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A Survey on Self-Organizing Tree-Based Energy-Balance Routing Protocol

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ABSTRACT: Wireless Sensor Networks (WSNs) are one of the emerging technology with a wide range of applications. A wireless sensor network (WSN) consists of hundreds to thousands of sensor nodes, working in any physical environment, and having sensing, computation and communication capabilities. Each sensor node in WSN is capable of communicating with each other and the base station (BS) for the purpose of data integration and dissemination. As the battery replacement is not easy for WSN with thousands of physically embedded nodes, energy conservation becomes one of the most important challenges in WSNs. And hence there is a need for energy efficient routing protocol to offer a long-life work time. Along with the minimization of total energy consumption we also need to balance the WSN load. Till now many protocols have been proposed such as LEACH, HEED, PEGASIS, TBC and PEDAP. In this paper, we propose an Enhanced Self-Organizing Tree-Based Energy-Balance routing protocol (ESTBEB). This protocol builds a routing tree using a process where, for each round, BS assigns a root node and broadcasts this selection to all sensor nodes. And then each node selects its parent by considering only itself and its neighbour'sinformation, thus making it a dynamic protocol.

KEYWORDS: Network lifetime;Energy-balance;routing protocol; dynamic protocol; wireless sensor network

I. INTRODUCTION

A. *NETWORK ARCHITECTURE*

A WSN is usually composed by a large number of nodes deployed in a region of interest. The region of interest is often a harsh environment, and the nodes are randomly deployed. The sensed data are transmitted through the nodes to special entities called sinks. The nodes with two or more network interfaces that act as gateway between the WSN and the user network (e.g. a LAN, or the Internet) are known as sinks. The sink usually collects and processes the data from the network sending only relevant information to the user. Sink also receives commands from the user. A sensor node can communicate directly to the sink (single-hop) or use a multi-hop communication passing the information to its neighbor. Single-hop communication leads to long distance transmission, while multi-hop communicationresults in high energy consumption. Multi-hop network architectures are typically divided in flat or hierarchical as represented in Fig.1.

In flat architecture each node plays the same role in sensing and transmitting the information. In hierarchical architectures the nodes are organized into clusters. In each cluster, one or more nodes (head node) are responsible to communicate with other clusters or directly to the sink. The head node may be dynamically selected by various criteria, including its available energy, distance between cluster members and other cluster heads, and node homogeneity.

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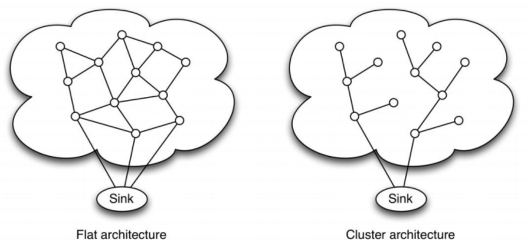

Fig.1. Network architecture

B. *Clustering*

In order to reduce the energy consumption a clustering and node redundancy approach is used. In Clustering approach, sensor nodes are divided into groups to form clusters. Cluster head (CH) is the leader of each cluster. This CH aggregate all the data received by nodes in cluster and sends aggregated data to Base Station (BS). Aggregation of data helps in removing the redundant data and combining the useful data. It also limits the data transmission. The cluster system improves the network lifetime by reducing the network traffic.

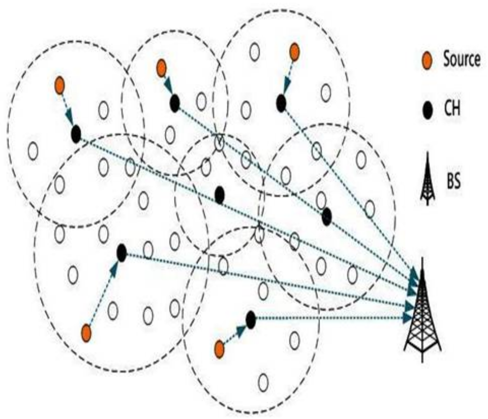

Fig. 2 Cluster System

Energy consumption of a node involves either “useful” or “wasteful” operations. The useful operationsconsist of transmitting or receiving data messages, and processing requests. While the wasteful consumption involves the operation of constructing routing tree, overhearing, retransmitting because of harsh environment, dealing with redundant broadcast overhead messages, and idle listening to the media.

