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# Providing a Solution to Reduce Energy Consumption in IoT-Based WSNs Based on Node Activity Management

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*Abstract*—**Nowadays, the energy consumption of wireless sensor networks has increased dramatically due to the significant growth of these networks, especially their use in the Internet of Things. Also, reducing the energy consumption in these networks has been considered to protect the environment. Energy consumption in nodes is critical, and many research studies have been conducted to reduce it. Most methods are based on clustering and cluster selection, while this work presents a solution based on managin g nodes' activity. The nodes were scheduled so that almost all of them were active. The energy of all nodes should be consumed equally. The proposed solution was compared with the DSP-SR algorithm. The results demonstrated that the proposed method can work much better than DSP-SR. According to the evaluation, the proposed method had strengths such as optimal energy allocation and almost no dead nodes in the time periods.**

**Keywords:** Internet of Things; Energy Consumption; Energy Saving; Activity Level; Sink Node.

**Article type:** Research Article


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## I. INTRODUCTION

The Internet of Things (IoT) concept was introduced by Kevin Ashton in 1999[1]. The basic idea of the IoT was connecting a growing number of physical objects to the internet at an unpredictable and rapid rate. The IoT can be used in various applications such as transportation, healthcare, industrial automation, and smart home and enables physical objects to see, hear, think and perform jobs by talking together, sharing information, and making decisions. Today, almost every tool and equipment in any home can be smartened up and connected to a single central processor [1]. The IoT is expected to have significant home applications, to improve the quality of life; for example, smart homes will enable their residents to open their garages when reaching home automatically, prepare their coffee, control climate control systems, TVs, and other appliances [2].

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On the other hand, Wireless Sensor Networks (WSNs) is one of the essential components of the IoT [3]. WSNs are widely used for measuring and monitoring purposes, such as environmental monitoring, military care, and industrial automation [4-6]. A WSN includes several sensor nodes and one or more sink nodes. Sensor nodes read environmental parameters such as temperature, pressure, sound, and vibration and then send them to the sink node [7]. Several studies have integrated WSNs with the Internet Protocol (IP) to develop the Internet of IoT for connecting any objects to the internet [8].

One of the most critical challenges in the IoT is the issue of energy consumption, which is a significant problem in the IoT. The limitation of energy resources in the sensor nodes (Sensor nodes are battery powered devices) is one of the most important problems in exploiting IoT-based WSNs. Therefore, the study of methods that can reduce energy consumption and thus increase the battery life of sensor nodes has always been the interest of researchers [9,10]. The main factor in energy consumption in WSNs is the sending and receiving of data. Thus, designing energy-efficient routings is a significant consequence [11-18].

In addition, sometimes, the particular position of a sensor node in the network exacerbates the problem. For example, a sensor node located one meter away from a sink node loses its energy quickly due to a high workload. On the other hand, its failure causes the sink nose to be disconnected from the entire network and consequently disrupts it. Therefore, optimizing the energy consumption of network nodes can increase the overall life of the network and prevent it from being inaccessible [1,19]. Some solutions go back to the network structure to solve the problem. For example, an automated structure is an effective solution in the above case. Since most decisions are made locally in the automated structure, the transmission traffic from the local node will be reduced, and the node life will be increased, resulting in a longer network life.

In this paper, we will present a solution to reduce energy consumption in the IoT-based WSNs, which is based on regulating the activities of nodes. The remainder of this article is organized as follows: In the second section, we discuss the related works that were done. In the third section, we will propose our method for reducing energy consumption in IoT-based WSNs. The fourth section also evaluates the efficiency of the proposed method, and in the final section, we conclude from the research findings.

## II. Related Works

As shown Hernández and Blum [20] used ant colony and fuzzy networks to compensate for the energy shortage problem. This method uses a suitable MEB algorithm (minimum energy broadcasting). The result obtained by both algorithms is very close to each other. Of course, the answers obtained from the ant colony are better, depending on the antennas that use the wireless sensor network.

In [21], a simple routing method called direct forwarding was proposed, in which when the source node generates a message, it stores it in its buffer and carries it until a collision with a destination node and delivers the message to it. This method generates one copy of the message, and as a result, the least data transfer is performed to deliver the message, and the overhead is minimized on the network. However, the message's delivery may be delayed too much because there are no restrictions on the delivery delay.

In 2016, researchers used content-oriented routing technology to solve the traffic congestion problem in the central network area [22]. Routing data related to intermediate relay nodes for processing makes it possible to achieve data at a higher speed, thus effectively reducing network traffic. As a result, a significant reduction in latency can be achieved. In addition, duplicate data transmission can be eliminated after data collection, reducing wireless communications' energy consumption and saving battery life. Therefore, two methods for implementing this technology were proposed and simulated in this paper. The first method is content-centric routing (CCR), and the second method integrates the first method with the Internet Engineering Task Force Routing Protocol for Low-Power and Lossy Networks (IETF RPL) protocol implemented on the Contiki operating system using the TelosB platform. The simulation results show the superiority of the first method in low network latency, high energy efficiency, and reliability.

