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Optimal Routing-Clustering Aware of Energy Consumption in Wireless Sensor Networks based on Deep Tree Learning

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Abstract—**Today due to using Wireless Sensor Networks (WSNs) in many application, some challenges are facing in these kinds of networks. The most important challenge is battery in sensor which defined as energy consumption. Sensor nodes located and employed in geographical environment as their application and they use battery because of collecting data. Setting up sensor nodes and distribute them in an environment will lost at the beginning and also in data collection and transmitting some other energy will be use. Transmitting means data routing in network and it will use many energy. To cover this problem, clustering will be used before or simultaneous of routing. This article use clustering-routing by sleep and wake scheduling in sensor nodes to save energy. For this purpose, this research presents an optimal Constrained Anisotropic Diffusion Routing (CADR) protocol called OCADR and optimizes it with Deep Adelson-Velskii and Landis (DAVL) tree rotation clustering algorithm. The results represented that the proposed approach can perform a proper scheduling in comparison to previous methods in the sensor node's sleep and wake time and can also transmit packets to the base station through the head clusters. The total of 50 Joules energy defined at first and after using this method in simulation, only 22 Joules of energy are consumed which 28 Joules remain for the survival of the network that is an improvement over previous methods.**

Keywords- **Wireless Sensor Networks (WSNs), Constrained Anisotropic Diffusion Routing (CADR), Sleep and Awake Scheduling, Clustering, Velskii and Landis (AVL) Tree, Clustering, Routing, Deep Learning**

1. Introduction

Wireless Sensor Networks (WSNs) consist of hundreds or thousands of small devices that are able to communicate with each other with limited battery power. These wireless sensors are placed in a real world environment to sense various environmental effects. The sensor nodes have limited power, so the data collected from the target environment is transmitted directly to the base station. A base station is a node that is interested in receiving information from a set of sensor nodes. This node analyzes and reduces the similarity between its data that is used for decision making. In addition, the base station can not only use this data locally, but it can also transmit this data to other networks in a remote area [1]. However, this creates high communication overheads that are not tolerated by the sensor nodes. In WSNs, the process of collecting data from all sensors and reporting them to the base station is known as data collection. WSNs technology has been developed for using in many different applications. These programs may include military programs, survival monitoring, traffic control, smart buildings, and object tracking. However, WSNs have extensive limitations such as limited memory, low computing power, no rechargeable battery and limited battery, security and global address setting for all sensor nodes. Saving energy is a sensitive issue for sensor nodes that are supposed to work without care for a long time. In addition, energy consumption depends on the requirements of the programs. So, it is sometimes placed in an inconsistent environment where no one can charge or replace the battery [1]. Therefore, the battery plays a major role in WSNs which indicate its lifespan. In a wireless network, most of the energy is consumed in the data transmission process. Therefore, energy efficient routing protocols are required. Many research papers have addressed this issue to design more energy-efficient WSNs [1-20]. Different types of research have been introduced to save energy. This research begins with the physical layers of routing protocols, which are based on how advanced data collection techniques are developed. On the other hand, clustering-based protocols have attracted a large number of researchers. This work consists of two stages: the start-up phase and the permanent phase. In the start-up phase, WSNs are divided into clusters (node groups). In each cluster, there is a node that acts as a cluster heads (CH). Members sense in clusters (non-clustered nodes) and transfer their data to the CH system in the permanent state phase. Each sensor node in the cluster has its own time to transmit its CH-sensitive data.

An important issue in a WSNs is energy consumption which is directly related to network life. Therefore, it is necessary to provide a method that can reduce energy consumption and also lead to improved quality of service standards including throughput, latency, bit error rate and etc. This research presents a method based on the sleep and wake scheduling of sensor nodes. Therefore, the sleep / wake programming technique is implemented in the network in order to reduce this energy consumption by nodes that are not able to transmit information or communicate in clusters with sinks. Energy retention in the grid is possible through this sleep / wake scheduling process. This is possible by dividing the node from the cluster into active nodes and inactive nodes. Active nodes are high-energy nodes capable of communicating with the cluster and passive nodes are low-energy nodes that are unable to communicate with the cluster head. These inactive nodes are transmit to sleep with low energy and the remaining nodes remain awake able to communicate with the eunuch. Through this method it is possible to conserve network energy as well as increase network lifetime [1-20].

