광역 WSN 을 위한 클러스팅 트리 라우팅 프로토콜

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A Cluster Based Energy Efficient Tree Routing Protocol in Wireless Sensor Networks

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요 약

무선센서네트워크는 여러 분야에 사용되고 있으며 그 특성상 에너지를 효율적으로 사용할 수 있도록 설계되어야 한다. 무선 센서들은 한 번 설치되면 다시 교환할 수 없으며 제한된 배터리를 활용하여 운영된다. 따라서 네트워크 수명을 늘리기 위해서는 이러한 센서들의 효율적 활용이 필수적이다. BCDCP 에서는 CH(클러스터 헤드)가 BS(베이스스테이션)에 모든 데이터를 전송한다. BCDCP 는 적은 규모의 네트워크에서는 잘 동작하지만 큰 규모에서는 무선 통신을 위한 에너지 소모가 많아 적절하지가 았다. TBRP 는 큰 규모의 네트워크에서는 잘 동작하지만 다중 홉 전송에 따는 에너지 고갈 현상이 빨리 발생한다. 본 논문에서는 균형화된 에너지 소모를 통해 네트워크 수명을 늘리기 위한 기법인 CETRP 를 제안하였다. CETRP 는 클러스터 헤드를 트리구조로 선정하여 에너지 효율을 극대화하였으며 다른 기법과 성능을 비교하였다.

Abstract

Wireless sensor network are widely all over different fields. Because of its distinguished characteristics, we must take account of the factor of energy consumed when designing routing protocol. 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 sends data from the CH (Cluster Head) and then to the BS (Base Station). BCDCP works well in a small-scale network however is not preferred in a large scale network since it uses much energy for long distance wireless communication. TBRP can be used for large scale network, but it weakness lies on the fact that the nodedry out of energy easily since it uses multi-hops transmission data to the Base Station. Here, we proposed a routing protocol – A Cluster Based Energy Efficient Tree Routing Protocol (CETRP) in Wireless Sensor Networks (WSNs) to prolong network life time through the balanced energy consumption. CETRP selects Cluster Head of cluster tree shape and uses maximum two hops data transmission to the Cluster Head in every level. We show CETRP outperforms BCDCP and TBRP with several experiments.

Key words: Wireless Sensor Network, Tree Routing Protocol, Clustering, BCDCP, TBRP, CETRP

1. INTRODUCTION

Wireless sensor networks consist of hundreds to thousands of low power multi-functioning sensor nodes, operating in unattended environment, with limited computational and sensing capability. 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 load of sent data placed upon the base station. The alternative protocol TBRP (Tree Based Routing Protocol), also have a weakness even though it uses multi-hops data transmission. It weakness lies on the fact that if any nodes in the network dried out of energy and is unable to send data to another node or to the Cluster Head (CH), then there will be errors for all routing protocol. Hence the CH would not be able to send data into the BS

Those are the disadvantages of BCDCP and TBRP, and hence, we propose A Cluster Based Energy Efficient Tree Routing Protocol (CETRP) in Wireless Sensor Networks to balance energy consumption and prolong network life time.

This method is based on TBRP and BCDCP. The sensor node deploys random in field area network. The field area network is divided into two equal sizes horizontal area and divided into partition levels which are later grouped into sensor node or groups in cluster tree shape with maximum two hops data transmission to CH. One node in each cluster tree shape is chosen as the Cluster Head and the Cluster Head sends data to another Cluster Head of the cluster-tree. Each level selects one Cluster Head Gate to collect data from CH in each level. The node with high energy which is closer to the Base Station is chosen as the Cluster Head Leader Node. The Cluster Head Gate in every level sends data to another Cluster Head Gate in another level which then relay it to the next Cluster Head Leader Node and finally to the BS.

The structure of this paper is as follows: the second section describes related work, the third describes A Cluster Based Energy Efficient Tree Routing Protocol in Wireless Sensor Networks, the fourth describes simulation and analysis and finally the fifth is the conclusion.

