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Research Article

Application Specific Sleep-Awake Strategy for Increasing Network Lifetime in Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSN) is a technology that provides distributed data collection. However, these networks have some limitations. The most important constraint is energy limitations. The lifespan of sensor nodes that run on small battery depends on the battery life. Although there are many studies in the field of energy efficiency to extend the life of nodes, enough improvement has not been obtained yet. The most basic way to achieve energy efficiency is to sleep and awake the nodes or clusters of nodes. In this study, we proposed an application specific method to wake up and sleep nodes in WSNs. In traditional strategy, the nodes in the cluster sense data and send it to the Cluster Head (CH), if CHs detect redundancy of some data; they remove the duplication and send it to the base station. This is causing energy loss. Our method puts some nodes to sleep state if there are similar data in a certain period. By this way, the life of the network is extended.

Keywords: *Wireless sensor networks, routing, sleep-awake, energy efficiency*

Kablosuz Algılayıcı Ağlarda Ağ Ömrünü Uzatmak İçin Uygulamaya Özel Uyu-Uyan Stratejisi

ÖZET

Kablosuz Algılayıcı Ağlar (KAA) dağıtık veri toplamaya olanak sağlayan bir teknolojidir. Ne var ki bu ağların bazı kısıtları vardır. En önemli kısıt enerji kısıtıdır. Küçük bir bataryaya bağlı olarak çalışan sensör düğümlerin ömürleri bataryalarının ömürlerine bağlıdır. Düğümlerin yaşam sürelerinin arttırılmasına ilişkin birçok çalışma olmasına rağmen henüz tam olarak bir gelişme sağlanamamıştır. Enerji etkinliğini sağlamak için en temel yol düğümleri veya düğüm kümelerini uyutup uyandırmaktır. Bu çalışmada, KAA'da uygulamaya özel olarak düğümleri uyutup uyandıran bir yöntem geliştirdik. Geleneksel stratejilerde, bir küme içerisindeki düğümler algıladıkları verileri Küme Başına (KB) iletirler. Eğer KB, algılanan veriler içerisinde tekrarlar tespit ederse, tekrarlanan verileri siler ve kalan verileri baz istasyonuna göndedir. Bu da enerji kaybına neden olur. Bizim yöntemimiz, belirli bir periyotta eğer düğümlerin algıladıkları veriler aynı ise bazı düğümleri uyku konumuna geçirir. Böylece, ağın ömrü uzatılmış olur.

Anahtar kelimeler: *Kablosuz algılayıcı ağlar, yönlendirme, uyut-uyandır, enerji etkinliği*

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I. INTRODUCTION

Wireless sensor networks are formed by the combination of many sensor nodes. The most important constraints faced in wireless sensor networks are the energy consumption. The reason for this is that sensor nodes acquire the energy through the battery. Thus, in regions that are difficult to reach, the end of node energy can prevent the nodes' communication with the other neighbor nodes. Besides, the life of the network is consumed in proportion to this which leads to major problems both in terms of cost and data communication [1].

There are a lot of methods proposed for WSNs that will increase energy efficiency and extend network life. There have been many studies that provide energy efficiency, especially at the Medium Access Control (MAC) layer and the routing layer [2]. Network clustering in routing layer and the use of a multi-hop network structure actually improves energy efficiency. However, the nodes distributed randomly in the cluster structure cause the perceived data in the nearby regions to be the same [3]. In this case, both nodes consume energy for the same or similar data, and CHs are spending energy to make similar data to single. In this study, the nodes that have the same or similar data are identified in the first cycle in the cluster and the nodes having the same data are slept and awakened according to an algorithm [4].

Our contributions are summarized as follows:

- Nodes that measure similar data are planned to sleep so a simpler TDMA scheme is created.
- The developed method is highly applicable because it is a simple method that can be integrated into LEACH.
- The developed method can be easily adapted to different applications by changing the similarity threshold of data.

The rest of this paper is organized as follows. In section 2, we mentioned related works. The proposed method explained in section 3. Materials, methods and experimental results are presented in section 4 and 5. In section 6, the results are discussed and the suggestions are given.

