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An Efficient Routing Protocol for Wireless Sensor Network

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Abstract

Thousands of energy-constrained sensor nodes work together in Wireless Sensor Networks (WSNs) to complete a sensing task. Several routing protocols have been developed for use in WSNs. For heterogeneous WSNs, we suggested the Zonal-Stable Election Protocol (Z-SEP), a hybrid routing protocol. With this protocol, some nodes transmit data to the base station directly, while others use the clustering approach used in SEP. LEACH is a hierarchical clustering algorithm for the network's efficient use of energy. The local cluster head is rotated randomly via LEACH. LEACH operates effectively in uniform environments. Every node in LEACH has the same chance of becoming a cluster head. Normal nodes and advanced nodes are the two categories of nodes introduced by the two-level heterogeneous protocol known as SEP.

Keywords—Wireless Sensor Networks, LEACH, SEP, Z-SEP

I. INTRODUCTION

To monitor physical or environmental factors such as temperature, sound, vibration, pressure, motion, or pollution at various locations, WSNs are made up of a large number of sensor nodes that are randomly placed. Because of their low cost and wide range of uses, such as in the military, home, and healthcare, WSNs have developed thanks to advances in wireless communications, electronics, and technology. There is research being done to address various technical problems in numerous application areas. Sensor nodes are made up of parts that can sense data, process data, and use communication to send or receive more data. Such networks' protocols and algorithms must be able to self-organize to guarantee accurate and effective operation. Depending entirely on the application, numerous forms of communication take place in WSNs.

There are three primary forms of communication:

- Clock-driven: Sensors sense and collect data continuously and sporadically.
- Event-Driven: When a certain event occurs, communication is prompted.
- Query Driven: When a question is made, communication follows.

To increase the sensing time and total lifetime of the network, efficient energy use is a consideration while researching, constructing, or deploying such networks in all three modes of communication. It has been established that hierarchical routing protocols are more energy efficient. There are numerous protocols created for homogenous networks. One of the earliest clustered based routing protocols for homogeneous networks is LEACH. LEACH gives each node the same chance of becoming the cluster head. LEACH, however, struggles in varied environments. The longer lifespan of WSNs has also been demonstrated by the heterogeneity of nodes in their energy level. SEP 2 was proposed to increase the effectiveness of WSNs. A two-level heterogeneous protocol is SEP. Based on the nodes' energy level, SEP assigns various probabilities (to become cluster heads) for those nodes. SEP, however, does not effectively utilize the greater energy of higher level nodes.

We need as little energy dissipation as possible when sending messages from nodes to the base station. Better routing protocols are required for this reason, and they must effectively use energy.

A. Associated work and inspiration:

LEACH is a hierarchical clustering algorithm for the network's efficient use of energy. The local cluster head is rotated randomly via LEACH. LEACH operates effectively in uniform environments. Every node in LEACH has the same chance of becoming a cluster head. LEACH, however, does not work well in heterogeneous environments. SEP is a two-level heterogeneous protocol that introduces normal and advanced nodes as two different sorts of nodes. Compared to regular nodes, advanced nodes have greater energy. In SEP, there is a weighted likelihood that both nodes—normal and advanced nodes—will become cluster heads. Compared to standard nodes, advanced nodes have a greater likelihood of becoming cluster heads. SEP does not ensure effective node deployment. For three-level hierarchies, the Improved Stable Election Protocol (ESEP) was proposed. An intermediate node with energy somewhere between a normal and an advanced node was introduced by ESEP. Based on their energy level, nodes choose themselves to be the cluster head. Similar to SEP, ESEP has a downside. Multilevel heterogeneity is demonstrated by Distributed Energy-Efficient Clustering Protocol (DEEC). In DEEC, the average energy of the network and the node's residual energy are used to produce the cluster head. High-energy nodes have a greater likelihood than low-energy nodes of becoming cluster heads in DEEC. Reactive protocol TEEN is used in situations when time is of the essence. A homogenous network was suggested for Adolescents. The criteria for choosing the cluster head are the same in TEEN as they are in LEACH. TEEN adds hard and soft thresholds to reduce the number of transmissions and conserve energy on nodes. The network's lifespan and stability time are increased in this way.

