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Hybrid and Multi-Hop Advanced Zonal-Stable Election Protocol for Wireless Sensor Networks

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ABSTRACT Wireless sensor network comprises of thousands of sensor nodes that are deployed in an area to monitor the physical environment. These sensor nodes have limited energy as they are battery powered. To reduce this problem, several routing protocols are designed in order to minimize energy consumption and increase the lifetime of the sensor network. In this paper, we introduced a new heterogeneous routing protocol known as advanced zonal stable election protocol (AZ-SEP) in which communication of sensor nodes with the base station is hybrid, i.e., some nodes communicate directly, while others use clustering mechanism to transmit data to base station. The dimensions of the field are unknown and are divided into three zones on the basis of nodes energy. We examined Z-SEP protocol regarding cluster head selection and communication of cluster head with the base station and introduced a new mechanism of cluster head selection on the basis of residual energy and distance from the base station. The communication between nodes with the base station occurs in a multi-hop fashion. Furthermore, the AZ-SEP is evaluated by taking different evaluation scenarios such as the changing position of the base station, skewed nodes, and variable node energy to compare it with the parent protocol. We implemented the AZ-SEP and compare it with the traditional routing protocol like Z-SEP and SEP protocol. The proposed protocol and its parent protocol are compared through simulation using simulator MATLAB 2014a. The simulation results show that our proposed protocol increases the stability period by increasing the number of alive nodes, packet delivery ratio, and optimizes average energy consumption as related to the existing protocols.

INDEX TERMS Hybrid cluster head selection, LEACH protocol, node residual energy, SEP, wireless sensor networks, Z-SEP protocol.

I. INTRODUCTION

In recent years, WSN has increased worldwide attention because of the rapid growth of Micro-Electro-Mechanical System (MEMS) technology [1]. With the help of WSN technology [2], it becomes easier to develop cost-effective sensors [3]. These sensors are small in size, low-cost and have restricted processing resources. They have limited computation and processing capability and are cheap as related to old-style sensors. Along with this, they have the capability to sense the environment, gather information from the field, process gathered information and transmit data to the user [4]. Although smart sensor nodes have limited processing, when they are combined with other nodes, they sense the physical environment in detail [5].

The deployment of a node in WSN is divided into two types, (1) unstructured WSN (2) structured WSN. In unstructured WSN, Sensor nodes randomly deployed in an area. But the problem with this is that nodes are large in number so network management becomes difficult such as failure detection and connectivity management. While in structured WSN, Sensor nodes are organized in a pre-defined manner [4]. In addition, nodes in an environment can be implemented in two ways (1) Controlled environment (2) Uncontrolled environment. In Control environment, each sensor node position is constantly monitored and easily accessible. While in an uncontrolled environment, the accessibility of a sensor node is not easy and the location of the sensor node is not predefined. These nodes are not monitored regularly [6]. The infrastructure of WSN constitutes of BS and several nodes spread in an area. Each node has the ability to detect an event from the environment, process it, and then send it

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to BS either ''directly'' or in ''multi-hop'' way by passing the data from one node to another in the network. For this process, hardware components and software modules of a node need to program in a helpful manner. The fundamental task of the sensor is to monitor the area, gather data from it, process it and send it to BS. If the message can be sent directly to BS, Sensor nodes need high power to transmit data to BS, thus, in this way their resources could be quickly exhausted. In this manner, data is transmitted from one node to another and to the BS with multiple hops in order to reduce energy consumption [7]. In WSN, energy efficiency is known as the most important problem. Therefore, emerging an energy efficient routing protocol is an interesting research work in this field. the aim of these protocols is to lower energy consumption. Many protocols like LEACH [8], V-LEACH [9], SEP [10], HEED [11] are designed to enhance the performance of a network. Hierarchical protocols are used to cluster the sensor nodes resulting in data aggregation are done on CHs to save energy. Specifically, in energy consumption, hierarchical routing protocols give extensive savings for WSN. In hierarchical base routing protocol, clusters are formed having a head node (CH) which allocated to each cluster. The CH has responsibilities like a collection of data from member node, aggregation of data and sending that data to the BS [12]. A cluster-based routing protocol is used to minimize network traffic to the BS [13]. Cluster-based sensor networks are divided into two categories: (1) homogeneous sensor networks (2) heterogeneous sensor networks. In homogeneous networks, all nodes have the same energy while heterogeneous sensor network, all nodes have a different energy from one another [14]. In homogeneous networks, all nodes have the same energy. While heterogeneous sensor network, all nodes have a different energy from one another. In a homogenous network, CHs are static, once CH is selected then these CHs can work for the lifetime period of the network. However, CH performs data aggregation, transmit data to the long-range remote BS resulting in overloaded. In this manner, CH expires first then other nodes resulting instability in the sensor network [15]. In node heterogeneity, the performance of the network becomes unstable when the first node dies. For this purpose, different routing protocols have been introduced which increase stability period and increase the lifetime of the sensor network.

A. MOTIVATION AND ISSUES IN THE EXISTING SYSTEM

Z-SEP is heterogeneous wireless sensor routing protocol in which the nodes have a different energy. In this protocol, the sensor node communicates with the BS in the hybrid approach i.e. Direct communication with BS and communication via CH. In Z-SEP, nodes are of two types: (1) Normal nodes and (2) Advance nodes. Normal nodes have low energy than advance nodes. However, the area of the field is restricted and divided into 3-zone (1) zone 0 (2) zone 1 (3) zone 2. Normal nodes are placed near BS and placed in zone 0. Half of the advance nodes are placed in zone 1 and a half is placed in zone 2. Normal nodes send data directly to BS while in advance nodes, CHs are formed and data is collected from member nodes in the CH, aggregate it and transmit data to BS. If the same scenario is applied to an unrestricted area, means that we change field length then communication problem arises between advance nodes and BS because nodes that are distant from BS consume a lot of energy. Thus, decrease the lifetime of network and effect the selection of CH in the advance nodes. However, there are some issues exists in Z-SEP protocol which is discussed below:

- As battery power and computation capability of the nodes are limited, so, direct communication with BS uses a lot of energy. According to Z-SEP, CHs are formed in advance nodes which collect data from member nodes, aggregate it and transmit data to BS which consumes more energy and will die quickly causing instability in the sensor network. Thus, decreases the sensor network lifetime.
- Z-SEP is a heterogeneous routing protocol and CH is chosen randomly in advance nodes. Therefore, there is a chance that low energy advance node is selected randomly as CH which drains out quickly produces instability in the sensor network. The instability occurs when the first nodes die, the cluster is imbalanced and when a large number of nodes dies, there is a possibility of having no CH for that cluster.
- In Z-SEP, normal nodes and CHs in advance nodes communicate directly with BS. If the dimension of field is increased, CHs consume greater energy to send data to BS and will die rapidly because the distance is directly proportional to the energy consumption. This causes instability in the sensor network.

