

# Gateway–based Threshold Distributed Energy Efficient Clustering (G-TDEEC)

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## ABSTRACT

Wireless sensor network basically is made up of several sensor nodes that sense physical quantities such as temperature and pressure in a physical environment, capture these quantities and relay the data to another node called the Base station (BS). The transmission of the sensed information from the deployment area to the BS has been observed to drain the limited energy resource of the sensor nodes. Some researchers are of the view that, placing the BS at the centre of the sensing field will sufficiently reduce the energy consumption during data transmission. Based on this, some of the descendants of DEEC protocol such as TDEEC (Threshold Distributed Energy Efficient Clustering) protocol also placed the BS at the centre of the deployment field to conserve network energy. So what happens to TDEEC scheme if it was to be deployed at a place such as military surveillance where the BS may be far from the sensing field? In this research work, a gateway-based TDEEC, G-TDEEC protocol is proposed. The new scheme introduced a gateway at the centre of the sensing area and then installed the BS far away from the sensing field. The cluster heads relay their data to the gateway which will then aggregate the data and then send the final report to the BS. Simulation was performed to assess the performance of the proposed protocol and the TDEEC scheme using MatLab 2017a. The simulation results showed that, the proposed protocol performed better than the existing scheme in terms of stability period, throughput, residual energy and the network lifetime.

## General Terms

Algorithm-Routing protocol

## Keywords

G-TDEEC Protocol; Network lifetime; Centre, Outside; Gateway; MatLab simulation.

## 1. INTRODUCTION

Improvements in technology has made the shifting from wired networks to wireless networks possible where fix infrastructure is not needed. Among these wireless networks is a wireless network that is composed of thousands of sensor nodes mostly deployed to collect measurement quantities such as temperature and humidity in any physical environment. This kind of network is referred as wireless sensor networks. When the sensor nodes in these networks sensed data from the environment, they convey the information wirelessly to a well-resourced node called the Base station (BS). Once the data gets to the BS, the user can access and analysis it satisfactorily. However, the nodes in this network are very tiny, constrained in terms energy (they are battery operated), limited in ability to process, store and even transmit large data over a long distance. And their ability to transmit data over a longer distance is very crucial in a very hostile environment. Although, in some of the heterogeneous routing protocols, the Base stations are mostly placed at the centre of network to

reduce energy consumption, other strategy can be adopted to still allow them function very well in areas where the BS must be far from the deployment areas. Several energy saving methods have been proposed. Among them is the energy efficient cluster-based routing algorithm for both heterogeneous and homogeneous networks. These routing protocols are gaining more attention from the researchers. This is proven in some of the following literature.

Heinzelman et al. [1] explained the earliest single-hop clustering routing protocol called Low-Energy Adaptive Clustering Hierarchy (LEACH). The scheme conserved the network energy better compared to the non-cluster-based routing schemes such as the direct transmission protocol and since then, several clustering algorithms were developed based on LEACH.

A centralized form of LEACH (LEACH\_C) was suggested by Heinzelman et al. [2]. In this algorithm, the Base station manages the affair of the network. In the setup phase, all the sensor nodes send a message containing, their energy level and location details to the BS. The Base station then select the cluster heads based on the node location details. It then introduces the selected cluster heads and their IDs to all the nodes. However, the usage of GPS receiver in each round affects the performance of the protocol.

Kaur and Kaur [3] described Enhanced M-Gear scheme for Wireless Clustering System. In this protocol, the number of gateway nodes were increased to ensure evenly distribution of load among them. The network was divided into a number of sections and each section is assigned a gateway node. The nodes of a region will transmit their data to their assigned gateway node which will then send to either BS or nearest gateway to the BS. Although, the simulation results proved that, the proposed scheme performed better than MGEAR in terms of throughput, energy consumption and network lifetime the cost of the network will high because of the number of gateway nodes.

Author in [4] presented an improved version of M-Gear Protocol for homogeneous wireless sensor network. The protocol modified the threshold for choosing cluster heads by taking into account the distance between the nodes and the gateway as well as their residual energy. The scheme also introduced hard and soft thresholds to reduce unnecessary transmission of data to the Base station. The simulation results showed that, the scheme performed better than M-Gear in terms of stability period, throughput, residual energy and network life time.

