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Strategies for Enhancing the Performance of (RPL) Protocol

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Abstract
Wireless sensor networks have many limitations such as power, bandwidth, and memory, which make the routing process very complicated. In this research, a wireless sensor network containing three moving sink nodes is studied according to four network scenarios. These scenarios differ in the number of sensor nodes in the network. The RPL (Routing Protocol for low power and lossy network) protocol was chosen as the actual routing protocol for the network based on some routing standards by using the Wsnet emulator. This research aims to increase the life of the network by varying the number of nodes forming it. By using different primitive energy of these nodes, this gives the network to continue working for the longest possible period with low and fair energy consumption between the nodes. In this work, the protocol was modified to make the sink node move to a specific node according to the node's weight, which depends on the number of neighbors of this node, the number of hops from this node to the sink node, the remaining energy in this node, and the number of packets generated in this node. The simulation process of the RPL protocol showed good results and lower energy consumption compared to previous researches.
KEYWORDS: Distance vector, WSN, PRL protocol, Moving sink, DODAG.

I. INTRODUCTION

Recently, after the increasing need to connect networks of wireless sensors with various smart devices on the Internet, the RPL protocol was proposed to work within networks composed of a very large number of nodes, which also has many advantages and great flexibility. The development of user needs with the emergence of some challenges, such as increasing the network lifetime or increasing the percentage of received packets, there was a need to modify this protocol according to these special cases [1, 2]. This will be done in this research to extend the lifetime of the network. The RPL protocol allows for the intent the user wants the application to be met by forming paths according to the parameters that fulfill the user's desire. For example, when forming paths, the network can contain more than one path between the source node and the receiving node, and each path has characteristics that distinguish it from the other path. In other words, Path 1 has the best transmission value (weight) which avoids connections that do not encode data passing through it, Path 2 has the best value in terms of delay (weight) which avoids low-power nodes [3-5]. This protocol also has the advantage of maintaining the path through periodic correction messages sent to check the state of the path periodically. It is evident from the above that this protocol is important in dealing with modern devices and that it can be modified according to the user's need, especially with the rapid development in the world of smart devices (home, office, industrial, etc.).

II. RELATED WORKS

Several studies have *modified* this protocol to take into account the moving sink nodes and goals of the network, such as increasing the network life. The study [6] suggested two strategies: **The first strategy** involves moving the sink node towards high energy nodes. Where the aggregation node receives data through this node, whether it is in the packet-generating node or just an intermediate node. Which leads to uniformity of the load distribution. If it is not the node generating of the packet, the energy of the previous nodes of the most energy complex located on the same path will be depleted, which will cause them to be out of work and to form holes. **The second strategy** involves giving weights to the nodes in the network, each node having a weight related to the number of neighbors. The remaining energy and the number of hops between the sink and the sensor node, as the sink node moves towards the node with the highest weight. This study neglected the parameter of the packets generated by the node, a parameter affecting the node weight, which could positively affect the life of the network, and this is what this research added to the weight, simulated the results, and compared them with the results of the two previous studies. The study [7] came to develop the network in terms of delay and energy, taking into accounts

the study [6], where the cost of the calculation was modified. The connection and timer are in the original protocol and did not extend the lifetime of the network. The study [8] indicated a strategy in the study [6] which noted that the parameters taken to calculate the cost of the path are insufficient, as they do not take into account all network conditions and low energy loss.

III. RPL BACKGROUND

It is a routing protocol based on the distance vector algorithm; it builds a tree structure called the DODAG (Destination Oriented Acyclic Graphs). [9, 10]When starting to configure the paths and form the structure, the root node (which is the same as the sink node when implementing this protocol in the algorithm) sends a control message containing information about the structure to be formed The neighboring nodes listen to this message, re-send it to the neighboring nodes, and decide whether they want to join these structures or not. It will decide to join based on specific constraints: Delay, Power, and Purpose of the application [11- 13] Fig. (1) Shows how the network is formed.
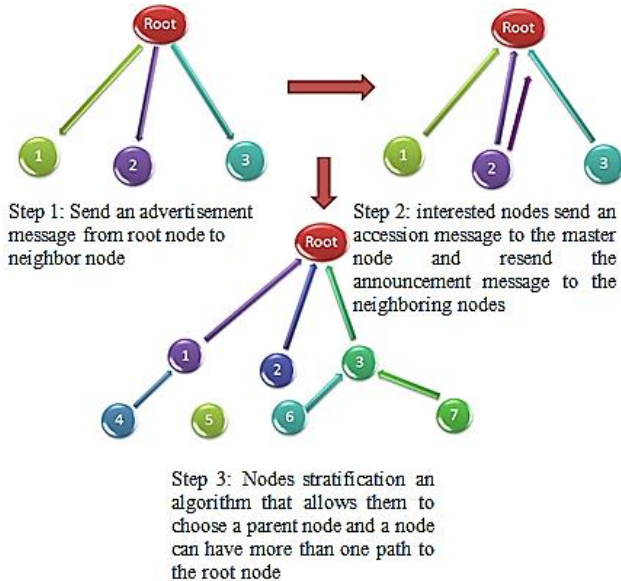