Normal and advanced nodes are randomly placed in SEP. The majority of typical nodes need more energy to transmit data when deployed distant from the base station, which reduces throughput and shortens the stability period. SEP's effectiveness consequently declines. We divided the network field into areas to fix these issues. Corners use the most energy to transfer data to the base station because they are the farthest away regions in the field. Normal nodes are thus positioned close to the base station and transmit data to the base station directly. However, because they use more energy, advance nodes are typically located far from the base station. Advanced nodes utilize more energy when transmitting data straight to the base station, hence clustering is only used for advanced nodes to conserve energy.

B. Organization of paper:

The remainder of the essay is structured as follows: Literature reviews are included in Section 2. The suggested Z-SEP protocol framework is described in Section 3. The simulation result is presented in Section 4. Section 5 contains the outcome. The conclusion appears in Section 6.

II. LITERATURE REVIEW

Sensor nodes' primary function is to detect the surrounding area and gather data from the scene, process it, and send it to the Base Station. If the message can be sent straight from the sensor node to the base station, the sensor nodes would need to create a lot of power to send the data, which would soon deplete their resources. To save energy, data is sent in this manner with several hops from one node to another and finally to the Base Station. Energy efficiency is one of the most significant issues in WSN. As a result, an intriguing piece of study in this area is the energy-efficient routing protocol. These methods are designed to reduce energy usage. Low Energy Adaptive Cluster Hierarchy is a clustering approach that Heinzelman et al. [8] presented for a homogeneous network (LEACH). LEACH is a cluster based routing technology that uses a random

Cluster Head rotation to distribute the network's sensor nodes' energy loads equally. There are two stages to the LEACH procedure.

(1) The setup phase; (2) the steady-state period. Clusters are created and Cluster Heads are chosen during the setup process. A predefined node "p" identifies itself as Cluster Head as follows: Node chooses a random number "r" between 0 and 1. The random number becomes Cluster Head for the current round if it is less than the threshold value, T(n). The value is determined using the following equation, which represents a proportion of nodes that will become cluster Heads, existing rounds, and nodes that were not picked as Cluster Heads in the previous (1/P) rounds. If n G, then

$$T(n) = \frac{P}{1 - P(r * mod(1/p))} \quad if\ n \in G \qquad (1)$$

Where G stands for a group of nodes involved in the Cluster Head election.

Every node has a probability of "P" to become a Cluster Head in round 0 (r = 0). Nodes chosen for Cluster Heads in the current round (round 0) are ineligible for Cluster Head selection in the ensuing 1/P rounds. As a result, fewer nodes qualify to be cluster heads, increasing the likelihood that a node may still become a cluster head. The remaining nodes receive a broadcast message from each newly chosen Cluster Head. Following receipt of the message, all non- Cluster Head nodes make their cluster selection based on the strength of the advertisement message they are receiving. The Cluster Head node creates a Time Division Multiple Access (TDMA) schedules after receiving messages from nodes and assigns a time slot for each node to transfer data. Every node in the cluster receives a broadcast of this TDMA schedule. The steady-state phase is when the actual data is sent to Base Station. Compared to the setup phase, this step takes more time to complete. Nodes collect data during this phase and send it to the Cluster Heads. All of the data from the member nodes are collected by the Cluster Head node, which then sends it to the Base Station. After a specified amount of time, the network returns to the setup phase and enters a new round of Cluster Head selection. LEACH, however, struggles to function in a varied setting. For the heterogeneous network, the Distributed Energy-Efficient Clustering (DEEC) protocol is created. DEEC makes use of the node's initial and residual energy levels. A cluster-based routing protocol system called DEEC is designed for two- and multi-level heterogeneous WSNs. Nodes are categorized as (1) Advanced nodes and (2) Normal nodes. Advance nodes are more energetic than standard nodes. The initial and remaining energy of each node forms the foundation for Cluster Head selection. Compared to low-energy nodes, nodes with high initial and residual energy have a higher likelihood of becoming Cluster Heads. Let Ni be the total number of rounds used in Cluster Head to choose the nodes Si. The ideal number of Cluster Heads for each round is indicated by Popt N. Nodes with higher energy levels are more likely to become Cluster Heads than sensor nodes with lower energy levels. The Cluster Heads value is therefore Popt N for each round. High energy node Pi has a bigger value than Popt because every node Si has the probability Pi of becoming Cluster Head. The network's average energy at round r can be expressed as E' (r).