Qing et al. [5] proposed a heterogeneous routing scheme, DEEC which has now become the basis upon which several heterogeneous routing protocol are developed and continue to be developing. The protocol select cluster head based on the ratio between residual energy of each node and the average energy of the network. The algorithm uses two type of nodes,

the normal and advanced nodes in its two level hierarchy. However, the challenge in the scheme is the continuous discrimination against the advanced nodes when their residual energy becomes equal to the normal nodes in the network.

Elbhiri et al. [6] suggested a new form of DEEC algorithm for heterogeneous network. DDEEC, presented a better solution to the main problem that was observed in DEEC scheme. The problem exist where the advanced nodes are constantly being punished when their residual energy becomes at equal level with that of the normal nodes. To solve this, DDEEC algorithm introduced threshold residual energy value,  $Th_{REV}$  for all the nodes based on which the average probability of each node is determined.

Another version of DEEC model, E-DEEC for heterogeneous networks has been described by Saini et al. [7]. The scheme added another sensor nodes, super nodes to the normal and advanced nodes. So, E-DEEC is made up of three types of sensor nodes with different initial energies. The nodes with highest initial energy is the super nodes followed by advanced nodes and normal nodes with the lowest initial energy. Simulation was conducted to see the performance of the scheme and the simulation results showed that, E-DEEC outperforms DEEC in terms of stability period and network life enhancement.

Authors in [8] proposed improved form of DEEC protocol, TDEEC algorithm. This model also adopted three level of sensor nodes with different initial energies as in [7]. The algorithm however modified the value of the threshold, upon which a node decides to be a cluster head or not. The threshold is based on ratio of residual energy and average energy of that round with respect to the optimum number of cluster heads. This is to make the nodes with more energy to become the cluster head. TDEEC also suggested the probabilities for two levels, three levels and multilevel heterogeneity. The simulation results proved that, TDEEC performed better in terms stability period and network lifetime especially, in its three levels and multilevel.

The remainder of this research is organized as follows: **Section 2** described the methodology used, simulation results and analysis are discussed in **Section 3** and conclusion is then drawn in **Section 4**

## 2. METHODOLOGY

DEEC protocol was the basis upon which many heterogeneous routing protocols have been proposed. The protocol places the Base station at the centre of the sensing field for simplicity according to [5] but to large extend is to sufficiently reduce the energy consumption in the network. So, TDEEC also placed the BS at the centre with the aim of minimizing energy depletion in the network. It was observed that, when the BS is placed outside the sensing area, the TDEEC protocol performed poorly in term of throughput and energy conservation. This means that, when it comes to applications where the BS must be placed outside the network, TDEEC cannot performed well. In order to solve this problem, a new algorithm called gateway-TDEEC (G-TDEEC) is proposed. In this new scheme, a gateway node is introduced and placed at the centre and re-installed the BS far from the deployment field. The cluster heads which receive information measurements from the normal sensor nodes relay the data to the gateway. The gateway then aggregate the data and then convey the report to the BS far from the sensing field.

## 3. SIMULATION RESULTS AND ANALYSIS

To assess the performance of G-TDEEC protocol and T-DEEC scheme, MatLab 2017a was used for simulation. In this experiment, a random network of 100 nodes is used in 100m x100m cross-sectional area. The gateway is placed at the middle of the deployment area (50m, 50m) and the Base station installed outside the field (50m, 200m). For the composition of the nodes used, 20 advanced nodes were deployed with 1.5 times more energy than normal nodes and 30 super nodes with 3 times more energy than the normal nodes ( $m = 0.5, mo = 0.4, a = 1.5$  and  $b = 3$ ). Other parameters used in the simulation are shown in the Table 1.