In this paper, we are considering a situation in which the network collects information periodically from a terrain where each node continuously senses its surrounding environment and sends the data back to BS [6]. We are going to consider the definition for network lifetime, that is The time from the start of the network operation to the death of the first node in the network [2].

II. RELATED WORK

During the past decade, considerable research efforts have been investigated in developing clustering mechanisms for deployed sensor nodes in WSNs. The first well known clustering protocol developed by Heinzelman et al [8] is Low Energy Adaptive Clustering hierarchy with Deterministic CH Selection (LEACH). LEACH has been developed based on a clustering mechanism to select CHs using optimal probability. The protocol works on periodic randomized rotations of the CH within the cluster range between zero and one. If the random number is less than the pre-determined threshold value, the node becomes a CH for the current round. The authors have succeeded to achieve a

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reduction in energy dissipation compared to direct communication and transmission protocols. However, since in the protocol the number of clusters is predefined, LEACH cannot guarantee an acceptable CH distribution. Additionally, due to lack of support in deploying network with a large number of sensor nodes, the protocol cannot be used in a large region. Moreover, LEACH suffers from significant energy consumption when there is no CH selected in some rounds.

In [5], the authors have proposed a hybrid, energy-efficient, distributed clustering algorithm (HEED). HEED is an improvement of LEACH on the manner of CH choosing.In HEED CHs are selected based on the residual energy of each node and secondary parameter considered is nodes proximity to their neighbours. By iterations and competition, only one CH is ensured by HEED within a certain range, so that uniform CHs distribution can be achieved across the network. HEED effectively prolongs network lifetime as compared to LEACH and issuitable for situations such as where each node has different initialenergy.

LEACH and HEED consume energy heavily in the head nodes, which results in head nodes dying quickly.S. Lindsey *et al.* proposed an algorithm related to LEACH, and it is called PEGASIS [7].PEGASIS uses GREEDY algorithm to make all the sensor nodes in the network form a chain, its nearly optimal power efficient protocol. In PEGASIS, the (i mod N)th node is chosen to be a leader. The leader is the only node which needs to communicate with BS in round i. N is the total number of nodes.Data collection begins from both endpoints of the chain, and then transmitted along the chain. The data is fused each time it transmits from one node to the next until it reaches the leader. This is how PEGASIS reduces the total amount of data for long-distance transmission and achieves a better performance than LEACHin terms of network lifetime.

Tree-Based Clustering (TBC) [4] is also an improved protocol of LEACH. It forms several clusters in the same way as LEACH, and each cluster has a cluster-head (CH). The nodes within a cluster construct a routing tree where the cluster-head is the root of it. For tree configuration, the cluster-head uses the distance information between the member nodes and itself. Each node is location-aware, it can estimate the distance between the root and itself. Every cluster is divided into some levels. The distance of a node to the root is the basis for determining its level in the cluster. The cluster-head is at level-0(root) and a node in level L(i) will choose the node in L(i)-1 and nearest to itself as its parent node. Data transfer simultaneously happens between the nodes in two neighbouring levels, and each node fuses the received data and transmits it to its parent. TBC is an excellent protocol in which each node records the information of its neighbour'sand builds topography through computing, which is similar to GSTEB. But some cluster-heads in the network consume more energy than other nodes when BS is located far away.