II. RELATED WORK

We have already said that energy efficiency studies are generally at the MAC layer and the routing layer. The protocols that provide energy efficiency in the MAC layer can generally be group into 2. These are protocols that provide energy efficiency on the preamble and sleep model. Protocols that provide energy efficiency in the routing layer can be divided into hierarchical and non-hierarchical protocols. S-MAC [5] protocol is a planned protocol, which is one of the protocols that provide energy efficiency at the MAC layer. This protocol providing energy efficiency by putting nodes in sleep mode, but it is very difficult for this protocol to provide the same performance for large-scale networks. Another work done in this area is named T-MAC [6]. However, this protocol is an improved version of the S-MAC protocol. In this study, it is very probable that the proposed method will cause problems in large networks. Another protocol that further improves these protocols is the P_MAC protocol [7]. While this protocol dynamically performs the sleep and wake model, but the simulation is made with 25 nodes. The proposed system in this protocol is not considered sufficient for large-scale networks. The second group of energy efficient protocols in the MAC layer is the B-

MAC [8] and the derivatives of these protocols. In such protocols, the preamble of the transmitted data is processed to provide energy efficiency. However, there are a lack of energy efficiency and communication in these protocols.

In the routing layer, the most important protocol emerging is the LEACH [9] protocol, and the protocols called the hierarchical routing protocol, which is its variants, is also confronted with energy efficiency issues. In the LEACH protocol, which one of the most basic protocols, all nodes see the base station. However, this protocol does not offer a proposal for the next node block for nodes where located at a distance that the base station cannot see. C-LEACH [10], which is a protocol derived from LEACH protocol, centralizes cluster formation of nodes. For this process, the nodes send their own locations and their energy to the base station using GPS. In this way, the base station decides which nodes will be the CH. Another work in this area, the MH-LEACH [11] protocol, communicates using the nodes lying on the base station path. This protocol makes CH selection and cluster formation same as LEACH. In this protocol, nodes send data to the destination via neighboring nodes instead of sending them directly to the destination. Another protocol, PEGASIS [12], performs chain and spreading for data collection. In this protocol, each node provides a receiver and forwarder service for its neighbors. APTEEN [13] and TEEN [14] protocols adopt 2 level clustering schemes to send the obtained data to the base station. In fact, APTEEN is derived from the TEEN protocol. One of the studies in the sleep-wake area was proposed as location-based sleep scheduling (CLSS). In this method, mobile cloud computing (MCC) and WSN integration are provided. Here, CLSS dynamically decides that each sensor node sleeps and wakes up. This process is based on the location of the mobile user [15]. In another study, the author went on overhearing to the transmission of the neighbor who was awake. Here this work proposes a cross-layer cluster routing and scheduling protocol. The MAC layer, the network layer and the application data are considered in this work. By this means nodes which are similar to each other and which have similar data are grouped and the network life is extended [16]. In another work in this area, problems that occur in multi-hop broadcasts in WSN's low duty cycles have been identified and a delay sensitive protocol called DCEB have been proposed. DCEB uses neither time synchronization nor duty cycle to plan sleep. Broadcast has a delayed or non-delayed conclusion according to the conditions of transmission time [17].

Some other work done in this area in recent years can be explained as follows. A new short path and coverage algorithm (SPCCA) has been proposed for sensor networks to improve energy efficiency in the network. At the SPCCA, first, each node is given whether it is an unnecessary node or not. After, the unnecessary nodes go into sleep-ready mode with the node selection method. The other nodes are in active mode. Finally, unnecessary nodes on the shortest path are awakened to increase network connectivity[18]. In another study, a new Energy Efficient Connected Coverage (EECC) scheme is proposed to increase the life span of the WSN. In the proposed system, the energy level varies depending on Quality of Service (QoS) measurements such as coverage and connectivity. The sensor, which is not involved in coverage at EECC, acts as a relay node to assist the sensing node. When the target is detected, the relaying node transmits the detected information to the sink node [19]. Another approach in this area is Energy Efficient Dynamic Scheduling Hybrid MAC Protocol (EDS-MAC) for Wireless Sensor Networks. The proposed approach occur two stages as cluster formation and data transmission. In the course of cluster formation, the VSSFFA algorithm is proposed for the generation of energy efficient clusters by optimal selection of cluster heads. The VSSFFA based approach is proposed for intra cluster. In this case, a semi-distributed method has emerged. In this way the delay in data communication has been reduced, and overloading has been tried to be controlled [20]. In this paper, a Sybil attack detection scheme is proposed for hierarchical network with cluster base. Here, a two-stage detection scheme is proposed. Initially, Sybil nodes are detected by high energy nodes. Each

nomination packet used in this study includes the identity of the selected cluster head and a special query of an end user. The unidentified identities of the Sybil nodes are present in the distinct clusters. The goal is to convey high false negative warnings to the end user [21].