B. LIST OF MAJOR CONTRIBUTIONS

In this paper, we assumed that the base station is not energy limited and the dimension of the field is unknown. We assumed that low energy nodes are placed near to the base station while high energy nodes are placed far away from the base station. Under this model, we proposed a new protocol known as AZ-SEP protocol. In AZ-SEP, CH of advance nodes will pass data to it neighbor CH and so on until reaches it to BS in a multi-hop fashion. This will decrease energy consumption of CH and increase the lifetime of the sensor network. Furthermore, CH in advance nodes will select on the bases of three factors: (1) Threshold value (2) Residual energy of node (3) Distance from BS. In beginning, every node picks a random number between 0 and 1 as described in LEACH. If that selected number is fewer than the threshold value, then that node is selected as a CH for the current round. After completion of the first round, the residual energy of the nodes will be checked. If the node has greater residual energy, that node will be nominated as a CH for that round. If nodes have same residual energy, CH will be selected on the bases of distance from the BS. Lesser the distance from BS, greater the chances to become a CH. This increased time interval before the death of the first node which is important for many applications where the response from network much is consistent. Also, the performance of AZ-SEP will be calculated and compared with parent protocol by taking three different evaluation scenarios like (1) Changing position of BS (2) Skewness of nodes (3) Nodes having a different energy. We showed by simulation that AZ-SEP increases stability period and lifetime of the network compared to that of existing clustering heterogeneous protocol.

C. PAPER ORGANIZATION

The rest of the paper is organized as follows: Section 2 delivers a literature review. Section 3 defines the proposed framework of AZ-SEP protocol. In Section 4, we define a solution to the problem. Section 5 presents the simulation result. Section 6 defines the comparison of AZ-SEP with other protocol. Section 7 concludes the whole research work.

II. LITERATURE REVIEW

The main role of sensor nodes is to sense the environment/area and collect data from the field, process it and send it to BS. If the message can send directly from sensor node to BS, sensor nodes need to produce high power to reach data to BS, thus in this way, their resources could be quickly exhausted. In this way, data is sent from one to another node and at last to BS with multiple hops to reduce energy consumption. In WSN, energy efficiency is a most important problem. Therefore, energy efficient routing protocol is an interesting research work in this field. The aim of these protocols is to lower energy consumption. Heinzelman *et al.* [8] presented a clustering algorithm for a homogenous network known as Low Energy Adaptive Cluster Hierarchy (LEACH). LEACH is cluster-based routing protocol that uses a randomized rotation of CHs for equal distribution of energy load among sensors nodes in the network. The process of LEACH is divided into two phases. (1) Setup phase (2) Steady-state phase. In the setup phase, clusters are prepared and CHs are selected. A predetermined node "p" designates itself as CH as follows: Node selects a random number "r" between 0 and 1. If the random number is lesser than the threshold value, T(n), then it becomes CH for the current round. The value is calculated on the bases of below equation that is a percentage to become CH, existing round, and nodes "G" that are not chosen as a CH in last (1/P) rounds. T(n) can be calculated as:

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

where G denotes a set of nodes that is associated in CH election. In round 0 (r = 0), every node has probability "P" to become a CH. Nodes that are selected for CHs in current round (round 0) cannot be selected CHs for the succeeding 1/P rounds. Thus, the probability of remaining node to become a CH increases, since a lesser number of nodes that are qualified to become cluster-heads. Each newly selected CH sends a broadcast message to remaining nodes. After receiving the message, all non-CH nodes choose cluster on the bases of the signal strength of the advertisement message to which they receive. After getting messages from nodes, the CH node generates a Time Division Multiple Access (TDMA) schedule and allocates a time slot to each node when it can send data. This TDMA schedule is broadcast to every node in the cluster. In the steady state phase, actual data is transmitted to BS. The time duration of this phase is greater as compared with the setup phase. In this phase, nodes sensing the data and passes it to the CHs. CH node receives all the data from member nodes, aggregates it and transmits it to BS. After a certain time, network moves back again to set up phase and goes into another round for choosing new CH [16].

However, LEACH does not perform well in the heterogeneous environment. Distributed Energy-Efficient Clustering (DEEC) protocol is designed for the heterogeneous network [14]. DEEC utilizes initial energy and remaining energy level of the node. DEEC is a cluster-based routing protocol scheme for two-level and multi-level heterogeneous WSN. Nodes arranged into (1) Advance nodes (2) Normal nodes. Advance nodes have greater energy than normal nodes. CH selection is built on initial energy and remaining energy of each node. Nodes having high initial and residual have a greater probability to become CHs to that of low energy nodes [17]. Let Ni denote the number of rounds for CH selection of nodes Si. Popt N denotes the optimum number of CHs in each round. Nodes that have high energy have a greater probability to become CH than sensor nodes having low energy. Thus, for each round, the CHs value is equivalent to PoptN. All node Si has probability Pi to become CH, so high energy node Pi has greater value compared to that of Popt [21]. At round r, the average energy of network can have represented as E'(r).

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

CH selection probability in DEEC is

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

During each round, the total number of CH is

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

The probability of an individual node in a round to become CH can represent through Pi. G denotes set of nodes that are appropriate to CH for round r. A random number is selected between 0 and 1 by the indidual node during each round. If the selected number is lesser than the threshold value, then that node is selected as a CH for that round else not.

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

In a homogenous network, all nodes have equal initial energy and use Popt as energy of node while in a heterogeneous network, the value of P_{opt} is changed because each node has changed initial energy. Value of Popt can be given as:

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

The above equation 6 used instead of P_{opt} in equation 3 and can be given as:

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

The equation 7 extended to the multi-level heterogeneous network as:

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

The above equation 8 can be replaced by equation 3 to get Pi as given below:

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

The average energy of network E(r) in DEEC at any round and can be calculated by means of

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

R represents total network lifetime and calculated by means of

$$R = \frac{Etotal}{Eround} \tag{11}$$

The total energy of the network can be represented as Etotal and energy consumption during each round can represent as Eround. Stable Election Protocol (SEP) is a heterogeneous routing protocol based on two levels of heterogeneity namely advance nodes and normal nodes which use a cluster-based routing technique [10]. Sensor network becomes very unstable when the first node expires. To increase the life period of stable regions, SEP maintains well balanced energy consumption. Thus, advance nodes have a greater possibility to become CH as related to that of normal nodes that prolong the network lifetime and well balance energy consumption. SEP is heterogeneous-aware routing protocol and selection of the CHs based on weighted election probability of every node on the bases of remaining energy [18]. In SEP advance nodes have greater chance to become a CH than normal nodes. Suppose E0 is the initial energy of the normal node and E0 $(1+\alpha)$ is the energy of advance node. Where α denotes higher energy than normal nodes. The total energy of the new network is $n.(1-m).E0 + n.m.E0(1+\alpha) = n.E0.(1+\alpha.m)$. The energy of the system is improved by $1+\alpha.m$ times. To enhance the stability period, a new epoch is equal to $1/P_{opt}(1+\alpha.m)$ because the system has $\alpha.m$ times more nodes and $\alpha.m$ more energy. Initially, P_{opt} is CH probability. An average n * P_{opt} must become CHs per round per epoch. CH nominated in the current round cannot select as CH for same epoch. Each node produces a random number between 0 and 1 to become a CH. If generated number is lesser than a given threshold, T(s), then it has a probability to become CH for the current round. Threshold value rises as a number of rounds increases and is equivalent to 1 in last round means residual nodes become CH in the last round with a probability 1. CH can be selected by using the best probability of individual node divided by it energy using a formula