Fig. 1: Network construction steps

By the time a node becomes part of the structure, it will have a path to the root node and this node will act as a parent node for this node, so the process continues until the entire network is built. The RPL protocol supports the presence of several structures within one network that may depend on one or more root nodes called "DAG Instance". One node can belong to one or more structures at the same time, where each node has one ID Instance for each structure belongs to a DOG. The advantage of this feature is that the paths can be built according to the required purpose, for example, paths for normal data avoiding nodes that operating only on battery and a path for data of maximum importance where the delay is minimal. [14- 16] Fig. 2 illustrates this feature.
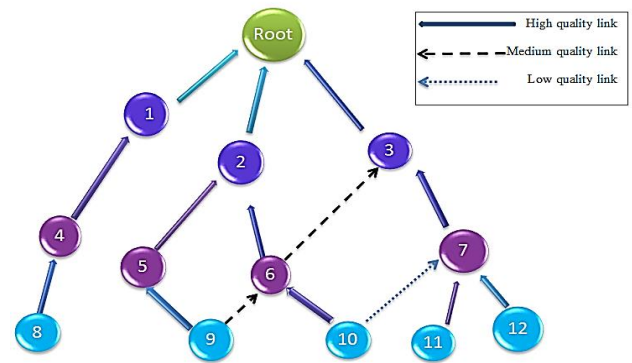

Fig. 2: Multipath of PRL protocol

IV. PROPOSED MODIFICATION TO THE RPL PROTOCOL

The proposed modification in this research will take into account several parameters: the remaining node energy, number of hops between node and sink, the number of neighbors in addition to the number of packets generated by the node, it will be explain as follows:

A. Residual Energy

When the remaining power level falls below the sensor-operating threshold, this means that the node is out of work, and as a result, the network life is reduced. If E_0 is the remaining energy in the node and E_c is the energy expended in, the unit of time. The lifetime of the sensor will be (T) [17-19]

$$T = \frac{E_0}{E_c} \qquad (1)$$

E_c can be calculated by:

$$E_c = f_i (E_t + E_r) \qquad (2)$$

Where E_t and E_r are the transmit and receive energies, respectively, it is measured in joules, f_i is number of times the transmit and receive it.

B. Number of HOPS

To increase the life of the network, the energy consumed across the network as a whole should be low, so the number of fewer Jumps when transmitting and receiving means reducing the energy consumed (because the nodes consume the largest part of their energy in transmitting and receiving), i.e., increasing the life of the network. If E_{pkt} is the energy needed to send the packet from a sensitive node to a sink node, then: $E_{pkt} \approx H * E1$ That is, the energy required to send the packet is proportional to H the number of hops to the sink node and E_1 is the energy needed to send the packet one hop [20,21,22].Therefore, to increase the life of the network, the number of hops between the sensitive node and the root node must be minimized, which depending on the routing protocol used, the number of hops varies according to the protocol, its mode of operation and the parameters it takes in mind, the number of hops also depends on the location of the root node and its movement settings. One method used to reduce the number of hops without changing the routing protocol is to configure the root node settings and direct it towards sensitive nodes.

C. Number of Neighbors

The greater the number of neighbors surrounding the sink node, the greater the probability of an evenly distributed load, which means consumption energy balance and avoidance of critical nodes out of work [6] The number of neighboring nodes will be denoted by N_i.

D. Number of Packets Generated by the Node

Whenever the greater the number of packets that generated by the node, the greater the need to travel towards it to reduce the energy required to send the packets [23,24,25]. The number of packages will be symbolizing by P_i.