2. RELATED WORK

In Base-Station Control Dynamic Clustering Protocol (BCDCP) every node has similar clustering like LEACH. Firstly, one cluster head is randomly chosen to forward data to the base station. Because the cluster head in each cluster will send data to the cluster head closest to it based on the minimum spanning tree, this burdens the routing process to the base station (BS). Thus, BCDCP is at a 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 the energy consumption and thus decreases network lifetime. BCDCP [4] 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.

In Tree Based Routing Protocol (TBRP) [5] process the data transmission phase begins after the tree is built. All of the leaf nodes will start sending sensed data towards their parent nodes. The parent nodes will collect the received data together with their own data that is then sent to their parents. The transmission process will be repeated until all of the data received by the root node is sent. After the root node has aggregated the data, it sends the collected data directly to the sink. The process is repeated until the root node has no more data to send. The WSN will then re-select a new root node. The new root identification number would be j+1. The initial phase is then repeated and the tree path will not change until the root node is dead. TBRP used multi-hop transmission data; hence if there is one root node that died there will be errors for this routing to send data to the BS. This is the disadvantage of TBRP.

So we proposed An Energy Efficient Cluster Based Tree Routing Protocol in Wireless Sensor Network. The main idea is for inter and intra cluster data transmission we divided the network into two equal horizontal sizes and divide the field area into partition level. CETRP selects Cluster Head of cluster tree with maximum two hops in each cluster tree. Each level has one Cluster Head (CH) Gate Node whose function is to receive data from CH of each level and sends it to the CH Leader Node. CH Leader Node is the CH with maximum residual energy level and minimum distance from BS. Finally the CH Leader Node sends the aggregated data to the BS. Simulation results show the network lifetime and balance energy consumption of BCDCP and TBRP compared with CTRP.

3. A CLUSTER BASED ENERGY EFFICIENT TREE ROUTING PROTOCOL IN WSNs.

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.

The 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 [6]. 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:

$$E_{Tx}(l,d) = l.E_{elec} + l.\varepsilon d^{\alpha} = l\, E_{elec} + l.\varepsilon_{fs}.d^2,\ d < d_0$$
$$= l\, E_{elec} + l.\varepsilon_{tg}.d^4,\ d < d_0 \qquad (1)$$

E_{Tx} 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 $\varepsilon_{tg}.d^4$, depends 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:

$$E_{Rx}(l) = lE_{elec} \qquad (3)$$

A Cluster Based Energy Efficient Tree Routing Protocol (CETRP) in Wireless Sensor Networks contributed to balance energy consumption and prolongs network life of sensor node. Thus for this important advantage, we are proposing it in this paper. The cluster tree shape method, similar to binary tree method reduces the number of transmission by each node because each node does not send data directly to the Base Station. Each node only has a maximum of two childs. Typically the first node is known as the parent and the child nodes are called left node and right node. Binary trees are commonly used to implement binary search. We made the algorithm a clustering tree routing protocol with the assumption:

- Node is deployed randomly in network area and each node becomes static after being deployed
- The network field divides into two equal sizes

horizontal

- The field area is divided into equal partition levels and nodes are grouped into cluster tree in each level with maximum two hops transmission data to CH
- Each cluster tree choose one node as the Cluster Head
- Each level chooses one Cluster Head as the Gate Node, so every Cluster Head in each partition level sends data to CH Gate Node which will then send it to the Base Station
- If the energy of a CH dries up because it is close to the Base Station, another CH can send data directly to the BS
- Include 2 phases: Initial or formation of cluster tree phase and Construction of cluster tree phase.

Initial phase is the formation of Cluster Tree Routing Protocol. The network field divides into to two equal sizes of horizontal. Then the network field is divided into equal partition level vertically. After the random sensor node deploys in the network area, the sensor becomes static. It consists of all the information about ID node, Residual Energy node and distance from node to the Base Station. The node selects the Cluster Head and Cluster Member. Cluster Head is parent of tree and Cluster Member is right child (leaf) or left child (leaf) of tree. Selection of Cluster Head is based on energy and distance between nodes to the Base Station. Node with the highest energy compared to the other nodes and closest to the Base Station will be chosen as the Cluster Head in every Cluster Tree. One CH is then chosen as the CH Gate Node in every level. The Cluster Head (CH) Gate Node with the highest energy and closest to the Base Station from each level will be chosen as the Cluster Head Leader Node.