2. Literature Review

In [16], a method is proposed that combines energy efficiency and selection of multiple paths for data fusion in WSNs. The network is divided into different clusters and the node with the highest residual energy is selected as the cluster. The sink calculates multiple paths for each CH to transmit data. Source-wavelet distribution and conversion programming is used to compress data in CH. The path changes in a rotating manner to conserve energy during each transmission cycle. This process is repeated for each cluster. But this method consumes more energy because all the nodes in the network remain inactive without transferring anything. This work can reduces the life of the network. To overcome this problem, this paper proposes a guaranteed distributed sleep / wake schedule in which only the transmission node remains active and the other nodes go to sleep.

In [4] a distributed sleep / wake schedule is proposed with guaranteed coverage. The main purpose of this method is to extend the lifetime of the WSN while ensuring network coverage. In this method, the sensor nodes are divided into clusters based on the measurement coverage criteria and allow more than one node in each cluster to be kept active simultaneously through a dynamic node selection mechanism. The main advantage of this method is that it ensures an efficient way of energy conservation in the network.

In [6] proposed an energy-efficient sleep scheduling protocol called BSMac for WSN while maintaining high efficiencies and low latency based on a new architecture called BoostNet which is the base for scheduling coordination information. It propagates the critical using a wide transmission range to reach all sensor nodes in one hop. The main contribution of this paper is the energy saving planning approach that it conserves energy during the event and does not require any transmission by sensors during inactivity and the high bandwidth transmission power from the base station to optimize network parameters without the need for the second transmitter and receiver are used in sensor nodes.

In [7], an optimal sleep / wake scheduling algorithm is proposed that satisfies a threshold of the probability of recording a given message with the least energy consumption. In this method, there is an inherent alternative relationship between energy consumption and message delivery performance. The advantage of this paper is that the authors have developed an optimization problem that aims to determine the recording probability threshold in each hop so that the network lifespan is maximized.

In [10] introduced an energy-aware sleep scheduling algorithm called SSMTT to support multiple target tracking sensor networks. SSMTT results in the awakening of annoying targets to save energy in hyperactive communication. Researchers have proposed a solution that involves sensor node sleep pattern scheduling. The advantage of this method is that it is possible to achieve better energy efficiency compared to managing multiple targets separately through single target tracking algorithms.

In [11] introduced a quorum-based MAC protocol that enables sensor nodes to sleep longer under light loads. As traffic flows to the sink node in WSNs, the next hop group is also proposed to reduce transmission delay time a new concept. The advantage of this proposed method is that it reduces energy loss because the nodes are kept awake for only a certain time. It also prevails when a method fails to adjust the sleep duration of a sensor node based on its traffic load, resulting in lower energy efficiency or longer latency. Also, the sensor nodes may be located in inconsistent environments and as a result may fail unexpectedly.

In [17] presented an energy-aware method based on scheduling in WSNs for smart cities. The approach of this research is to use an algorithm called Grouping Memetic Algorithm (GMA) which simulation results indicate energy reduction. In [18] provided an efficient and reliable adaptive coding cluster routing protocol for WSNs. RS and LDPC coding methods have been applied to LEACH and BRE-LEACH routing protocols and the results have been very promising. In [19] presented a method called SEEDGT that works with the goal of a secure approach to energy-aware routing in IoT-based WSNs. The approach of this research is to use the public key algorithm and Compressive Sensing (CS) which shows high efficiency. Also in [20] presented a recursive and independent scheduling method for energy-aware WSNs with high performance.

Some formulation of this current article is based on [21-25]. But some of routing protocols especially Constrained Anisotropic Diffusion Routing (CADR) discussed in [26]. Also, some of the main and must challenging routing protocol discussed in [27]. In [28] studied about some energy aware of routing protocols and some methods to optimize them. There is another study which provided in [29] to study energy aware of hybrid routing protocols to select the best cluster heads in clustering. This article optimized some hybrid routing protocols in terms of energy consumption based on two algorithms means Golden Eagle Optimization Algorithm (GEOA) and Improved Grasshopper Optimization Algorithm (IGHOA).

3. Proposed Method

The proposed approach is to use sleep-awake scheduling technique for WSN which is similar to CADR protocol and the developed ones, CADR-DAVL model. It is necessary to provide a more optimal approach to eliminate the gaps of CADR protocol. One of the main weaknesses of this protocol and the proposed approach is clustering around different repetitions of sensor node movements, which logically leads to sensor node movements leading to re-clustering [21-25]. But this clustering select the clusters and checking the node states (sleep and awake mode) to find energy consumption and optimized some of the quality of services criteria such as throughput, latency, bit error rate, signal-to-noise ratio and high bandwidth. Therefore, to address this gap, a new approach called the Adelson-Velskii and Landis (AVL) tree rotation clustering algorithm based on deep leaning technique is used.

