Review Article

Gateway-Stable Election Protocol for Heterogeneous Wireless Sensor Network

ABSTRACT

An in-depth study of Stable Election Protocol (SEP) revealed that~~,~~ distance was not considered in selecting the cluster heads in the network. This allows a distant node ~~which~~ that is selected as the head to dissipate huge energy in transmitting data to the Base station (BS). It was further observed that, whenever the Base station~~-~~ is relocated outside the field, the energy consumption of the network is high and hence shortening the lifetime of the network. In this paper, a Gateway-SEP protocol is proposed. The G-SEP modified the election probability of electing cluster heads by considering the distance, average distance and residual energy of the advanced nodes. The scheme also introduced a gateway node at the centre of the network and then installed the BS outside the field. Simulation results using MatLab R2017a showed that~~,~~ the G-SEP performs better than Zonal-Stable Election protocol (ZSEP) in terms of coverage, stability period, throughput and network lifetime.

Keywords: Distance, Energy consumption, Gateway, G-SEP Network lifetime~~-~~.

1. INTRODUCTION

Modifications in routing algorithms have paved the way for more efficient routing protocols to be proposed in a newly discovered field called Wireless Sensor Network (WSN). The WSN seeks to reduce the burden and suffering among people by providing reliable monitoring services to mankind. These sensor nodes can be deployed in any physical environment where human monitoring can be very dangerous. However, the nodes in these networks face some challenges such as energy, storage capacity and processing ability. Therefore an efficient use of these limited resources always enhances the lifetime of the network [1]. There are several ways by which information from the nodes can be sent to another node or Base Station (BS) within the network [2].

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Firstly, the nodes can disseminate the information directly to the BS. This method of sending information is called direct transmission. The disadvantage of this method is that~~,~~ the distant nodes spend a lot of energy to get their information to the BS. Secondly, through the relay nodes. The challenge with this mode of communication is that~~,~~ the nodes which are closer to the BS tend to suffer because of communication overheads. Finally, through the clustering technique where the nodes can be grouped into clusters. Each cluster will be managed and coordinated by an elected head called the cluster head. The head receives the measured data from the non-cluster heads, aggregates it and then forwards it to the BS. This third method proved to be better than all the other methods in terms of energy utilization [3].

Therefore, for larger area coverage, the clustered communication combined with multi-hop communication is usually adopted to reduce energy depletion [4]. In literature, several routing protocols have been proposed with the Base station placed at the centre of the fields. Faisal et al. [5] explained Zonal-Stable Election Protocol (ZSEP) for Wireless Sensor Networks which is a modified form of Stable Election Protocol (SEP). ZSEP put the network into three zones: Zone 0, Head Zone 1, and Head Zone 2. The nodes with lesser energy are deployed in Zone 0 near the Base Station.

These nodes adopt ~~single~~ single-hop communication method while the advanced nodes closer to the boundaries relay their data through cluster heads (CHs). The results showed that ZSEP performs better than SEP in prolonging the lifetime of the network. Another version of SEP has been described by [6]. M-SEP (Modified Stable Election Protocol) elect cluster heads in two, three and up to ninth level hierarchical wireless sensor networks. The protocol improved SEP schemes significantly in terms of network lifetime, energy consumption and data transmission to BS. However, failed to consider distance in selecting the heads.

~~Author~~ The author in [7] presented an improved version of SEP protocol. The protocol, I-SEP (Improved Stable Election Protocol), has two main features: reactive routing and also uses three levels of heterogeneity. In order to reduce the energy depletion due to data transmission, the scheme introduced a specific threshold. The data communication begins when this threshold is reached. The outcome of the simulation revealed that~~,~~ the ISEP prolongs the stability period and network lifetime compared to the SEP, LEACH (Low Energy Adaptive Clustering Hierarchy) and ZSEP. Divya et al. [8] explained a modified form of SEP for heterogeneous wireless sensor networks. EE-SEP (Energy Efficient Stable Election Protocol) introduced a new threshold value which tends to decrease the number of cluster heads during its operation.