$$P_{nrm} = \frac{P_{opt}}{1+\alpha m} \tag{12}$$

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

where P_{nrm} and P_{adv} is the weighted election probability for normal and advances nodes. Padv has a greater probability to become a CH then P_{nrm}, m represents the fraction of advanced nodes and α is an added energy factor among normal and advanced nodes. As discussed earlier, each node produces a random number between 0 and 1. If the number is lesser than the given T(s) then this node becomes CH. Different formulas can be implemented for all types of nodes for calculating the threshold value as given below:

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

Nodes that do not become CHs in the current round are denoted by G'. Pnrm is normal node probability to become a CH and Tnrm is the threshold for normal nodes to become CH.

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

Nodes which do not become CHs in the present round are denoted by G'. Padv is advance node probability to become CH and Tadv is the threshold for normal nodes to become CH. This improves the stability period before the death of the first node. SEP gives better performance than LEACH because it consumes extra energy of the advance node equally hence increase in the stability period of the sensor network. SEP does not guarantee well-organized distribution of nodes.

In [19], Hierarchal Stable Election (HSEP) is introduced which is based on hierarchal clustering routing protocol having two levels of energy and the main goal of this protocol is to reduce transmission energy between CH and BS. HSEP reduces transmission energy by selecting secondary CHs from current primary CHs in each round and this secondary CH is selected based on some probability. In order to minimize transmission cost, H-SEP introduces clustering hierarchy where CHs consist of two types. (1) Primary CHs (2) Secondary CHs. Primary CHs check the distance between two CH and send data to the minimum distance CH. These lowest distance CHs are called secondary CHs. HSEP is a heterogeneous-aware protocol consist of two kinds of nodes

(1) Advance nodes (2) Normal nodes. Normal nodes have lesser energy than advance node. The CH is formed only in advance nodes. The probability of sensor nodes to become CHs is based on initial energy of the node. This technique increases stability period before the death of the first node. The secondary CHs are based on existing primary CHs. The secondary CH can be selected on the bases of previously selected primary CHs and only primary CHs can choose secondary CHs. Primary CHs check the distance between each other's and send data to minimum distance CH. This minimum distance CHs are called secondary CHs. Primary CH can be selected by selecting a random number between 0 and 1. If a random number is lower than the threshold value, then node nominated as primary CH. This primary CH receives data from member nodes, aggregates it, and sends it to secondary CHs. The secondary CH then sends data to BS. In H-SEP, two levels of clustering hierarchy are used. First, sensor senses data and sends it to primary CH. Secondly, primary CH sends aggregated data to secondary. Now secondary CHs further sends aggregated data to BS thus diminishing transmission distance, which consumes lesser energy. This entire procedure is defined in three phases. The first phase, nodes sense environment. The second phase, nodes matching the random number with a threshold value to become primary CHs. If the node is selected as primary CH, then it sends a broadcast message in a network. Nodes become associated with primary CH using RSSI and send data to their CH. In this phase, primary CHs once again a member of secondary CHs because of shortest distance among them. These secondary CHs get data from primary CHs and transmit it to BS. In [22], a hierarchal routing protocol known as self-organized cluster-based energy balanced routing protocol (SCERP) was proposed in which issues regarding CH section method in LEACH protocol are examined. SCERP balances network energy consumption and uses a new approach for CH selection that enhances the energy efficiency of the sensor network. In SCERP, new CH can be selected on the basis of remaining energy which is greater than threshold energy after completion of the 1st round. Moreover, distance from the BS, residual energy and number of nodes can also be considered in selecting new CH. Let us assume that all the nodes have the same initial energy. Initially, there is no CH and all the nodes n are normal and have S nodes in the sensor field. CHs counter is denoted as J where J=0. The selection of CH is as fellows:

1) At the beginning of the first round, CHs are chosen on the basis of residual energy and average energy consumed of a node. It also considers the distance from the BS using Euclidean distance formula and chooses only those nodes as CHs which have shortest distance from the BS.
2) In the second round and onwards, CHs are chosen based on the residual energy of the nodes. If current CH node has greater residual energy than the threshold value than that CH will remain as a CH for next rounds. If CH has lesser energy than the threshold value, then that CH will be replaced on another CH according to the LEACH algorithm.
3) The selected CHs then broadcast their information to other nodes. The non-CH nodes send their cluster joining information to its own CH. The CHs receive data from member nodes, aggregate it and send it to BS.

In [20] a hybrid routing protocol has been introduced called Zonal-Stable Election Protocol (Z-SEP) for heterogeneous WSNs. In Z-SEP, the field of the sensor network is divided into zones and communication in a hybrid approach is implemented mean normal nodes send data directly to BS while advance nodes use clustering procedure to transmit data to BS. In Z-SEP, network field is divided into three zones: Zone 0, Zone 1 and Zone 2. Normal nodes are deployed in Zone 0, half of the advance nodes are installed in Zone 1, and half of the advance nodes deployed in Zone 2. Nodes in zone 0 communicate directly to the BS as they sense the data. Zone 1 and Zone 2 nodes send data to BS through a cluster algorithm. Let (m) be a fraction of total nodes (n), which have (α) time more called advance nodes. Normal nodes are (1-m)∗n. Suppose optimum numbers of the cluster are (K_{opt}) and advance nodes are (n). According to SEP, CH probability is $P_{opt} = K_{opt}$.

$$P_{opt} = \frac{K_{opt}}{n} \tag{16}$$

Z-SEP threshold equation is same like LEACH for the CH selection and its equation is

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

G represents a set of nodes that has been designated as CH in the last 1/Popt rounds. The probability of advance nodes to become CH is

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

The Threshold T(n) for advance nodes is

$$T_{adv} = \begin{cases} \dfrac{P_{adv}}{1 - P_{adv}[r * mod\frac{1}{P_{adv}}]} & if\ adv \in G' \\ 0 & otherwise \end{cases} \tag{19}$$

Set of advance nodes which are not designated for CH in the last 1/Padv rounds in G' set. Same like LEACH, Z-SEP have same cluster formation. The CH broadcasts message when the CH is selected. The node can become a member of CH and respond to the CH based on RSSI. Then node can send data to CH in its TDMA schedule that allocated to it. When data is received from the member node, it is then aggregated and sent to BS. Clusters are not formed in normal nodes. The reason is that normal nodes have less energy than the advance nodes and CH consumes more energy. If CH is formed in normal nodes, they will die quickly resulting in the shortening of the stability period. As corners are most distant areas in the field, where nodes need more energy to transmit data to base station. Therefore, Normal nodes are set near BS and transmit their data directly to BS. While advance nodes are placed distant from BS because they have higher energy than normal nodes. If advance nodes directly transmit data to BS, they consume a lot of energy. To save energy consumption a clustering technique is applied in advance nodes only.