In this research, the energy consumption during the cycle can be estimated based on the amount of energy consumption of the nodes to receive or transmit in each cycle. The first-order radio model is used to measure energy consumption. The energy used to transmit a one-bit packet from transmitter to receiver at distance d can be defined as equation (1) [24, 25].

$$E_{TX} = \begin{cases} lE_{elec} + l\varepsilon_{fs} d^2 & .d < d_0 \\ lE_{elec} + l\varepsilon_{mp} d^4 & .d \geq d_0 \end{cases} \quad (1)$$

In this regard, E_{elec} is the scattered energy to work with the transmitter or receiver circuit per bit, d is the transmission distance. ε_{mp} and ε_{fs} are the amplifying energy factors for open space and multidirectional dimming channel models, respectively. The intersection d_0 is the threshold distance that depends on the specific scene and the amplifying energy factors, which can be given as $d_0 = \sqrt{\varepsilon_{mp}/\varepsilon_{fs}}$. The energy used to receive one-bit data can be written as equation (2) [24, 25].

$$E_{Rx}(l.d) = lE_{elec} \quad (2)$$

And the energy consumed for the aggregated data is also as equation (3) [24, 25].

$$E_{Agg}(l.d) = lE_{DA} \quad (3)$$

In this regard, E_{DA} is the energy used to transmit the bit of aggregated data. It is necessary to balance the energy between the energy of the sensor nodes to increase the network life time. The communication distance between the clusters should be limited to the d_0 threshold and ensure that the sensor-energy loss is in contact using the vacuum model to reduce energy consumption in the cluster. Under single-hop mode, the CH can transmit data directly to the central station. If the central station is far from the monitoring area, CH should use the multi-route attenuation model to deal with energy boost losses. This greatly increases the energy consumption of the central station. Therefore, CH are more likely to consume more energy and die sooner than its member nodes, which greatly reduces the entire network lifetime. Therefore, determining the optimal competition radius of the sprig and forming uniform and evenly distributed clusters is very important for energy balance. When a node broadcasts a candidate's CH message, the range is called the sink candidate's competition radius. Only nodes in the radius of the sensor network can receive the message from the CH candidate. In this context, the Adelson-Velskii and Landis (AVL) tree rotation clustering algorithm based on deep learning, which is a graph-like optimal tree, comes into play that works competitively. This algorithm can limit the spatial distribution of CH by adjusting the competition radius in the CH selection stage. In single-hop mode, the sensor node energy may be used primarily to transmit data to the central station. Therefore, the competition radius can be considered as the main parameter influencing the network life expectancy. If the value of the radius is larger, it leads to a smaller number of clusters and more energy is consumed due to the higher signal strength due to the transmission over longer distances. In short, an appropriate competitive radius will lead to a balance in the energy consumption of the clusters and the overhead of intra-cluster communications [3, 21].

It is assumed that the monitoring area is a square area with the lengths of the sensor nodes M and N located, then the node density is $\rho = N/M^2$. Assuming that d_{CH} represents the radius of the eclipse competition, d_{toBS} represents the transmission distance from the CH to the central station. Some redundant nodes are programmed to sleep. It is assumed that the number of redundant nodes in the V cluster is the percentage of active member nodes in the cluster member node $\sigma = 1 - V/(n-1)$. For simplicity, the length of the packet delivered from the active member node to the thread is set to l bits in each round. E_{toCH} indicates the amount of energy consumed to transmit l-bit packets from the node to the header, E_{re} indicates the amount of energy used by the CH to receive such packets, and E_{toBS} indicates the amount of energy used to transmit l-bit packets from the CH. In addition, the energy consumption of all active nodes with the radius of competition of the CH to transfer their collected data to the CH can be obtained as equation (4).

$$E_{toCH} = \sigma \int_{d_{CH}}^{0} 2\pi x \times \rho \times \left(lE_{elec} + l\varepsilon_{fs} x^2\right) dx = \sigma l \pi \rho \times \left(E_{elec} d_{CH}^2 + \frac{1}{2}\varepsilon_f d_{toBS}^4\right) \quad (4)$$

For each cluster, the energy consumed for the monitored data received from members of its own nodes in a cluster is estimated as equation (5) [3, 24, 25].

$$E_{re} = l \times (\pi r_i^2 \rho - 1) \times E_{elec} \tag{5}$$

The energy consumed for the accumulation of data in it is calculated as equation (6) [24, 25].

$$E_{Agg} = l \times \pi r_i^2 \rho \times E_{DA} \tag{6}$$

In addition, the energy consumed by the CH to transfer data to the base station is calculated as equation (7) [24, 25].

