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Modified W-LEACH Protocol in Wireless Sensor Network

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ABSTRACT

In this paper, a Modified Weighted Low Energy Adaptive Clustering Hierarchy (MW-LEACH) protocol is implemented to improve the Quality of Service (QoS) in Wireless Sensor Network (WSN) with mobile sink node. The Quality of Service is measured in terms of Throughput Ratio (TR), Packet Loss Ratio (PLR) and Energy Consumption (EC). The protocol is implemented based on Python simulation. Simulation Results showed that the proposed protocol provides better Quality of Service in comparison with Weighted Low Energy Cluster Hierarchy (W-LEACH) protocol by 63%.

Keywords: W-LEACH, Modified W-LEACH, improve QoS in Wireless Sensor Network.

تحسين بروتوكول تكييف الطاقة المنخفضة لرئيس عقود العقد

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الخلاصة

في هذه المقالة ، بروتوكول (MW-LEACH) المحسن صمم لتحسين جودة الخدمة (QoS) في شبكة الاستشعار اللاسلكية (WSN) مع محطة استقبال مركزية متحركة. يتم قياس جودة الخدمة (QoS) من حيث نسبة إنتاجية الشبكة (TR) و نسبة خسارة الرزم (PLR) واستهلاك الطاقة. يتم تنفيذ البروتوكول على أساس محاكاة بلغة بايثون وتظهر نتائج المحاكاة أن البروتوكول يوفر جودة خدمة أفضل بالمقارنة مع بروتوكول W-LEACH بنسبة 63 % .

الكلمات الرئيسية : بروتوكول تكييف الطاقة المنخفضة لرئيس عقود العقد ، تحسين بروتوكول تكييف الطاقة المنخفضة لرئيس عقود العقد ، تحسين جودة الخدمة في شبكة الحاسبات اللاسلكية .

1. INTRODUCTION

A Wireless Sensor Network (WSN) contains sensor nodes and mobile sink node as shown in **Fig. 1**. A large number of sensor nodes are set up in the monitoring area. The monitoring data aggregated by the sensor nodes is transmitted to the sink node. The WSN's nodes are divided into groups each group has a central node which is called the Cluster Head(CH); that is responsible for storing the sensory data of all group nodes and sending them to the mobile sink

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node. Cluster-based routing is an effective research area in WSN. Conventional Low Energy Adaptive Clustering Hierarchy (LEACH) protocol has many pluses in energy efficiency, data aggregation **Kaur, et al., 2015**.