III. PROPOSED FRAMEWORK

In this section, we proposed our protocol known as Advance Zonal Stable Election Protocol (AZ-SEP), which is a heterogeneous routing protocol. Our protocol is an improved form of Z-SEP protocol, which decreases transmission cost from CH to BS. The functioning of our proposed protocol is discussed below in detail:

A. NETWORK ARCHITECTURE

In some protocols, nodes are randomly organized in the field, so the energy of these nodes is not efficiently utilized. In our protocol, we divide the sensor field into three zones (Zone 0, Zone 1, Zone 2) to use the optimal energy consumption of the node. We assume that nodes in the field are not mobile and the dimensional of the field is not known. Similarly, some nodes are equipped with more energy of the total nodes. Let (m) be a fraction of total nodes (n), which has time more called advance nodes. Normal nodes are $(1 - m)^n$. As AZ-SEP is a two levels heterogeneous routing protocol, therefore the nodes are of two types (1) Normal nodes (2) Advance nodes. Normal nodes have low energy as compared with advance nodes. Normal nodes are placed near to BS in Zone 0 and advance nodes placed far away from BS in Zone1 and Zone 2. As corner is more distant from BS and requires more energy to transmit data that is why advance nodes are placed far away from BS as they have more energy than normal nodes while normal nodes are placed near BS. Normal nodes communicate directly to the BS station while advance nodes form a cluster and, in that cluster, one node is as a CH and CH then communicates with the BS which is shown in Figure 1.

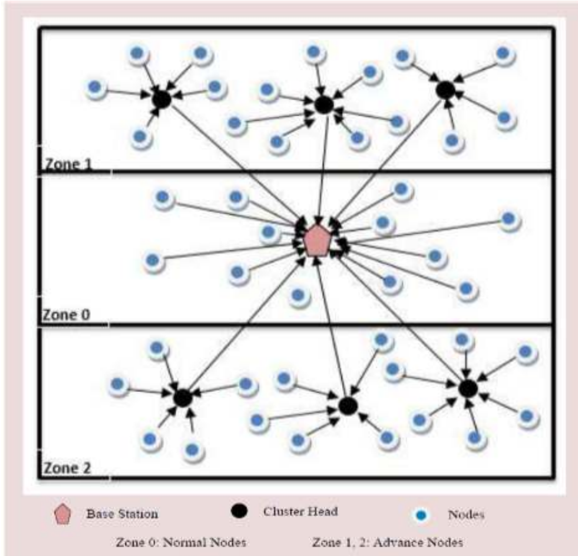

FIGURE 1. Communication of nodes with BS.

B. OPERATION OF AZ-SEP

AZ-SEP protocol uses two methods to send data to BS

1) DIRECT COMMUNICATION

In Zone 0, normal node senses data from the environment and sends it directly to BS, as they are low energy nodes and placed near BS.

2) COMMUNICATION VIA CH

In zone 1 and 2, which consist of advance node, have high energy than normal nodes. Advance node sends data to BS using clustering technique. In advance nodes, clusters are formed and in that one node is selected as CH and rest are a member of that cluster. Member nodes sense data and send it to CH. CH then aggregates data, processes it and sends it to BS. Communication of CH with BS consumes a lot of energy as they are far away from BS. In Z-SEP, CH communicates directly with BS which consumes a huge amount of energy. In the proposed protocol, a multi-hop communication with the BS is introduced. CH will communicate through a multi-hop fashion. The CH that is in the corner of the field will send data to its neighbor CH and neighbor CH will send it to its own neighbor CH and so on until it reaches the BS. With this technique, little amount of energy is consumed as compared with direct communication. As a result, sensor nodes have larger residual energy and this will improve the lifetime of a network.

Selection of CH in advance nodes is of main consideration. In Z-SEP, selection of CH is same as LEACH. Assume an optimal number of clusters Kopt and n is the number of advance nodes. According to SEP optimal probability of cluster head is

$$P_{opt} = \frac{K_{opt}}{n} \tag{20}$$

Each node decides whether to become CH in the current round or not. Therefore, each node generates a random number between 0 and 1. If the selected value is lesser than the threshold value then that node is selected as a CH for that round. Z-SEP threshold equation is given below:

$$T_n = \begin{cases} \dfrac{P_{opt}}{1 - P_{opt[r*mod\frac{1}{P_{opt}}]}} & if\ n \in G \\ 0 & otherwise \end{cases} \tag{21}$$

G denotes set of nodes that has been designated as a CH in the last 1/Popt rounds. P is the desired %age of CH and r is the current round. However, there is a possibility that low energy advance node is nominated randomly as CH, which drains out quickly and produces instability in the sensor network.

For this purpose, we introduce new CH selection criteria. CH in advance nodes will be selected on the bases of 3 factors.

- Threshold value
- Residual energy of the node
- Distance from BS

In beginning, every node picks a random number between 0 and 1. If that selected number is lesser than the threshold value, then that node selected as a CH for the current round. AZ-SEP threshold equation is given below:

$$T_n = \begin{cases} \dfrac{P_{opt}}{1 - P_{opt[r*mod \frac{1}{P_{opt}}]}} & if\ n \epsilon G \\ 0 & otherwise \end{cases} \tag{22}$$

where G is the set of nodes which has not been cluster heads in the last 1/Popt rounds. After the completion of the first round, the residual energy of nodes is checked. If the node has greater residual energy, then that node will be nominated as a CH for that round. If nodes have the same residual energy, the CH is then selected on the bases of distance from BS. Lesser the distance from the BS, greater the chances to become a CH. With this approach, the stability period of the sensor network increases, as well as less amount of CH, will die. In our protocol, we introduced a multi-hop communication with the BS. CH will communicate with the BS through a multi-hop fashion. The CH that is in the corner of the field will send data to its neighbor CH and neighbor CH will send it to its own neighbor CH and so on until it reaches BS. With this technique, little amount of energy is consumed as compared with direct communication. As a result, sensor nodes have larger residual energy and this will improve the lifetime of a network. Furthermore, the selection of CH in advance nodes is of main consideration. In Z-SEP, selection of CH is same as LEACH. Each node decides whether to become CH in the current round or not. Therefore, each node generates a random number between 0 and 1. If the selected value is lesser than the threshold value then that node is selected as a CH for that round. In our proposed protocol, we introduced new CH selection criteria. CH in advance nodes will be selected on the bases of 3 factors.