$$E_{toBS} = lE_{elec} + l\varepsilon_{mp} R_i^4 \tag{7}$$

In this regard, R_i is the distance from the head to the base station. Therefore, according to the above-mentioned equations, the total energy lost in a cluster can be calculated through equation (8).

$$E_{cluster} = E_{toCH} + E_{toBS} + E_{re} + E_{Agg} = l\pi\rho r_i^2(\sigma + \frac{1}{2}\sigma\varepsilon_{fs} r_i^2 + E_{elec} + E_{DA}) \tag{8}$$

Then, the average energy consumed by one node in each cluster is calculated as equation (9).

$$E_{avg} = \frac{E_{clutser}}{\pi r \rho_i^2} \tag{9}$$

The desired radius of competition d_{CH} can be obtained as described in equation (10) by taking the derivative r_i in formula (9),

$$d_{CH} = \sqrt[4]{\frac{2\varepsilon_{mp}}{\sigma\pi\rho\varepsilon_{fs}}} d_{toBS} \tag{9}$$

From equations (4) and (5) it can be seen that the optimal competitive radius of each node increases with the distance between the node and the base station. Local energy consumption can be minimized by noticing to the optimal competition radius of each node and an uneven hierarchical structure can be created for cluster-sensitive sensor networks. In the area close to the base station, the distribution density of the clusters will be relatively small. Clustering and selection of the cluster will be done easily when using the rotational clustering algorithm of the DAVL tree. During the CH determination phase, CHs are determined based on a linear combination of probability selection and local competition. Upon completion of the operation, all nodes in the member position may be nominated candidates. Initially, each node is identified as a common node and given the distance from the base station and the energy remaining, creates a special probability that the CH will be nominated. Sensory nodes that are close to the base station are more likely to run for office compared to nodes away from the base station. Thus, performance can probably be defined by describing equation (11) [3, 24, 25].

$$CHs(i) = \alpha \times \frac{d_{\{max\}} - d_{toBS}(i)}{d_{\{max\}} - d_{\{min\}}} + (1-\alpha) \times \frac{E_{res}(i)}{E_{init}} \tag{11}$$

In this regard, $d_{\{max\}}$ represents the largest distance from the base station and $d_{\{min\}}$ represents the closest distance. α is a constant parameter. In the DAVL tree rotational clustering algorithm in the WSN, each node obtains the probability of being CH to determine whether it should have eligibility in the current CH cycle. In addition, nodes that are happy candidates change their position and calculate the desired competitive radius according to their distance from the base station. Other nodes that are not eligible candidates can turn off the wireless communication module during the eligibility selection step to save energy. In addition, the eligible candidate must obtain information about the location and competitors in their area of communication. Each CH candidate contains a Neighborhood CH candidate table that includes the node ID, energy flag, and residual status of adjacent CHs. After selecting the CH, the CHs spread the message which includes their identities and a list of member nodes and wait for adjacent member nodes to join. Depending on the strength of the received signal, the non-CH node estimates the distance of its neighboring CHs and chooses to be located in the nearest member or cluster. This can reduce the energy consumption of nodes in a cluster for data delivery and also allow nodes close to the base station to carry more load to transmit or collect data to achieve balanced energy consumption of the entire network. Next, the member nodes are sent to the CH with a message containing the node ID and the distance between the CHs. Upon receiving this message from a non- CH, the CH candidate transmits an ACK message and updates the cluster membership list at the same time.

In the following, the mechanism of sleep-wake scheduling with energy saving with the optimal approach should be considered which the main purpose of this study. Sleep-awake scheduling is a distributed competitive mechanism based on unequal clusters in WSNs and makes local decisions to determine the radius of competition and select clusters. In order to estimate the radius of competition for experimental clusters, the sleep-awake scheduling mechanism uses the residual energy and distance from the central station parameters. In addition, it uses the DAVL tree rotational clustering algorithm to obtain the optimal competition radius based on a probabilistic model used to compete between CH candidates.

Candidate CHs disseminate information about their participation to adjacent nodes within the competition radius with the corresponding transmission power. The $comp_{MSG}$ message contains the candidate ID and residual energy. Upon receipt of this message, the other candidate's CH records the candidate's CH ID in the CH table of the CH neighbors. Due to the different size of the competition radius of the eligible candidates, the following may occur. Assuming that the radius of competition of candidate i CH is larger than candidate s header and j can receive the $comp_{MSG}$ message from s_i. However, the $comp_{MSG}$ message from s_j could not be transmitted to s_i due to limited s_j transfer range, leaving it unaware of the existence of the s_j CH candidate. To obtain complete information about nearby competitors, each candidate CH must estimate the distance from the transmitter after receiving the $comp_{MSG}$ message. If they are longer than their competition radius, they need to reuse a $comp_{MSG}$ message to the transmitter. In this way, it can help the transmitter to get complete information about the candidate e-mail and update the e-mail list of the eligible neighbor.