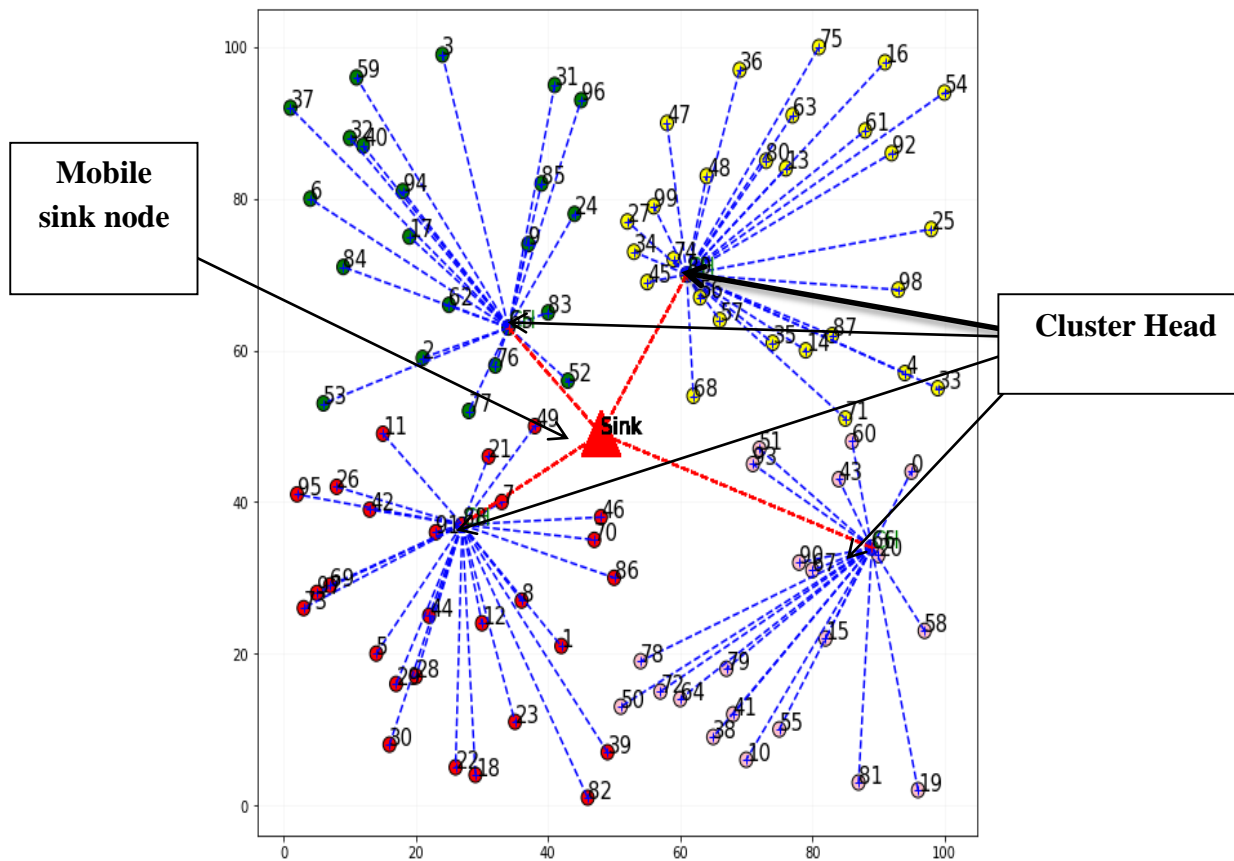


Figure 1. Networking Topology in WSN.

Sensor nodes have limited energy and memory that is difficult to change the battery and to increase the memory; especially in places that are hard to reach, such as war field, polluted area **Rad, et al., 2017**.

There are few different approaches that are applied in the literature to reduce EC in WSN and extended network lifetime. Some of these methods are: improving routing protocols, minimizing the amount of packets that travel through the network, making the sink node mobile which is another method for improving the lifetime of wireless sensor network and putting some sensor nodes into sleep mode and using only a necessary set of sensor nodes for sensing and communication **Vinutha, et al., 2017, Soua, and Minet, 2011**.

Weighted Low Energy Adaptive Cluster Hierarchy (W-LEACH) Protocol is one of the efficient types of LEACH protocol, that is a centralized algorithm, similar to LEACH, W-LEACH consists of two phases, setup, and a steady phase. In the first phase, W-LEACH chooses a maximum of probability $p\%$ of alive sensor nodes to be cluster-heads(CHs). Every CH in the network is selected based on a weight value w_i , that is assigned to each sensor node s_i , without



taking into account the free size of the buffer for each sensor in the cluster. Different from LEACH, each sensor node in cluster sends data to its CH during steady state phase, CH collects data from all, W-LEACH elects only x% of sensor nodes in each cluster for sending sensory data to their CH. Elected x% of sensor nodes based on the proximity between sensor nodes, as an example, if there are two sensors, and the distance between them is close, one of them is chosen to send the data and the other to put in a sleep state. The candidates for sending data to CHs are also chosen based on their weights, **Snigdha, and Gosain, 2015**.

In general, W-LEACH works well. However, when the number of nodes in each cluster is larger; the performance of the protocol will be severely degraded. This is because W-LEACH uses x% of sensor nodes in each cluster. Which is easy to cause network congestion when the number of nodes in each cluster is large and the elected x% is also large. Therefore, it is the key to improve network performance by changing the number of the active sensors for each cluster. Solving the problems, via modifying W-LEACH protocol that will be done by coordinating x% with CH's capacity of the buffer to avoid buffer overflow.

The aim of this paper is how to modify routing protocol, which is able to enhance QoS network by minimizing energy consumption this will be achieved by increasing Throughput Ratio and reducing PLR of the network. Finally, the results will save the energy and extend the network lifetime.

2. W-LEACH PROTOCOL

Supposing that a WSN consist of n alive sensors, for each round, W-LEACH assigns a weight w_i for each sensor node; based on two factors, the residual energy e_i , and the density d_i . The e_i is the energy remaining in the sensor node s_i after some round t . d_i is the density refers to the ratio of the number of alive sensors that are within a range r of s_i to the total number of alive sensors in the network n , at some round t , d_{th} is the minimum density threshold, represented in the Eq. (1) and Eq. (2):

$$w_i = \begin{cases} e_i \times d_i & \text{if } d_i \geq d_{th} \\ d_i & \text{otherwise} \end{cases} \quad (1)$$

$$d_i = (1 + \text{number of alive sensor nodes in range } r)/n \quad (2)$$

Thus, the value of density for every sensor node is updated during rounds depending on whether or not other sensor nodes in their ranges die. Choosing a CH has a high-density area leads us to save sensors' energy for its cluster. Since the distance between the sensor nodes and the CH is relatively short, energy consumption will be reduced. However, choosing a CH in low-density regions would result in that the cluster members lose more energy while sending their data when it is compared to long distances. Accordingly, W-LEACH efficiency is not affected by the remaining memory in the sensor that causes dissipated energy by sending sensory data. **Koc, and Korpeoglu, 2014, Luo, et al., 2014, Abdulsalam, and Kamel, 2010 and Liu, and Wen, 2011**.



3. MW-LEACH PROTOCOL

Buffer-overflow is a challenge that occurs in the CH. It is noted from the above that W-LEACH protocol does not take into account the remaining memory in the sensor as a factor to select CH, which leads to loss of sensory-data because it does not choose the suitable buffer size from the sensor nodes. Here it is proposed by this work to include an additional factor to the weight that chooses the CH and the size of the memory to reduce the Packet Loss Ratio (PLR) as it is demonstrated in the Eq. (3) and Eq. (4) :

$$w_i = \begin{cases} e_i \times b_i \times d_i & \text{if } d_i \geq d_{th} \\ d_i & \text{otherwise} \end{cases} \quad (3)$$

$$b_i = b_{Max}^i / \text{number of alive sensor nodes in range } r \quad (4)$$

b_i is the factor of buffer size capacity for every sensor to determine the ratio of b_{Max}^i which refer to the maximum capacity of buffer size in sensor s_i to the number of alive sensor nodes in range r for s_i . The term density of one node is the amount of aggregated neighboring nodes in a place in range r .