**Table I: Simulation Parameters**

S/N	Parameter	Values
1	$E_{elect}$	50nJ/bit
2	$E_{fs}$	10pJ/bit/m <sup>2</sup>
3	$E_{mp}$	0.0013pJ/bit/m <sup>2</sup>
4	$E_0$	0.5J
5	Message size, k	4000
6	n	100
7	$P_{opt}$	0.1
	$E_{DA}$	5nJ/bit/message

**Table 2: Round vs Node death during simulation process**

Protocol	Death count	Round
TDEEC	50	256
	100	1750
G-TDEEC	50	538
	100	2375

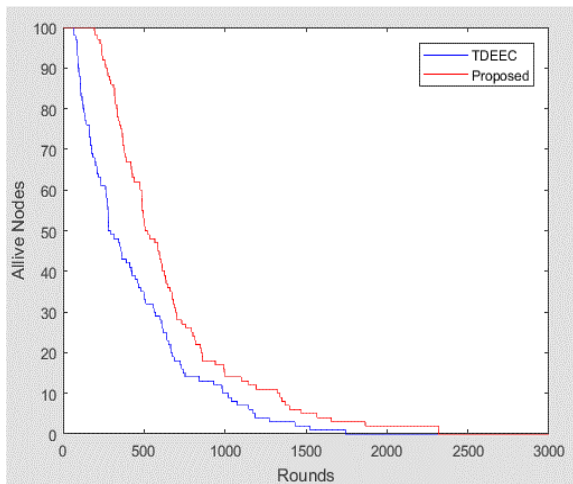
**Table 3: Round vs Residual energy during simulation process**

Protocol	Round	Residual energy
TDEEC	20	0.3
	50	0.0
G-TDEEC	20	0.42
	460	0.0

Round numbers of deaths of all the nodes during the simulation process for both the proposed and existing protocols have been gathered. To ensure effective comparison, data for death of half of the sensor nodes and all the sensor nodes in both protocols have been shown in Table 2 and the detailed plot of the whole data displayed in Fig 2. Table 3 also shows the residual energies of the two protocols with the detailed plot of the whole data in Fig 4. From the Table 2 and

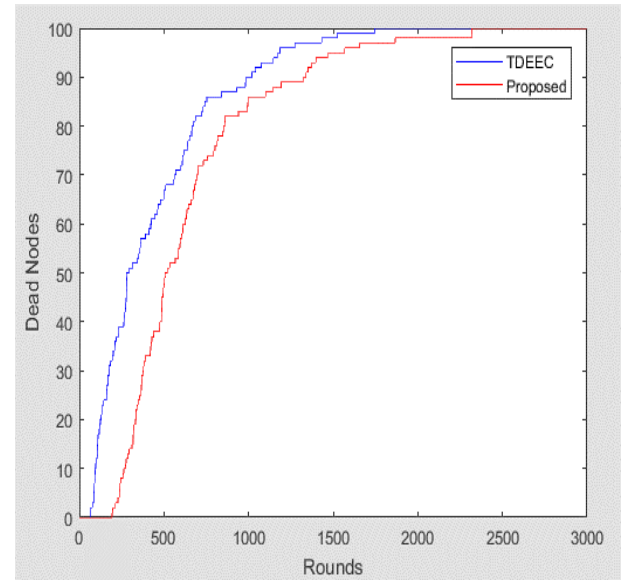
Table 3, it is clear that, the proposed algorithm has better network lifetime and residual energy than the existing scheme.

Figure 1 shows the number of alive nodes per round during simulation process for the G-TDEEC protocol and T-DEEC scheme. It can be observed from the graph that, the lifetime of the network has been extended in G-TDEEC compared to T-DEEC. The nodes in T-DEEC survived up to 1750 rounds and vanished but remained alive up to 2375 rounds in G-TDEEC before disappearing. This shows that, nodes remain a live for longer time in G-TDEEC and hence better lifetime than T-DEEC routing scheme. The longer lifetime of the new algorithm is as a result of the multi-hop communication method adopted in the protocol. The cluster heads send their data to the gateway which then relay it to the BS. So energy of the cluster heads are conserved as well as other nodes in the network.