4. Simulation and Results

The simulation is performed in MATLAB environment. The main purpose of this study is to provide a structure of the sleep-awake networking mechanism of the WSN in an energy-aware manner and quality of services criteria. First, it is necessary to configure the WSN which settings listed in Table (1).

Table (3), WSN settings

Number of sensor nodes	100
WSN scale (m^2)	100x100
Energy of each nodes (Joules)	0.5
Total Network Energy (Joules)	50
Network Runtime (sec)	500
Sink position (m^2)	50x50
Node probability selection for CH candidate	0.1
Alpha time for sensor node	0.2
Homogenous percentages of each node	0.1

When the simulation starts, the sensor nodes settle on the initial environment and are randomly distributed. The initial placement of the sensor nodes can be seen in Figure (1).

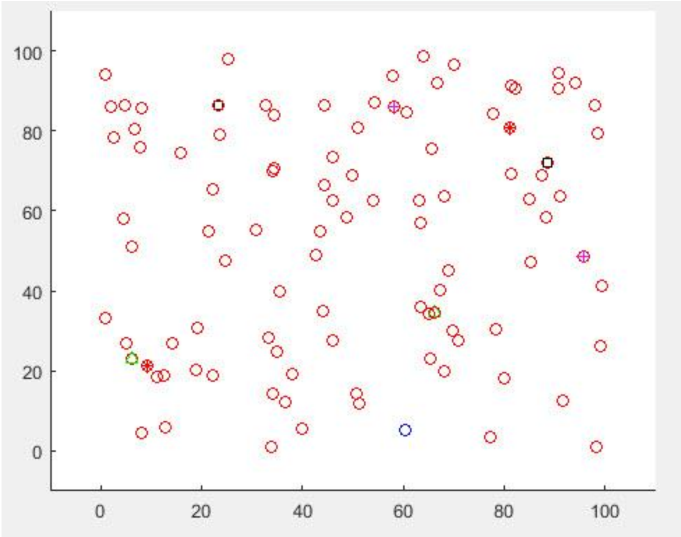


Figure (1), Initial deployment of sensor nodes in the WSN environment

Figure (1) represented that 100 sensor nodes with dimensions of 100×100 square meters are randomly placed. The first deployed sensor nodes are red, but there are also blue, purple, green, and black nodes that are likely to be selected as clusters in that area. Next, the initial clustering and selection of candidate CHs is performed, an output sample of which is shown in Figure (2). It should be noted that this output may be varied at different outputs due to the mobility of the sensor nodes.

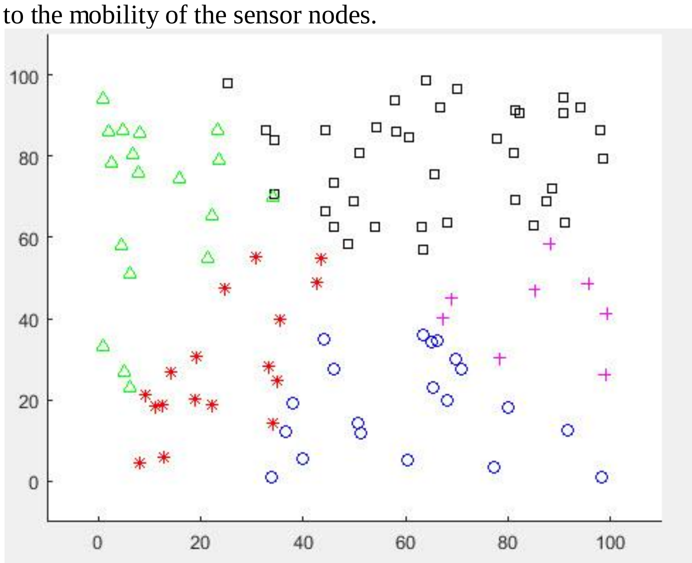


Figure (2), clustering and CH candidate selection

According to Figure (2), it can be seen that 5 regions or 5 clusters have been created in total and in each of them as the same node that was identified as a CH candidate in Figure (1) with a different color has been selected as a block. Now, clustering and CH have been done, the sleep-awake mechanism should be considered which a practical comparison with the two methods is presented in references [21] and [22]. Figure (3) represented for awake nodes and Figure (4) for sleep nodes.

