무선 센서 네트워크에서 삼각 클러스터링 라우팅 기법

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Clustering Triangular Routing Protocol in Wireless Sensor Network

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요 약

무선 센서 네트워크는 한정된 에너지 자원과 전원 공급 장치, 그리고 소형 배터리로 구성되어 있다. 센서 노드는 설치가 되면 사용자가 다시 접근할 수 없고 에너지 소스의 배포 및 교체가 가능하지 않다. 따라서, 네트워크의 수명 향상을 위해서는 에너지효율성이 네트워크 디자인의 핵심 요소가 된다. BCDCP 에서는 모든 센서는 CH (클러스터 헤드)로 데이터를 보내며 CH 는 BS(베이스 스테이션)로 이를 전송한다. BCDCP 는 소규모 네트워크에서는 잘 작동하지만 대규모 네트워크에서는 장거리 무선 통신을 위해 많은 에너지를 사용하기 때문에 적합하지 않다. 본 논문에서는 균형 잡힌 에너지 소비를 통해 네트워크 수명을 연장할 수 있는 삼각형 클러스터링 라우팅 프로토콜(TCRP)을 제안하였다. TCRP 는 삼각 모양으로 클러스터 헤드를 선택한다. 센서 필드는 에너지 레벨을 기준으로 지역을 나누게 되며 나뉘어져 있으며 모든 레벨에서 게이트 노드를 하나 선택하여 이 노드가 그 레벨 내에 있는 노드들의 데이터를 수집하고 리더 노드로 보낸다. 마지막으로 리더 노드가 BS 로 집계된 데이터를 보낸다. TCRP 는 몇 가지 실험을 통하여 BCDCP 보다 훌륭한 성능을 보여주었다.

주요 단어 : 무선 센서 네트워크, 라우팅 프로토콜, 클러스터링

Abstract

Wireless sensor networks consist of small battery powered devices with limited energy resources. Once deployed, the small sensor nodes are usually inaccessible to the user, and thus replacement of the energy source is not feasible. Hence, energy efficiency is a key design issue that needs to be enhanced in order to improve the life span of the network. In BCDCP, all sensors send data from CH (Cluster Head) and then to BS (Base Station). BCDCP works well in small-scale network but in large scale network it is not appropriated since it uses much energy for long distance wireless communication. We propose a routing protocol - Triangular Clustering Routing Protocol (TCRP) - to prolong network life time through the balanced energy consumption. TCRP selects cluster head of triangular shape. The sensor field is divided into energy level and in every level we choose one node as a gate node. This gate node collects data and sends it to the leader node. Finally the leader node sends the aggregated data to the BS. We show TCRP outperforms BCDCP with several experiments.

Key words: Wireless Sensor Network, Routing Protocol, Clustering

1. INTRODUCTION

Recent advances in wireless communication and electronics have enabled the development of low cost, low power, small sized sensor node. In WSN, sensor nodes can be deployed to collect useful information from the field. Many new routing protocols are proposed for wireless sensor networks. The energy efficiency is the most important factor, to prolong network lifetime and balance energy consumption. Although in small-scale network, BCDCP works well to route data energy efficiently; their network topology constrains them when applied to large scale network. Because the club topology in clusters is a one-hop route scheme, it is not appropriated for long distance wireless communication. Furthermore, when there are many nodes, the sensor node closest to base station will die quickly because of the burden of sent data on base station.

This is the disadvantage of BCDCP, because of this we

propose Clustering Routing Protocol based on Triangular selection method in Wireless Sensor Network to balance energy consumption and prolong network life time. This method is based on Concentric and BCDCP, but we added levels and made cluster node in triangular shape to prolong network life time and balance energy consumption. The sensor node deploys random sensor field network and sensor field network is divided into levels which is later grouped into sensor node or groups in triangular shape in every level. One node in each triangular shape is chosen as the cluster head and cluster head sends data to another triangular cluster head. Each level selects one Cluster Head Gate to collect data from CH in each level. The node with high energy and which is closer to base station is chosen as the cluster head leader. The cluster head gate in every level sends data to another cluster head gate in another level and again it is sent to the next cluster head leader and finally to the base station.

The structure of this paper is as follows: the second section describes related work, the third describes clustering triangular routing protocol in wireless sensor network, the fourth describes simulation and analysis and finally the fifth is the conclusion.

2. RELATED WORK

LEACH clustering method is made by grouping nodes into cluster and it consists of cluster head and cluster members. Information is fused into Cluster Head (CH) before transmitting to base station. The operation is divided into rounds; each round comprises of set-up phase and steady set phase. Set up phase defines the organization of the clusters while steady set phase defines the process where cluster head receives data from all cluster members and transmits it to the base station. To balance energy load, LEACH incorporated the random rotation of the high energy cluster head position among the sensors. But the method in which cluster head directly transmits data to the sink consumes more energy of cluster head.