- Threshold value
- Residual energy of the node
- Distance from BS

In beginning, every node picks a random number between 0 and 1 as described in LEACH. If that selected number is lesser than the threshold value, then that node selected as a CH for the current round. After the completion of the first round, the residual energy of nodes is checked. If the node has greater residual energy, then that node will be nominated as a CH for that round. If nodes have the same residual energy, the CH is then selected on the bases of distance from BS. Lesser the distance from the BS, greater the chances to become a CH. With this approach, the stability period of sensor network increases, as well as less amount of CH, will die as shown in Figure 2.

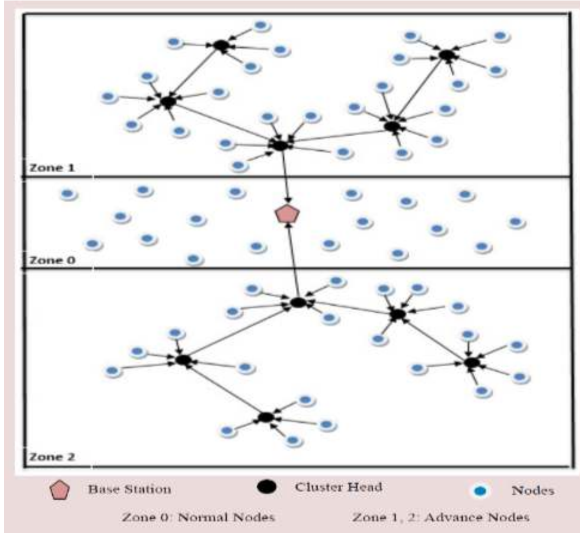

FIGURE 2. **Multihop communication.**

IV. IMPLEMENTATION

AZ-SEP is a heterogeneous cluster-based routing protocol, which is an enhanced form of the Z-SEP routing protocol. The goal of AZ-SEP is to decrease energy consumption with an increase in the lifetime of the network. To achieve this goal, AZ-SEP illustrates well-organized energy usage and prolong protocol in terms of dead nodes, average energy consumption, and packet delivery ratio to the BS during communication. In this section, we define a solution to the problems that exist in Z-SEP and is described below:

A. COMMUNICATION OF CH WITH BS

To alleviate energy consumption of advance nodes during their communication with the BS, AZ-SEP protocol introduce multi-hop approach. In multi-hop approach CHs do not communicate directly with BS rather, it communicates using other CH nodes. Each CH node is used a sending object and as a router. The distant CHs, which is incapable to transfer its data to BS directly because of low energy or large distance now uses the multi-hop approach to communicate with the BS as shown in Figure 3 (right).

At beginning of the first round, nodes form a cluster in which one node is selected as CH from that cluster as illustrated in Figure 3 (left). Each CH gathers data from its member nodes, aggregates it and forwards it to its nearest CH and vice versa. In Figure 3(right) CH that is far away from BS sends its data to its nearer CH and so on until the CH that has the lowest distance and with respect to BS receives data from all other CHs and forwards data to BS. The basic mechanism for selecting the neighbor CH is that each source node (CH) produces a data packet and transmit its neighbor CH. The neighbor CH nodes pass data packet to next CH node and this process continues until it reaches BS. The CH nodes in the field are static and transmission range of all nodes is same. Furthermore, all CH nodes are able to calculate its residual

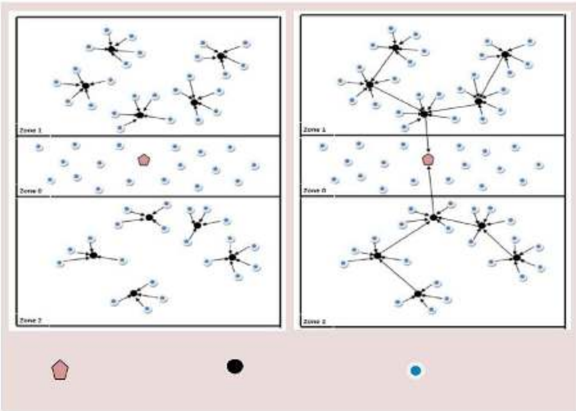

FIGURE 3. Communication of CH with BS in a multi-hop fashion.

TABLE 1. Hello packet structure.

2 byte	1 byte	4 byte	1 byte	1 byte
Packet ID	Source ID	Eres	HOPmin	DFBS

energy at any time and also calculate the reliability of the link among neighbor CH node and itself. The notation that is used in our study is as fellows

- Number of cluster head nodes: Cs
- Set of cluster head: C = c1, c2, . . . , cN,
- $a^t h$ sensor Ca: 1 a Cs;
- Neighbor set of cluster head node ca: n = c1, c2, . . . , cm, 1 M Cs;
- Residual energy of the node ca: Eres, a
- Minimum hop count from node to BS ca: HOPmin, a
- Link reliability among cluster head nodes ca and cb: LinkRab
- Selected set of Cn: SCn
- Next hop node of Cn: CHn

In beginning, BS broadcast HELLO packet to all nodes through which the nodes can calculate their distance from the BS. Each CH node then produces a data packet known as HELLO packet and sends them to neighbor CH nodes. The fields of the HELLO packet consist of Packet ID, Source ID, Residual energy and minimum hop count as shown in Table 1.

The order of the Hello packet is denoted by Packet ID. The functionality of Packet ID is that it avoids duplication of the packet that is received on neighbor CH node. Source ID indicates the source node from where the data packet is originated. Eres is remaining energy of node. HOPmin denotes the number of hops to the BS and is calculated as

$$HOP_{min,a} = minimum\,(HOP)_b\,|b\varepsilon N_n + 1 \tag{23}$$

where HOP_b represents minimum hop count between CH node cb to the BS. The minimum hop count is added to its neighbor node because the node ca and neighbor nodes is 1. DFBS denotes Distance from the BS which is calculated at the start of the network initialization. When the HELLO packet is received to the neighbor CH node, a new entry is added in the neighbor table of that node. If the entry already exists then the table is updated automatically. The structure of the neighbor table is given in Table 2.

TABLE 2. Neighbor table structure.