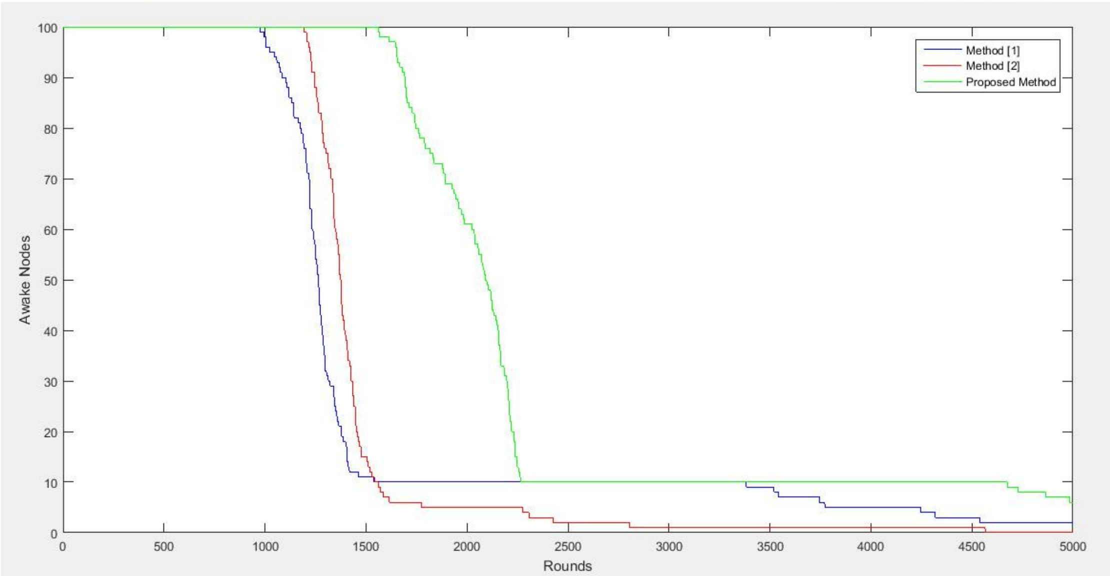


Figure (3), awake nodes

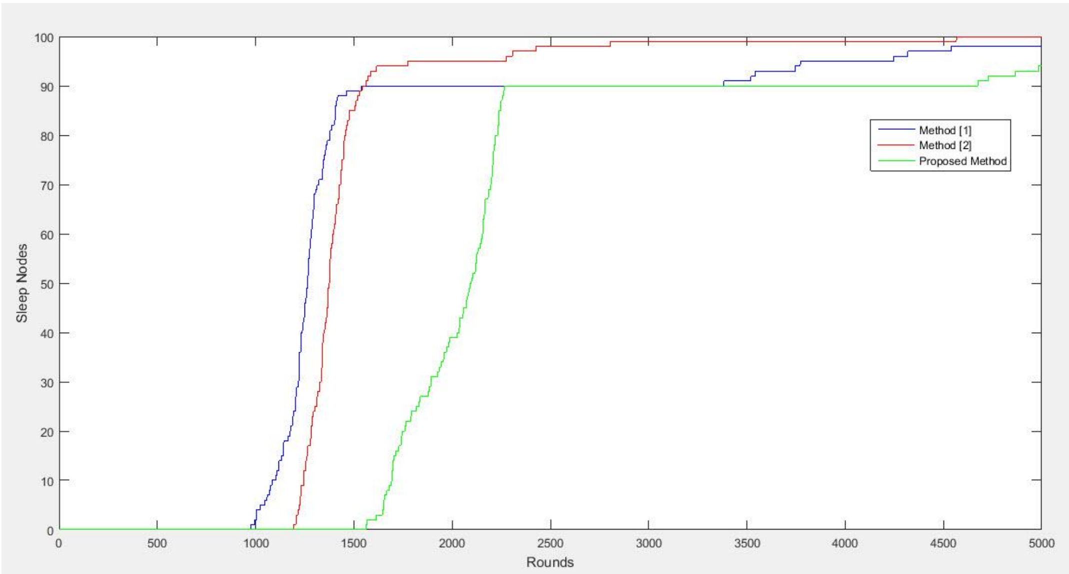


Figure (4), sleep nodes

It is shown in Figures (3) and (4) that the performance of the awaking and sleeping nodes of the sensor nodes at 5000 cycles or the time of execution of the WSN is shown. According to Figure (3), the wake-up time which produces less energy consumption, reaches the lowest energy consumption of about 2200 rpm, i.e. 10 Joules of energy which is a more optimal rate compared to the methods presented in [21] and [22]. Also, according to Figure (4), the time to fall asleep, which consumes a lot of energy is done in 1550 rounds of the implementation of the WSN and consumes less energy than the two methods presented in [21] and [22]. Note that the green diagram in the two figures above is for the proposed approach, the blue diagram for reference [21] and the red diagram for reference [22]. Next, the packets transmit rate to the base station through the CH between the proposed approach and the two methods presented in [21] and [22] should be considered, the output of which is as shown in Figure (5).