In BCDCP every node has similar clustering like LEACH. First, one cluster head is randomly chosen to forward data to base station. Because the cluster head in each cluster will send data to the cluster head closest to it based on minimum spanning tree, this burdens the routing to base station (BS). The cluster heads send data to the selected cluster head Finally CH sends the data to BS. Thus, BCDCP is at disadvantage when there is a large number of sensor node and cluster heads. Due to the large number, sensor nodes need more energy for intra and inter cluster data transmission. This creates an unbalance in energy consumption and decreases network lifetime.

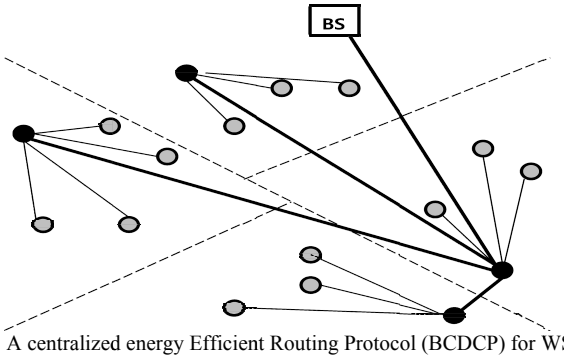

Fig. 1. A centralized energy Efficient Routing Protocol (BCDCP) for WSN

We can see that BCDCP [6] is more efficient than LEACH in two aspects; first by introducing Minimal Spanning Tree (MST) [2] to connect to CH which randomly chooses a leader to send data to sink. Second, BCDCP makes the best use of high energy BS to choose CHs and form cluster by interactive cluster splitting algorithm. Thus BCDCP reduces far more energy dissipation of network than LEACH, but both have weakness in small-scale network. LEACH and BCDCP work well to route data energy efficiently but their network topology constrains them in large scale network. Because the club topology in clusters is a one-hop route scheme, it is not appropriated for long distance wireless communication.

So we proposed Clustering Triangular Routing Protocol (CTRP) in Wireless Sensor Network for large network area. The main idea is: for intra-cluster and inter-cluster data transmission we divided network area into levels. Each level has one cluster head gate whose function is to receive data from cluster head of each level. Simulation results show the network lifetime and balance energy consumption of BCDCP compared with CTRP in a large network area.

3. CLUSTERING TRIANGULAR ROUTING PROTOCOL IN WIRELESS SENSOR NETWORK

The model for routing protocol system is based on following assumptions:

1. Base station is located far from the sensor field. Sensor node and base station becomes static after random deploy in network area
2. Sensors are homogeneous and have same capabilities; each node is assigned a unique identifier (ID).
3. Sensors are capable of operating in an active node or low power sleeping mode.
4. Sensors can use power control to vary the strength of transmission power according to the distance of the desired recipient.

A. Radio Model

Radio model consists of three parts: transmitter, the power amplifier and the receiver. There are two propagation models: free space model and two-gray ground propagation model [7]. Both the free space (d^2 power loss) and (two gray propagating) the multipath fading (d^4 power loss) channel models are used depending on the distance between transmitter and receiver. In this research paper the energy spent for transmission of an *l*-bit packet from the transmitter to the receiver at a distance d is defined as:

$$ET_x(l,d) = l\mathrm{E}_{\mathrm{elec}} + l\varepsilon \mathrm{d}^{\alpha} \begin{cases} l\mathrm{E}_{\mathrm{elec}} + l\varepsilon_{fs}\, d^2, d < d_0 \\ l\mathrm{E}_{\mathrm{elec}} + l\varepsilon_{fstg} d^4, d \geq \mathrm{d}_0 \end{cases} \quad (1)$$

ET_x is energy dissipated in the transmitter of source node and the electronic energy E_{elec} is the per bit energy dissipation for running the transceiver circuitry. Here the amplifier energy, $\varepsilon fs d^2$ or $\varepsilon tg d^4$, depend on transmission distance and acceptable bit-error rate. The cross over distance d_0 can be obtained from: $d_0 = \sqrt{(\varepsilon fs \ / \varepsilon tg)}$ (2)

The energy expended to receive message is:

$$ER_x(l) = l\mathrm{E}_{\mathrm{elec}} \quad (3)$$

B. Clustering Triangular Routing Protocol (CTRP) in Wireless Sensor Network

This routing protocol contributes to balance energy consumption and prolongs network life of sensor node. Thus for this reason we propose Clustering Triangular Routing Protocol for short routing. The triangular shape method, similar to binary tree method reduces the number of transmission by each node because each node does not send data directly to base station. The triangular method, similar to binary tree is a tree data structure in which each node has at the most two children. Typically the first node is known as the parent and the child nodes are called left node and right node. In type theory, a binary tree with node of type A is defined inductively as TA = μα. 1 + A × α × α. Binary trees are commonly used to implement binary search. We made the routing with the assumption:

• Node is deployed randomly in network field and each node becomes static after being deployed
• The network field divides into partition levels and nodes are grouped into small triangular clusters in each level
• Every level chooses one node as gate, so every cluster head in each partition level sends data to node gate which is further sent to base station
• If the energy of a CH dries up because it is close to base station, another CH can send data directly to base station
• Have 3 phases: initial or formation of cluster, construction of cluster, reconstruction of triangular cluster.

Initial phase or formation of cluster: The network field is divided into equal partition level. After the random deploy of node in network area, the sensor becomes static. It consists of all the information about ID node, Residual energy node and distance from node to base station. The node selects the cluster head and cluster member. Selection of cluster head is based on energy and distance between node to base station. Node with highest energy and close to base station will be chosen as the cluster head in every level. And cluster head with the highest energy and closest to base station in every level will be chosen as the cluster head gate.

Construction of cluster: The node is grouped into small triangular clusters similar to tree formation. One node is chosen as cluster head and two nodes as cluster members. Every level has a cluster head gate. The node with highest energy and closest to base station is chosen as cluster head gate. Every node sends data to cluster head in small triangular cluster and then the cluster head sends data to neighboring cluster head with higher energy. Next CH sends data to CH Gate, And CH gate sends it to CH Leader, finally CH leader send it to BS. After sending data to base station the energy of the node or cluster head decreases Therefore, every node and cluster head can rotate to balance energy consumption.

Reconstruction of triangular phase: This phase is for maintenance. After sending data to base station if cluster head gate energy becomes lower than energy in neighboring node, it can choose another cluster head as the leader for sending data to base station. The cluster head can rotate to balance energy consumption and prolong network lifetime.

The algorithm of CTRP is explained and shown with a figure below:

1. At first we deployed random sensor in network area, sensor node becomes static after deploy;
2. Divided network area into equal partition level;
3. Every sensor node sends information (ID, Level, Residual energy (RE), distance) to Base Station;
4. BS calculates all information and saves in information table (ID, Level, RE, d);
5. Every node chooses closest neighboring node to make triangular cluster in every level;
6. Check for node with information that matches to info table (ID, Level, RE, d) in Base Station;
7. Every node sends data to Cluster Head (CH), in each level, and the algorithm chooses one CH as Cluster Head Gate to collect data ;
8. CH gates at every level send aggregate data to CH Leader and finally CH Leader sends it to base station

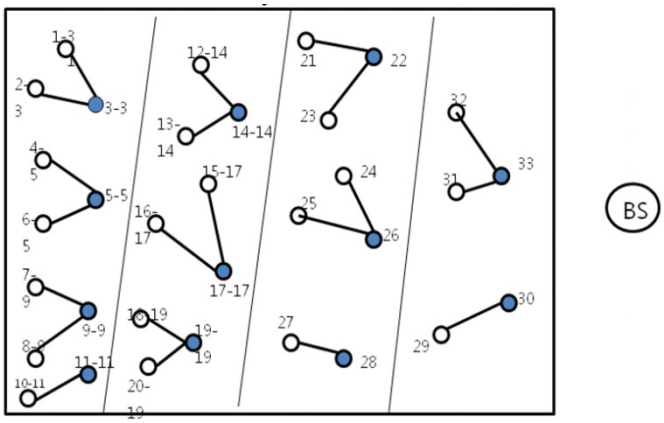

Fig. 2. Clustering of triangular shape in wireless sensor network

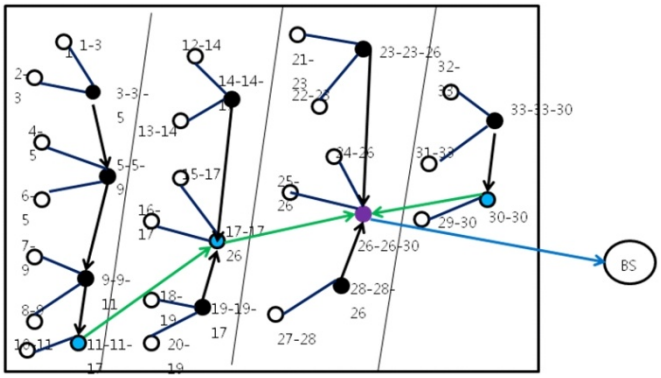

Fig. 3. Routing in TCRP

4. ANALYSIS AND SIMULATION RESULTS

In this section we evaluated the performance of Clustering Triangular Routing Protocol (CTRP) via simulation and compared it with BCDCP. First we studied characteristics of clustering and triangular routing algorithm, then we investigated parameter setting and energy efficiency of CTRP in terms of network life time, because this paper focuses on balancing energy consumption and efficiency of network life time. In this paper network life time is defined by number of rounds made by a node until first node dies. First node dies means first node exhausts its energy in the network. One round defines the operation from beginning of cluster formation until the final base station receives all data from cluster head leader.