As the number of CHs are reduced, there is a corresponding increase in the number of alive nodes. The existence of more alive nodes in the network increases the stability period and network lifetime. Simulation results show that EE-SEP algorithm performs better compared to SEP. From the literature review, each of the routing protocols placed the Base station at the centre. So when it comes to applications such as wild~~-~~life monitoring where we need the Base station to be far away from the deployment area, then these protocols cannot be applied. This is the challenge this study seeks to address. The remainder of this research is organized as follows: **Section 2,** explained the methodology used, simulation results and analysis are discussed in S**ection 3** and the conclusion is then drawn in **Section 4.**

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

In this section, both the existing and the proposed protocols are explained

2.1 The Existing SEP Protocol

The SEP (Stable election protocol) is a heterogeneous routing protocol ~~which~~ that has enhanced the performance of popular homogeneous LEACH protocol [9]. The protocol is made up of two types of nodes: the normal nodes (nodes with the lowest energy) and the advanced nodes (nodes with the highest energy) with the BS at the centre of the network. The selection of the cluster head in this scheme is based on the energy remaining of the nodes and this gives the advanced nodes a better chance of being selected as cluster heads in the network. The election probability of nodes becoming cluster heads in normal nodes is given by e~~E~~quation (1) and that of the advanced nodes is given by e~~E~~quation (2).

If we choose P_{nrm} and P_{adv} for probabilities of becoming normal and advanced nodes respectively then we have:

$$\boldsymbol{P_{nrm}} = \left(\frac{P_{opt}}{(1+am)}\right) \quad \textbf{(1)}$$

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$$\boldsymbol{P_{adv}} = \left(\frac{P_{opt}(1+a)}{(1+am)}\right) \quad (2)$$

Where $\boldsymbol{m}$, is the percentage of sensor nodes equipped with $\boldsymbol{a}$ times more energy resources than the normal sensor nodes in the network and $\boldsymbol{P_{opt}}$ is the probability by which each node can become a cluster head. Their respective~~ly~~ thresholds, $T(n_{nrm})$, and $T(n_{adv})$ are given in e~~E~~quations (3) and (4)

$$T(n_{nrm}) = \begin{cases} \frac{P_{nrm}}{1-P_{nrm}(r \bmod (\frac{1}{P_{nrm}}))} & if\ n_{nrm} \in G \\ 0, & otherwise \end{cases} \quad (3)$$

where G is the set of normal nodes that ~~has~~ have not become cluster head in the past $\frac{1}{P_{nrm}}$ rounds of epoch.

$$T(n_{adv}) = \begin{cases} \frac{P_{adv}}{1-P_{adv}(r \bmod (\frac{1}{P_{adv}}))} & if\ n_{adv} \in G^1 \\ 0, & otherwise \end{cases} \quad (4)$$

where G^1 is the set of advanced nodes that ~~has~~ have not become cluster head in the past $\frac{1}{P_{adv}}$ round of epoch.

Therefore, the normal sensor nodes capture data and transmit it to the cluster heads which will then forward it to the BS. The sensor nodes such as TelosB, MicaZ, Mica2, etc which are used by some of the routing protocols, have short transmission ranges [10]. Therefore, placing the BS at the centre of the deployment field will surely reduce ~~the~~ energy consumption during communication. This, however, limits the application of SEP in areas where the BS must be located far from the sensing fields.

2.2 Proposed Protocol

In this section, the proposed scheme, G-SEP (Gateway Stable Election Protocol) which operates similarly to the SEP (Smaragdakis et al., 2004) is explained. The proposed protocol modified the election probability of advanced nodes by introducing a ratio of distance to the average distance of the advanced nodes from the BS. The modification allows the advanced nodes with higher residual energy at the same time closer to the BS to have a better chance of becoming the cluster head. This will reduce the energy depletion of the head since energy will not be wasted as a result of the distance between the head and the BS. Furthermore, in order to relocate the BS away from the centre, a new node called gateway node has been introduced at the centre of the sensing field to cover the gap between the cluster heads (CHs) and the BS. This node is rechargeable and has energy better than the advanced and normal nodes. So, the cluster heads receive the measured quantity from the normal nodes and then transmit it to the gateway node. The gateway node then ~~aggregate~~aggregates the data and then finally sends the report to the BS. So the new protocol adopts a multi-hop communication approach to get data to the BS. The model is shown in Figure 1 below