Construction of cluster phase begins with the grouping of nodes into small cluster tree with the maximum of two hops, to the CH Gate Node in each level. This is done before the CH Gate Node sends data to another CH Gate Node of the level area field of the Sensor Networks. One node is chosen as a Cluster Head and 0 to 2 nodes as cluster members. Every level has a Cluster Head Gate Node which is the node with the highest energy level and located closest to base station. Every node sends data to the Cluster Head in small Cluster Tree and then the CH sends data to neighboring cluster head with higher energy. Following that. The CH then sends data to CH Gate Node, and the CH Gate Node will relay it to the CH Leader Node which finally will send it to the BS. After sending the data to the Base Station, the energy of the node or the Cluster Head decreases. Therefore, every node and Cluster Head can rotate to balance energy consumption. The CH Gate Node energy becomes lower than the energy in the neighboring node; it can choose another Cluster Head as the CH Leader Node to send data to the Base Station. The cluster head can rotate to balance energy consumption and prolong network lifetime.

The algorithm of CETRP is explained and shown in the figure below:

1. At first random sensor in network area is deployed. The sensor node becomes static after deploy;
2. The network area is divided into two equal size of horizontal;
3. The network area is divided into equal partition level;
4. Every sensor node sends information (ID, Level, Residual energy (RE), distance) to the Base Station;
5. The BS calculates all information and save it in the information table (ID, Level, RE, d);
6. Every node chooses the closest neighboring node to build the Cluster Tree in every level;
7. Confirmation process for node with information that matches to the info table (ID, Level, RE, d) in the Base Station;
8. Every node sends data to the Cluster Head (CH) in each level, and the algorithm chooses one CH as the Cluster Head Gate Node to collect data;
9. CH Gate Nodes at every level sends aggregated data to CH Leader and finally the CH Leader sends it to the Base Station.

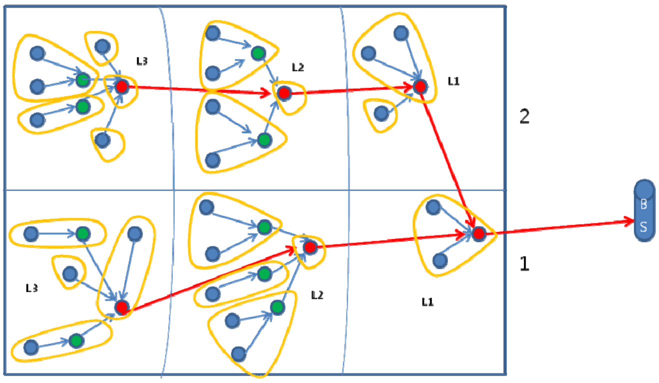

Fig.1. A Cluster Based Energy Efficient Tree Routing Protocol (CETRP) in Wireless Sensor Networks

4. ANALYSIS AND SIMULATION RESULTS

This paper focuses on network lifetime specifically on the efficiency of energy for a large area of wireless sensor network. In this paper network life time is defined by the number of rounds made by a node until the first node dies. The first node is pronounced to be died off when it has exhausted all of its energy within the network. One round defines the operation from the beginning of cluster formation until the final stage when the Base Station has received all the data from the Cluster Head Leader Node. The assumed parameters utilized in our simulations are summarized in 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:

Figure 2 shows the average energy dissipation over the number of rounds when we used CETRP as compared to BCDCP and TBRP as existing protocols. CETRP reduces significant energy consumption over BCDCP and TBRP, because the cluster tree method for selecting Cluster Head and Cluster Head Gate Node in each level in CETRP is profoundly more efficient and consume less energy for both the intra and the inter cluster data transmission in each level. In the graph it can be observed that the CETRP consumes about 21% less energy than BCDCP and 23% less energy than TBRP. In the energy dissipation graph, we can also that the curve of BCDCP and TBRP are higher than the CETRP which shows that the CETRP has a better performance than BCDCP and TBRP in terms of energy efficiency and hence can prolong network lifetime of the sensor nodes