IoT integrates several technologies for gathering data in the intercommunication world. Latency-sensitive applications need complicated processing such as that of time series analysis. However, IoT devices enable limited computing and energy resources to store large amounts of data and cannot perform complex task processing. The work proposed by [23] addresses the resource allocation and routing for IoT tasks that require efficient assignment in multi-cloud environments. The authors propose an energy-efficient, congestion-aware resource allocation and routing protocol (ECRR) for IoT networks based on hybrid optimization techniques.

Bi et al. [24] argue that task offloading leads to extra communication latency and energy costs. The work evaluated the offloading by finding an optimal offloading scheme that maximizes the system and seeks a balance between throughput and fairness.

Although MEC servers have allowed intensive task computing in heterogeneous clouds, data transmission over the internet incurs high levels of access delay and jitter, according to Zhao et al. [25]. This work minimizes MEC energy consumption and satisfies task processing delay requirements. The solution uses dynamic programming to minimize energy consumption by allocating bandwidth and computational resources to mobile devices.

Low energy adaptive clustering hierarchy protocol (LEACH) [26] is the first and most well-known protocol based on wireless clustering in sensor networks in which clustering is done in a distributed manner. The most crucial goal of LEACH is to have local base stations (eclipses) to reduce the energy consumption of data transfer to a remote base station. LEACH randomly selects a few nodes as headers and organizes local nodes as local clusters. Nodes are



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assigned to the corresponding header based on proximity (distance). Non-clustered nodes (called normal nodes) transmit their data to clusters. So, the only overhead for them is intra-cluster communication. Ecliptic nodes require more energy than normal nodes. Therefore, the selection of fixed ecliptic nodes leads to premature depletion of energy and premature death. The energy balance of the threads is established by rotating the role of the thread between different nodes. Also, using community/data combinations in eclipses reduces the volume of messages sent to the base station and saves energy. The performance of the LEACH protocol is divided into several cycles. Each cycle begins with the installation phase (cluster formation), in which the clusters are organized.

Following the installation phase is the data transfer phase, in which normal nodes send their data to the base station, and the headers, after completing/combining the data, transfer the integrated packet to the base station to the amount of information that needs to be transferred to the base station. In LEACH, node data transmission is scheduled by code-sharing multiple access protocol (CDMA) or time-division multiple access (TDMA). The selection of the header is made through a probability function. Each node selects a random number between zero and one, and if the selected number is less than T (n), that node is selected as the current round eclipse:

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

Where P is the probability of being eclipsed, r is the current round number, and G is the node set that was not eclipsed in the last 1/p round. Based on the simulation model, it is proved that only five percent of the nodes need to be spun. The strength of LEACH in the rotation mechanism is the role of the headers and the data community, and it can extend the life of the network, but it also has disadvantages:

First, it assumes that all network nodes have sufficient power to send information to the base node and sufficient computing power to support different MAC protocols. Therefore, it is not applicable in large-scale networks. It also assumes that nodes always have data to send and that nodes close to each other have interdependent data. This protocol assumes that all nodes in each selection cycle start with an equal energy capacity, assuming that the ellipse consumes approximately as much energy as the other nodes. The main disadvantage of LEACH is that it is unclear how a predetermined number of headers (i.e. p) wants to be evenly distributed across the network.

Centralized LEACH [27] is a clustering algorithm in which the formation of clusters is done centrally by the base station. This algorithm has a data transfer phase (permanent mode) similar to the LEACH algorithm. Each node sends information about its current position and energy level to the base station. It is usually assumed that each node has GPS. The base station must ensure a uniform distribution of energy among the clusters. Therefore, it sets a threshold for the energy level and selects nodes with more energy than the set threshold as possible branches. Determining the optimal number of headers is an NP-Hard problem. LEACH-C uses a simulated fusion algorithm to solve this problem. After determining the current remote headers, the base station sends a message containing the header I.D. to each node. If the node's header I.D. matches its I.D., that node is a header. Otherwise, it is a normal node and can go to sleep until its data transfer stage. LEACH-C is more efficient than LEACH, and for each unit of energy, it transmits about 40% more data. The base station has universal knowledge about network nodes' location and energy level. Moreover, LEACH-C guarantees the optimal number of clusters (k) per cycle, unlike LEACH.

The DSP-SR algorithm [28], which will be the basis for comparing the results in the evaluation, consists of three main parts, which are mentioned below:

1. Sorting user requests based on maturity time: In this step, the node request is first sorted based on the maturity of each request (note that the relay nodes in the network do not generate traffic from themselves, and only the requested traffic transmitter is responsible for other nodes). EDD method was used for this sorting. In [28], it is shown that EED is an optimal sorting method based on the due time of requests in scheduling. In addition, this method will help select the appropriate nodes in the next phase.

