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Improved- Gateway-Based Energy-Aware Multi-Hop Routing Protocol for WSNs

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Abstract:- In wireless sensor networks (WSNs), prolonging the lifetime of a network is the main focus in designing any routing protocol. In this research, the performance of a gateway-based energy-efficient routing protocol (M-GEAR) for Wireless Sensor Networks (WSNs) was observed and analysed. It was realized that, the threshold that was used in selecting cluster heads among the nodes whose distance is beyond the gateway and Base station is on the basis of probability. This allows selection of weak nodes as cluster heads which will not have enough energy to transmit the captured data to the gateway. In this paper, a new reactive gateway-based energy-efficient routing protocol for Wireless Sensor Networks (WSNs) called TEEN-MGEAR (T-MGEAR) is proposed. The new algorithm modified the threshold for selecting cluster heads in M-GEAR by taking into consideration the distance between the nodes and the gateway as well as the residual energy of each node. Furthermore, hard and soft thresholds are implemented in the new scheme to determine when nodes can transmit their sensed data. The performance of the proposed algorithm is evaluated using MatLab 2017a. Simulation results showed that the T-MGEAR protocol outperforms M-GEAR protocol in terms of stability period, throughput and network life time.

***Keywords**:- Distance, Residual Energy, T-MGEAR, Gateway, M-GEAR, Wireless Sensor Networks.*

I. INTRODUCTION

Wireless Sensor Network (WSN) consist of a large number of sensor nodes with limited resources such as energy, processing power, and transmission range for monitoring of physical environment. In order to reduce their energy depletion, clustering technique has been proposed where the sensor nodes are put into groups called clusters. Each cluster is monitored by a node with high residual energy called a Cluster Head (CH) and the rest of non-cluster heads referred to as cluster members. These cluster members capture data and transmit it through wireless means directly or indirectly to the Cluster heads (CHs). The CHs then aggregate the data and then send the report to Base Station (BS) for further analysis. This clustering technique reduces the number of sensor nodes which could have wasted their energy sending data to the BS hence the technique gives a better energy management in the network.

Routing is also a challenge in wireless sensor network since the sensor nodes require it to either transport data from one sensor node to the other or to the BS. It is complex because of its dynamic nature and other constrains of sensor nodes [1], [4], [11]. This means that, the routing protocol must be cluster-based and energy efficient to prolong the lifetime of the network. In literature, several cluster-based routing protocols have been proposed. Heinzelman et al. [4] proposed the earliest single-hop clustering routing protocol in Wireless Sensor Network (WSN) called Low-Energy Adaptive Clustering Hierarchy (LEACH). The protocol saved network energy greatly compared to the non-cluster routing protocols such as the direct transmission protocol. Many other clustering algorithm were proposed based on LEACH.

Threshold Sensitive Energy Efficient Sensor Network protocol (TEEN) was also presented by Manjeshwar and Agrawal [7]. It is a hierarchical protocol designed for the situations like quick changes in the sensed attributes such as temperature. The network works in a reactive mode and therefore, places importance to sensitivity which is needed for time-critical applications. In this scheme the CH announces two thresholds to its members: the Hard Threshold (HT) and the Soft Threshold (ST). The HT is a threshold value for the sensed attribute, from which, the node sensing this value will switch on its transmitter and send the report to its cluster head. The ST is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit to CH. The nodes sense their environment continuously. The sensed value is stored in a variable in the node, called the sensed value (SV).

Another version of LEACH called LEACH Centralized protocol (LEACH_C) was developed by Heinzelman et al. [3]. In this protocol, the Base Station coordinates the affair of the network. In the setup phase, all the nodes send a message containing their energy level and location information to the BS. Based on that, it chooses the CHs based on their location information. It then conveys a message to all the nodes about the chosen CHs and their ID. However, the activation of GPS receiver in each round affects the performance of the protocol.