1 byte	4 byte	4 byte	1 byte	4 byte
Neighbor ID	LinkR	Eres	HOPmin	NHcost

Neighbor ID identifies the neighboring node. LinkR identifies the reliability of the link among two CH nodes. Link reliability disturbs QoS requirements as well as energy consumption of the node because if the link reliability between two nodes is low then high retransmission packet occurs causing an increase in energy consumption. The link reliability is computed in Eq 24.

$$LinkRab = (1-\gamma)LinkRab + \gamma\left(\frac{Tx_{succ,ab}}{Tx_{total,ab}}\right)Tx_{succ,ab} \tag{24}$$

denotes packets transmitted successfully through the link among node ca and cb while $Tx_{total,ab}$ denotes transmission and retransmission attempts of all data packets. γ denotes average weighting factor and its value is 0.4. Eres and HOPmin fields are taken out from Hello packet. Residual energy of the node ca (Eres, a) is given below

$$E_{res,a} = E_{init,a} - E_{con,a} \tag{25}$$

$E_{con,a}$ represent consumption of energy inside node a. In order to find out the $E_{con,a}$, the total transmission and reception energy of the node is calculated in Eq 4.

$$E_{con,a} = Pa * Etx + Qb * Erx \tag{26}$$

Pa and Qb represent the number of bit send and received in node ca. Etx and Erx are given as

$$Etx = Etx_{elec} + Eamp * d2 \tag{27}$$
$$Erx = Erx_{elec} \tag{28}$$

Etx_{elec} and Erx_{elec} represent the energy for the transmission and reception which the radio needs, Eamp denotes transmit amplifier energy and distance between nodes ca and cb is denoted by d. Cost represents the link cost of the neighbor nodes. To find out the next hop node, the NHvalue is used. NHvalue denotes the next hop values which are directly proportional to Residual energy and inversely proportional to the distance from the BS. A node with the highest next-hop value will be selected as a next hop.

$$NH_{value} = \frac{Res}{DS} \tag{29}$$

Res is residual energy of next hop node and DS denotes the distance from the BS.

B. CLUSTER HEAD SELECTION

We change the overall operation of advance nodes in the second part of our network operation. After completion of first round nodes energy changes because of their communication. The criteria for CH selection should also be according to the network environment and operation. The new parameters that we want to introduce are

1) Residual energy of the node
2) Distance from the BS

Now CH selection process, they use residual energy as criteria for selection as CH in the second round as shown in Figure 4 (left). Residual energy of all nodes is compared and the node with the highest residual energies got chance to become CHs. The residual energy of the node can be calculated as follows:

$$P(t) = \frac{Eres}{E_{avg}} * \frac{D_{max}}{D_{bs}} \tag{30}$$

Eres denotes remaining energy of node at that time. Dbs is the distance from the node to the BS. If residual energy of nodes that are candidates for CH is same, then a new parameter i.e. distance of elected CH from BS is measured. If the distance of elected CH node from BS is low, the node selected as a CH. Dmax represents value factor that is calculated after the network is deployed. Eavg is the average energy of all nodes in the network and is calculated as

$$E_{avg} = \frac{\sum_{i=1}^{n} E_{res}}{n} \tag{31}$$

where n is the total alive nodes at that time. At beginning of network, all nodes have the same energy. Thus, a node which is close to the BS has greater chances to become a CH.

After the completion of the first round, the residual energy of each node is different from others in the network. So, equation 2 shows that node which has higher residual energy than average energy of node in the current round, and that node is nearer to BS, have greater chances to be selected as CH. Once the CH is formed, then they communicate with each other by passing the data from on CH to another CH in a Multihop fashion as shown in Figure 4 (right).

In this approach, a little amount of energy is consumed. CH that is near BS collects all the data from the other CH and then transmit it to BS. This increases the stability period of network because it has the highest possible communication time. Below Figure 5 presents a flowchart of the proposed algorithm. The pseudo code for the above study is as follows:

1) Network setup phase
2) Broadcast HELLO packet
3) For
4) Compute threshold value, residual energy, Distance from the BS Select CH/
5) End
6) Compute Next hop value

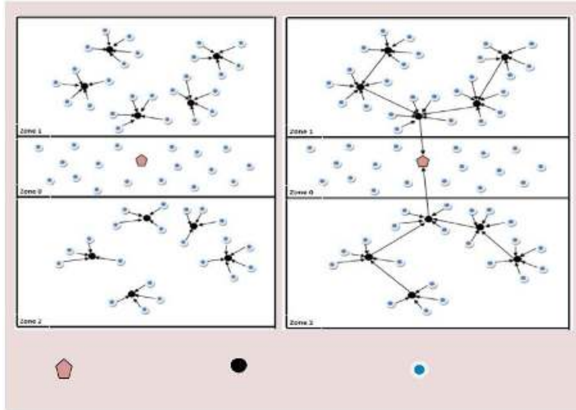

FIGURE 4. Diagram showing selection of CH and communication of CH with BS.

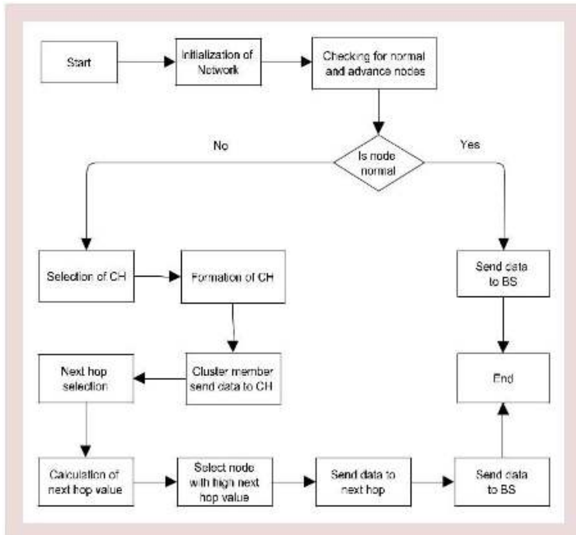

FIGURE 5. Flow chart of proposed algorithm.

7) For
8) HNvalue = RE / D(from base station)
9) Select node with higher HNvalue
10) End

V. SIMULATION RESULTS AND DISCUSSION

Simulation terms as objects, parameters, area in which the network operates for gathering data and forwarding it to sink for further processing. In this section, we simulate our protocol and parent protocol in terms of nodes heterogeneity and also take different evaluation scenarios of our proposed protocol to check the behavior in terms of performance. Let us consider M number of nodes which are distributed randomly in a network area of Xm and Ym. Xm represents x-axis while Ym represents y-axis. BS is placed in the middle of the network for reaching all the nodes for communication with x and y coordinates listed below. BS as the role of main authority defines the possible number of CHs for network represented by Q. Number of rounds in a network is dependent on the

TABLE 3. Different parameters of network nodes.

Parameter	Value
Xm, Ym	300
X, Y	150
Rmax	8000
M	100
Q	0.1
Sink. X	150
Sink. Y	150

TABLE 4. Different values of nodes energy.

Energy	Value
E0	0.8 J
En	0.8 J
Efs	10*0.000000000001
Emp	0.0013*0.000000000001
Etx	50*0.000000001
Erx	50*0.000000001
Eda	5*0.000000001

application denoted as Rn. A total number of rounds used in this network is represented by Rmax. The possible parameters are shown in Table 3 and 4.

Where Eo is the energy supplied to each node and En is the energy of normal nodes. Emp is amplification energy of node and Efs is the energy used when data is forwarded from one CH to another CH and Eda is the energy consumed during the delay of data transmission. Etx and Erx is the energy conserved during transmission and receiving of the data packet. With these parameters and nodes, network operation starts using AZ-SEP protocol for routing improving the following parameters.