2. Selecting the appropriate subset of requests: According to the EED method in the previous step, the submission time of each node will be close to its deadline. At this stage, according to the network topology, traffic and transmission interference delay of other nodes in the network relays, based on a linear algorithm and weighting given to the nodes, a subset of requests for selection are selected. The criterion for sending is the end-to-end delay guarantee of the user's request. Therefore, at this stage, some requests, although they prioritize sending according to EDD, will be removed due to the lack of guaranteed end-to-end delays due to traffic and other requests.

3. Assign time slots based on the second step: After selecting a subset of requests to send (for which delay is guaranteed), the channel is provided to the nodes. At each stage, if it is possible to send simultaneously, other nodes' requests are allowed to send. It is shown that the problem's degree of difficulty is in reusing the frequency space of O (n3 × r2). n is the number of requests, and r is the maximum number of relays in the network.

## III. Proposed Method

The In this section, the proposed method is conceptually explained. As mentioned, a significant problem with IoT-based WSNs is that the sensor nodes are short-lived. The life of the sensor nodes is short due to the limited energy of the power supply. There is also the problem of premature depletion of energy in the case of nodes in low-density areas in the non-uniform distribution of nodes. In such cases, it would be appropriate to have management within the nodes and provide informed power solutions so that the critical nodes are used the least. Providing a suitable structural model and providing management methods and power-



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aware algorithms to increase network life are important issues.

The goal of an optimal energy grid is to reach a point where the wasted energy is reduced to a minimum, and the energy consumed to send node information to sink nodes is also reduced. The proposed method, which is described here, tries to achieve two goals:

1. Achieving a state in which nodes consume approximately equal amounts of energy in communication.

2. The network enters a state that increases its lifespan, and messages transmission occurs during the nodes' active times. In inactive times, the nodes go to sleep, so their energy consumption is almost zero.

In general, when the amount of energy consumption is controlled and the amount of use is considered, the life of the network increases, so in this case, it can be seen that by reaching the first goal, the second goal is automatically met. In the proposed method, the unnecessary transfer of continuous information to the sink nodes is prevented; also, it can be said that the energy of the nodes has been managed. In this proposed method, nodes send when they have enough data to transfer. If the data is not enough, data is collected and sent when it is enough. This energy management method is powerful because the more times the data is sent, the faster the nodes lose their energy. It should be noted that the purpose of the proposed algorithm is not to reduce the quality of the channel, but the proposed algorithm works in such a way that the remaining energy in the nodes increases, and it should work together. The method described here can be used in all applications of IoT-based WSNs, such as smart homes, military applications, and Smart Agriculture.

Here, the proposed method manages the nodes' energy consumption and controls the nodes' activity levels in time intervals. Moreover, this method does not provide a consumption pattern. In military cases, we can refer to environmental control, and nodes are spread in the environment that can intelligently care for the environment. For example, each node can be armed robots with limited energy and have to take care of the environment. In such a case, the energy consumption of the nodes is essential. Here, too, the nodes considered in intelligent homes have limited energy, and nodes permanently connected to direct electricity are not considered. Our goal is to reduce energy consumption. The energy of the nodes is with the battery, and by reducing the energy consumption of these nodes, the energy consumption of the whole building can be saved because the number of these nodes can be very high in the building.

In wireless sensor networks, two architectures are mostly used when multi-hop nodes are considered. Multiple hops are the common mechanism utilized in the network for sending data to the sink node. One of these architectures is the flat architecture in which the sensor nodes send data to the sink nodes. The second architecture is the multilevel architecture that uses clustering methods[29,30]. In this paper, flat architecture is used. It is supposed that sensor nodes and sink nodes can move, so the greater distance between nodes to send data, the more nodes consume energy.

In general, the battery of nodes is divided into rechargeable and non-rechargeable. The proposed algorithm considered both categories. Of course, ordinary nodes or sensor nodes spend most of their energy transferring information to the sink nodes. Here we use the term activity level to specify the rate of transmission and connection to the sink nodes. Here we use this term to express the number of times nodes use energy to communicate with sink nodes. The node will connect to the sink node for a longer time if the activity level of a node is higher. The communication process occurs in frames, called specific time intervals, that the nodes go through. Each frame is a unit of time and is divided into time sections (or time slots). This research considers the activity level a fraction of slots in a frame that the nodes communicate with the sink nodes. Due to the movement of nodes (both sensor nodes and sink nodes), it is difficult to determine the appropriate and optimal activity level for nodes. The proposed method's goal is to specify the optimal activity level to increase network life dynamically. This proposed method can be used in almost any network of sensor nodes with the sink nodes as the centralized management nodes and can operate optimally in these networks.