Lei et al. [6] presented an improved multi-hop routing protocol called LEACH-L. It depends on the distance between the CHs and the BS before using either multi-hop transmission or single-hop transmission. If the CH is far from the BS, it uses multi-hop communication otherwise single-hop transmission is used. It considers residual energy and distance to BS in selecting the CH for the next hop. The results of the simulation showed that LEACH-L protocol balanced the network load and prolonged the lifetime of the network.

Gong et al. [2] discussed a distributed, multi-hop routing protocol with imbalanced clustering for WSNs which also prolonged the network lifetime. It places the BS at the middle of the sensing field and selects the CHs based on the residual energy. As a homogeneous network, all the nodes have the same initial energy with unique ID at the beginning of the clustering process. Its effectiveness is affected by the fact that, it requires more memory space to store the table containing the distance values of each sensor node. That brings about adjusting the energy utilization.

A new version of LEACH (V-LEACH) protocol which improves the performance of the original LEACH protocol has been described by Yassin et al [13]. When a CH dies, the cluster becomes less important because all data gathered by the sensors in that cluster will not reach the sink. In order to prevent this, the protocol chooses backup-Cluster Head (back-CH) that replaces the CH in case it dies. By doing this, cluster nodes data will always reach the BS. Also the election of a new CH each time the old CH dies would no more be needed and this has extended the life time of wireless network.

Another scheme that adopts both multi-hop and single-hop communication modes to reduce energy expenditure called, MS-LEACH has been proposed by Qiang et al. [10]. The protocol takes into account the critical value of cluster area size. If the cluster area size is smaller than the critical value, single-hop transmissions are employed in the cluster for data transmission to the BS else multi-hop communications are used. The results indicated that, it has enhanced the network lifetime.

Singh et al. [11] suggested a new algorithm called energy-efficient homogeneous clustering algorithm for wireless sensor networks. It enhanced the lifetime and throughput of the network by taking into consideration the residual energy and the nearest hop count in selecting the CHs.

A cluster-based routing protocol which partitioned a network into four quadrants after sensor nodes are deployed in the territory has been presented by Manzoor et al. [8]. The approach is to ensure better coverage of the whole network. It adopts the concept of randomized clustering applied in [4] where individual nodes are allowed to decide to become CH based upon given a probability value, p and a threshold, $T(n)$. The simulation results showed that, it has enhanced stability period, network lifetime and throughput quiet significantly

Kaur and Kaur [5] proposed Enhanced M-Gear Protocol for Lifetime Enhancement in Wireless Clustering System. In this protocol, the number of gateway nodes were increased so that the load can be distributed equally among them. The network was divided into a number of sections and each section has its own gateway node. The nodes of that region will transmit their data to their gateway node which will then send to the BS. It also introduced gateway to gateway communication to reduce energy consumption. The results of simulation showed that, it outperforms MGEAR in terms of throughput, energy consumption and network lifetime. However, having several gateways will lead to increase in the cost of the network.

Considering the review above, it is clear that, the distance between the nodes and the base station as well as the residual energy of nodes were not considered in selecting the cluster heads. This is the major gap in this literature reviewed.

In this paper, a new version of MGEAR called T-MGEAR has been proposed. The new protocol enhances the Threshold of selecting cluster heads of nodes which are not closer to the gateway and the Base station in MGEAR protocol. The threshold now take into account the distance between the nodes and the gateway as well as their respective residual energies. The proposed protocol was simulated using MATLAB2017a and the results showed a better performance compared to existing MGEAR protocol.

The remainder of this work is organized as follows: In Section II, explained the Materials/Methods, while the Simulation Results and Analysis are discussed in Section III, and conclusion is drawn in Section IV.

II. MATERIALS/METHODS

MatLab R2017a was used to evaluate the performance of the proposed algorithm and the existing algorithm.