In a small size CH buffer, the communication between the boundary cluster node and the CH consumes too much energy and buffer. Additionally, too many group members causing more collision. In contrast, a big size CH buffer has a large detection range which also would cause additional power consumption. Thus, it requires to coordinate the buffer size of Cluster-Head with a number of active sensors in range nr , to enhance incoming traffic rate from sensors to CHs; in order to ensure less buffer-overflow which leads to saving energy. The above mentioned will be presented mathematically by the following Eq. (5)

$$nr \propto \text{Buffer size for CH} \quad (5)$$



Changing the state of sensors that are out of dynamic elected CH range to sleep state; in this way, the real profit will be in energy saving and minimizing the redundant data that is sent to CH and sink node. Since the selected sensor as a CH has a low energy, the CH will die before sending the entire data and this will result in data loss. To overcome this drawback, the energy threshold must be checked to select CH from sensor nodes, which is showing in **Fig. 2**.

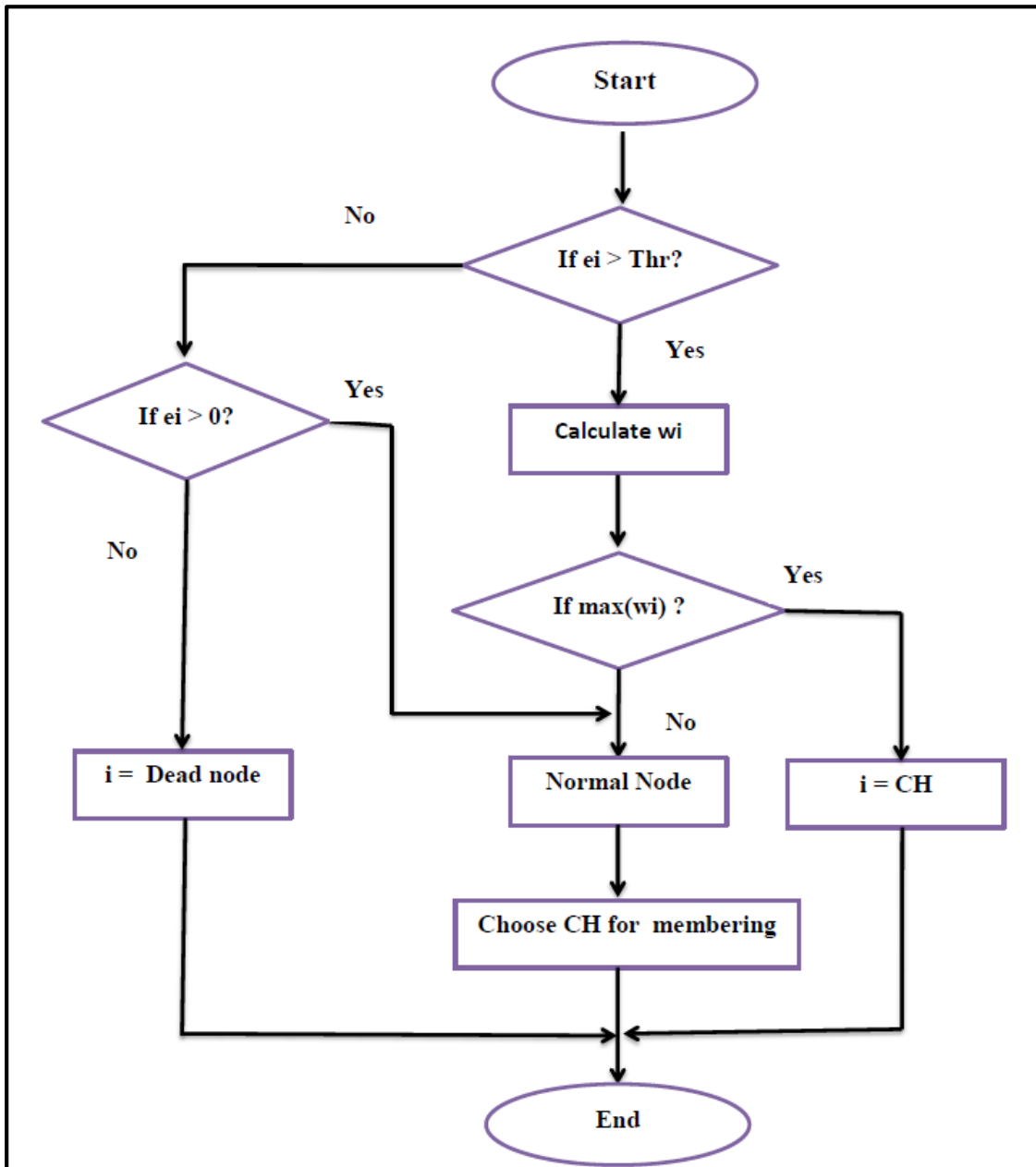


Figure 2. Flowchart of MW-LEACH.