Before discussing the proposed method, it is better to specify some definitions and parameters, as presented (Fig. 1):

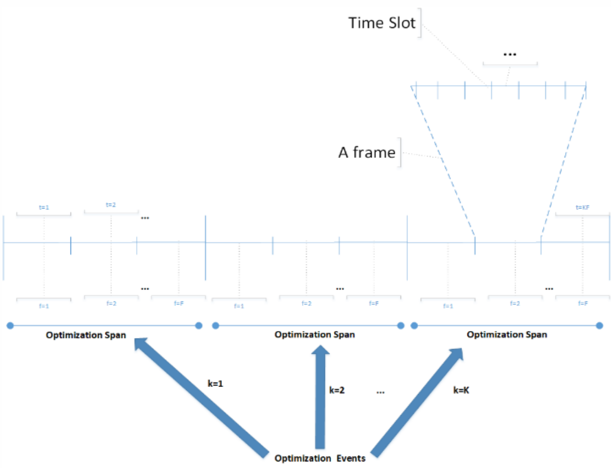


Figure 1. Parameters used in the proposed method.

As shown in Fig. 1:

- k = 1, 2, …, K represents the number of rounds, or we can say that it is several improvements because every time we move forward, we improve the previous improvement, that is, we improve the network in the previous round, so k can be called round or improvement. As discussed earlier, there are frames in each of these improvements, which are divided into time slots. If the mobility of sensor nodes is lower and the network is more stable, less k is needed because the network is not disturbed, so fewer improvements are needed.



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Conversely, if the mobility of the sensor nodes is higher, the greater k or improvements are needed. Therefore, we choose the value of k depending on the conditions and the nodes' degree of mobility or stability. From this point, we can see that our proposed method can be used for both fixed and mobile sensor nodes. Here, the number of frames or F also depends on the mobility of the nodes because if the mobility of nodes is higher, the more updates they need, and the network must be updated at shorter time intervals. Thus, we can consider k as the number of improvements and F as the rate of improvement.

- The KFparameter is the execution time of the whole algorithm. Of course, the value of KF cannot be obtained in the real world. However, in the simulation, this value can be specified.
- The number of sensor nodes is denoted by N, and each node is denoted by an index (n = 1, 2, …, N).
- The energy specified in the sensor nodes is associated with the improvements or K. The amount of residual energy also depends on the parameter K and, in different frames, is specified as an energy matrix that stores for all nodes. So, for the remaining energy we have: $S(k)=[s_1(k), s_2(k),\dots,s_{F+1}(k)]\in R^{N\times(F+1).}$

This is while the initial stored energy in the battery is considered equal to $s_1(1)$. It is generally stated that the nodes initially have residual energy $s_1(1)$, and after k their residual energy recovery is equal to $s_1(k+1)=s_{F+1}(k)$:

- The activity level matrix is expressed as $X(k)=[x_1(k), x_2(k),\dots,x_F(k)]\in R^{N\times F}$ where $x_f(k)\geq 0$ and $1^T x_f(k) = 1$. It corresponds to the following vector N whose all arrays are equal to 1, and T represents the transition. For example, $x_{n,f}(k)=0.1$ indicates that node n in frame f and recovery k should occupy 10% of the time slot. So the maximum amount of activity that can be assigned to a frame is 1. The amount of energy consumed by the sensor nodes is proportional to the activity level of the nodes depending on the channel conditions between the sensor nodes and the sink node. These channels, in turn, depend on the relative position of each sensor node to the sink node, which is assumed to be unknown here as the estimation of this operation is a computational process associated with increased energy consumption and system complexity.
- If we consider the maximum amount of activity for the sensor nodes, which is the same value as 1, the energy that these nodes expect for transitions in F frames is equal to the maximum consumption matrix $B(k)=[b_1(k), b_2(k),\dots,b_F(k)]\in R^{N\times F}$ where B(1) represents the maximum energy consumption in the initial F frame. The expected energy consumption of the sensor nodes in the F frame of improvement k is equal to B(k)*X(k) where * represents the multiplication of the elements. In the real world, B(k) in sensor nodes depends on the distance and channels between nodes and the sink node.
- This research assumed that the energy consumption estimated in the first F frames is constant, meaning that $b_1(1)=b_2(1)=\dots=b_F(1)$. This means that transitions are made in the first frame, while the nodes do not move at all (before they start moving). These transfers do not contain critical information; only these transfers are made so that the energy consumption can be appropriately prepared for the next improvement or period.
- The recharge matrix is expressed as $R(k)=[r_1(k), r_2(k), \dots, r_F(k)]\in R^{N\times F}$where $r_f(k)$ indicates the amount of energy that has reached the battery of the sensor nodes to recharge them. In the real world, recharging depends on parameters such as the battery and the amount of energy transferred. Here we hypothesize that nodes continuously receive energy for recharging using radio frequencies (RF) and we Consider that recharging by RFis done in frame f and round or improvement k. In this case, it can be easily understood that R(k) should be a sparse matrix because many of its elements take zero value. This means that $r_f(k)=0$ equals zero in many f and k. We consider that recharging occurs at time $t=t_r$ during the analysis period, so since recharging is done only once, we have only one f and one k, which is true in the equation $t_r=f+(k-1)F$.
- On the other hand, a ceiling should be considered for recharging. Recharging cannot be more than the battery capacity of the nodes. First, the energy of the nodes is assumed to be complete, so $r_r$, which represents the fraction of the battery capacity of the nodes, can be considered as the maximum energy for recharging: $r_f(k)\leq r_r\max\{s_1(1)\}$.
- Each row of the maximum energy consumption of matrix B(k+1), which is the input of the improvement (k+1), is calculated in the sink node. This calculation is based on the energy consumption of the nodes in the F frame of the improvement k and their activity level (The maximum energy consumption matrix consists of the energy consumption of the node whose activity level is one). Energy consumption consists of residual energy and the level of energy that has been recharged. Here, suppose we assume that the sensor nodes have fully used their level of activity to kth improvement. In that case, the energy remaining in the battery of these sensor nodes after the (f+1) frame is equal to the energy remaining after the fth frame of the kth improvement minus