$$E'(r) = \frac{1}{N}\sum_{i=1}^{N} Ei(r) \qquad (2)$$

In DEEC, Cluster Head selection probability is

$$P_i = P_{opt}[1 - \frac{E'(r) - Ei(r)}{E'(r)}] = P_{opt}\frac{Ei(r)}{E'(r)} \qquad (3)$$

The total amount of Cluster Head in each round is

$$\sum_{i=1}^{N} P_i = \sum_{i=1}^{N} P_{opt}\frac{Ei(r)}{E'(r)} = P_{opt}\sum_{i=1}^{N}\frac{Ei(r)}{E'(r)} = NP_{opt} \qquad (4)$$

node will become a Cluster Head in a round, and G stands for a group of nodes that are suitable for the position for round

r. Each node chooses a random number between 0 and 1 for each round. That node is chosen as a Cluster Head for that round if the selected number is smaller than the threshold value, otherwise not.

threshold value, otherwise not.

$$T(si) = \begin{cases} \dfrac{P_t}{1 - P_t(r * mod \frac{1}{P_t})} & if\ si \in G \\ 0 & otherwise \end{cases} \qquad (5)$$

The value of Popt changes in a heterogeneous network because each node has a different initial energy, but in a homogeneous network, all nodes have the same initial energy and utilize Popt as their energy. You can calculate Popt's value by

$$P_{nrm} = \frac{P_{opt}(1+\alpha)}{(1+\alpha m)}, \quad P_{adv} = \frac{P_{opt}}{(1+\alpha m)} \qquad (6)$$

Equation 6 above was substituted for Popt in equation 3 and can be written as

$$Pi = \begin{cases} \dfrac{P_{opt}Ei(r)}{(1+\alpha m)E'(r)} & if\ si\ is\ the\ normal\ nodes \\ \dfrac{P_{opt}(1+\alpha)Ei(r)}{(1+\alpha m)E'(r)} & si\ is\ the\ advanced\ nodes \end{cases} \qquad (7)$$

The multi-level heterogeneous network was included in equation 7 as

$$P_{multi} = \frac{P_{opt}N(1+\alpha i)}{(N + \sum_{i=1}^{N} \alpha i)} \qquad (8)$$

Equation 3 can be used in place of equation 8 above to obtain pi, as shown below

$$Pi = \frac{P_{opt}N(1+\alpha i)Ei(r)}{(N + \sum_{i=1}^{N} \alpha i)E'(r)} \qquad (9)$$

To train the images we require pre-trained weights. By using both the configuration file and pre-trained weights we perform training of images. After training, we obtain the trained weights, which we are used further to perform testing of images. The testing results are shown below.