The assumed parameters utilized in our simulations are summarized in the table 1.

< Table 1> Simulation parameters

Parameter	Value
Network field	(0, 0)–(100,100) m
Base station location	(150, 50) m
N	100
Initial energy	1 J
E_{elec}	50 nJ/bit
ε_{fs}	10 pJ/bit/m2
ε_{mp}	0.0013 pJ/bit/m4
d_o	87 m
E_{DA}	5 nJ/bit/signal
Data packet size	4000 bits

The result of simulation is as follows:

a. A comparison of TCRP's average energy dissipation with BCDCP.

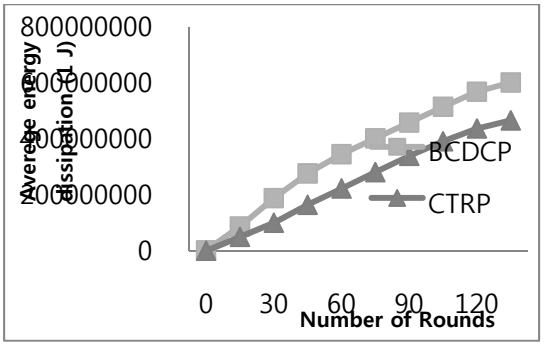

Fig.4. A comparison of TCRP's average energy dissipation with BCDCP.

Figure 4 shows average energy dissipations over the number of rounds when we used CTRP and BCDCP as existing protocol. CTRP reduces significant energy consumption over BCDCP, because triangular shape method for selecting cluster head and cluster head gate in each level in CTRP is more efficient in that it consumes less energy for both intra and inter cluster data transmission in each level. 30% reduction in average energy dissipation can be obtained through BCDCP over CTRP that means CTRP consumes about 30% less energy than BCDCP. Next we can see in the graph that curve of BCDCP is higher than CTRP and the dissipation varies between rounds. So CTRP has better performance than BCDCP in terms of energy efficiency and can prolong network lifetime of sensor node.

b. System lifetime of sensor nodes until first node dies

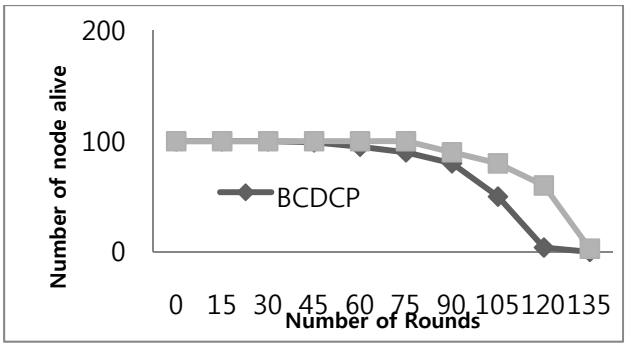

Fig.5. A comparison of CTRP's system lifetime with BCDCP

Figure 5 the number of lifetime of nodes (numbers of live sensor nodes until the first node dies) for CTRP over BCDCP is seen clearly. In case of BCDCP life time starts deceasing at round 60 and in case of CTRP it starts at more than 90 rounds. We calculated that in case of BCDCP node died 36% faster than CTRP. That means average number of live sensor nodes in CTRP is 36% higher than BCDCP. So CTRP prolongs network life time and balances energy consumption than BCDCP. Also the graph of CTRP is smoother than BCDCP.

5. CONCLUSION

In this paper we propose Clustering Triangular Routing Protocol (CTRP) that utilizes high-energy base station to perform most energy efficient task. By using base station the sensor node are relieved of performing energy intensive computational task such as cluster setup, cluster head selection, routing formation. The sensor nodes are made into clustering node and divided into different levels. Each level has one cluster head gate to receive all data from another cluster head which is then sent to another level and finally to the base station. This Clustering Triangular Routing Protocol rotation and selection cluster head is based on higher residual energy in sensor node and distance node to base station, node with higher energy and close to base station will be chosen as cluster head in each round. We assumed that base station has all information of sensor nodes, and residual energy and distance of node have been defined. All results shown in simulation for the network lifetime and balance energy consumption of BCDCP was poor when compared with CTRP in large area network. The results for CTRP are better than the result of BCDCP. This proves that CTRP can prolong network lifetime and balance energy consumption.

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