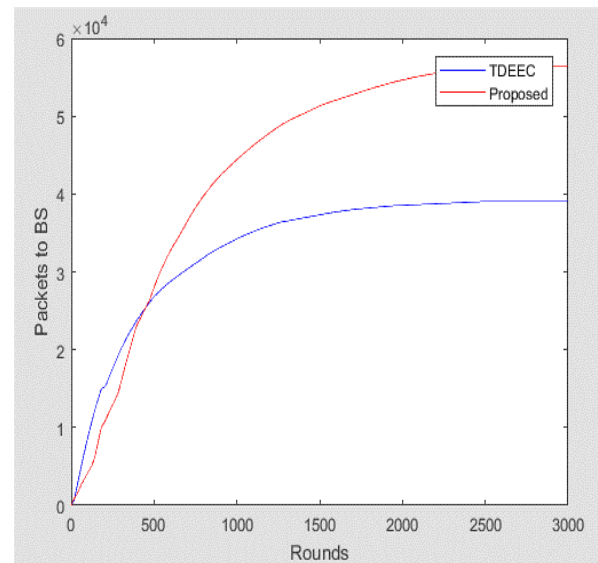
**Figure 1: Number of the Alive nodes per round**

Figure 2 shows the number of dead nodes per round for the G-TDEEC protocol and the existing scheme. It was again realised from the graph that, the death rates in G-TDEEC is lower compare to that of T-DEEC as seen in Figure 2. At 1750 rounds, all the nodes in T-DEEC are dead where as in G-TDEEC, it was 2375 rounds. Also, the new scheme has better stability period than the T-DEEC scheme. As early as 100 rounds, T-DEEC first node died where as in G-TDEEC, it is in 400 rounds. This shows that the proposed scheme has effectively reduced the number of dead nodes resulting into a better network lifetime and stability period.



**Figure 2: Number of the dead nodes per round**

Figure 3 also shows the magnitude of data sent to the BS per round in both G-TDEEC and the existing protocols. It can be seen that, the amount of data sent to the BS by T-DEEC increases from 0 to approximately 40000 at the end of the experiment sending less amount of data to the BS. In the new scheme, large quantity of data was observed being conveyed to the BS which is more than even 50000. This performance is as result of the multi-hop communication mode used and reduction of burden on the cluster heads. The heads are supposed to aggregate the data received from the normal nodes in the existing scheme but in the proposed protocol, the gateway rather perform such function thereby reducing the energy that would have been used by the heads for such purpose. So the heads have transmitted more data with less energy expenditure.



**Figure 3: Number of packet to the BS per rounds**

Figure 4 displays energy dissipation of the network in both routing algorithms. As early as 100 rounds, the existing protocol has drained its energy. Though this is understandable since T-DEEC was not designed for such long distant Base station. The new algorithm on the other hand shows relatively reduction in energy consumption because of the presence of

the gateway. It manages the energy consumption of G-TDEEC until 400 rounds. This shows that, the energy remaining per round in the proposed model is better than the T-DEEC protocols.

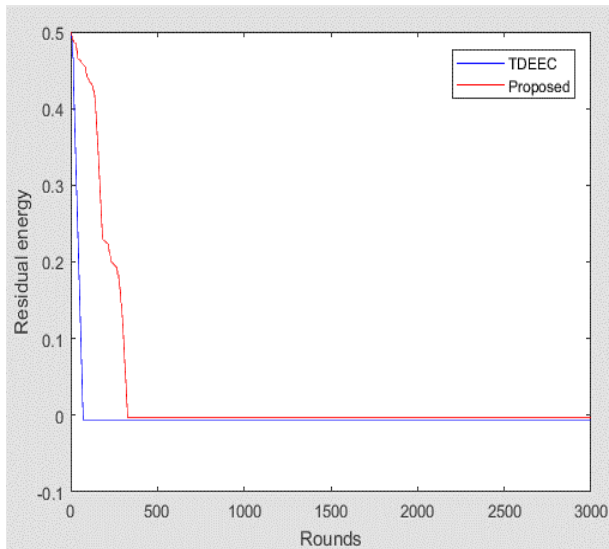


Figure 4: Remaining Energy per round

#### 4. CONCLUSION

In this work, gateway-TDEEC (G-TDEEC) protocol for heterogeneous networks is proposed. In the model, gateway node was introduced at the centre of the network while installing the Base station outside far from the deployment area. The gateway receives the measurement data from the cluster heads, aggregate it and convey the final report to the Base station. This has reduced the energy expenditure of the cluster head which they could have used for the data fusion. The scheme also adopted multi-hop communication from the normal sensor nodes to the Base station. And this has also reduced the energy consumption in the network. The simulation results showed that, the proposed protocol performed better than the T-DEEC in terms of coverage, stability period, and throughput and network life time.

#### 5. REFERENCES

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