A. GATEWAY-Based Energy-Aware Multi-Hop Routing Protocol (M-GEAR)

M-GEAR is a routing protocol proposed by [9]. The scheme divided the network into regions based on the distance of the nodes to the BS and the gateway. The gateway is placed at the center and Base station installed outside the network. The Sensor nodes which are closer to the base station adopt single-hop transmission mode to convey their data straight to the BS without passing through the gateway. However, the nodes which are far from the Base station and gateway also adopted clustering technique where they select their cluster heads (CHs). These CHs received data from the distant nodes and then send the captured data to the gateway which will also forward the report to the Base station

The predefined threshold T(s) value used by the distant nodes to becomes CH in the current round in MGEAR protocol [12] is given by (1)

$$T(S) = \begin{cases} \frac{p}{1-p[r mod \frac{1}{p}]} & if\ s \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Where
r = current round
G = set of nodes that are not selected as cluster head
p = desired percentage of cluster head

The main challenge of this protocol is the fact that, the threshold for selecting these CHs is done on probability basis which permits weaker nodes to also become cluster heads. These weaker CHs cannot forward their data to the gateway thereby wasting the data they have collected. This affects the effectiveness of the protocol. Also, when a node is selected from a far corner of the field as a CH, it will dissipate a large amount of energy to transmit the data to the Gateway. As a result, the CH dies faster and this also affect the throughputs of the network.

B. Proposed Scheme

In this section, the new M-GEAR protocol called TEEN- MGEAR (T-MGEAR) is proposed. The operation of the new scheme is similar to MGEAR, however, the threshold, T(s) for determine whether a node can become cluster head or not has been modified. The threshold now depends on the residual energy of the node and its distance from the gateway. So the node with high residual energy and also closer to the gateway will have the higher chance of becoming cluster head. This will prevent the nodes which are either weak or far from the gateway from being elected as cluster heads.

The new predefined threshold T(s) value used by the distant nodes to becomes CH in the current round is given by (2)

$$T(S) = \begin{cases} \frac{p}{1-p[r mod \frac{1}{p}]} * \frac{distance(_i)}{Residual\ energy(_i)} & if\ s \in G \\ 0 & otherwise \end{cases} \quad (2)$$

After the cluster heads are elected, the heads then broadcast the hard and soft thresholds to the cluster members so that, data transmission will not be done frequently.

III. SIMULATION RESULTS AND ANALYSIS

In this section, MGEAR and proposed routing protocol T-MGEAR for wireless sensor network are simulated in MATLAB R2017a environment to evaluate the performance of our protocol. For the simulation, a network consisting of 100 nodes randomly deployed in a field of dimension 200m x 200m. A gateway is located at the centre (50m, 50m) and the Base station installed out the field (50m,250m). All nodes are stationary after deployment and energy loss due to signal collision and interference between signals of different nodes are ignored. Table 1 defines the simulation parameters used in this research work.

Parameters	Values
Network field	(200,200)
Number of nodes	100
Initial energy of normal nodes(E_0)	0.5J
Message size	4000 bits
E_{elec}	50Nj/bit
E_{fs}	10Nj/bit/m^2
E_{mp}	0.0013Pj/ bit/m^2
P_{opt}	0.1

Table 1:- Simulation Parameters

We run extensive simulations and compare our results with MGEAR using the following metrics:

A. Network Lifetime

Fig. 1 shows the number of alive nodes during each transmission round for the MGEAR and T-MGEAR routing protocols. From the graph, the network life time is enhanced significantly in T-MGEAR compared to MGEAR. Nodes alive effectively up to 2500 rounds in MGEAR and remained alive up to 3050 rounds in T-MGEAR. This indicates that, nodes live longer in T-MGEAR than in MGEAR and therefore making the proposed protocol to sustain more alive nodes than MGEAR protocol. The extension of lifetime that was observed in T-MGEAR are as a result of the clustering technique adopted, the residual energy and distance that were considered in selecting the heads. The weak nodes are not elected as cluster heads and therefore, their energy is not also wasted. Also, the sensor nodes do not transmit frequently because of the hard and soft thresholds implemented [7]. Furthermore, even among the nodes which have high residual energy, but far from the gateway are not chosen as cluster heads and hence the energy of the distant nodes are conserved.