the energy consumed plus the amount of energy that has recharged the battery so we have: $s_{f+1}(k)=s_f(k)-b_f(k)*x_f(k)+r_f(k)$ (* means multiplication of one element to another) so the fth column of B(k+1) is equal to $b_f(k+1)=[s_f(k)-s_{f+1}(k)+r_f(k)]*\frac{1}{x_f(k)'}$.

- $B_{min}$ and $B_{max}$ are the node's minimum and maximum energy consumption, respectively, when the activity level is equal to one and the node is at the closest and farthest point from the sink node. The correlation coefficient between two consecutive frames is shown with ρ.

- A network's lifespan is when all sensor nodes are fully operational. In a way, we consider that the network's life ends when the first sensor node is not working correctly, is out of operation, or dies due to a lack of energy. A node's death time is when the energy remaining in a target network node is less than or equal to a fraction of the maximum stored energy, denoted by $t_d$. We express the death energy parameter, denoted by $s_d$, which is equal to the voltage level of the battery from which the node begins to fail.

As mentioned, the proposed method increases the energy remaining in the nodes. It should also conserve the nodes' potential energy, leading to a higher activity level. In this case, the transfers are done at a higher speed because the quality of the channel is high. At the same time, if the potential energy is low and the residual energy is low (precisely the opposite of the previous case), the activity level of the nodes decreases. As a result, the relevant sensor nodes are practically inactive, so the network loses its original coverage. We tried to make optimizations in this case. Suppose we want to express the matter stated mathematically. In that case, we can say that in the optimization event k, there is a two-criteria optimization problem in which the objective function is formed by the sum of the weight of the two objective functions, which this objective function can be expressed as (2).

$$f_0[s_f(k)] = \{\omega_1 \max(s_f(k)) + \omega_2 \max\left(s_f(k) - b_f(k)\right)\} \qquad f = 1,2,3,\dots,F \qquad (2)$$

We have: $\omega_1 \geq 0, \omega_2 \geq 0$, which in this case if:

- $\frac{\omega_1}{\omega_2} > 1$ : Then the target function goes in a direction that reduces the network's life because the nodes die sooner in this case.

- $\frac{\omega_1}{\omega_2} > 1$: In this case, the improvements go in the direction of the activity level of the nodes with more residual energy and better channels. In this case, the network life increases even in nodes with bad channels and low residual energy.

In the proposed algorithm, for each improvement k, a series of theorems must be observed, which are:

- The activity level assigned to the nodes cannot be negative: $x_f(k)\geq 0$ for f = 1,2, ..., F.

- The sum of the activity levels assigned to nodes in a frame is one, $\sum_{n=1}^{N} x_{n,f}(k) = 1$, and $x_{n,f}(k)$ is equal to the nth element of $x_f(k)$.

- In each improvement, the level of activity and the amount of energy remaining in the nodes are calculated in the previous improvement. This means that the energy remaining in a frame (f+1) equals the energy remaining in frame f minus the energy consumed in frame f. According to $s_{f+1}(k)=s_f(k)-b_f(k)*x_f(k)$, the maximum energy consumption that is used as the input of each improvement is from the information data of the remaining energies and the charge of the previous improvement.