$$E'(r) = \frac{1}{N} Etotal(1 - \frac{r}{R}) \qquad (10)$$

R stands for the entire network lifetime and is determined using

$$R = \frac{Etotal}{Eround} \qquad (11)$$

The network's overall energy is denoted by Etotal, while each round's energy usage is denoted by Eround. The Stable Election Protocol (SEP) is a cluster-based routing technology that uses two degrees of heterogeneity, namely advanced nodes and normal nodes. When the first node expires, the sensor network becomes extremely unstable. SEP supports well-balanced energy consumption to lengthen the lifespan of stable zones. As a result, compared to standard nodes, advanced nodes have a higher likelihood of becoming Cluster Heads, which increases network longevity and efficiently balances energy usage. SEP is a routing system that is aware of heterogeneity and chooses the CHs based on the weighted election probability of each node according to its remaining energy. Advance nodes in SEP have a higher possibility of becoming a CH than regular nodes. Assume that E0 is the normal node's initial energy and E0 (1+) is the advanced node's beginning energy. Where α means that the node has higher energy than usual. The new network has a total energy of n.(1m). E0+n.m. E0(1+α) = n.E0.(1+α.m). The system now has an increased energy of 1 + m times. Because the system has α.m times more nodes and.m times more energy, a new epoch is equal to 1/Popt(1 +α.m) to lengthen the stability period. Popt starts as Cluster Head probability. Every round of every epoch, n * Popt must become Cluster Heads on average. Nominees for Cluster Head in the current round are ineligible to be chosen for the same epoch. To become a Cluster Head, each node generates a random number between 0 and 1. A generated number has a chance of becoming Cluster Head for the current round if it is less than a specified threshold, T(s). The threshold value grows as the number of rounds increases and equals 1 in the last round, meaning that the remaining nodes become Cluster Head with a probability of 1 in the final round. Using a formula, the Cluster Head can be chosen by dividing the best probability of each node by its energy.

$$P_{nrm} = \frac{P_{opt}}{1+\alpha m} \qquad (12)$$

$$P_{adv} = \frac{P_{opt}}{1+\alpha m} * (1+\alpha) \qquad (13)$$

the weighted election probabilities for normal and advanced nodes, respectively, are Pnrm and Padv. The likelihood of Padv becoming a CH is higher than that of Pnrm, where m denotes the proportion of advanced nodes and denotes the additional energy factor between normal and advanced nodes. Each node generates a random number between 0 and 1, as was mentioned earlier. This node becomes CH if the number is smaller than the specified T(s). The following formulas can be used to determine the threshold value for all sorts of nodes:

$$T_{nrm} = \begin{cases} \dfrac{P_{nrm}}{1 - P_{nrm}[r * mod \frac{1}{P_{nrm}}]} & if\ nnrm \in G' \\ 0 & otherwise \end{cases} \qquad (14)$$

G stands for nodes that do not become Cluster Heads in the current round. The chance of a normal node becoming a cluster head is given by Pnrm, and the threshold is given by Tnr.

$$T_{adv} = \begin{cases} \dfrac{P_{adv}}{1 - P_{adv}[r * mod \frac{1}{P_{adv}}]} & if\ nadv \in G' \\ 0 & otherwise \end{cases} \qquad (15)$$

G' is used to indicate nodes that do not become Cluster Heads in the current round. The threshold for normal nodes to become Cluster Head is Tadv, and Padv is the advanced node probability to become Cluster Head. This lengthens the time of stability before the first node's demise. Because SEP uses extra energy from the advance node equally and lengthens the sensor network's stabilization period, it performs better than LEACH. SEP does not ensure that nodes are distributed in an orderly manner.

Zonal-Stable Election Protocol (Z-SEP), a hybrid routing protocol, has been developed for heterogeneous WSNs. The sensor network's field is segmented into zones in Z-SEP, and communication is implemented using a hybrid technique, meaning that standard nodes communicate data to the base station directly while advanced nodes use a clustering procedure. The network field is split into three zones in Z-SEP: Zone 0, Zone 1, and Zone 2. Zone 0 hosts normal nodes, Zone 1 hosts half of the advanced nodes, and Zone 2 hosts the remaining advanced nodes. Nodes in zone 0 exchange data with the base station directly as they feel it. Data is sent to the base station by Zone 1 and Zone 2 nodes using a clustering method. Let (m) be a portion of all nodes (n), also known as advance nodes, which have (α) time more. Nodes in nature are (1-m)n. Assume that the cluster's optimal numbers are (Kopt) and that its advance nodes are (n). Cluster Head probability is Popt = Kopt according to SEP.

