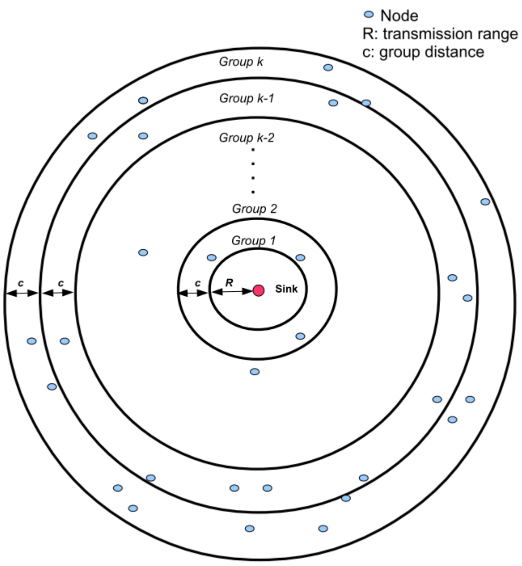

Figure 1: node deployment in WSN

III. Node Scheduling and Data Routing

We apply the sleep/wakeup technique to the network, thus each sensor is only active in wake up period and sleep for the rest of node interval. In WSN, the energy losses while communicating is the same as being idle. Therefore, to prolong the network lifetime, we should turn off the sensors' communication unit as long as possible. However, sleeping for a such long period can definitely cause high E2E delay. This limitation is a big barrier in several applications that require quite low E2E delay.

After modeling the network, we propose the way of transmitting packet in the sensor network. If a node in group i have packet to transmit, it will forward the packet to the first node that has been active among all neighbor nodes in the closer group. To guarantee communicating between two nodes in the neighbor groups, the value of c should not exceed the transmission range and we need to have the sufficient value of node density. Each node can maintain the schedule of its neighbor nodes, thus it can easily find the next hop to forward the data. At the beginning, sensors need to exchange the their node intervals, thus neighbor nodes will create a table that stores neighbor nodes' information. Whenever this kind of information changes, sensors have to notice to their neighbors to update the table. This requirement can lead to loose synchronization in the network. To avoid using synchronization, sensors can broadcast their schedule frequently. Then, if a node need to transmit packet, it has to be active and wait until the next hop active. However, broadcasting schedule can actually make more traffic, and then probably more collision in the network.

IV. E2E Delay Calculation

In this section, we propose the method to calculate E2E delay in the network. According to the packet transmission method which we mentioned before, we can estimate the E2E delay for a packet of node in group m. Firstly, we denote that Y_j is referred to one-hop delay of group j, i.e, the time for packet transmission from group j to group $j-1$. Thus, E2E delay (denoted Y) can be evaluated below:

$$Y = Y_m + Y_{m-1} + \ldots + Y_2 + Y_1 \quad (2)$$

Notice that the node in the circle region with radius R, centre sink can transmit packet immediately because the sink is always active. From equation (2), if we can calculate one-hop delay, we can calculate the E2E delay.

References

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