Therefore, it can be said that in kth improvement, (k-1) the improvement must be solved at first. It means that for current improvement, the previous improvement must be improved:

$$\begin{aligned} &\text{Minify} \quad f_0[s_f(k)] = \{\omega_1 \max(s_f(k)) + \omega_2 \max\left(s_f(k) - b_f(k)\right)\},\ f = 1,2,3,\dots,F \\ &x_f(k)\geq 0 \\ &1^T x_f(k) = 1 \\ &s_{f+1}(k)=s_f(k)-b_f(k)*x_f(k) \qquad (3) \end{aligned}$$

Equation (3) can be converted to Equation (4):

$$\begin{aligned} &\text{Minify z in frames } f=1,2,\dots,F \\ &\{\omega_1 \max(s_f(k)) + \omega_2 \max\left(s_f(k) - b_f(k)\right)\} - z \leq 0 \\ &x_f(k)\geq 0 \\ &1^T x_f(k) = 1 \\ &s_{f+1}(k)=s_f(k)-b_f(k)*x_f(k) \qquad (4) \end{aligned}$$

Equation (4) requires very little processing time. The optimal variables that need to be identified to kth improvement are:

- Matrix X(k)
- The matrix S(k) predicts the residual energy and is not necessarily the actual value.
- N is the number of sensor nodes
- F is the number of frames in the improvements
- The initial energy of the nodes
- The maximum estimated energy consumption in the initial F frame, which is equal to $B(1)=[b_1(1),b_2(1),\dots,b_f(1)]$

In Fig. 2, the pseudocode for the proposed algorithm has been shown, which aims to optimize the level of activities and increase the network's life. The last step of the algorithm is that the activity level should be converted to a fraction of the time per frame. That is how many fractions of a frame each node operates.



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This is the resource management part of the proposed solution.

| ***Pseudocode*** |
|---|
| ***Input:*** |
| ***Number of sensor nodes, N,*** |
| ***Optimization span, F,*** |
| ***Initial energy levels of the batteries, $s_1(1)$*** |
| ***Estimated consumed energies in the first F frames, $B_1(1)$*** |
| ***for k = 1, 2, . . . (up to the network death),*** |
| ***Solve the optimization problem (3) or (4) to determine X(k).*** |
| ***Compute matrix B(k + 1) from sensor node information on actual residual energies*** |
| ***and recharge.*** |
| ***Assign time or time-frequency slots to the sensor nodes according to the activity levels*** |
| ***in X(k).*** |
| ***end for*** |

Figure 2. Pseudocode of the proposed solution.

For describing the proposed algorithm in Fig. 3, the connections between the sink node and the other nodes are specified.

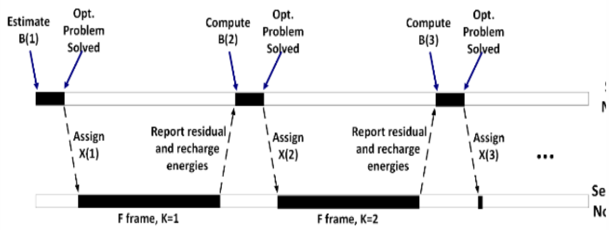


Figure 3. The proposed algorithm and the connections between nodes.

## IV. Evaluation

In The program is implemented in MATLAB R2015b environment. The implementation uses the CVX plugin, which helps to simulate algorithms such as the proposed algorithm and speeds up coding. CVX is a software program that runs on MATLAB. This program uses MATLAB to turn the convex optimization problem into a form to solve. How to write equations in CVX is very similar to writing mathematical equations on paper. A defined format must be used to define the problem in this software. Also, use rules to maintain convexity. By voluntarily accepting a series of constraints, CVX can solve any problem defined for it. The implementation here is based on simulation on the MAC layer, and here we considered virtualization granulation at the node level. Virtualization granulation represents a set that can manage itself, and this is the virtual set that we have considered here at the level of each node. Each of our nodes means a virtual set. Our network protocol is also a wireless sensor network protocol (such as IEEE 802.15.4).

We compare the proposed method with the DSP-SR algorithm. This method is somewhat better than the other methods mentioned for scheduling and resource allocation and is closer to our proposed method, so we chose this method for comparison and evaluation.

First, to evaluate our method, we examine the parameters w1 and w2 and the different values w1=1, w2=0; w1=0, w2=1, and w1=1, w2=2. Other parameters values:

- N=10
- K=400
- F=1
- $B_{min}$=0.001
- $B_{max}$=1
- $S_1(1)$=10
- $S_{max}$=10
- ρ=0.98

As seen in Fig. 4, all sensor nodes can communicate with the sink node at any time. This relationship is such that almost all nodes have the same energy at time slots. This causes them to die together eventually. In this case, the energy is used correctly, and the energy is not wasted in the nodes. In this case, if F>1 and ρ is smaller, in case w1 = 1, w2 = 0, the further we go in the frames, the possibility that the nodes can use almost the same amount of energy decreases. It decreases because the farther we go to the front frames, and if the correlation coefficient becomes smaller, the effectiveness of the current frame information is less than the previous frames.