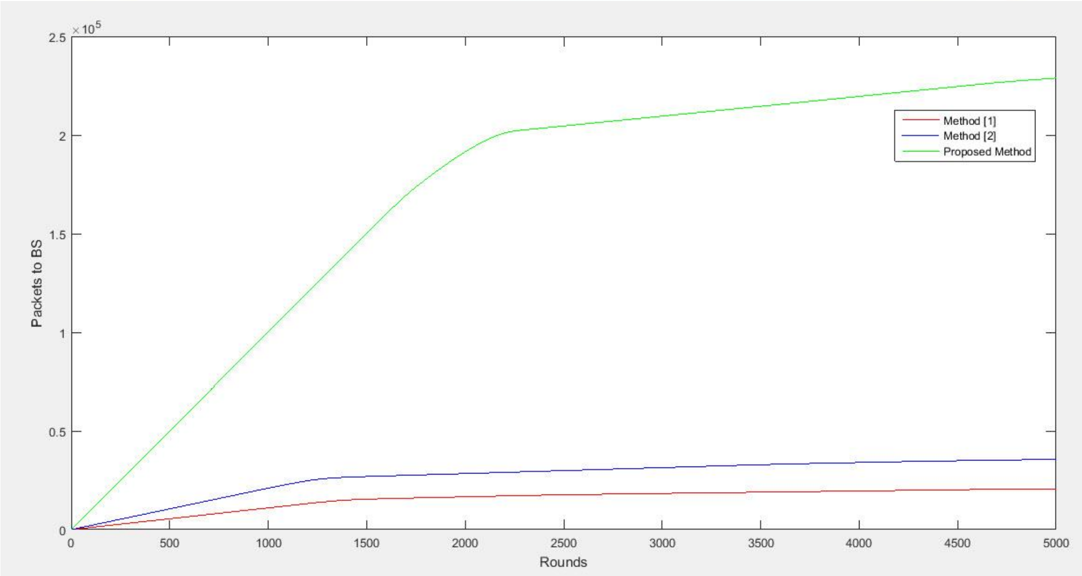
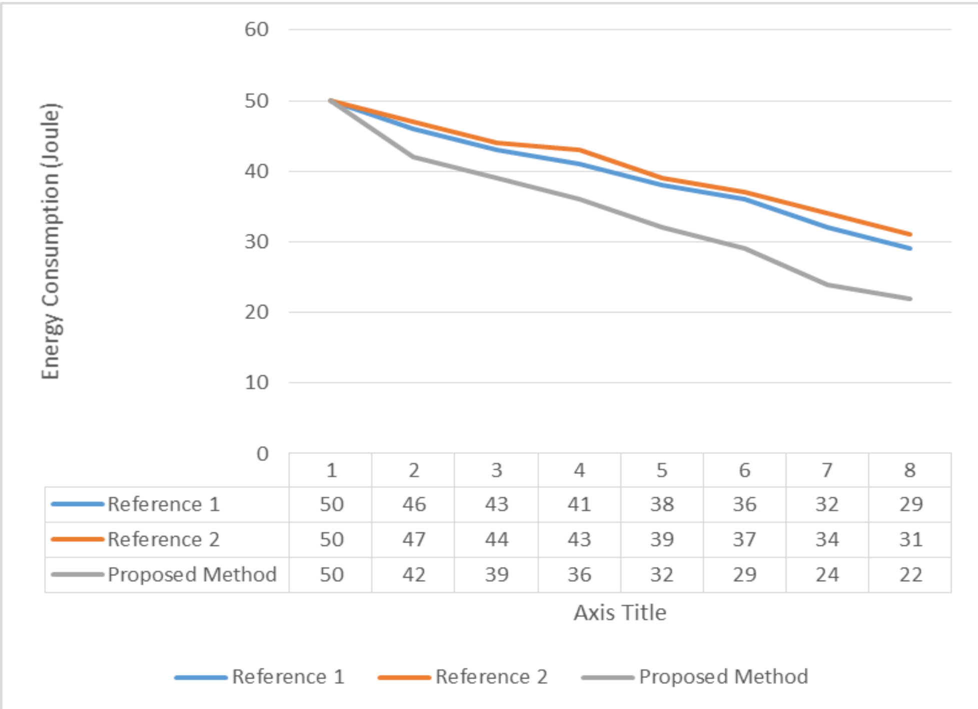


