지그비 네트워크에서 효율적인 에너지 관리를 위한 가상 백본 설계

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Design of the Energy Efficient Virtual Backbone Construction in the Zigbee Network

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요 약

무선 센서 네트워크에서 효율적인 에너지 사용을 위하여 분산적(distributed)이며 지역적인(localized) 방법으로 가상 백본을 구성하는 것은 매우 중요한 연구 대상이다. 라우팅이나 메시지 broadcast와 같은 목적으로 센서 네트워크에서 가상 백본을 구성하기 위하여 연결 Dominating set이 주로 사용되고 있다. 네트워크의 전체 성능을 향상시키기 위하여 연결 Dominating set은 최대로 작은 수의 노드로 가상 백본을 구성는 동시에 각 노드들의 에너지 상태를 고려해야만 한다. 이 페이퍼에서는 현재 센서 네트워크를 구성하는데 가장 많이 논의되고 있는 IEEE 802.15.4를 기반으로 한 Zigbee 네트워크에서 differ time을 사용하여 효과적으로 에너지를 관리하며 가상 백본을 구성하는 프로토콜을 제안한다. 제안된 가상 백본 프로토콜의 효율성은 시뮬레이션 결과를 통해 증명한다.

ABSTRACT

IN wireless sensor networks (WSNs), one challenging issue is to In wireless sensor networks (WSNs), one challenging issue is to construct a virtual backbone in a distributed and localized way while considering energy limitation. Dominating set has been used extensively as core or virtual backbone in WSNs for the purposes like routing and message broadcast. To ensure network performance, a good dominating set construction protocols should be simple and avoid introducing extra message. In addition, the resulting dominating set should be small, connected, and take into account the energy level at each node. This paper studies efficient and simple virtual backbone construction protocol using defer time in IEEE 802.15.4- based WSNs (e.g. Zigbee). The efficiency of our proposed protocol is confirmed through simulation results.

키워드

Wireless sensor network, Zigbee, EEE 802.15.4 Virtual backbone, Connedted dominating set, Defer timer

Ⅰ. 서 론

At present, there are several standard and proprietary devices that support sensor networks. IEEE 802.15.1 (Bluetooth)[1] and IEEE 802.15.4 (Zigbee)[1] are the most promising standards for wireless sensor networks because Bluetooth and Zigbee devices are generally inexpensive and consume relatively little power. Among them, Zigbee

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present the next great challenge for WSNs, built on the IEEE 802.15.4 standard [1]. Zigbee is wireless communication standard created to satisfy such requirements; a limited amount of delay, a low energy consumption, and a low data rate in a multi-hop mobile environment.

To take full advantage of wireless sensor networks, many research issues such as virtual backbone construction [2, 3, 4], a mesh routing [5, 6, 7], and message broadcasting [8, 9, 10] remain to be addressed. Among these issues, virtual backbone construction is considered one of the most important issues limiting wireless sensor networks. In addition, virtual backbone should be able to deal with real-world problems such as energy consumption, nodal mobility, scalability, and mesh connectivity in WSNs to improve network performance.

Dominating set has been used extensively as core or virtual backbone in WSNs for the purposes like routing and message broadcast. To ensure routing performance, a good dominating set construction protocols should be distributed, simple, and adapt to energy *constrain. In addition, the* resulting dominating set should be small and connected.

In this paper, we present a Timer-based Connected Dominating Set construction Protocol for virtual backbone in WSNs. In our protocol, each node sets up a defer timer based on the number of uncovered neighbors and determines whether or not to join the dominating set when the timer expires. Unlike other dominating set construction protocols, the node in our protocol obtains the necessary information strictly through the exchanges of extended beacons with its immediate neighbors.

Ⅱ. Background

The IEEE 802.15.4 Atandard [1] is initially developed by the Zigbee alliance. Zigbee is a new technology for wireless sensor networks. It is designed to support low data rate, low power consumption, and low cost wireless communications. The primary applications of Zigbee include automation and remote control. It supports a data rate of 250 kbps using 2.4 GHz unlicensed bands within a range of 10 to 75 m. Based on IEEE 802.15.4, the Zigbee protocol stack is shown in Figure 1. The physical layer and the media access control (MAC) layer adopt the IEEE 802.15.4, while the Zigbee Alliance specifies the standards for network and application layer.