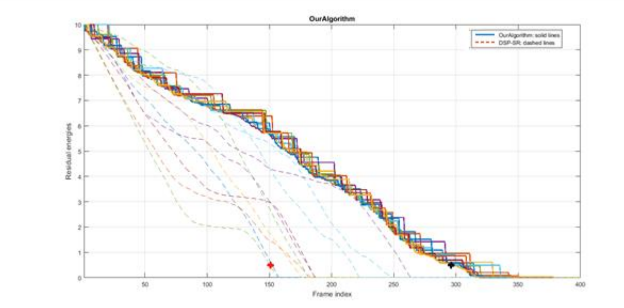


Figure 4. The remaining energy of the nodes in the state w1=1, w2=0.

As demonstrated in Fig. 5, w1=0, w2=1 can be seen in this case; the nodes have almost different energy ratios than before. Of course, this theorem is also shown earlier: if the number of nodes is high, this mode is better than w1=1, w2=0.

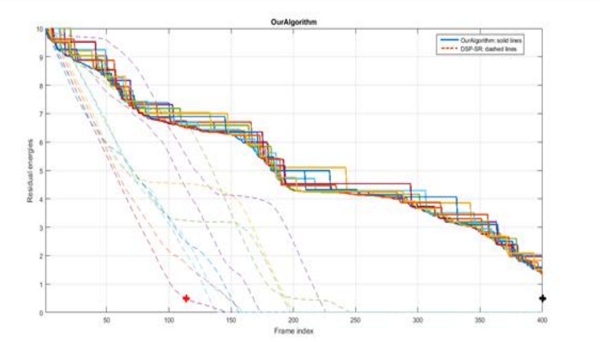


Figure 5. The remaining energy of the nodes in the state w1=0, w2=1.

As seen in Fig. 6, the weights assigned are equal to w1=1 and w2=2. The system has a more normal state than previous modes, as it is not necessary to perform the algorithm once in actual conditions depending on the number of nodes. However, in this case, regardless of whether the number of nodes is low or high, it is a normal state.

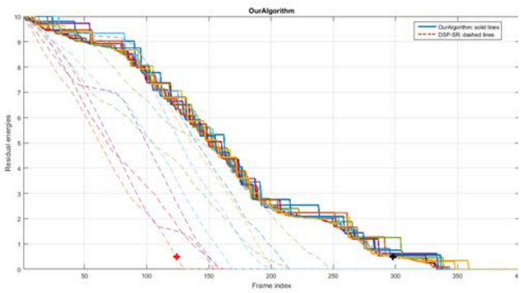


Figure 6. The remaining energy of the nodes in the state w1=1, w2=2.

As seen in Fig. 4, Fig. 5, and Fig. 6, the average death time is 385. If w1=1, w2=0, all nodes regularly send information to the sink node at all time slots, so node energy runs out sooner than other nodes. In this case, the network lifespan is less than in other cases. While in the case of w1=0, w2=1, the graph is stepped (Fig. 5). The reason for stepping is that some nodes have not been active in some sections, resulting in energy savings and the network lifespan, in this case, is very high. In the case of w1=1 and w2=2, it can be seen that, in practice, we use the benefits of both previous cases. This means that the nodes can have a longer life, and also, the activities of nodes are almost similar in different time slots.

As it is clear in these figures, all three mentioned cases of the proposed method are better than DSP-SR method because they have a longer network lifespan. The death of the first node in the network is marked with a cross in the figures. In the proposed method, the death of the first node takes about twice as much time as the death of the first rival node based on the evaluation. Moreover, according to the hypothesis we said at the beginning, the network collapses with the death of the first node; therefore, the death of the first node is the network's lifespan. The network's lifespan in the proposed method is twice the lifetime of the DSP-SR method, which shows the excellent performance of the proposed method.

As seen in Fig. 7, the activity level of nodes in w1=0, and w2=1 is almost equal in different time slots. In Fig.8, the activity level of nodes is not divided equally and compared to w1=0, w2=1, it does not have an equal activity level.

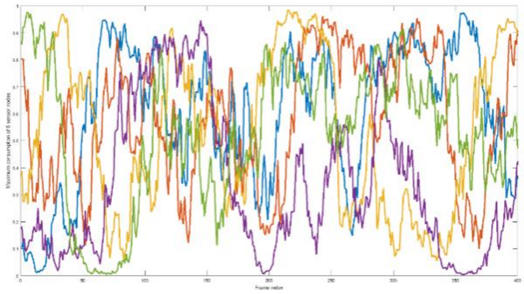

Figure 7. Node activity level in w1=0, w2=1.