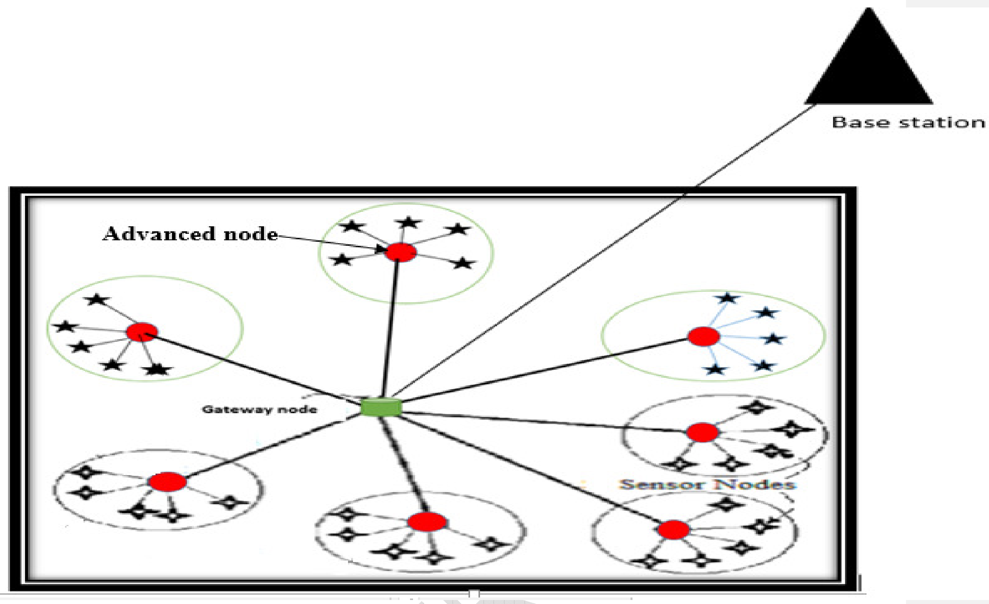

Fig. 1: G-SEP model

The election probability of the advanced nodes to become cluster heads is given by Equation (5)

$$\boldsymbol{P_{adv}} = \left(\frac{\boldsymbol{P_{opt}(1+a)}}{\boldsymbol{(1+am}}\right) * \frac{E_i}{E_0} * \frac{D_i}{AVD} \tag{5}$$

Where, E_i is the residual energy of the node, E_0 the initial energy of the node, D_i the distance of each advanced nodes and AVD, the average distance of the advanced nodes to the BS. Each non-cluster head dissipated energy in transmitting k bits data to CH and is given by Equation (6).

$$E_{non-CHg} = E_{TX}(k, d_{to\ CH}) \tag{6}$$

Where E_{TX}, is the energy consumed by the nodes in transmitting data and $d_{to\ CH}$ is the distance from the normal nodes to the CH.

The total energy dissipated by each cluster head is given by Equation (7)

$$E_{CHg} = \left(\frac{n}{c} - kE_{elect}1\right) + E_{TX}(k, d_{to\ GW}) \tag{7}$$

where $d_{to\ GW}$ is the distance from the CH to the gateway node.

The energy dissipated by the gateway node in transmitting aggregated k bits of data to the BS is given by Equation (8)

$$E_{GWN} = kE_{elect}\left(\frac{n}{c}\right) + k\left(\frac{n}{c}\right)E_{DA} + E_{TX}\left(k, d_{to\ BS}\right) \quad (8)$$

where $d_{to\ BS}$ is the distance from the gateway node to the BS.

The energy dissipated in a cluster per round is given by Equation (9).

$$E_{cluster} \approx \left(\frac{n}{c} - 1\right)E_{non-CHg} + E_{CHg} \quad (9)$$

The total energy consumed by the network is given by Equations (10) and (11)

$$E_{total} = c\,E_{cluster} + E_{GWN} \quad (10)$$

$$E_{total} = c(\left(\frac{n}{c} - 1\right)E_{non-CHg} + kE_{elect}\left(\frac{n}{c} - 1\right) + E_{TX}\left(k, d_{to\ GWN}\right)) + kE_{elect}\left(\frac{n}{c}\right) + k\left(\frac{n}{c}\right)E_{DA} + E_{TX}\left(k, d_{to\ BS}\right) \quad (11)$$

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3. RESULTS AND DISCUSSION

In this section, ZSEP scheme and proposed routing protocol, G-SEP are simulated in the MatLab 2017a environment. This is to evaluate the performance of the routing protocols when the BS is placed far from the sensing field. For simulation, a network consisting of 100 nodes randomly deployed in a field of dimension 100m x 100m and a BS located at (50m, 300m) away from the field. There are 20% advanced nodes ~~which~~ that are equipped with more energy than the normal nodes (m = 0.2 and $\alpha = 1$). All nodes are stationary after deployment. Table 1 defines the simulation parameters used in this research work.