4. SIMULATION MODEL

4.1 Simulation Tool

The well-known simulation tool that is used is PYTHON 2.7. Different simulations results are presented with a different number of clusters in order to check the performance of the proposed modifying. The goal of the paper is to investigate the behavior of modified W-LEACH, conventional W-LEACH for Throughput, Energy Consumption, Lifetime and Packet Loss Ratio.

4.2 Simulation Setup

Extensive simulations are carried out to analyze the effectiveness of the proposed MW-LEACH. 100 sensor nodes are randomly placed in a space of 100 x 100 m, with inner energy 2 joules for each sensor. Packet size is assumed to be fixed at 800 bytes and each node source generating data at a maximum rate of 5 packets per millisecond(msec.). In this simulation, the assumed sink buffer capacity is 150 packets and the initial presence of one sink located in the center of WSN. Simulation time for each scenario was set to 250 msec and repetitive simulations for each scenario were performed to verify the reliability of the results.

Table 1 summarizes the simulation parameters. Evaluation metrics used performance test are Throughput, Energy Consumption (EC), Lifetime and Packet Loss Ratio(PLR).

Table 1. Simulation parameters.

Parameter	Measurement
Ground's dimensions	100 * 100 (m*m)
Number of nodes	100
Number of clusters	4,6,8
Node's inner energy	2 Joule
Packet size	800 byte
Sink's buffer size	150 packets
The initial location of the Base Station	50,50

4.3 Performance Metrics for Evaluation

❖ Throughput Ratio

The Throughput Ratio reflects the effective network capacity. It is defined as the total number of packets successfully delivered at the input sink buffer and a total number of packets generated by the active sensor nodes on the network in a given period of time. Throughput Ratio shows the protocol's successful deliveries for a time: this means that



the value of Throughput Ratio nearest to one is the better will be the protocol performance.

❖ **Energy Consumption**

The energy metric is taken as the average energy consumption for network calculated through simulation time.

❖ **Lifetime**

Time spent until the death of all wireless sensor nodes in WSN.

❖ **4. Packet Loss Ratio**

It is defined as the ratio of the number of packets dropped at cluster head and sink buffer due to overflow and a total number of packets generated by the active sensor nodes on the network: this means that the value of Packet Loss Ratio nearest to zero is the better will be the protocol performance.

5. RESULTS & DISCUSSIONS

Fig. 3 displays the Throughput Ratio of the network. This figure shows that, maximizing the Throughput Ratio of the network is achieved by using MW-LEACH in comparison with W-LEACH; this feature is more benefit and it is achieved by decreasing traffic via making coordination between active sensor and maximum capacity of buffer in cluster head to send suitable amount of packets from sensors to the available buffer of the network, that lead to reducing packets drop, which is caused by overload on cluster heads limited buffer and sink node. It is noticeable that the starting chart of MW-LEACH Throughput Ratio is increasing after about 60 round t ; because of the energy factor for each sensor e_i is high, therefore, will effect on the weight w_i , then the MW-LEACH work better because the energy is more consumed.

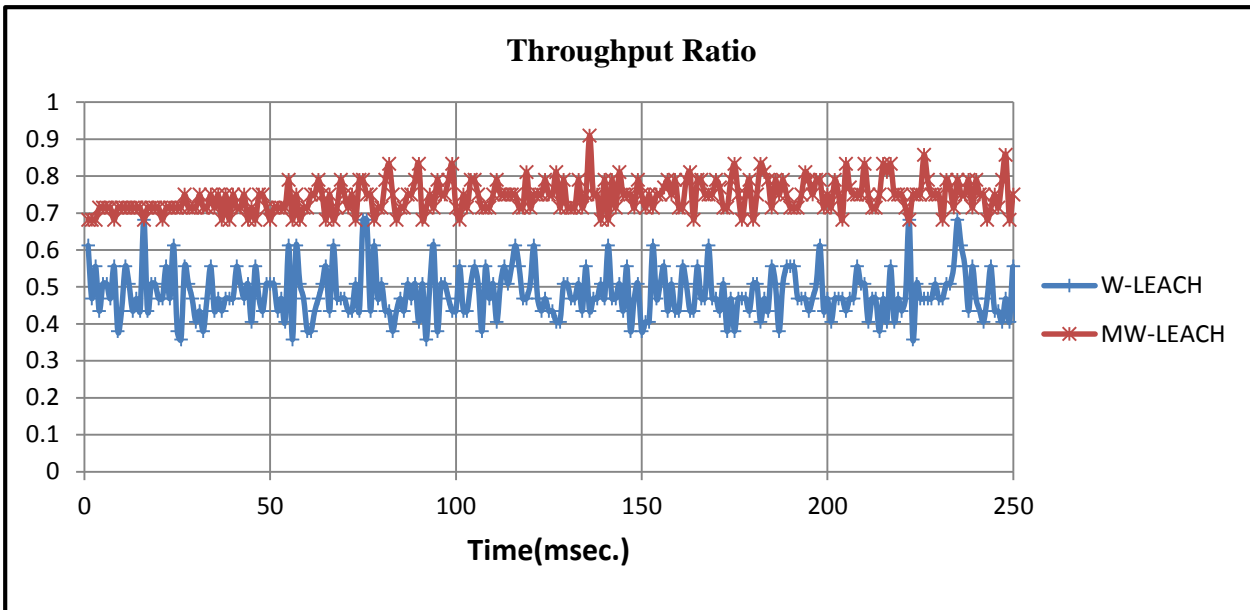


Figure 3. Comparison between W-LEACH and MW-LEACH Throughput Ratio.

