AN OPTIMIZED APPROACH TO DETERMINE ALTERNATIVE CLUSTER HEAD IN WIRELESS SENSOR NETWORK CLUSTERING STRUCTURE

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Abstract

Wireless sensor networks consist of hundreds or thousands tiny nodes that work together to do some special tasks. Generally, to reduce energy consumption in the network, just some of the nodes send the data to the sink. This structure is called clustering and the nodes linked to the sink are called cluster head. The other nodes send their data to the nearest cluster head. Choosing a node as alternative cluster head can improve the network efficiency because clustering formation is a costly approach. When the cluster head stops working it is necessary to do the clustering formation but when we have alternative for the cluster head no clustering formation is needed, just the alternative introduces itself as the new cluster head and informs the other nodes in the cluster about this matter. In this paper we propose a novel approach to determine alternative node for cluster head. The existing methods impose high overhead on the network and some of them has very low accuracy while the proposed method has high accuracy also imposes almost no overhead to the network by using in-network data and eliminating the array data structure.

Keywords: *Wireless sensor network, clustering, alternative cluster head.*

I. INTRODUCTION

Wireless sensor networks consist of hundreds or thousands tiny nodes that work together to do some special tasks. Each node generally consists of sensor, processor, antenna, memory and energy supply. Since a large number of nodes are used in the network, the nodes components should be selected in a way that the network be economical. This matter is one of the main fundamental challenges in WSNs. The low capacity, irreplaceable and non-rechargeable energy supply is one of the limitations in nodes. Thus, with complete depletion of the node power supply (battery), the node practically loses its effectiveness and becomes cumbering. So most algorithms that are used in WSN try to reduce nodes energy consumption.

Clustering algorithm is a structure that is introduced to reduce energy consumption in WSN. The nodes sensed values should be transferred to a station for processing and decision-making. This station is called base-station or sink. If each node sends its data directly to the sink, a lot of energy will be consumed. Since the sensed values by the close nodes are a little different, there is a possibility of redundancy in the transmitted data. For example, two adjacent nodes' sensed values are the same and these two nodes send the same data to the sink. Generally, to reduce energy consumption in the network, just some of the nodes send data to the sink. This structure is called clustering and the nodes linked to the sink are called cluster head. The other nodes, which send their data to the nearest cluster head, are called cluster member. Cluster head can perform actions such as compression on the cluster member data. Consequently, small amount of data transmitted to the sink and energy consumption is reduced.

Clustering structures are usually implemented in two forms: Clusters are built from the beginning and remain fixed to the end, or new clusters are produced alternately at determined time intervals.
In both cases, if cluster head loses its effectiveness, a part or the entire of the network will be shutdown at least for a short time. It is not acceptable in any way and an efficient strategy should be devised to deal with this phenomenon. One of the best methods is selecting a node within the cluster as cluster head reserve that is called alternative cluster head. When cluster head loses its ability, alternative cluster head introduces itself as new cluster head and informs other nodes in this cluster about this matter. Selecting the best node as alternative cluster head will causes energy consumption and delay in the network and if cluster heads change periodically, this task will be very costly. In addition to energy consumption and delay, existing methods to determine alternative cluster head usually applied just for specific clustering structures.

FATP [1] is a robust approach to detect faulty nodes in clustering structure but has some major weaknesses in the field of determining alternative cluster head such as having high delay, computational complexity and not considering energy remaining just consider distance from cluster head, etc.

The regular methods [2][3] consider both energy remaining and distance from cluster head to determine alternative cluster head. These methods are more accurate than FATP but still have some weaknesses such as delay and energy consumption.

In this paper, we have proposed a new approach to determine alternative cluster head. This method will be used in the most of clustering structures. The proposed method has very low computational complexity and imposes negligible overhead on the network. We will show that the proposed method will overcome on the weaknesses of FATP and regular methods and it is an accurate, low-delay (fast) with efficient use of energy and less memory-required approach.