1) Number of alive nodes
2) Packet Delivery Ratio
3) Energy Consumption

This below listed in graphs evaluated number of alive nodes, Packet delivery ratio and Average energy consumption in compared three protocols of WSNs. The red color line represents SEP protocol, Blue color represents AZ-SEP protocol and green color represents Z-SEP protocol. The Figure illustrates that in the start of the network operation SEP is the worst protocol as compared to the other two. The SEP protocol starts declining alive nodes at 8 while in Z-SEP protocols the death of the first node occurred at 600th round. The proposed AZ-SEP protocol does not show improvement over Z-SEP protocol in the beginning by recording first node dead at 500th round. But in 2500 round, the performance of the proposed protocol improved. As network operations continue a number of death nodes in AZ-SEP protocol are much lower than the other compared protocols. The two protocols consider death to all nodes in 5000 rounds while AZ-SEP protocol extends it further results in extension of the network lifetime as shown in Figure 6.

The following listed graph evaluates packet delivery to BS. The main aim of WSNs is to transfer data from nodes to BS. If the network alive for more time more data will be sensed

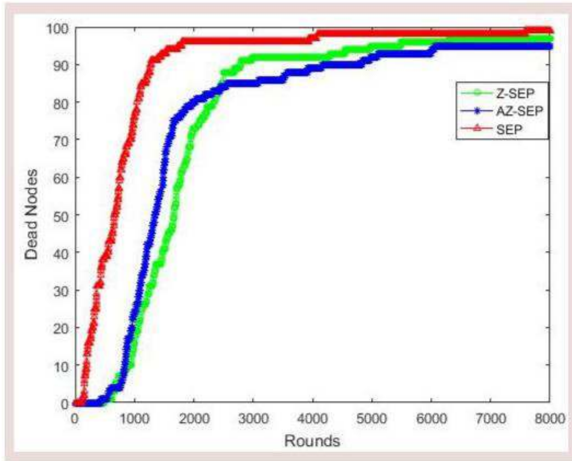

FIGURE 6. Dead nodes in protocols.

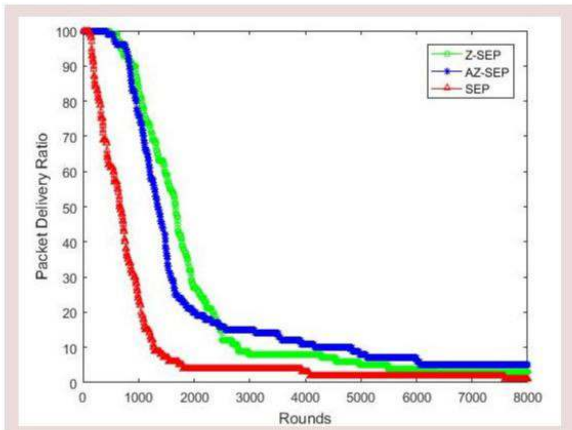

FIGURE 7. Number of packets delivery to BS in protocols.

and transferred to the BS resulting in an efficiency of the network. The graph below gives a view of data packet delivery in all three protocols. It is clearly visible that AZ-SEP is much better in performance than the other two protocols by delivering about 8000 packets to the BS. The other two protocols hardly deliver packets of about 7000 which shows its inability to counter the new proposed protocol as shown in Figure 7.

The below-listed graph illustrates energy consumption during network operation. The graph shows us that our proposed protocol is much better than the compared two protocols. AZ-SEP has the lowest energy consumption in a given number of rounds. The total energy consumed in the 1000th round of stated protocol is 1.5J for AZ-SEP, 3J for Z-SEP and 6.5 for SEP protocol. The lowest amount of energy consumed is in our proposed protocol AZ-SEP which increases the number of alive nodes alternatively increasing packets delivery ration as well as network lifetime and efficiency as shown in Figure 8.

Different scenarios: Taking three scenarios each for Dead nodes, Packet delivery ratio and Average energy consumption

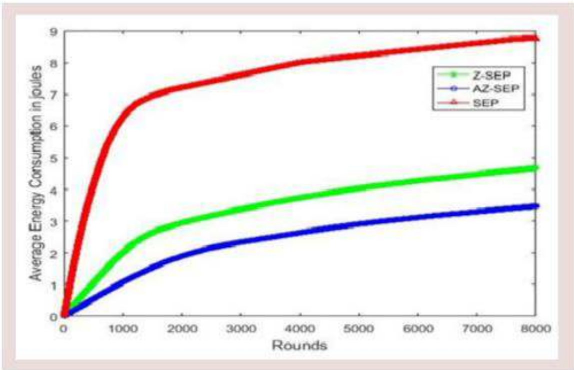

FIGURE 8. Energy used in protocols.

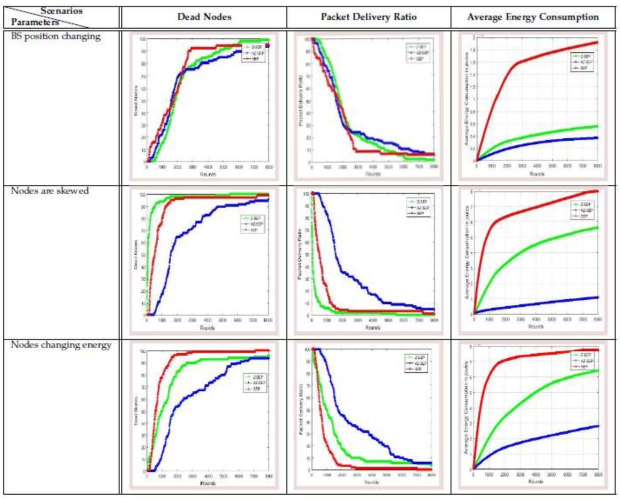

FIGURE 9. Comparison matrix of different Scenarios.

in which performance of the proposed protocol is checked by changing its parameter. The scenarios are as follows:

A. CHANGING THE POSITION OF BS

In the first scenario, the performance of our proposed protocol is checked by changing the BS position. When the position of BS is changed, it affects the performance of dead nodes, packet delivers ratio and average energy consumption. The parameter of BS is changed from (Sink.X, Y) 150 to 100 while other parameters remain same. When the BS is located at Sink.x and Sink.y value 100, a number of dead nodes, packet delivery ratio, and average energy consumption show better result compared to that of parent protocol. Figure 9 demonstrates that AZ-SEP performs well after changing the position of BS. At the beginning of rounds, Z-SEP shows better as compared with our protocol but after few rounds, AZ-SEP protocol got improved. SEP protocol starts declining as compared to Z-SEP and AZ-SEP. The proposed AZ-SEP protocol improved until the last round. Furthermore, in packet delivery ratio, AZ-SEP delivers more packet compare with that of existing protocol. In energy consumption, the SEP protocol consumes greater energy associate to that of other protocol. This shows that our proposed protocol consumes lesser energy which helps in increase in lifetime and stability period of the sensor network.