$$P_{opt} = \frac{K_{opt}}{n} \qquad (16)$$

The equation for the Z-SEP threshold is the same as LEACH for Cluster Head selection, and it is

$$T_n = \begin{cases} \dfrac{P_{opt}}{1 - P_{opt[r*mod\frac{1}{P_{opt}}]}} & if\ n \epsilon G \\ 0 & otherwise \end{cases} \qquad (17)$$

G stands for a collection of nodes that have been assigned the Cluster Head title throughout the previous 1/Popt rounds. The likelihood of advanced nodes turning into Cluster Heads is

$$P_{adv} = \frac{P_{opt}}{1 + \alpha m} * (1 + \alpha) \qquad (18)$$

For advanced nodes, the threshold is T(n).

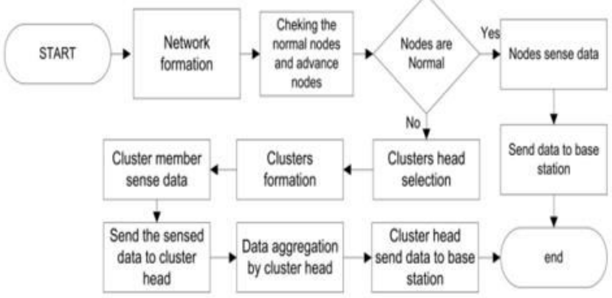


Fig 1: Flow chart of z-sep

III. PROPOSED FRAMEWORK

A. NETWORK ARCHITECTURE:

The majority of routing protocols install nodes in the network field at random, inefficiently using their energy. We changed this theme such that the network field is divided into three zones based on energy levels and the Y coordinate of the network field: zone 0, Head zone 1, and Head zone 2. We suppose that some of the total numbers of nodes have access to more energy. Let m represent the portion of the total number of nodes n that has time more energy than the other nodes. These nodes are referred to as advanced nodes, while (1-m)n are normal nodes.

Zone 0: Ordinary nodes are randomly placed between the coordinates 20 and 80 in Zone 0.

Head zone 1: Half of the advance nodes are randomly placed in this zone, which is located between 0 and 20.

Head zone 2: Half of the advance nodes are randomly distributed in Head Zone 2, which is located between 80 and 100 Y.

This kind of deployment is possible since advanced nodes have more energy than standard nodes. We planted high-energy nodes (advance nodes) in Head zone 1 and Head zone 2 since corners are the farthest places in the field, thus if a node is at a corner, it requires more energy to connect with a base station.

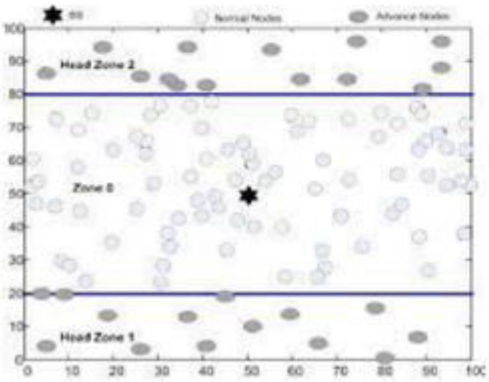


Fig 2: Network Architecture

B. OPERATION OF Z-SEP:

To send data to the base station, Z-SEP employs two methods.

- Direct communication is a technique.
- Cluster head transmission.

Direct Communication:

Nodes in Zone 0 communicate with the base station directly. Typical nodes perceive their surroundings, collect pertinent data, and communicate it immediately to the base station.