The rest of this paper organized as following: In section II, we do an overview on clustering; the new method to determine alternative cluster head is proposed in section III; at the end of this paper, in parts IV and V comparing and conclusion is done.

II. CLUSTERING

There are various challenges in WSN because of its special features. One of these challenges is node limited power supply. So it is required to use some methods to reduce nodes' energy consumption. If each node sends its data directly to the sink, a lot of energy consumed. Since the sensed values by the close nodes are a little different, redundancy may occur in transmitted data. For example, two adjacent nodes data are the same and these two nodes send the same data to the sink.

Generally, to reduce energy consumption in the network, just some of the nodes send the data to the sink. This structure is called clustering and the nodes linked to the sink are called cluster head. The other nodes send their data to nearest cluster head. Cluster head can perform actions such as compression on the data sent by other nodes. Consequently, small amounts of data transmitted to the sink.

As mentioned, a lot of energy is consumed to send data to the sink. As a result, cluster heads face the challenge of fast reducing energy. As soon as the cluster head turned off, a part or the entire network falls of working. A method to avoid this problem is that cluster heads equipped with high capacity, replaceable and rechargeable energy source [4][5][6]. Another way is continuously changing cluster heads among the nodes to distribution energy consumption in the network [7][8][9][10][11].

The famous clustering algorithm in WSN is LEACH [12]. In this method clusters is changed continuously. We assume that clusters have been created by LEACH then the proposed algorithm performs to determine alternative cluster head. LEACH consists of two steps that are repeated continuously until the end of the network. Each repetition is called a round.

In most of the clustering algorithms, initially cluster head nodes are selected and then the clusters are formed. In the case of LEACH to become a cluster head, each node (e.g. n) chooses a random number between 0 and 1. If the number is less than the threshold T(n), the node becomes the cluster-head for the current round. The threshold is set at:

$$T(n) = \begin{cases} \dfrac{p}{(1-p)*(r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{Otherwise} \end{cases} \tag{1}$$

Where, p, r, G are respectively the cluster-head probability, the number of the current round and the set of nodes that have not been cluster-heads in the last 1/P rounds.[13]

III. SELECTING ALTERNATIVE CLUSTER HEAD

As mentioned, selecting a node as alternative cluster head can improves the network efficiency. In the proposed method, cluster head chooses its alternative. As it was said, assume that LEACH algorithm was used to cluster formation. The proposed method also can be applied easily to other clustering techniques.

As soon as formation of clusters, the process begins to determine alternative cluster head. Alternative cluster head selection algorithm should be such that imposes the least cost to the network. Two parameters are considered in the proposed approach to select a node as alternative cluster head: Minimum distance to the cluster head and highest remaining energy. Since during formation of clusters, cluster head does not know the remaining energy and distance of the cluster members, a technique should be used to inform the cluster head about these values. By sending the first data from other nodes (cluster members) to the cluster head, by using Received Signal Strength Indicator (RSSI) technique [14][15] the distance between cluster head and other nodes is calculated easily. The relationship between RSSI values and distance is the foundation and the key of ranging and positioning technologies in wireless sensor networks. Log-normal shadowing model (LNSM), as a more general signal propagation model, can better describe the relationship between the RSSI value and distance, but the parameter of variance in LNSM is depended on experiences without self-adaptability; for more information refer to [14]. The cluster head in LEACH uses (Time Division Multiple Access) TDMA [16] algorithm to collect data from cluster members. In TDMA-based protocols, time is divided into several frames, and frame is divided into numbers of time slots. Since all transmissions within the frame are pre-scheduled, it is possible for a node to sleep when it is not expected to transmit or receive packets. After a short time, the cluster head receives the data from all the cluster members. As soon as a data received from a node, the cluster head calculates the distance between itself and that node.