The increasing of Throughput Ratio will decrease the energy consumption because of the dissipated energy for sending packets over the capacity of the buffer which is reduced. It is clear from Fig. 4 which show that EC, the MW-LEACH save power and prolong lifetime as represented in Fig. 5.

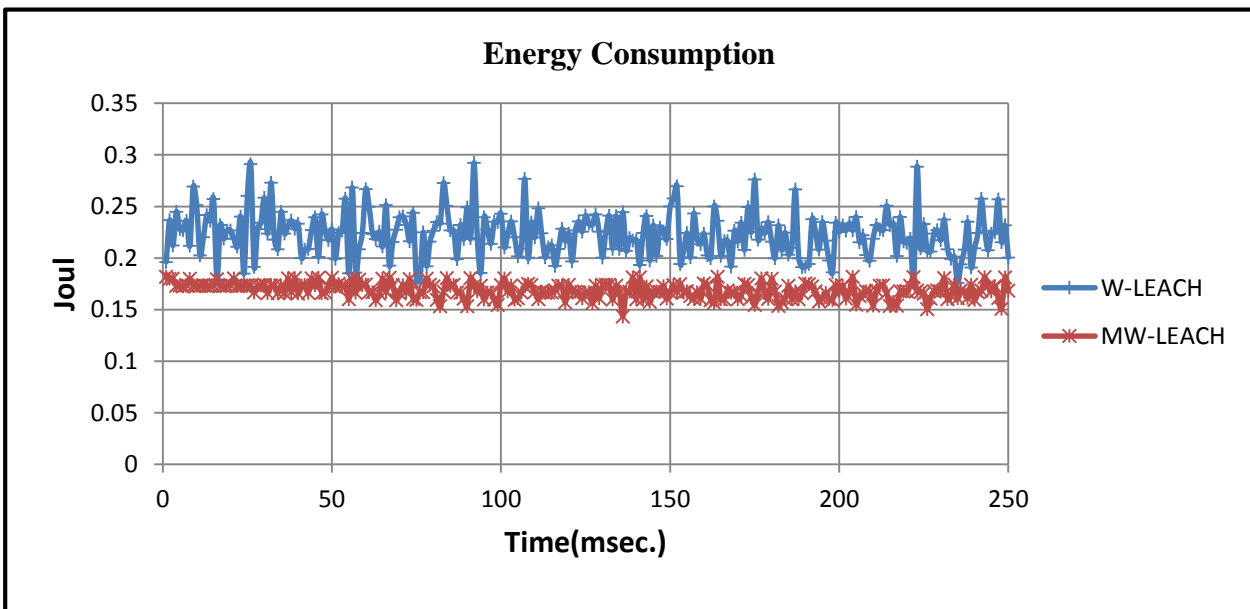


Figure 4. Comparison between W-LEACH and MW-LEACH in EC.