V. MODIFIED PROTOCOL WORKING ALGORITHM

For each node in the DODAG architecture, the weight of the W_i node is defined:

$$W_i = f(E_0\ H_i^k N_i P_i) \tag{3}$$

Where H_i^k is the number of hops from the source node i to the root node K. That is, the weight of the node depends on the remaining energy in the node and the number of hops from the node originating between this node and the root node, the number of neighboring nodes and the number of packets generated from this node. To convert the subordinate to an equation, we multiply by modulation constants (α, β, μ) as long as the units are different between [0, 1]:

$$W_i = \alpha(E_0 H_i^k) + \beta N_i + \mu P_i \tag{4}$$

This equation added the parameter (which expresses the number of packets generated within the node) to the calculation of the weight mentioned in the study [6]. When the sink node (root) moves towards the node generating a greater number of packets compared to the rest of the nodes, taking into account the previous parameters. This will reduce the number of hops and, as a result, the energy that consumed to send the packets, and the arrival of a larger number of packets to the sink node, which means an increase in throughput of the network.

Parameters are multiplied by modification constants equal to 1, i.e., they are all equally important in forming the node weight (in our case, we do not want a parameter to have more significance than another). The values of these constants can be changed according to what the designer deems appropriate, for example, the number of neighboring nodes can be given more importance; thus, multiply the variable that expresses the number of neighboring nodes by a greater number than the number multiplied by the rest of the variables. Sink node kinematics can be viewed as a change in the DAG Instance, a change in the DAG Root, a change of path and a change in sink node. For this change to become real, the $T_{instance}$ variable is defined, which is the time required to build a new Instance. The process of moving the sink node will go through three stages:

1. During $T_{instance}$ time: each node will hear its neighbouring nodes belonging to the same DODAG structure. When it does not hear any higher Rank, it will decide that it is the final node.

2. Before the end of the $T_{instance}$ time: each node will send its weight W_i.

3. At the start of the $T_{instance}$: the sink node will determine the final node, which has the highest order, and move towards it. Fig. 3 shows the proposed algorithm summarization.
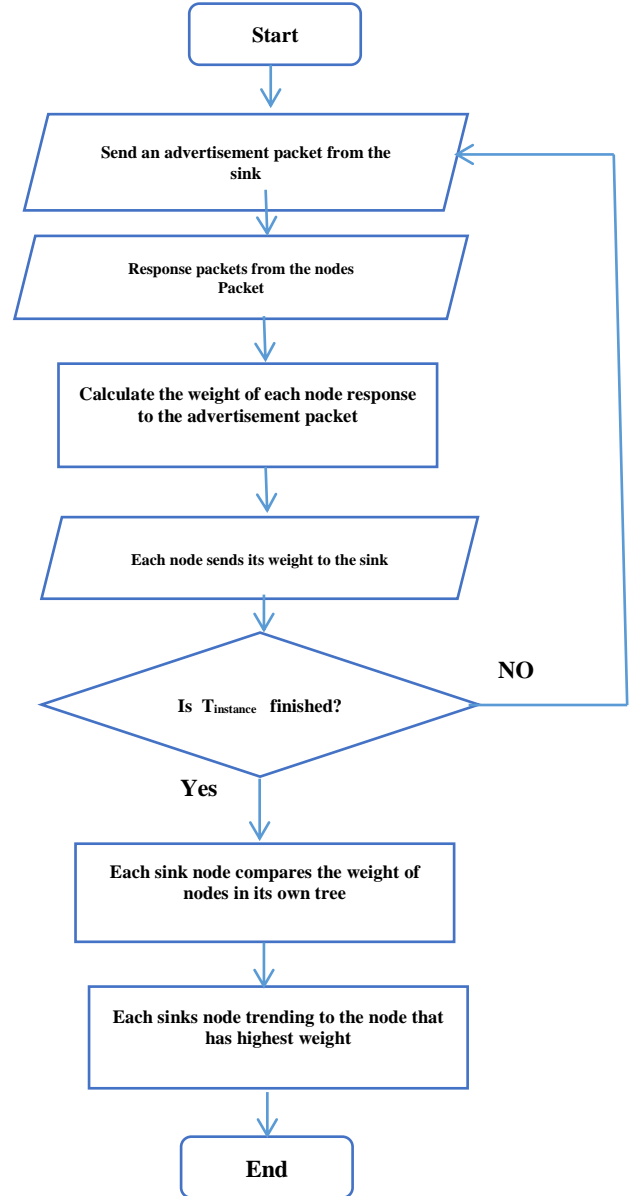

Fig. 3: The proposed algorithm summarization

VI. SIMULATION AND RESULTS

This research examines a wireless sensor network that contains three mobile sink nodes according to four network scenarios. These scenarios differ in the number of sensor nodes in the network. This is done by using the Wsnet emulator an open source emulator running on the Linux environment. This emulator offers many features, including simulating a random network scenario several times without the need to modify the randomness method in the simulation, or simulating several network scenarios

at the same time, in addition to many tools that can be add to the basic program to measure and obtain results. Table 1 shows the parameter of the simulation process on WSnet emulator.

