Power of a Defer Timer for the design of broadcasting protocol in Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) have merged to become one of the most promising applications of wireless ad hoc networks. A defer timer has been used in some of existing network protocols to solve a set of problems in WSNs. We first investigate the use of a defer timer to fully take the advantage of it in WSNs. We demonstrate that by properly setting up the defer timers, many difficult issues in sensor networks, such as power limitation, the broadcast storm problem, and the construction of the virtual backbone, can be easily tackled with only the help of simple localized information at each node.

In this paper, we present the power of a defer timer in the design of dominating set construction protocol for broadcasting. The ns 2 computer simulations are carried out for performance study.

Key Words: defer timer, wireless sensor network, broadcasting, connected dominating set, virtual backbone, energy

1. Introduction

In any type of network, broadcasting is the most fundamental service. In a broadcast, a packet generated by the source station needs to reach all the other stations in the network. The easiest implementation of a message broadcast is flooding, where each station retransmits a broadcast packet the first time it receives it. The main problem with flooding is that when it is adopted in WSNs, it typically causes an excessive number of retransmissions. This can result in high energy consumption, packet collisions and channel contention and is referred to in the literature as the broadcast storm problem [1].

Hence, the design of an efficient broadcast protocol to provide more reliable message broadcasts with fewer retransmissions is an important issue in WSNs.

To minimize the number of retransmissions for a broadcast, one promising approach is the Connected Dominating Set based (CDS-based) broadcast protocols [3] - [6]. In these protocols, a connected dominating set for the given network topology is first computed distributively. When a station generates a broadcast packet, the packet is propagated through stations in CDS using simple flooding. According to the definition of the dominating set, each station is either in the dominating set or is a neighbor of a station in the dominating set. Hence, as long as all the stations in the CDS transmit the broadcast packet, all the stations in the network will receive it. By allowing only stations in the CDS of the given network to retransmit the broadcast, CDS-based broadcast protocols reduce the energy consumption, message collision, and channel

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2. Existing defer timer based protocols

The concept of defer timer has been used in both theoretical and realistic network protocols. In the end-to-end communication protocols, the (defer) timer is used to guarantee the safe delivery of the packet and is normally set to be a constant [6]. In the design of many media access control protocols, such as IEEE 802.3 Ethernet [7] and IEEE 802.11b wireless LAN [8], the defer timer (called back-off timer) is used to avoid packet collisions and is set to be a random number (within an exponentially growing range). These protocols care very little on the order of events, so the value of timer is not based on a particular criterion. In this paper, we focus on the problems in WSNs with the following characteristics:

- A series of decisions is involved in solving the problem;
- The order of decision makings has great impact on the performance of the protocol;
- Although finding the solution of the problem requires global information, the localized information can be a good approximation for decision making;

If a research problem in ad hoc and sensor networks has these characteristics, we can set up a timer by a very simple formula in the protocol to manipulate the order of the decision makings so that the performance of the protocol improves significantly.

3. Timer based Broadcasting Protocol

A dominating set is a subset of nodes in a graph such that each node not in the subset has at least one direct neighbor that belongs to the subset. If the nodes in the dominating set form a connected graph, the set is called a connected dominating set. In ad hoc and sensor networks, connected dominating set (CDS) is commonly used as the virtual backbone of the network [9] due to its contributions in routing [3-5], broadcast [2], and collision avoidance [12].

However, it is well-known that constructing minimum CDS for an arbitrary graph is NP-hard [13]. The problem becomes more challenging when the knowledge of complete network topology is not available prior to computation, which is a practical assumption in mobile ad hoc networks.

In many sensor networks, the sensor nodes are immobile. In such networks, the energy level of nodes in a CDS becomes a more important factor in determining the lifespan of the CDS. Since the process of constructing a CDS is in general costly and time-consuming, in the case of a static network, it is desirable to prolong the lifespan of the CDS in order to avoid the need to reconstruct the CDS frequently. In other words, the CDS protocol should take into account the energy level at each node.