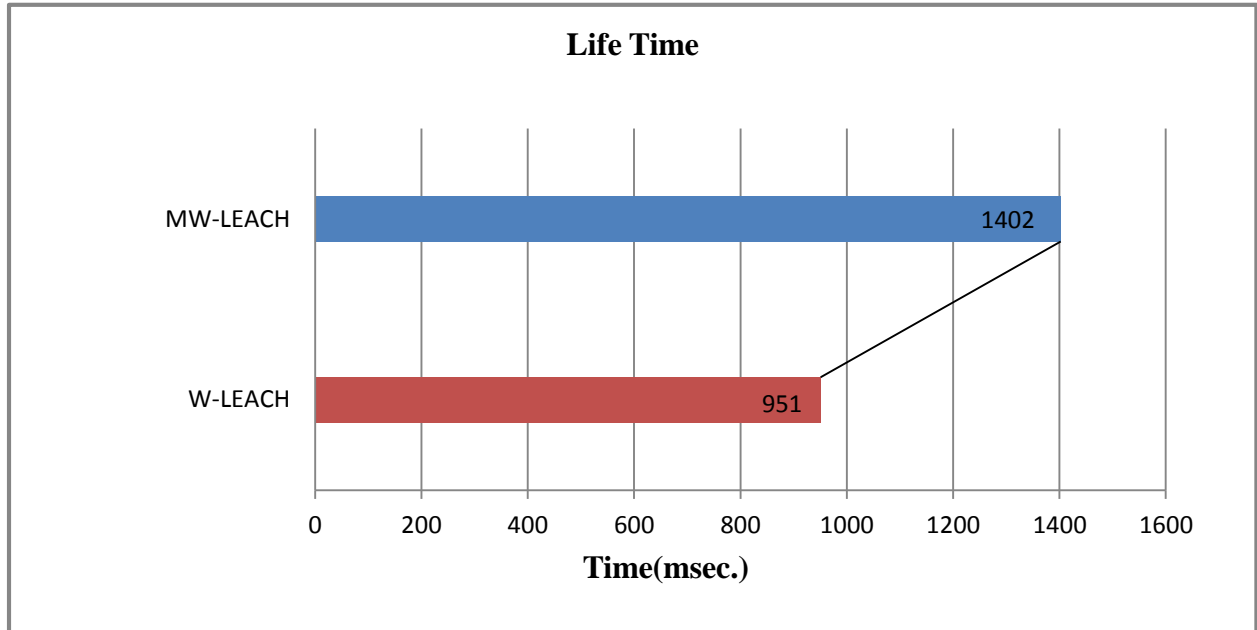


Figure 5. Comparison between W-LEACH and MW-LEACH in lifetime.

Packet Loss Ratio was reduced in MW-LEACH protocol, therefore the buffer overflow will be reduced in cluster head and sink node by sending suitable amount of packets from sensors to the available buffer via making sensor nodes that are out of cluster head capacity change to inactive mode (sleep), that is clearly noticed in Fig. 6 .

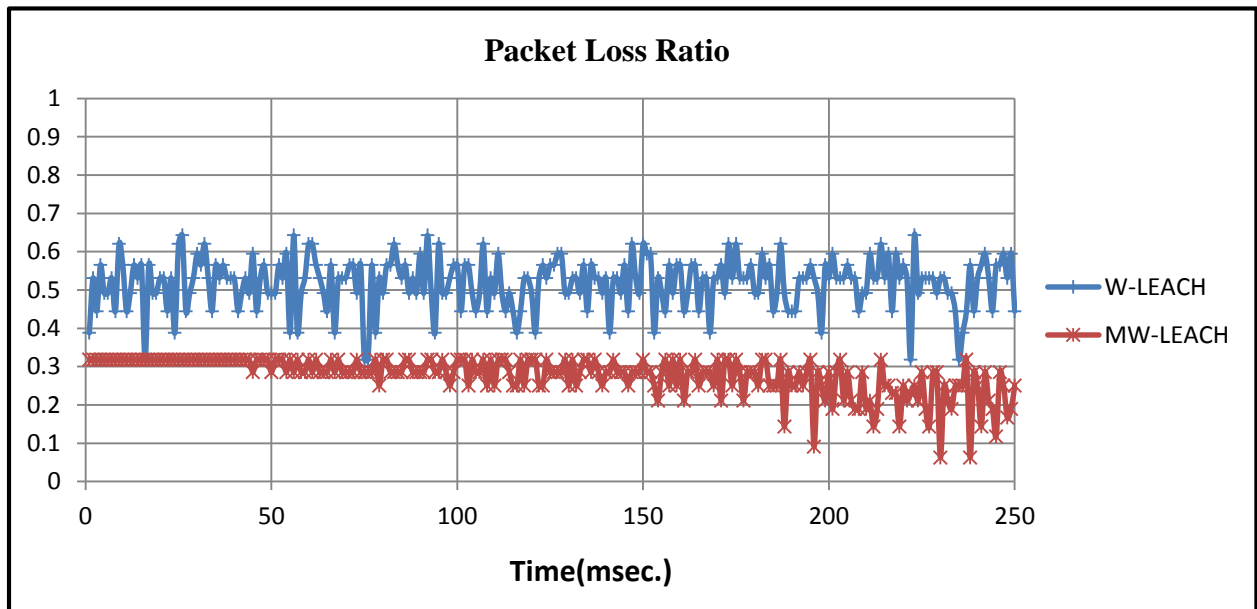


Figure 6. Comparison between W-LEACH and MW-LEACH in PLR.



As it is shown in **Fig. 7** the Throughput Ratio is increased when the number of clusters in the network is four while, the Throughput Ratio is decreased when the number of clusters is six and eight and that's because the M-WALLACH makes the number of active sensor nodes in every cluster suitable to the capacity of the cluster head buffer to avoid buffer overflow, which means increasing the number of clusters that will lead to increase the number of cluster heads that mean maximum the number of buffers that in turn increase the number of active sensor nodes in network. Traffic from six and eight clusters is greater than traffic that is coming from four clusters. Higher traffic causing more overflow on limited sink's buffer and decrease Throughput Ratio of the network by increasing Packet Loss Ratio because increasing number of packets dropped by overflow on sink buffer in high traffic in six clusters and higher in eight clusters as shown in **Fig. 8**.