It can also be observed that the death rates in T-MGEAR is lower compare to that of MGEAR as seen in Fig. 2. The MGEAR showed stability period between 50 and 1250 rounds after which the death rate increases. The new scheme on the other hand maintained stability period from 50 to 2400 rounds after which the death rate increases slowly. This gives the proposed protocol better network life time and stability period compared to the existing protocol.

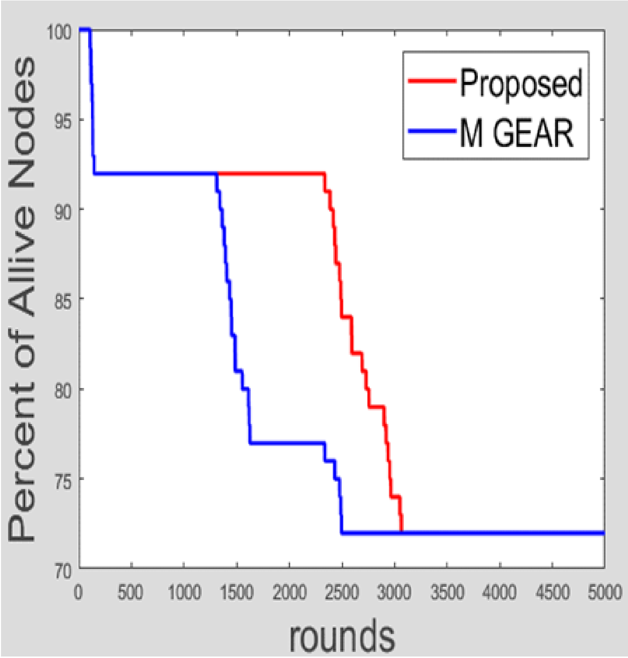

Fig 1:- Number of Alive Nodes per Number of rounds

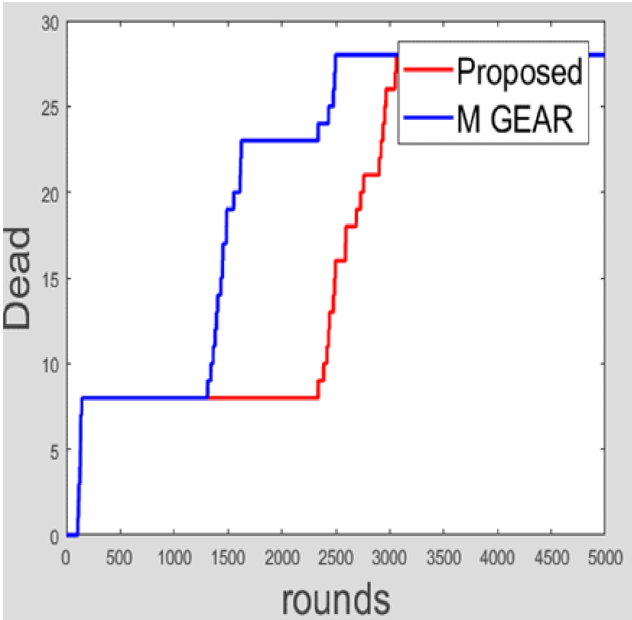

Fig. 2: Number of Alive Nodes per Number of rounds

B. *Throughput*

Fig. 3 also shows the amount of data sent to the BS per round in MGEAR and T-MGEAR protocols. It can be noticed that, the amount of data sent to the BS by MGEAR protocol increases from 0 to 2500 rounds and remains stable throughout the simulation period. Thus, sending less amount of data to the BS as shown in Fig. 3. In the new algorithm, large amount of data was sent to the BS, almost twice that of the MGEAR protocol. This performance is as result of the residual energy and distance criteria that were considered in electing the cluster heads. The nodes with high residual energy and also closer to the Base station are elected as the Cluster heads. Hence these nodes used less energy to transmit data to the BS.