The defer timer based protocol can easily modified to accommodate this need. Intuitively, if nodes with the most energy and neighbors are selected to the dominating set prior to those with fewer neighbors and less energy, it is more likely to result in a small dominating set. In other words, the order of nodes being selected into the dominating set plays an important role in determining the size of the resulting dominating set. To make sure the nodes in the dominating set are connected, we first elect the node with the most neighbors as the "initiator". Then starting from the initiator as the first node in the dominating set, the direct neighbors are marked as *covered* nodes. Let the number of *uncover* neighbors of a node be *UC*. For each *covered* node, a timer is set according to the following linear formula based on the number of its *uncovered* neighbors and the energy level of a node denoted as *E*, use the following formula instead to calculate the defer timer:

$$\Delta T = \Delta T_{\max} \cdot \frac{1}{UC} \cdot \frac{1}{E}$$

In this formula, nodes with more uncovered neighbors are given a smaller timer value, hence will expire earlier. When the timer expires, a node enters the dominating set if it still has uncovered neighbors.

4. Simulation

Using the concept of defer timer, the timer based broadcasting protocol is designed. The ns-2 computer simulations are carried out for performance study. The results have shown that our protocol is not able to produce smaller CDS but also to select nodes with higher energy level to form the CDS as shown in Figures 1 and 2. In addition, we have found that the order of retransmissions following this defer timer can effectively help identify the redundant retransmissions, thus enabling us to reduce the number of retransmissions and increase the broadcast reachability significantly without the need for collecting neighbor's location information. Figures 3 and 4 demonstrate how much performance gain the defer timer based broadcast protocol has achieved compared with simple flooding and the broadcast protocols proposed in [1] (denoted as Ni) and [5, 6] (denoted as Wu). Notice that Wu's protocol shows lower number of retransmissions because it requires 2-hop local topology information at each node, which will introduce extra message overhead not counted in Figure 3.

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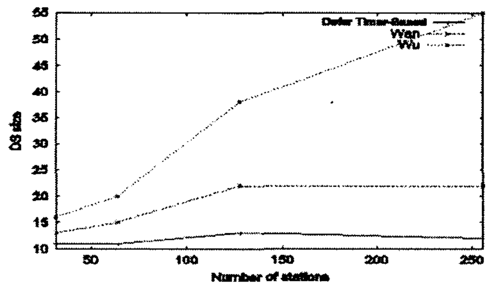

Figure 1. Number of CDS

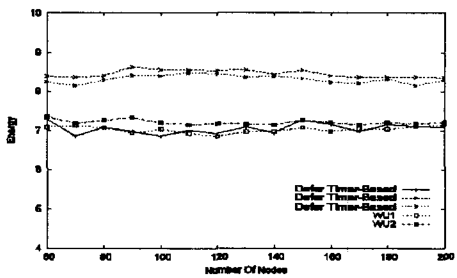

Figure 2. Average energy level of CDS

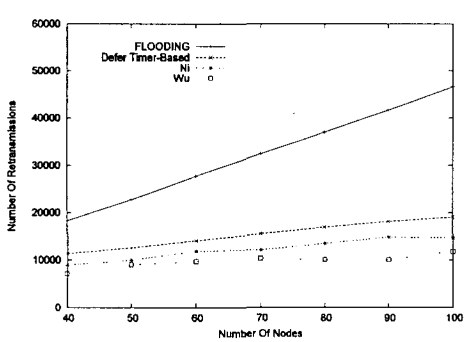

Figure 3. Number of Retransmission

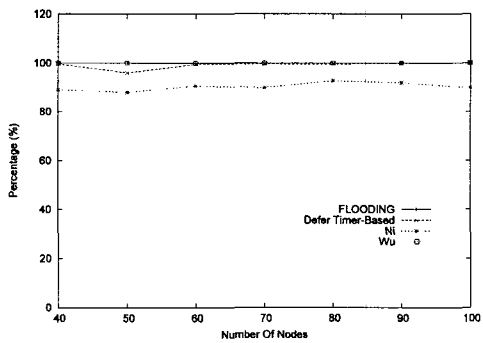

Figure 4. Broadcast reachability

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