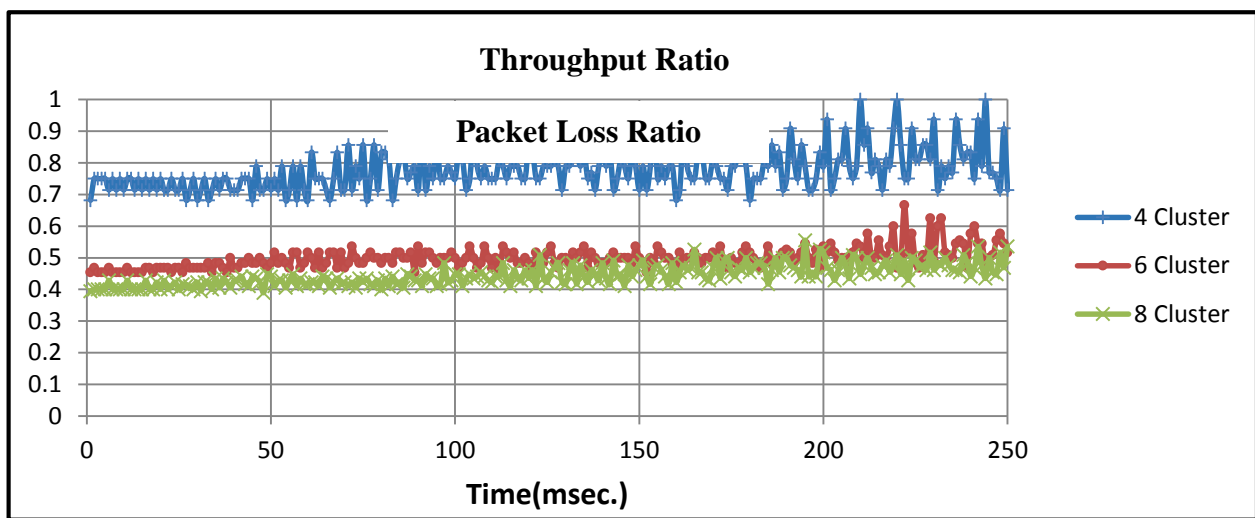


Figure 7. Comparison between 4,6 and 8 clusters MW-LEACH in **Throughput Ratio**.

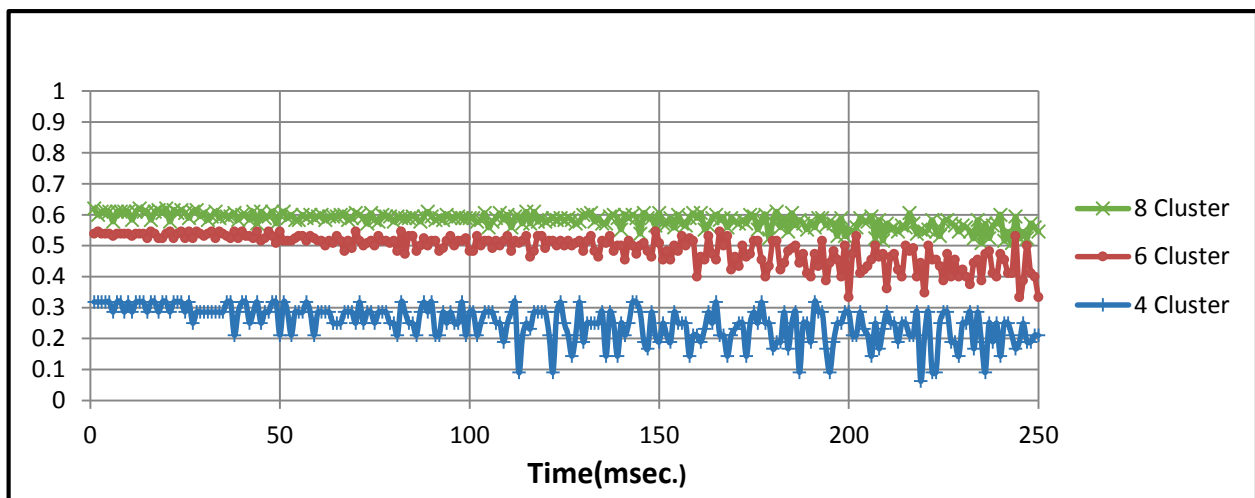


Figure 8. Comparison between 4,6 and 8 clusters MW-LEACH in **PLR**.

In **Fig. 9** and **10** there is a clear difference in energy consumption and network lifetime when compared with four, six and eight clusters in network where the energy depletion in four clusters



is decreased when compared with six and more decreased with eight clusters because the dissipated energy via PLR is increased with the increasing of the number of clusters in network.