TABLE1
The parameters configuration of network in simulation process on WSnet emulator.

Parameter	Value
Number of sink	3
Communication technology	IEEE 802.15.4
The required current to send	17 mA
The required current to receive	16.5 mA
Transmission range of node	10 m
Size of packet	127 b
Number of nodes	100-1500
the energy of node	1-5 j

The number of hops was chosen as a parameter to construct the DODAG, and the results were compared with the two previously mentioned algorithms:

1. RPLenergy: the sink node is oriented towards the most energy sensitive node.

2. RPLweight: sink node is directed towards the heaviest node in terms of residual energy, number of neighbors, and number of hops.

The proposed algorithm will be denoted by RPL_p. Table 2 illustrates the simulation scenario.

TABLE2
The Scenario of Simulation Process on Wsnet Emulator.

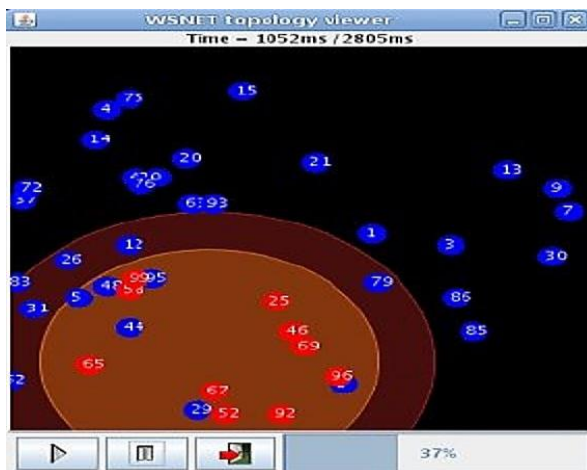| Scenario	Area	Number Of Nodes	Distribution
1	100m^2	100	Random
2	500m^2	500	Random
3	1500m^2	1000	Random
4	3000m^2	1600	Random

Fig. 4: The first Scenario on Wsnet Emulator.

These scenarios and simulation parameters were chosen to compare the results of the proposed algorithm with the results of the two aforementioned algorithms, which were obtained from the referred Studies:

A. Network Life Time

The life of the network ends when the first node in the network dies. Fig. 5 and 6 shows a comparison of the results obtained when implementing the proposed RPL_P algorithm with the two algorithms.
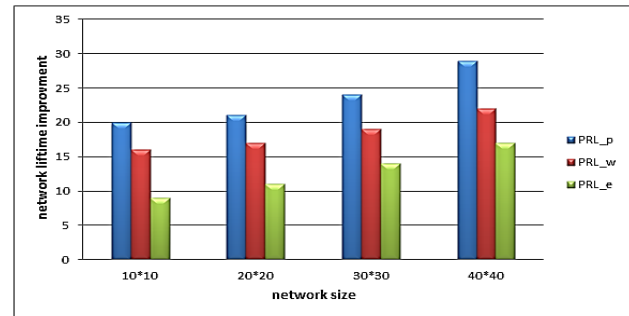

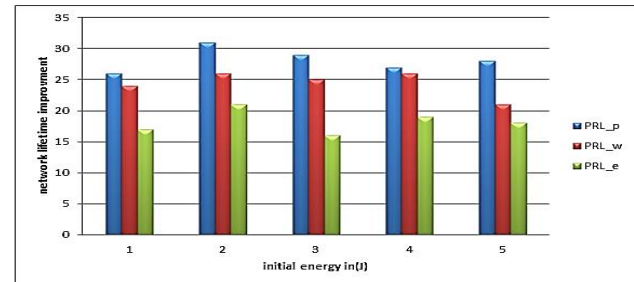Fig. 5: Increase network lifetime with increased number of nodes

Fig. 6: Increase network lifetime when change the initial energy of nodes

The previous two results and all results were for a network scenario using the original protocol (in which the sink nodes are fixed), that is, the result of the simulation of the original protocol was set as a basis (the value is zero). The results of the previous studies with the simulation result show that the proposed algorithm outperformed the results of the original protocol, RPL, by between 20% and 29% (considering that the performance of the original protocol was set as a basis for comparison).

As for the algorithm (RPL_e) in which the sink nodes move towards the most energy node in the network, whether it is generating data or not, so the increase in the network lifetime when applying the proposed algorithm ranges between 8% and 14% because the network life is not related to collecting data from the most energy node only. It is possible that it will not be the data generator, so, the generating node will repeat the data transmission to the most energy complex even if this depletes its energy and the energy of the nodes in the path leading to that most energy node; thus, some nodes out of work. By comparing the results of the proposed algorithm with the algorithm RPL_w in which the nodes move sink towards the higher node weight, regardless of the node carrying the data. The increase in the network lifetime when applying the

proposed algorithm was between 2% and 4% compared to this algorithm, which shows the importance of including the node parameter that generates the data when calculating the node weight.