The remaining energy of the cluster members is another parameters that cluster head needs to determine alternative cluster head. The cluster members should send their remaining energy to the cluster head. In the proposed method, each node allocates a number of limited bits to present its energy remaining that is send to the cluster head. Five bits are used for representing the energy in the proposed method, so each node has 32 level of energy. As soon as formation of clusters are done, each node selects a number from zero to 31 in terms of its remaining energy and they send these five bits along with the first sensed values to the cluster head then cluster head calculates the chance of becoming alternative cluster head for each node when receives the first sensed value of this node. The chance is obtained as following formula:

$$\text{Chance node}_i = \alpha \cdot \text{Energy}_i + \frac{\beta}{\text{distance}_i} \quad (2)$$

In this formula α and β are coefficients that can be changed in different environments. In most of the existing methods [17][18][19] cluster head inserts the obtained information from other nodes in an array and then try to find the best node for alternative cluster head. Operations on array such as sorting and searching are costly. We significantly reduce the computation cost and delay by elimination the array data structure.

After cluster formation, cluster head according to received information of the first node calculates the chance of this node and considers this chance as maximum. The other nodes send their data to the cluster head respectively. Cluster head calculates the chance of becoming alternative cluster head for each of them and compare it by the maximum chance. If the chance of a node was bigger than the maximum chance, it changed to the chance of this node then this node is considered as the best node for being alternative cluster head.

This procedure continues until a complete cycle. At this moment, the alternative cluster head is determined. As you can see, the cluster head just do a few simple multiplication and addition operations, so the computational complexity of this method is very low and even negligible. See the next section.

IV. ANALYSIS AND COMPARING

We compare the proposed method with regular alternative cluster head method and FATP. Consider figure 1. In this figure, nodes are shown by tiny circle, shaded node is cluster head and the other nodes are cluster members of this cluster head. The number, which is written on the cluster members, is their identification and the numbers beside cluster members are percentage of their remaining energy. If FATP runs on this cluster head creates an array of the cluster members and sorts them according to their distance to the cluster head then selects the first node in the array as alternative cluster head. In this cluster, node 1 is selected as alternative cluster head despite having very low energy and if it becomes cluster head will die rapidly. This is the major weaknesses of FATP.

In the proposed method node 3 is selected as alternative cluster head, which is better than the node 1. Because the focus of FATP is on detecting faulty nodes, it is not an efficient approach to determine alternative cluster head.

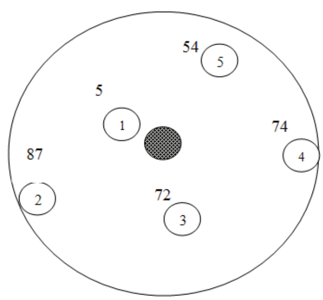

Figure 1. A sample of nodes arrangement in a cluster.

In regular approaches, each cluster member sends its remaining energy to its cluster head then according to energy remaining and the distance of cluster members creates an array of nodes. The cluster head after creating the array tries to find the maximum node in the array to choose it as alternative cluster head. These methods have some weaknesses such as sending energy is costly, a part of memory is occupied, the delay is increased, etc.

The proposed method by omitting the array does not need high memory and is very fast. This method has negligible computational complexity and high accuracy. Therefore, the proposed method has been overcome on the weaknesses of FATP and regular methods. The proposed method by omitting the array almost eliminate computation complexity and delay and is energy efficient, low-delay (or fast), accurate approach and needs insignificant computation and negligible storage. What was said is summarized in the following table.

Table 1. Comparing between some of the alternative cluster head selection methods

Memory usage	Delay	Accuracy	Energy consumption	Complexity	Properties / Method
High	Very high	Very low	Very low	$O(n^2)$	**FATP**
High	High	High	High	O(n)	**Regular method**
Negligible	Very low	High	Low	O(1)	**Proposed method**

V. CONCLUSION

Energy is the most important issue in WSN. The clustering structure is proposed to reduce energy consumption in the network however cluster formation is a costly task. When a cluster head losses its performance the cluster should be formatted. To avoid this matter consider a node in the cluster as alternative cluster head which becomes the cluster head when it is needed. We proposed a new approach to determine alternative node for cluster head by eliminating the array structure and leveling the remaining energy and in comparing with the existing methods it is energy efficient, low-delay (fast), accurate and useable in most clustering algorithms.

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