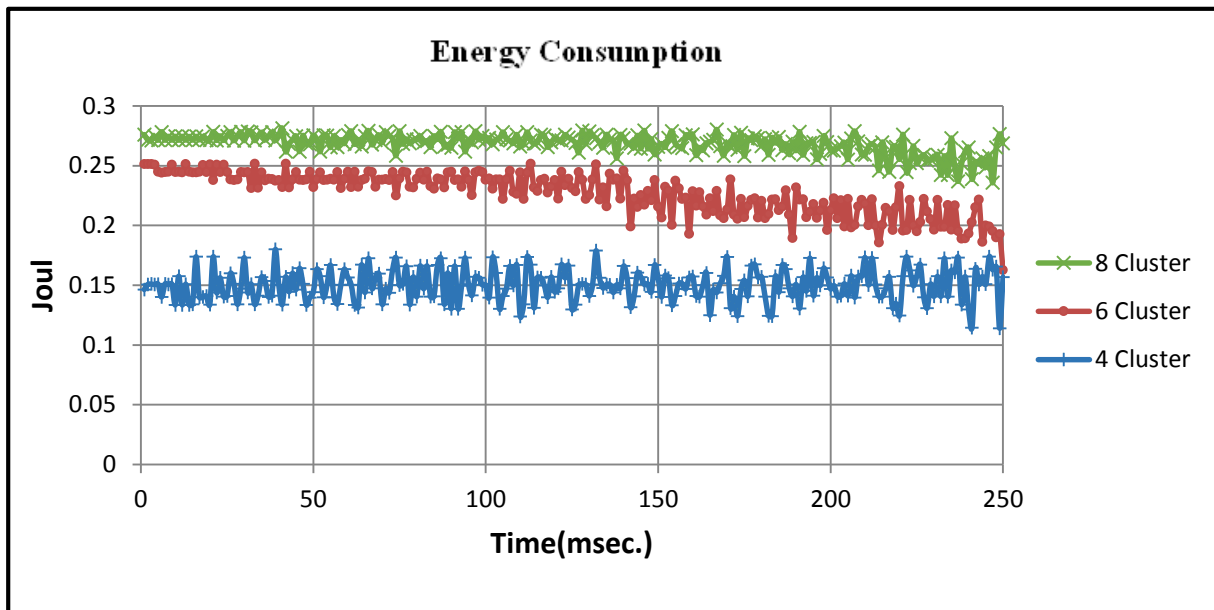


Figure 9. Comparison between 4,6 and 8 clusters MW-LEACH in EC.

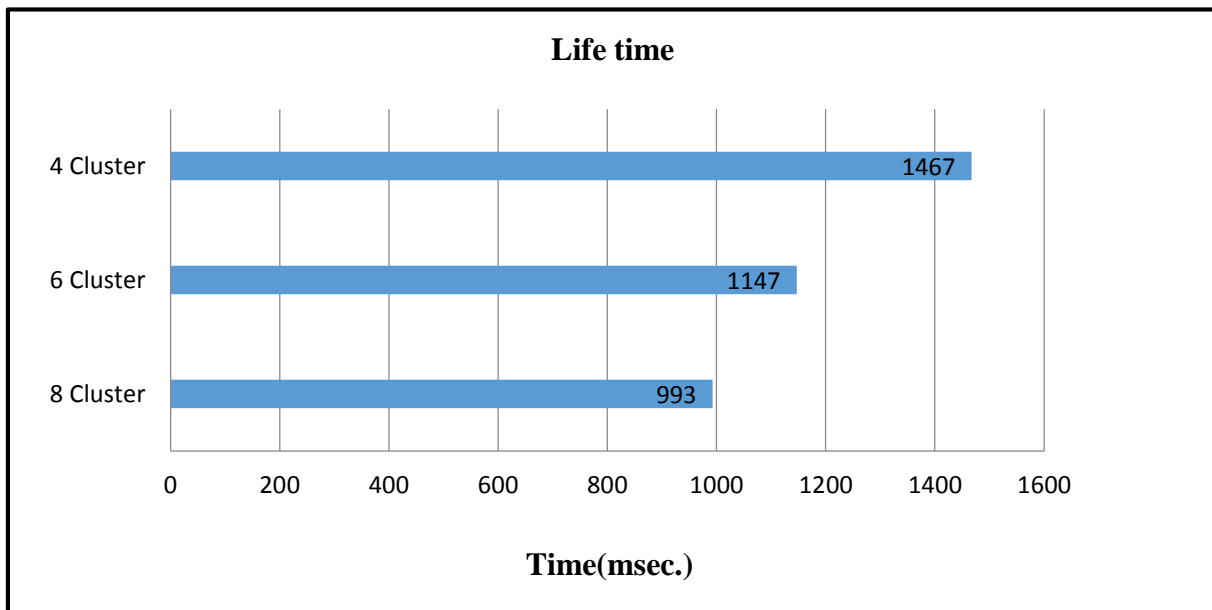


Figure 10. Comparison between 4,6 and 8 clusters MW-LEACH in Lifetime.



5. CONCLUSIONS

This paper presented the Modified W-LEACH protocol to enhance the Quality of Service (QoS) in WSN. The QoS in terms of Throughput Ratio, Energy Consumption (EC), network lifetime and Packet Loss Ratio(PLR). The simulation results and discussion show that the Throughput Ratio is more increased in MW-LEACH and PLR is more reduced than the PLR when using W-LEACH protocol, reducing the PLR means minimize dissipated energy, which in turn saving network energy and prolong network lifetime when using MW-LEACH.

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NOMENCLATURE AND ABBREVIATIONS

Symbol	Description	Unit
w_i	The weight assigned for sensor i	unit-less
e_i	Remaining energy in sensor i	joule
d_i	the density refers to the ratio of the number of alive sensors that are within a range of the sensor	unit-less
d_{th}	the minimum density threshold	unit-less
n	total number of alive sensors in the network	unit-less
b_i	the factor of buffer size for sensor i	unit-less
nr	number of active sensors in range	unit-less