Figure (5), packets transmit rate to base station through CHs

Based on Figure (5), it is clear that the proposed approach with the green diagram has a much higher ability in the sleep-awake mechanism of the sensor nodes and in the meantime, it can collect more information or data from the environment and transmit the nodes to the CHs and also transmit the CHs to the base station. This output indicates that the proposed approach in terms of data transmitting to the base database has a higher operational advantage and efficiency than the two proposed methods [21] and [22]. Finally, the output of energy consumption can be seen in comparison with the two methods presented in reference [21] and [22], which are shown in Figure (6).



	1	2	3	4	5	6	7	8
Reference 1	50	46	43	41	38	36	32	29
Reference 2	50	47	44	43	39	37	34	31
Proposed Method	50	42	39	36	32	29	24	22

Figure (6), Energy consumption

According to Figure (6), it can be seen that in a repetition cycle of 5000 seconds from the time of execution of the work, the proposed approach of 50 main energy consumes only 22 Joules of energy and minimizes compared to the other two methods [21] and [22] shows. It can be seen that the approach presented in [21] had 29 Joules of energy consumption with a residual energy of 21 = 29-50 Joules. Similarly, the approach presented in [22] had 31 Joules of energy consumption with a residual energy of 19 = 31-50 Joules. The proposed approach has only 22 Joules of energy consumption, which shows that 28 = 22-50 Joules of residual energy, which could be compared to the other two approaches, which have 21 and 19 Joules of residual energy, respectively, and the proposed method has 28 Joules of residual energy between 7 and improve 9 Joules of energy consumption.

5. Conclusion

WSN has emerged as one of the most promising technologies used in the world today. WSN can monitors the environment in a location to collect information and is also able to detect changes in areas that monitor temperature, pressure, humidity, sound, intensity, vibration, movement, and so on. WSN applications are widely used in environmental monitoring system, habitat monitoring system, building monitoring system, stairs, natural disaster monitoring system, military applications, traffic monitoring system, smart home monitoring system, inventory management system, industrial robotics system, medical applications Medicine and health monitoring systems have been used scientifically and practically. WSN can act as a static sensor node or a dynamic sensor node or even a mixture of both. WSN consists of sensor nodes which these sensor nodes are innumerable for the purpose of collecting data to provide valuable results. However, these low-power devices have very limited computing and processing capabilities. Therefore, to solve this problem to perform such a process, a remote unit with computability is needed. In addition, these devices are small and have a limited internal power supply (for example, a battery). Therefore, they must have enough power to reduce power consumption when monitoring and collecting data to maximize their maximum battery life. In fact, power consumption and reduced data transmission are affected by different areas of the network. In addition, these networks include many interconnected nodes that are built in to sense, collect, process, and transmit event-specific information to perform a specific task. WSN can be static (depending on specific nodes) or dynamic (dynamic with open nodes), allowing nodes to freely join or leave the network. Static networks are more vulnerable to security breaches than dynamic networks. For example, cross-authentication is an essential part of dynamic networks over static networks. In addition, the computations required in dynamic networks allow nodes to freely join and exit the network and are larger in terms of computations required than static networks. Due to the high energy consumption in clustering operations and the CH selection during the sleep-awake technique, WSN needs to be optimized which the approach of this research addresses this issue. The main innovations of this research are in the heterogeneous cluster of the network, the sensor nodes are proposed to select the best cluster from the rotational clustering algorithm of DAVL tree. To achieve the equilibrium network, the residual energy of each sensor node in the WSN is calculated. The sensor node with the highest residual energy is selected as the best node as the CH. Therefore, the proposed algorithm provides more energy and saves more energy, thus increasing the network lifetime and reducing the computational complexity. The DAVL tree rotational clustering algorithm creates a dominant mode that acts as the backbone of the network. By building the above method, data latency during data transfer is minimized which ensures the reliability of the transfer. Therefore, the message communication is successfully delivered to the end user with high speed which promises accuracy, energy efficiency and reliability. It is noteworthy that both of these innovations are carried out in the context of the WSN in the sleep-wake scheduling technique. During the simulation performed in MATLAB environment, it was shown that the proposed approach has better results in terms of energy consumption as well as quality of services criteria than previous similar methods.

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