Table I: Simulation Parameters

S/N	Parameter	Values
1	E_{elect}	50nJ/bit
2	E_{fs}	10pJ/bit/m^2
3	E_{mp}	0.0013pJ/bit/m^2
4	E_0	0.5J

5	Message size, l	4000
6	n	100
7	p_{opt}	0.1
	E_{DA}	5nJ/bit/message

Network performance parameters taken for analyses were as follows:

i. Network Lifetime
ii. Stability Period
iii. Packets to BS
iv. Residual energy

Figure 2 shows the number of alive nodes per round during the simulation process for both ZSEP and G-SEP routing protocols. It can be seen from the graph that, the lifetime of the network has been prolonged significantly in G-SEP compared to SEP. The nodes in ZSEP stay alive for a short period, less than 100 rounds and died out but continued to be alive up to 3500 rounds in G-SEP before vanishing. This indicates that~~,~~ nodes stay~~s~~ alive for a longer time in G-SEP and therefore, ~~has~~ have a better lifetime than ZSEP routing scheme. This outcome is ~~as~~ a result of the multi-hop communication approach implemented in the new protocol. The gateway receives the captured data from the cluster heads, and relay the final information to the BS. This conserved energy in the network and hence more alive nodes.

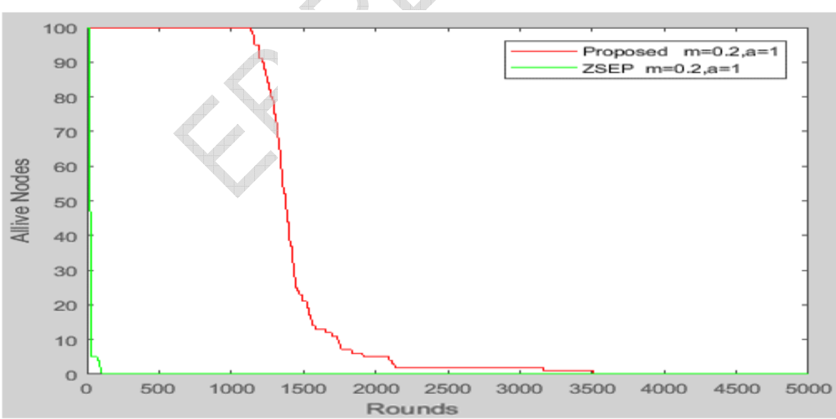

Fig. 2: Number of the Alive Nodes Per Round

Figure 3 displays the number of dead nodes per round for the G-SEP protocol and the existing scheme. It was again noticed from the graph that, the amount of death nodes in G-SEP is really very small compared to that of ZSEP as seen in Figure 3. Just at 100 rounds, all the nodes in ZSEP had disappeared compared with G-SEP, where all the nodes were dead at 3500 rounds. For the stability of the network, the proposed scheme has proven to be far better than the existing algorithm. The first node in the ZSEP died less than 50 rounds and that of the new scheme, at 1100 rounds. This indicates that the proposed scheme has efficiently cut-rate the number of dead nodes resulting in~~to~~ a better network lifetime and stability period as we have observed.

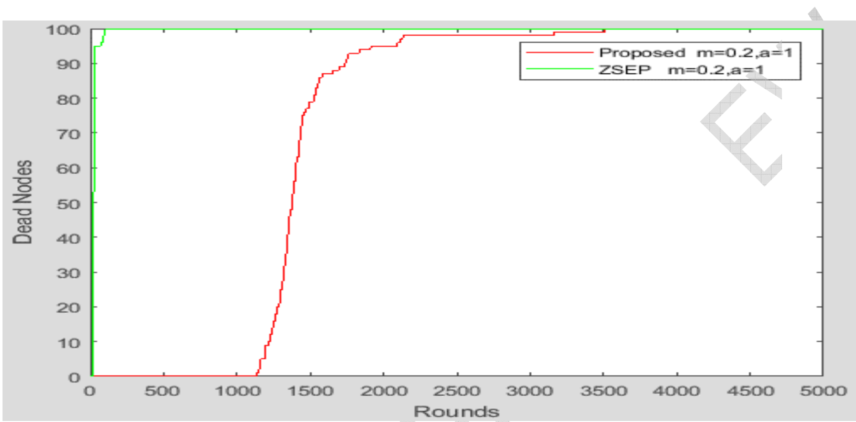

Fig. 3: Number of the Dead Nodes Per Round

Figure 4 also shows the quantity of data relayed to the BS per round in both G-SEP and the ZSEP protocols. It was noticed that~~,~~ the amount of data conveyed to the BS by ZSEP algorithm increases from 0 to approximately 2250 at the 5000 rounds. Thus forwarding a small amount of data to the BS. In the new algorithm, a huge amount of data was observed being sent to the BS which is more than 14000. This performance is a~~s~~ result of the large amount of energy that has been conserved by the nodes in the network. Firstly, data aggregation. In ZSEP, the cluster heads aggregate the received data and then transmit to the BS which consumes their energy. However, in the new protocol, the gateway node does the data aggregation in place of CHs and then transmit the final report to the BS. So G-SEP conserved energy of the heads and hence their ability to transmit more. Secondly, G-SEP adopts a multi-hop communication strategy ~~which~~ that is absent in the existing protocol.