III. The Proposed Algorithm

The proposed algorithm is an extension for LEACH protocol. So, we will talk a little about LEACH. LEACH divides nodes into clusters and assigns a Cluster Head (CH) to each cluster. CHS collect data from nodes and summarize the data for a specified period of time. The summarized data is sent to the base station. At the end of the cycle the CHs change and new clusters are created. Each sensing application has its own purpose. The desired data sensitivity differs from one application to another. For example, let's consider an application where temperature measurement is done. Let it be that it gets temperature data from the sensors sprinkled on the land and 1 °C changes for this application are meaningful. In this case, sensitivity ranges of 1 °C degree can be determined and only one of the sensors producing value in this range can be operated. The main motivation of our approach is to prevent the producing of repetitive data. For this purpose, CHs compare data generated by cluster members. One of the nodes that produce the same (or near) data for a certain period of time remains awake; CH puts the others to sleep until the end of the cycle. The proposed algorithm is shown in Fig. 1. The algorithm runs on CHs.

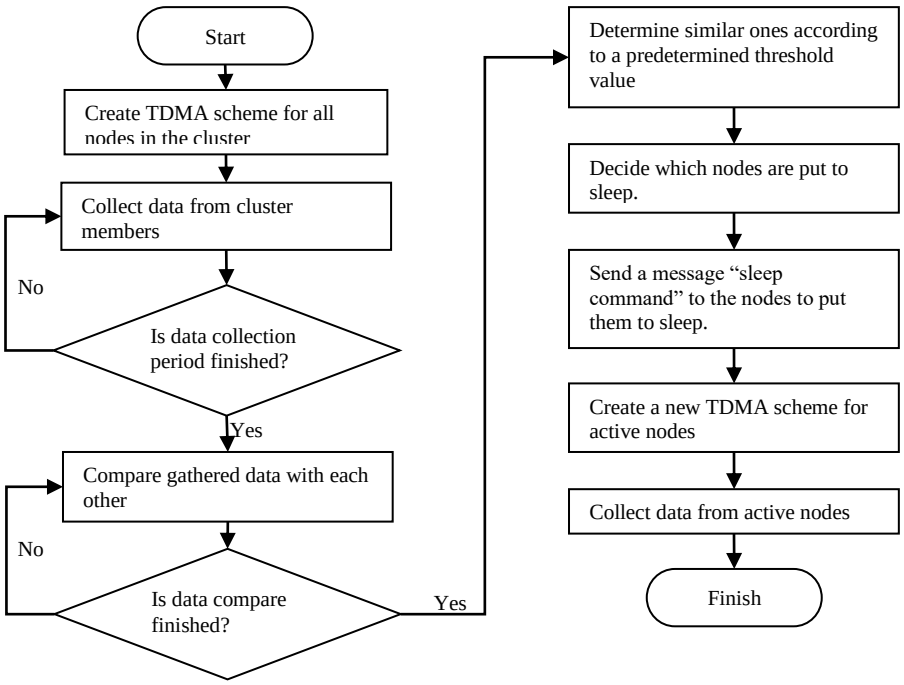

Figure 1. *The proposed algorithm*

When a node receives a sleep command from its CH, it goes to sleep mode until the next cycle. At the beginning of the new cycle, the new CH is selected according to LEACH. Newly selected CH executes the algorithm that in Fig. 1. The threshold value mentioned in the algorithm varies depending on the application. A sample topology is shown in Fig. 2. In the figure, sleeping nodes are shown as Passive Nodes; the sensing nodes are shown as Active Nodes.