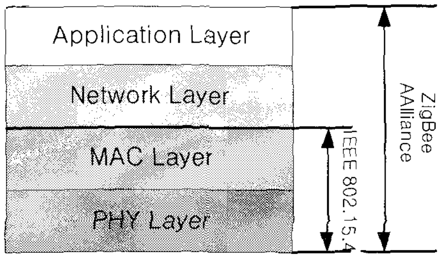

그림 1. 지그비 프포토콜
Fig. 1 Zigbee Protocol Stack

The defer timer is a countdown timer at each component. In general, before a defer timer expires, a component is forbidden to perform a certain set of events. By controlling the defer timer for each component, it is thus possible to determine the order of events. The concept of the defer timer has been used in many network protocols. For instance, 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 [11]. In an IEEE 802.11b wireless LAN [12], a station listens to the wireless medium and ensures the medium is available before it transmits *anything.* This medium access control mechanism is referred to as carrier sensing multiple accesses with collision avoidance (CSMA/CA). The (waiting) time a station listens to the channel before it transmits is defined as its inter frame spacing (IFS).

Ⅲ. Virtual Backbone Constrution

A wireless sensor networks is represented as an undirected graph $G=(V,E)$, where V is the set of all stations in the WSN and E is the edge set with $(u,v) \in E$ *if and only if* u and v are within each other's transmission range.

If G is connected, a set $DS \subset V$ is called a *dominating set* if for every vertex $v \in V - DS$, there exists a vertex $v \in V - DS$ such that $(v,w) \in E$.

A dominating set is said to be *connected* if its induced graph in *G* is connected.

A node $u \in V$ is said to be in the state of *inDS*, covered(by*DS*), or uncovered (by *DS*) according to the following;

- *inDS*: if $u \in DS$;
- covered: if $u \notin DS$ and there is an edge$(u,v) \in$ E for some $v \in DS$;
- uncovered: if $u \notin$ DS and there is no edge joining u to any node in *DS*;

There are four possible states for a node, namely *uncovered/*initial, *initiator, covered, and DS*. The state transition diagram is shown in Figure1.

Similar to every existing wireless system, namely including IEEE 802.11 [12], IEEE 802.15.4 [1] and Bluetooth [1], assume each node has an unique value or identifier in the network, such as its MAC address. The following refers to a node's unique identifier as its *id*. A node transmits a beacon at every fixed time interval. Before a node transmits its beacon, it encodes its own *id, energy level* at each node, *DS*, and *current state* in the header of the beacon. By doing this, each node learns its neighbors, the*DS, energy level* and the state of the neighbors without introducing extra messages.

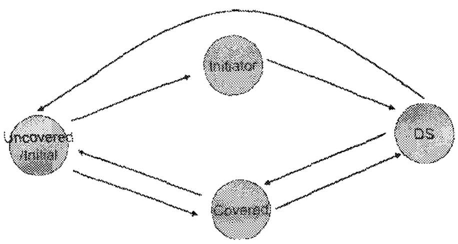

그림 2. 노드 상태 변환 다이어그램
Figure 2. Node's State transition diagram

We are interested in creating a CDS with a smaller size that contains stations with a higher energy level, so the energy level is used when the protocol picks the initiator.

- First, the node with the most energy is picked as the initiator.
- In cases where multiple stations have the same energy level, the one with the most neighbors is picked as the initiator.
- When multiple stations have the same number of neighbors and the same energy level, the node with the minimum MAC address is picked as the initiator to break the tie.

Starting from an initiator as the first node with the most energy in the CDS, the direct neighbors are covered as *covered* nodes. For each *covered node, a timer* is set based on the number of *uncovered* Neighbors (Nuncovered) and the *energy level(E)* at each node to compute ΔT. ΔT is calculated by multiplying ***Nuncovered*** and ***E***. Nodes with more *uncovered* neighbors or higher energy levels are given a smaller timer value, and hence will expire earlier. When the timer expires, a node enters the CDS if it still has *uncovered* neighbors. The pseudo code of the proposed CDS construction protocol for virtual backbone is given in the following.

```
/* node x in wireless sensor network executes the
following procedure until x has a inDS */
  while ( x has no inDS )
  init state :
  on receiving a signal from neighbors
  if ( x.id is smallest among its neighbors )
  then state = start
  else state = uncovered
  start state :
  start ΔT
  state = covered
  uncovered state :
  on receiving a beacon from a dominator neighbor
  start ΔT
  state = covered
  covered state :
  if ( x has an uncovered neighbor )
  then state = inDS
  else if ( x''s inDSr is no longer a neighbor of x)
```

then **state = init**
else **state = covered**
inDS **state :**
if **(none of x''s neighbors use x as its inDS)** ***and***
(a neighbor of x, y, is a inDS)
then **x''s inDS = y and state = inDS**

Ⅳ. Simulation Results and Analysis

Table 1 shows a list of parameters used in the simulations, if not specified otherwise.