B. NODES ARE SKEWED

In this scenario, the deployment of the nodes is changed. Nodes that are deployed randomly in the field are reformed in a way that greater number of nodes are arranged in one part of the field while a little number of nodes are placed in another part of the field. The BS is kept in the middle of the field. With this practice, the performance of AZ-SEP is measured and calculated. The skewness can be performed in x.axis and will be as in y.axis. Figure 5.4 shows that our proposed protocol gives a better result when the position of nodes in the network is changed. With this change, the overall network lifetime is changed. The Z-SEP does not show better result compared with that of SEP and AZ-SEP protocol. But AZ-SEP shows the great result in the case of the dead node. In packet delivery ratio, Z-SEP goes down at the beginning of the round while SEP starts dropping in round 15. But still, AZ-SEP protocol shows a better result than it parents protocol. In energy consumption graph, AZ-SEP consumes little amount of energy while SEP consumes a lot of energy as compared to that other protocols.

C. CHANGING ENERGY OF NODES

Energy consumption is on the key issue in WSN because sensor nodes are battery power and it is not possible to change the battery once they are deployed in the field. In this scenario, initial energy of nodes is changed randomly from Eo 0.8 to 0.9 before deployment to analyze the performance of our proposed protocol. Once the energy of nodes is changed, the behavior of sensor network changed which affect lifetime and stability period of the network. The energy of all nodes is same when the nodes are deployed. When the election of advance nodes starts, the energy of advance nodes will be changed while the energy of normal nodes will remain same throughout network lifetime. The advance nodes have a different energy from one another when advance nodes are selected. The CHs are then formed in advance node which depends on remain energy of node and distance from BS. The CH then sends data to its member CH in a multihop and in last sends it to BS. The below Figure 9 explains energy consumption during network process. Graphs show us that our proposed protocol is much better compared to the other two protocols when nodes have a different energy. In a dead node case, Z-SEP protocol nodes start dying at the beginning of round while SEP and AZ-SEP show better result but in round 7000 all the nodes completely die in SEP protocol case while Z-SEP have only 92 nodes died but in comparison with parent protocol, AZ-SEP have died only 90 nodes which means that our proposed have the best result when advance nodes have different energy. In packet delivery ratio and energy consumption case, AZ-SEP delivers more packets and have low energy consumption. The lowest amount of energy is consumed by AZ-SEP which increases the number of alive

TABLE 5. Comparison matrix of different properties.

Protocols	Parameters							
	Network Type	Energy Efficient	Data Aggregation	Routing	Scalability	Stability Period	Sum	Mean score
LEACH	2	2	2	3	2	2.5	13.5	2.25
DEEC	3	2	3	2	2.5	3	15.5	2.53
SEP	3	3	3	2	3.5	2.5	17	2.83
H-SEP	2	2	3	3	2.5	3.5	16	2.66
Z-SEP	3	3	3	4	3	3	19	3.16
Mean score	2.16	2.0	2.33	2.5	2.25	2.41	-	-

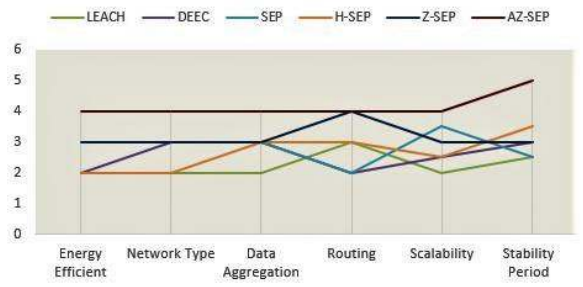

FIGURE 10. Energy used in protocols.

nodes alternatively increasing packet delivery ratio as well as network lifetime.

VI. COMPARISON AND EVALUATION MATRIX

This section defines our proposed protocol AZ-SEP which is the enhanced form of Z-SEP protocol. Table 5 shows different properties and point values of the above mentioned protocol. Network type identical that network is homogeneous or heterogeneous. Energy efficient shows how much a protocol is energy efficient. Scalability defines how much protocol is scalable and stability period defines the time interval from the start of the network to the death of the first node. Properties of each protocol assign a value between 1 and 5. Different scenarios and their parameters of our proposed protocol which are study above are combined and shown in Figure 9. It is also shown in the graphical representation of the descriptive analysis in Figure 10.

Legend: The properties are scaled by values 1 to 5, where:

- No support of the parameter by the protocol is denoted by (1)
- Little support denoted by (2)
- Average support denoted by (3)
- Sufficiently supports the parameter denoted by (4)
- Excellent support of the parameter denoted by (5)

The graphical representation showing evaluation between the proposed protocol and its parent protocol. Values from 0 to 6 show the comparison with respect to their properties. AZ-SEP protocol shows better performance than its parent protocol.

VII. CONCLUSION

Advance zonal stable election protocol (AZ-SEP) is hierarchical cluster based heterogeneous routing protocol that integrates different issues such as communication of CH with the BS as well as new CH selection scheme. As AZ-SEP is two levels heterogeneous routing protocol so communication occurs in AZ-SEP is hybrid mean normal nodes communicate directly with BS while advance nodes use clustering technique to send data to BS. The number of alive nodes in protocol increases because communication of CH with BS is in Multihop fashion rather than direct communication so little amount of energy is consumed to transmit data from the CH to BS also selection of CH is based on remaining energy of node, and distance from BS, this will also increase the stability period of network before the first node dies. As for stability period increases, the packet deliver ratio to the BS also increases thus a large number of events are sensed and forwarded it to BS for further action. The result shows that the stability period increases by 50 Contributions: After the resolution of the issues, the new protocol AZ-SEP is implemented and compared. Comparison results show that our proposed protocol performs well then its parent protocol. Our contributions in this study are as follows:

1) In AZ-SEP, communication of CH with BS is in a multi-hop fashion i.e CH will pass data to it neigh-bor CH and so on till it reaches to the BS. In this way, little amount of energy is consumed resulting in an increase in the lifetime of the sensor network.
2) In AZ-SEP, CH in the advance nodes is selected on the bases of three aspects.

- Threshold value
- Residual energy of the node
- Distance from BS

With this technique, all nodes energy is equally distributed producing an increase in the stability period resulting in an increase in the lifetime of the sensor network.

VIII. FUTURE WORK

WSN is an area where energy efficiency is of the main issue. For this purpose, the different routing protocol is developing in order to address this issue. AZ-SEP protocol is introduced which overcomes and makes enhancement in the parent protocol. There are still some issues exist such as the communication of normal nodes with the BS which is an interesting problem to explore further. Also, the proposed solution can be enhanced further to other routing protocol to make more energy efficient routing protocol which shows superior performance.

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