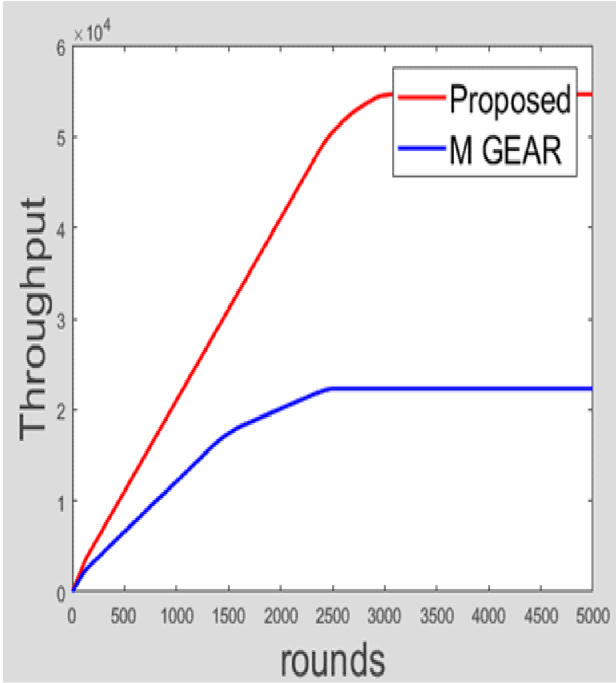

Fig. 3: Throughput per number of rounds

C. *Residual Energy*

Fig. 4 shows the average residual energy of network per round of the two protocols. The two protocols began with the same energy consumption from 0 to 50 rounds as seen in Fig. 4. After the 50 rounds, the rate of energy consumption of MGEAR protocol increases faster compared to the T-MGEAR protocol. This was evidenced by the low death rate and high packet sent to the BS in the new scheme. The Fig.4 clearly indicates that our protocol outperforms MGEAR routing protocol in terms of energy consumption per round.

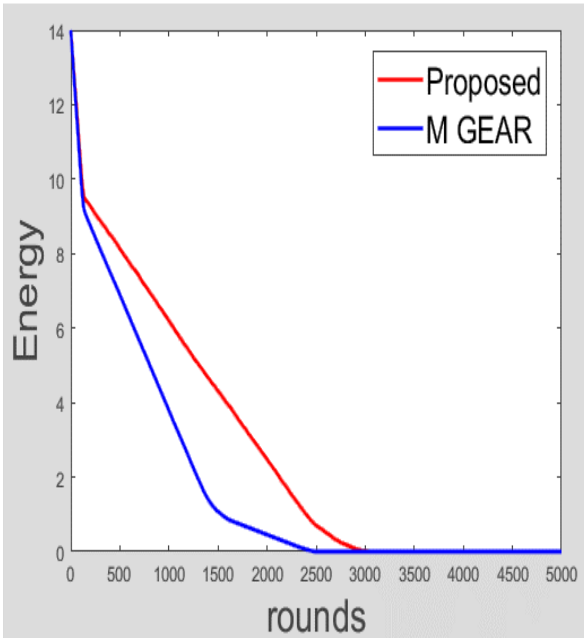

Fig. 4: Residual energy per number of rounds

IV. CONCLUSION

In this work, Improved-Gateway-Based Energy-Aware Multi-Hop Routing Protocol for WSNs called TEEN-MGEAR (T-MGEAR) is proposed. In this new protocol, cluster head selection algorithm for the sensor nodes which are far from the gateway and Base station in M-GEAR protocol has been modified. Three important techniques were taking into consideration in modifying the existing algorithm. 1) The distance between the nodes and the gateway. 2) The residual energy of each node. 3) The introduction of soft and hard thresholds which determine when data can be conveyed to the gateway. The captured data must be equal or above the given hard threshold before data can be sent. This has reduced energy consumption in the nodes which has resulted into better throughputs, stability period, effective energy utilization and longer lifetime of the network. So, we can conclude that, T-MGEAR, is more effective and efficient than MGEAR in terms of stability period, throughputs and network lifetime

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