표 1. 시뮬레이션 변수
Table. 1 Simulation Parameters

Parameter	Value
Space	4 X 4
Transmission Radius	1
Number of Nodes	60-200
T_{max}	100

Nodes are generated randomly on a 4 by 4 square plane. The plane is wrapped vertically and horizontally to eliminate If the generated network is partitioned into pieces, it the effect of the edge. Each node has the same range of transmission. is discarded and a new network topology is generated to ensure the connectivity of the whole network. The value *Tmax is chosen to be 100 time units.*

Similar to every existing wireless system, namely including IEEE 802.11 [12], IEEE 802.15.4 [1] and Bluetooth [1], assume each node has an unique value or identifier in the network, such as its MAC address. The following refers to a node's unique identifier as its *id.* A node transmits a beacon at every fixed time interval. Before a node transmits Other than TB protocol, we also implemented two other connected dominating set protocols, namely, Wu's protocol in [3] and Wan's protocol [2] All simulations were executed under the same parameters and network topology. By comparing the size of the resulting CDS and energy level for network with size between 60 and 200 nodes. We examine the network performance of our TB protocol.

In Figures 3, the x−axis represents the size of the network and the y−axis shows the size of the resulting CDS from the three different protocols. For the 4 × 4 grids, TB's DS size ranged between 13 and 17, Wan's protocol ranged between 20 and 25 and Wu's protocol ranged between 20 and 27. TB thus easily outperformed the other two protocols. In Figures 4, the x−axis represents the size of network and the y−axis shows the average energy level of the stations in the resulting CDS from the three different protocols. Hence, TB able to achieve an approximately 20% higher average energy level of stations in CDS than the others for the 4 × 4 grids.

In Figures 5, the x−axis shows the size of the network and the y−axis is the minimum energy level of the stations in the resulting CDS from the three different protocols. From these figures, we can see that our energy-aware TB protocol select the stations with higher minimum energy levels than any of the others, while Wu1 selects the stations having the lowest minimum energy level. These figures indicate that the CDS created by our energy-aware TB protocol live longer than any other protocols under a static network.

Ⅴ. 결 론

In this paper, we presented the timer based connected dominating set protocol for virtual backbone. In our new TB protocol, the energy level at each node is taken into consideration when constructing the CDS. TB effectively constructs an energy-aware CDS that prolongs the network's operational life under different levels of nodal mobility. The simulation results have shown that our protocols consistently generate significantly smaller CDS than those proposed in [2] and [3]. Additionally, the CDS generated by TB consistently results in stations with a higher energy level, which implies a longer lifespan for the CDS when the network is static.

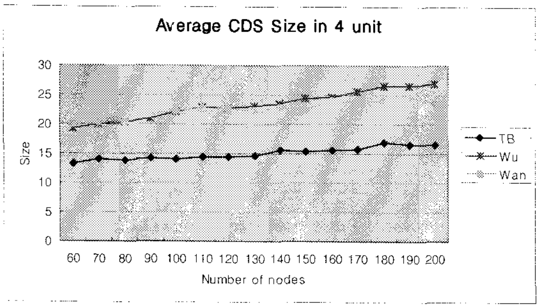

그림 3. 평균 CDS 갯수
Figure 3. Average CDS size

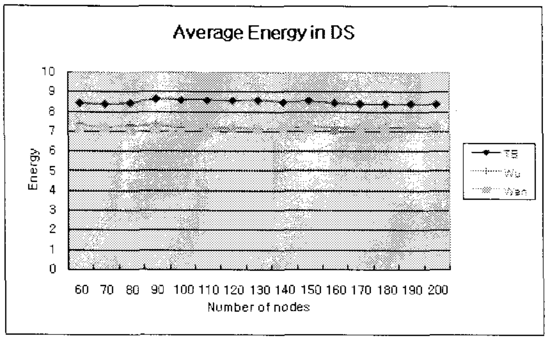

그림 4. CDS 구성시 사용된 평균 에너지
Figure 4. Average Energy in CDS

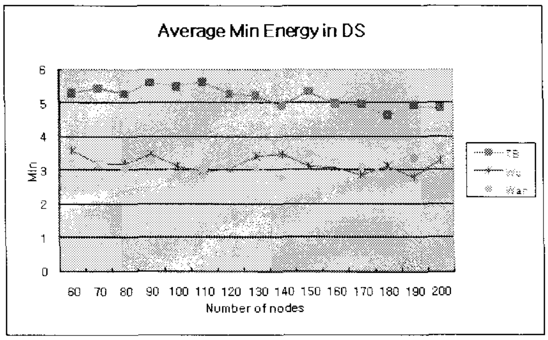

그림 5. CDS 구성후 관측된 최소 에너지
Figure 5. Average Minimum Energy in CDS

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