To calculate the effect of changing the primitive power of a complex on the life of the network, the four scenarios were chosen (to compare it with the performance of the previous two algorithms). Fig. 5 shows a comparison of the results of the three algorithms for the original protocol scenario (fixed sink nodes) which we considered as the basis of comparison (value zero).

As expected, the results of the proposed algorithm were better as the direction of the sink nodes towards the heaviest node ensures fair energy consumption between the network nodes, thus increasing the life of this network. The network life increased by 1% at a primitive energy of 4 joules (the lowest value of the increase) and 9% (the highest value of the increase) at the primitive energy of 5 joules compared to the algorithm RPL_w. The life of the network increased by 7% at a primitive energy of 4 joules (the lowest value of the increase) and 13% at a primitive energy of 3 J compared to the RPL_e algorithm. The increase in network life time compared to the performance of the original protocol with fixed sink nodes ranged between 26% and 31.

B. Residual Energy

When calculating the remaining energy of the nodes within the network at the end of the network's life when it is out of work, and as is the case, the lower the remaining energy in the nodes at the end of the network's life the better. The reason is that it gives an idea of a fair distribution of the load between the network's nodes, especially when the life span of this network was long compare to others. Fig. 7 shows the remaining energy in the nodes at the end of the grid life, as is evident from the fixed sink nodes scenario (Original Protocol)
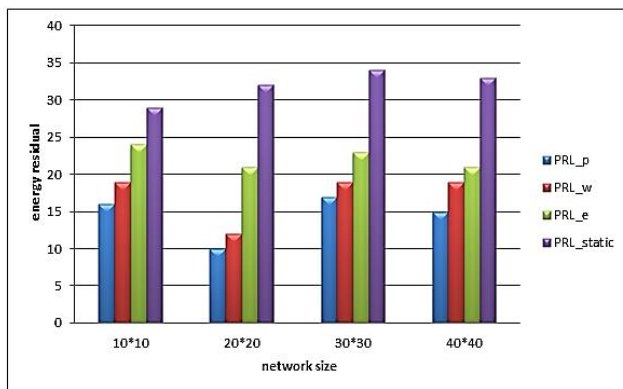

Fig. 7: Residual energy at the end life of nodes

The remaining energy in the nodes is at high levels at the end of the network's life, because at the end of the network, the use of a moving sink node will distribute the load; thus, convergent power consumption between nodes, as it has given. The proposed algorithm has a better result compared to previous studies. The proposed algorithm outperformed the algorithm by 2% over the algorithm (RPL_w) when there are 400 nodes in the network, and this figure is the lowest of its superiority. As the remaining energy in the

nodes at the end of the network life according to the proposed algorithm was 2% less than the remaining energy in the nodes, when the term expired the network life according to the algorithm, (RPL_w), which means an appropriate distribution of the load and less energy consumption with an increase in the life of the network, as seen in the previous results, and the highest superiority between the proposed algorithm and the aforementioned algorithm was 4%. In comparison between the proposed algorithm and the algorithm (RPL_e), the least difference in favor of the proposed algorithm is 6% at 1500 nodes in the network, and the highest difference is 11% at 400 nodes in the network. As for the comparison between the proposed algorithm and the original protocol, the minimum difference in favor of the proposed algorithm is 12% at 100 nodes in the network, while the highest number of superiority is 22% at 1600 nodes in the network.

VII. CONCLUSIONS AND RECOMMENDATIONS

In this research, an algorithm was proposed for the movement of the sink nodes, and this led to an increase in the duration of the network's life with the difference in the number of its constituent nodes and the difference in the primitive energy as the results shown. This algorithm also proved its effectiveness and superiority when used on a relatively large network (1644 nodes) compared to the algorithms that were used. Put it to extend the life of the network. The remaining energy in the nodes at the end of the life of the network with the application of the proposed algorithm was less than the remaining energy in the nodes when applying the two previous algorithms. When applying the original protocol, with the increase in the network life, this means a fair distribution of the load and a fair energy consumption in the network nodes. Besides, the algorithm also reduced the number of hops to reach sink nodes, which also gives greater reliability to the network in terms of receiving packets. This algorithm is recommended to be used in wireless sensor networks with moving sink nodes to increase network life it is suitable for large networks.in the future we will study the effect of the number of moving sink on the performance of the network.

CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

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