Cluster head transmission:

Data is transmitted to the base station by nodes in Head zones 1 and 2 using the clustering technique. Nodes in Head zones 1 and 2 are chosen to form the cluster head. Data from member nodes is collected by the cluster head, which then aggregates and sends it to the base station. The selection of the cluster head is crucial. Advanced nodes are randomly placed in Head zones 1 and 2, as depicted in Fig. 1. Only advanced nodes can create clusters. Assuming the ideal amount of clusters The number of advance nodes is n and Kopt. The best cluster head probability, according to SEP, is

$$Popt = \frac{Kopt}{n} \qquad (1)$$

Each node chooses whether or not to act as the cluster head in the current round. For each node, a number at random between 0 and 1 is created. The node is chosen as the cluster head if this random number is less than or equal to the threshold T(n) for the node. The threshold is provided by

$$T(n) = \begin{cases} \dfrac{Popt}{1 - Popt\left(r \times mod \dfrac{1}{Popt}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \qquad (2)$$

G is the collection of nodes that haven't served as cluster heads in the previous 1/Popt rounds. [2] proposes a probability for advanced nodes to become cluster heads, whereby

$$Padv = \frac{Popt}{1 + (\alpha.m)} \times (1 + \alpha) \qquad (3)$$

Hence, the requirement for advanced nodes is

$$T(adv) = \begin{cases} \dfrac{Padv}{1 - Padv\left(r \times mod \dfrac{1}{Padv}\right)} & if\ adv \in G' \\ 0 & otherwise \end{cases} \qquad (4)$$

that have not served as cluster heads in recent 1/Padv rounds. The cluster head broadcasts an advertisement message to the nodes after being chosen.

After receiving the message, the nodes choose which cluster head they would belong to for the round. The cluster-forming phase is known as this stage. Nodes reply to the cluster head and join the cluster head based on the strength of the received signal. Afterward, the cluster head gives each node a TDMA schedule during which they can communicate data to the cluster head. After the clusters are formed, each node collects its data and delivers it to the cluster head during the window of time that the cluster head has designated for that node. Fig. 3 illustrates this period

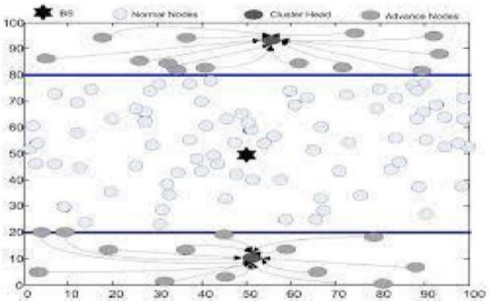


Fig 3: Nodes sending data to cluster head

The transmission phase begins when data is received from nodes, after which the cluster head combines it and sends it to the base station. This stage is represented in Fig.4.

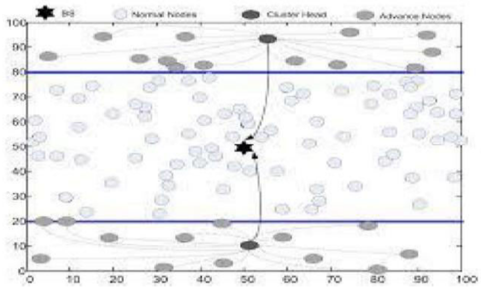


Fig 4: Cluster head sending data to base station

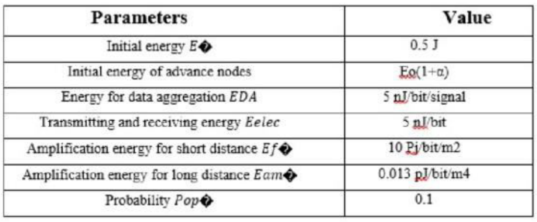
The energy of normal nodes (deployed in Zone 0) is less than that of advanced nodes, and the cluster head consumes more energy than cluster members when receiving data from cluster members. As a result, normal nodes (deployed in Zone 0) do not form clusters. Normal nodes quickly perish if we let them become cluster heads, shortening the stability time.

IV.SIMULATION RESULTS

In a field with dimensions of 100m by 100m and 100 nodes placed in different energy zones, we simulate our suggested protocol. The base station is positioned in the network field's middle. We are using the SEP-approved first-order radio model. The simulations are implemented using MATLAB. We have the following parameters, namely. Imagine that 20% of the nodes are advanced nodes and that they are distributed equally across Head Zones 1 and 2. We have 2 cluster heads per round because Popt is 0.1. In each round, there is one cluster head in Head zone 1 and one in Head zone 2.