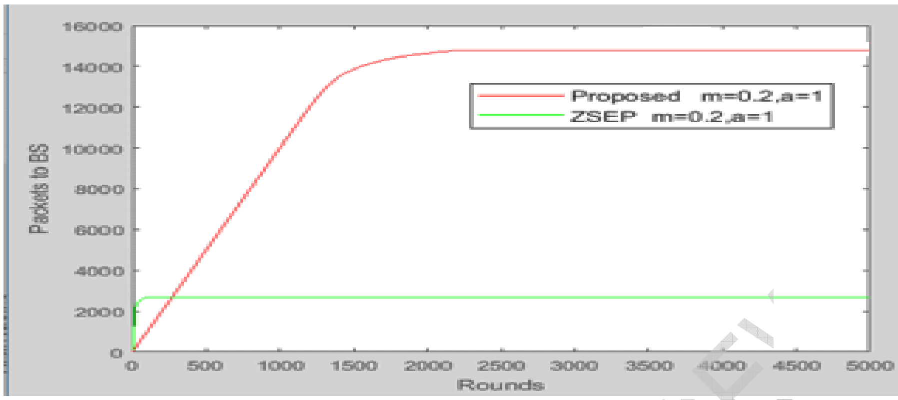

Fig. 4: Number of Packet to the Base Station Per Rounds

Figure 5 shows the residual energy of the network in the proposed and the existing protocols. It is also clear that~~,~~ the new algorithm utilizes its energy efficiently throughout the simulation period than the existing protocol. In the existing scheme, as early as 100 rounds, no more energy is available to support the nodes. This result is expected since ZSEP was not developed for the distant Base station. However, the proposed algorithm~~ on the other hand~~, on the other hand, shows relatively low energy consumption because of the presence of the gateway. It manages the energy consumption of G-SEP until 1500 rounds. This again proved that~~,~~ the energy remaining per round in the proposed model is better than the ZSEP protocols.

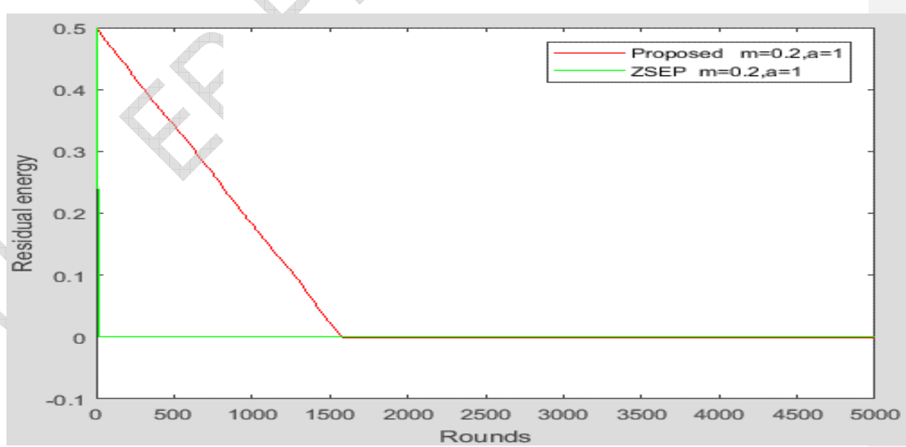

Fig. 5: Remaining Energy Per Round

4. CONCLUSION

In this work, Gateway-SEP (G-SEP) protocol for heterogeneous networks has been proposed. In this new protocol, the election probability of the advanced nodes has been modified to consider the distance, average distance, and residual energy. This has reduced the energy depletion of the heads. Also, the gateway node was introduced at the centre of the network and then placed the Base station outside the deployment area. The gateway node ~~collect~~collects the captured data from the cluster heads, aggregates it and conveys the final report to the distant Base station. The data aggregation by the gateway node also resulting in a reduction of energy consumption in the network. Finally, the multi-hop communication approach adopted in this scheme has also conserved the energy of the network. The simulation results showed that~~,~~ the proposed protocol performed better than the ZSEP in terms of coverage, stability period, throughput and network life~~-~~time.

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