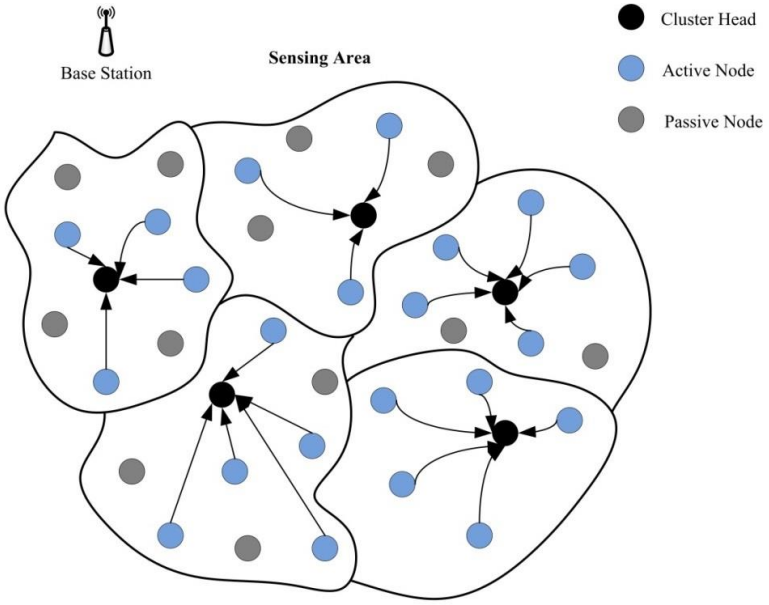

Figure 2. *Sample topology*

IV. Materials and Method

We created simulations to evaluate our approach in ns2 simulator. We used 100m x 100m topology, placed 100 nodes in the area randomly. Each node has 2J initial energy. Base Station is located at coordinate 50,175. Simulation duration is 1000 s and the number of CHs is 5. The detailed simulation parameters are given in Table 1. As we mentioned before, CH puts some nodes to sleep until the end of the cycle according to a threshold value. For simplicity, we assumed that 30% of the nodes in a cluster produce same data. So, CH puts 30% of the nodes to sleep in each cycle.

Table 1. *Simulation parameters*

Simulation Time	1000 s	
Base Station Location	(50,175) m*m	
Energy Model	**RXThresh watt**	6e-9
	CSThresh watt	1e-9
	Rb (Data rate) bps	1e6
	Excvr (Energy for radio circuitry) J/bit	50e-9
	Ebf (Beam forming Energy) J/bit/Signal	5e-9

V. Experimental Results

In the experiment, we compared LEACH and the proposed method in terms of number of alive nodes, consumed energy and produced data. The graphics of number of alive nodes, consumed energy and produced data vs simulation time are shown in Fig. 3, Fig. 4 and Fig. 5 respectively.

As shown in Fig. 3 and Fig. 4, the proposed algorithm has extended nodes' lifetimes. The total network life is extended about 80%. This means that the network will function for a longer period of time. Also, more data can be gathered as a natural consequence of this. Fig. 5 shows that approximately 70% more data is collected by using the proposed algorithm. In addition, the proposed method has also prevented mass node deaths. As shown in Fig. 3 and Fig. 4, between 150 and 250 seconds, the energy of the nodes in the scenario using LEACH is quickly consumed. However, in the scenario that the proposed method is used; the node energies are depleted more evenly.