Table 1 displays many additional simulation parameters.

Table 1: Simulation variables



Parameters	Value
Initial energy *E*�	0.5 J
Initial energy of advance nodes	Eo(1+α)
Energy for data aggregation *EDA*	5 nJ/bit/signal
Transmitting and receiving energy *Eelec*	5 nJ/bit
Amplification energy for short distance *Ef*�	10 Pj/bit/m2
Amplification energy for long distance *Eam*�	0.013 pJ/bit/m4
Probability *Pop*�	0.1

V. RESULTS

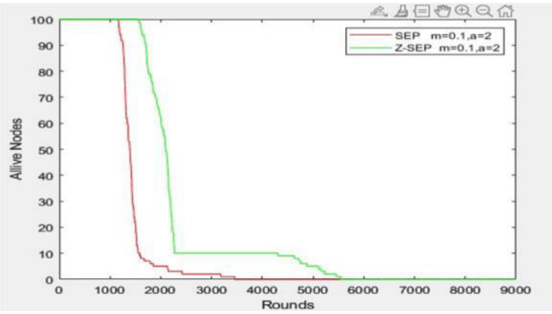


Fig.5: No of Alive Nodes

The comparison of the number of living nodes between the SEP and Z-SEP is shown in Fig. 5. In Z-SEP, more nodes are alive for a greater number of rounds than in SEP, so fewer nodes are alive for a smaller number of rounds in SEP. We can say that Z-SEP has more stability periods than the SEP protocol based on the concept of the stability period.

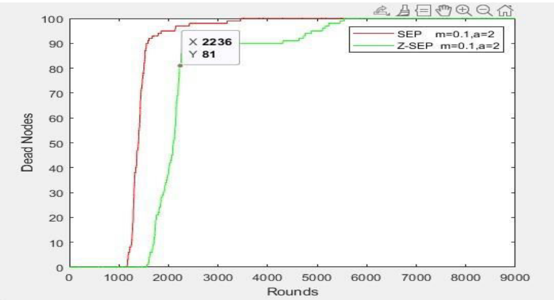


Fig.6: No of Dead Nodes

The number of dead nodes on the Y-axis and the number of rounds on the X-axis is depicted in Fig. 6. Here, we used SEP and Z-SEP to compare the number of dead nodes per round. We can see that using SEP results in more dead nodes per round for a smaller number of rounds, meaning the nodes are dying more quickly. Moreover, after more rounds of Z-SEP, there are fewer dead nodes. As a result, the Z-SEP had fewer dead nodes than the SEP Protocol.

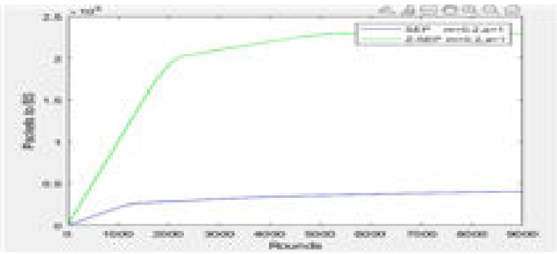


Fig.7: Packet Transmissions to the Base Station

As shown in Fig. 7, Z-SEP has a much higher throughput than SEP. When comparing the two graphs, it is evident from the one above that Z-SEP transmits more packets to the base station than SEP does. Thus, it is obvious that Z-SEP has higher throughput.

VI. CONCLUSION

In this study, we presented Z-SEP for two levels of heterogeneity in heterogeneous environments. Zone 0, Head Zone 1, and Head Zone 2 are the three zones that make up the playing field. To save energy, normal nodes are only set up in zone 0 and communicate with the base station directly. Advanced nodes use a clustering mechanism to broadcast data to the base station, with half of them deployed in Head Zone 1 and the other half in Head Zone 2. According to the results, just changing the deployment of the various types of nodes in the various zones following their energy requirements can increase the stability period by around 50%. Z-SEP has a higher throughput than LEACH and SEP.

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