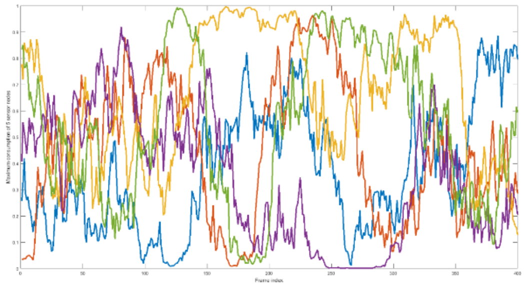

Figure 8. Node activity level in w1=1, w2=0.

In Fig. 9 it can be seen that in the state w1=1, w2=2 the activity level of the nodes is slightly lower than the state w1=1, w2=0, and more than the state w1=0, w2=1. Therefore, the state w1=1 and w2=2 is the intermediate state.

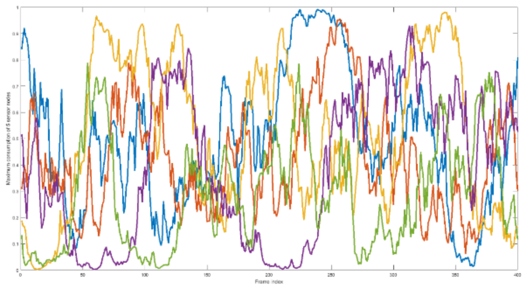

Figure 9. Node activity level in w1=1, w2=2

In another evaluation, the parameters are:

- N=10
- K=80
- F=5
- $B_{min}$=0.001
- $B_{max}$=1
- $S_1(1)$=10
- $S_{max}$=10
- $\rho$ =0.98
- W1=1
- W2=2

As shown in Fig. 10, the proposed method has done much better resource allocation. Furthermore, the energy in all nodes in different frames is almost equal. However, this is not true about DSP-SR, indicating that some nodes run out of energy sooner, while others may have too much energy. So resource allocation is not well done in DSP-SR.



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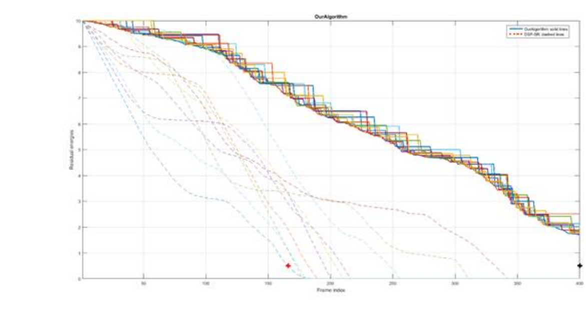

Figure 10. Energy allocation diagram for nodes in proposed method and DSP-SR

Fig. 11 shows the average activity of nodes over their lifespan for the proposed method and DSP-SR. Each node in the proposed algorithm has the same average activity, and at the same time, according to Fig. 10, it extends the lifespan of the proposed algorithm. This shows the efficiency and effectiveness of the proposed algorithm in the process of allocating resources to nodes. Of course, in DSP-SR method, some network nodes may have more activity, and activity in some of them is low. This shows that the main problem of the DSP-SR algorithm is that it does not replace the nodes when they have low energy.

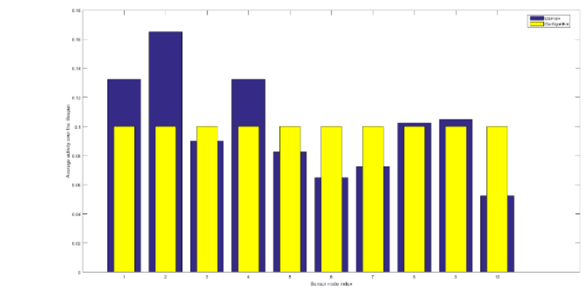

Figure 11. Mean activity of nodes over the lifespan for the proposed method and DSP-SR

## V. Conclusions And Future Work

This paper introduced the algorithm in which, by changing the weights, the activity level of the nodes could be changed in different modes. In the proposed algorithm mentioned here, it can be said that the useful life of the nodes is almost high, and the resource allocation rate has been done very well, which can be examined in the previous section. According to the evaluation, the proposed method had strengths such as optimal energy allocation and almost no dead nodes in the above periods. However, the same algorithm used some nodes for no reason. The proposed method, compared to DSP-SR works better as it tries to equal the activity level of nodes.

For future works package manager for sending and receiving packets could be added, which can find duplicate sent packets and store the received information in a table in which each of these rows has an identifier. In this case, instead of sending a duplicate message from the sink node to the workstation, only the I.D. of that packet can be sent to the workstation. The table is the same as the table in the sink of the workstation; in this case, the workstation can identify packets by receiving these identifiers. The volume of packages sent is reduced, increasing the lifespan according to our proposed method.

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