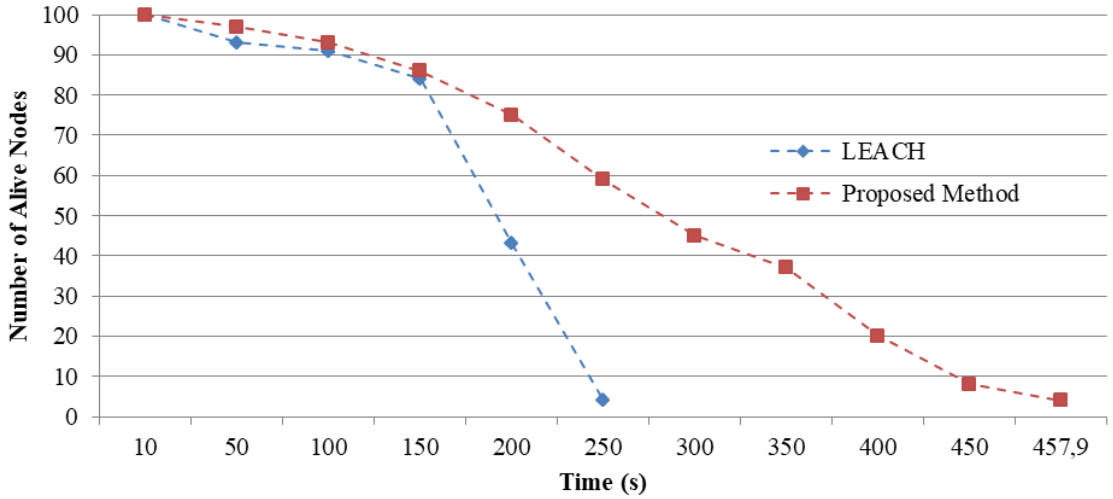

Figure 3. *Number of alive nodes*

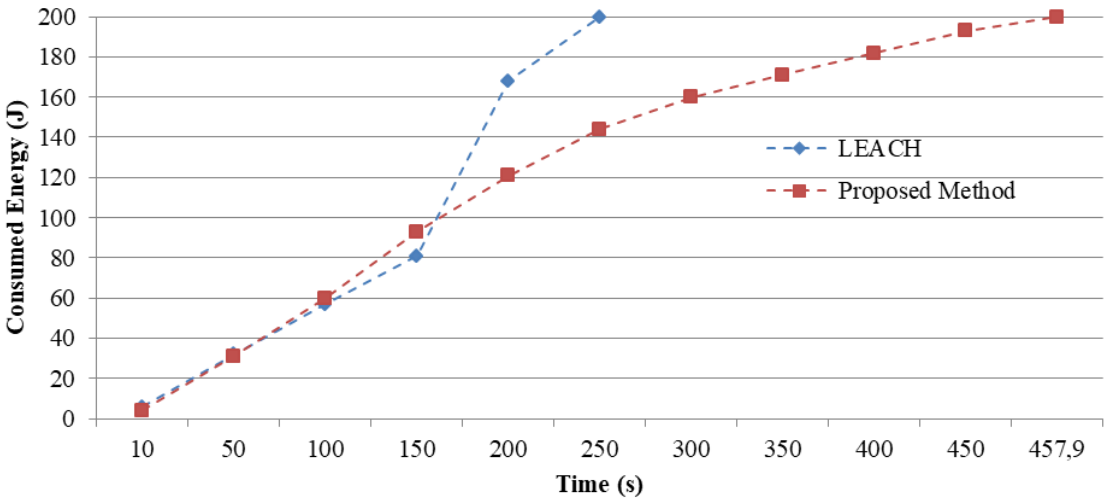

Figure 4. *Consumed energy*

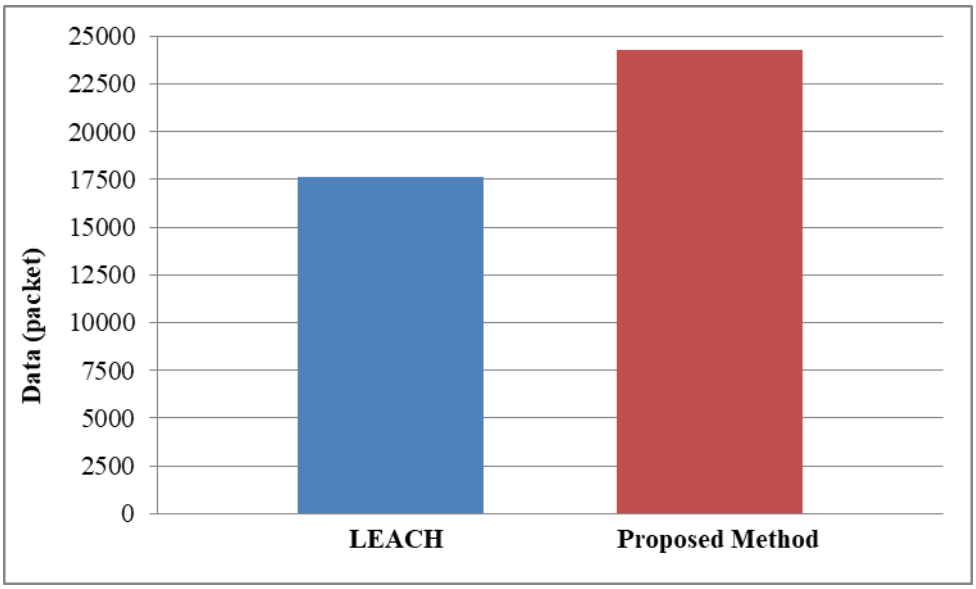

Figure 5. *Gathered data*

VI. Discussion and Conclusion

Experimental results show that the proposed method increases the network lifetime. Additionally, the proposed method has a simple logic and it is designed as an addition to LEACH. As we mentioned before, LEACH is a basic algorithm for WSNs. These features increase the applicability of the proposed algorithm. Additionally, putting some nodes in the network to sleep, simplifies the scheduling process. Thus, CHs create TDMA schemes for fewer nodes. Since the number of active nodes is reduced, the process of setting up a cluster is simplified.

Herein, we must say that this method does not provide any benefit if absolutely each sensor has to work during the sensing task. It will only be useful if a certain sensing sensitivity can be determined and it is possible to put some nodes to sleep.

This study is open to improvement. For example, the sensing threshold can be changed dynamically according to the task. Also, if there are very few sensor nodes in a cluster that need to work at the same time, the nodes in this cluster can be included in another cluster. So that clustering of very few nodes can be avoided.

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