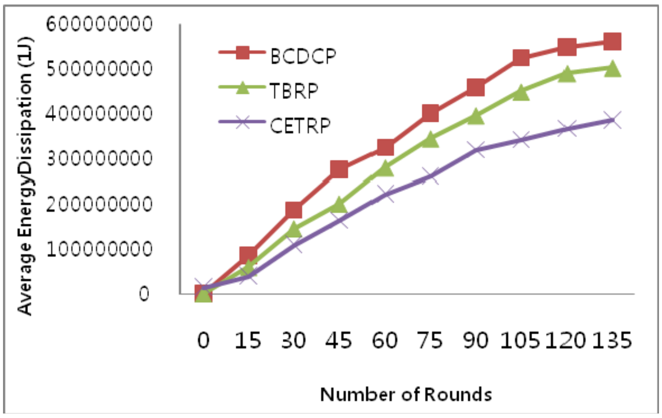

Fig.2. A comparison of CETRP's Average Energy Dissipation with BCDCP and TBRP

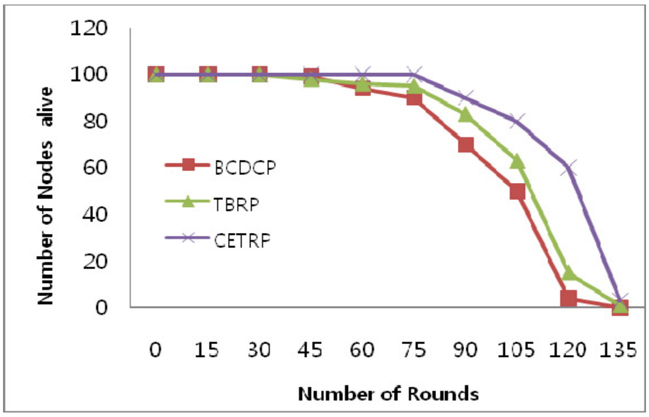

Fig.3. A comparison of CETRP's system lifetime: BCDCP and TBRP

In figure 3, the advantage of CETRP on the lifetime of nodes (numbers of live sensor nodes until the first node dies) over BCDCP can be seen clearly. In the case of BCDCP and TBRP, the life time of nodes starts deceasing at rounds 60, whereas in the case of CETRP it has only started after more than 75 rounds. In percentage value this means that BCDCP died 36% faster than CETRP, and similarly TBRP died 17% faster than CETRP. That means the average number of live sensor nodes in CETRP is 36% higher than BCDCP and 17% higher than TBRP. Therefore it is once again proven that the CETRP prolongs network life time and balances energy consumption much better than the BCDCP or TBRP.

5. CONCLUSION

The paper proposes A Cluster Based Energy Efficient Tree Routing Protocol (CETRP) in Wireless Sensor Networks that utilizes high-energy base station to perform a highly energy-efficient task. By using the BS, the sensor nodes are relieved of performing energy intensive computational task such as cluster setup, CH selection and routing formation. The sensor nodes are made into clustering nodes and then divided into two equal sizes horizontal which then are divided into levels. Each level possesses one CH Gate Node to receive all data from another CH which will then send it to another level and finally to the BS. This CTRP rotation and selection CH is based on higher residual energy in the sensor node and the distance of node to the BS. Node with higher energy value and closer to the BS will be chosen as the CH in each round. We assumed that the BS has all the information of the sensor nodes and we also assumed that the residual energy and the distance of node have been defined. All the results shown in the simulation for the network lifetime and balance energy consumption in large area of WSNs have shown that the BCDCP and TBRP were poorly efficient when compared to CTRP. In terms of energy efficiency, the results for CTRP are better than the result of BCDCP and TBRP and proved that CTRP can prolong network lifetime and balance energy consumption.

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