PEDAP [8] is a tree-based routing protocol. In PEDAP all the nodes form a minimum spanning tree, costing minimum energy for data transmission. In PEDAP-PA energy is slightly increased for data transmissionbut balances energy consumption per node. PEDAP has the same network assumptions as PEGASIS and uses data fusion. However, both PEDAP and PEDAP-PA are protocols that need BS to build the topography which will cause a large amount of energy waste. This is because if the network needs BS to build the topography, BS has to send a lot of information to the sensor nodes, including what time is the Time Division Multiple Access(TDMA) slot, who are their child nodes and who are their parent nodes. . This kind of information exchanging will cause a lot of energy to be wasted or will cause a long delay.

III. PROPOSED ALGORITHM

The main aim of ESTBEB is to achieve a longer network lifetime for different applications. In each round, BS assigns a root node and broadcasts its ID and its coordinates to all sensor nodes. The path is computed by the network either by transmitting the path information from BS to sensor nodes or by having the same tree structure being dynamically and individually built by each node. For both cases, ESTBEB can change the root and reconstruct the routing tree with short delay and low energy consumption. Therefore a better balanced load is achieved compared with the protocols mentioned in Section II.

The operation of ESTBEB is divided into Initial Phase, Tree Constructing Phase, Self-Organized Data Collecting and Transmitting Phase, and Information Exchanging Phase.

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A. *INITIAL PHASE*

The network parameters are initialized in the Initial Phase. Initial Phase is divided into three steps.

Step 1:At the beginning of Initial Phase, BS broadcasts a packet to all the nodes to inform them of beginning time, the length of time slot and the number of nodes N. After receiving the packet all the nodes will computetheir own energy-level (EL) using function:

$$EL(i) = [residual\_energy/\alpha]$$

Where EL is a parameter for load balance, and it is an estimated energy value, i is the ID of each node, and α isa constant which reflects the minimum energy unit and can be changed depending on our demands.

Step 2: After step1, every node will send its packet in a circle with a certain radius R_c during its own time slot.For example, the node whose ID is i will send out its packet in the i_{th} time slot. This packet contains information of the node such as coordinates and EL of node i. All the other nodes during this time slotwill monitor the channel. Nodes which are neighbour'sof i can receive this packet and record the information of node i in memory. The nodes which are in the range of R_c can only monitor the preamble in this slot, others cannot.So this is how they can know that they are not the neighbour'sof node i and will turn off their radios, then switch to sleep mode to save energy. . After all nodes send their information, each node records a table in their memory which contains the information of all its neighbours.

Step 3:Once step 2 is over each node starts sending a packet which contains all its neighbour's information during its own time slot. Then its neighbour's can receive this packet and record the information in memory.The length of time slots in Steps 2 and 3 is predefined, thus when time is up, each node has sent itsinformation before Initial Phase ended. After Initial Phase, each node records contain the information of all its neighbour'sand its neighbour'sin the form of two tables.

We can say that the Initial Phase is a significant preparation for the next phases. After Initial Phase, ESTBEB operates in rounds. In a round, the routing tree may need to be rebuilt and each sensor node generates a DATA_PAK that needs to be sent to BS. A round ends, when BS receives the data of all sensor nodes.Round is nothing but the ability for transmitting the collected data for sensors, that's why round is a suitable time measurement unit for WSN lifetime. Each round contains three phases, including Tree ConstructingPhase, Self-Organized Data Collecting and Transmitting Phase, and Information Exchanging Phase.

B. *TREE CONSTRUCTING PHASE*

Within each round following steps are performed by ESTBEB to build a routing tree.

Step 1:BS will assign a node as root. After that BS will broadcast root ID and root coordinates to all sensor nodes.As we are implementing data fusion technique only one node which communicates directlywith BS is supposed to transmit all the data with the same length as its own, resulting in much less energy consumption.In each round, a node with the largest residual energy is chosen as root, in order to balance the network load.After collecting the data from all the sensor nodes, root will fuse the data and send it to the BS over long distance.

Step 2:Using EL and coordinates which are recorded, each node will try to select a parent in its neighbours.Selection criteria are given below:

1) For a sensor node, the distance between its parent node and the root should be shorter than that between itself and the root.
2) Each node chooses a neighbour that satisfies criterion 1 and is the nearest to itself as its parent. And if any node can't find a neighbour which satisfies criterion 1, it selects the root as its parent.

Step 3:Each node can know all its neighbour'sparent nodes by computing because every node chooses the parent from its neighbour'sand every node records its neighbour's information. It can also know all its child nodes. Node which has no child node will define itself as a leaf node, from which the data transmitting begins.

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So as to achieve minimum energy consumption each node chooses the node nearest to it, because each packet sent to the parent nodes will be fused. But if all nodes choose their nearest neighbours, the network may not be able to build a tree. Thus in GSTEB, we use criterion 1 in Case1 to limit the search direction. By this approach, a routing tree is constructed and some nodes still have the possibility of connecting to their nearest neighbours.

C. *SELF-ORGANIZED DATA COLLECTING AND TRANSMITTING PHASE*

Once the routing tree is constructed, each sensor node collects information to generate a DATA_PKT which needs to be transmitted to BS. Both TDMA and Frequency Hopping Spread Spectrum (FHSS) are applied. This phase is divided into several TDMA time slots. In a time slot, only the leaf nodes try to send their DATA_PKTs. After a node receives all the data from its child nodes, this node itself will act as a leaf node and tries to send the fused data in the next time slot.

Each node knows the ID of its parent node. In each time slot, FHSS is applied in order to reduce communication interference. In which, each child node communicates with its parent node using the frequency hopping sequence which is determined by its parent node ID. . Each TDMA time slot is divided into three segments:

Segment1:

This segment is used to check if there is communication interference for a parent node. In this segment, beacon containing nodes ID to its parent node at the same time is sent by each leaf node.

Following situations may occur and they divide all the parent nodes into three kinds.

1) Parent node will receive nothing ,if no leaf node needs to transmit data to the parent node in this time slot
2) Parent node will receive an incorrect beacon, if more than one leaf node needs to transmit data to the parent node
3) Parent node will receive a correct beacon, , if only one leaf node needs to transmit data to the parent node

Second segment operation depends on the above three situations.

Segment 2:

During the second segment, the leaf nodes which can transmit their data are confirmed.

1) In the first situation, the parent node turns to sleep mode until next time slot starts.
2) In the second situation, the parent node sends a control packet to all its child nodes. This control packet chooses one of its child nodes to transmit data in the next segment.
3) In the third situation, a control packet is sent to this leaf node by the parent node.This control packet tells this leaf node to transmit data in the next segment.

Segment 3:

Leaf nodes which are permitted to send their data will start sending data to their parent nodes, while other leaf nodes turn to sleep mode.

D. *INFORMATION EXCHANGING PHASE*

As we know each node has to generate and transmit a DATA_PKT in each round. This may exhaust nodes energy and die. The topography can get influenced if any sensor node dies. Because of this the nodes that are going to die need to inform others. The process is also divided into time slots. In each time slot, a random delay will be calculated by the nodes whose energy is going to be exhausted. Thisresult in only one node can broadcast in this time slot. These nodes are trying to broadcast a packet to the whole network, when the delay is ended. All other nodes while monitoring the channelwill receive this packet and perform an ID check. Then they modify their tables. If no such packet is received in the time slot, the network will start the next round.

IV. CONCLUSION AND FUTURE WORK

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We simulate theEnhanced Self-Organizing Tree-Based Energy-Balance routing protocol (ESTBEB) using Network Simulator-2 (NS-2). In WSN, along with the minimization of total energy consumption we also need to balance the WSN load. The proposed algorithm provides energy efficient path for data transmission and maximizes the lifetime of entire network. The performance of the proposed algorithm can be compared with other energy efficient algorithm.The comparative results will show the performance analysis. Performance metrics that can be used are delay, throughput, packet delivery ratio (PDR).

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BIOGRAPHY

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