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Performance Analysis of LEACH, SEP and Z-SEP Protocols in Heterogeneous Wireless Sensor Network

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ABSTRACT: Wireless sensor networks use thousands of sensors to monitor the physical environment. This sensor node consumes a limited amount of energy since it is battery-powered. Researchers regularly develop energy-efficient routing protocols to extend the lifetime of WSNs. The threshold-based cluster head (CH) selection techniques used by hierarchical routing protocols have been shown to extend network lifetime in many studies. Through the implementation of several routing protocols, sensor networks can be made to last longer and consume less energy. Z-SEP introduces a new heterogeneous routing protocol using a hybrid communication mechanism. Others use clustering mechanisms, while others use the base station directly. Energy efficiency and stability are improved by 11% and 19%, respectively, over Z-SEP.

Keywords: Wireless Networks, LEACH, Routing, Energy Efficiency

1. INTRODUCTION

WSNs comprise many sensor nodes that can communicate, sense, and compute. These sensors deploy one or more Base Stations (BS) over a large area. Additionally, WSNs can manage disasters, conduct military reconnaissance, track forest fires, and monitor security incidents [1–3]. There is usually a random deployment of sensor nodes with limited battery life. Routing techniques determine how data is delivered from source to destination. Due to the inability to change sensors' batteries, ensuring that routing strategies in these networks are energy efficient is important. Depending on their applications and network architectures, WSNs have been proposed and developed with various energy-efficient routing protocols. As a result of power limitations, wirelines with low bandwidth, limited computational power, a lack of conventional addressing schemes, and sensor nodes that self-organize, designing a routing protocol is a challenge.

A WSN's communication is shown in Figure 1. A variety of environmental conditions are detected by SNs located in random locations. These conditions include air quality, atmospheric humidity, soil moisture, and temperature. SNs in a WSN are monitored by the base station (BS). BS determines the network's number of cluster heads (CHs), grouping it into several clusters. It varies from round to round because SNs are not connected. The design of a static or mobile WSN depends on the system application. Sensor devices are placed in predetermined locations to create a static WSN [4, 5]. Multi-hop communication is used when BS is outside the sensor node's transmission range. Heterogeneous and homogeneous networks are the two types of WSNs used.

Regarding mobility, WSNs differ from ad-hoc networks such as VANETs [6–8] and MANET [9]. WSNs with homogeneous initial energy and hardware complexity have the same initial energy. Networks with inhomogeneous topologies cluster statically. SNs in heterogeneous WSNs come in various types with varying battery functionality.

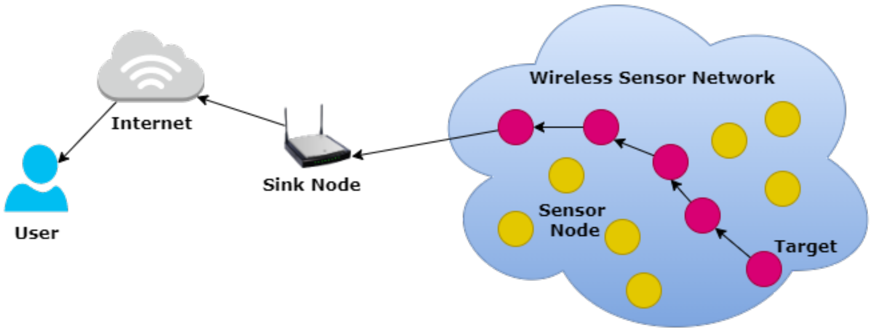

FIGURE 1. **An example of a wireless sensor network.**

2. LITERATURE REVIEW

Wireless sensor networks can have a longer lifespan by reducing their energy consumption through LEACH [10–12]. In LEACH, CH selection proceeds based on a random probability, ensuring that no one SN participates in CH selection more than once [11, 13]. An algorithm for wide-area wireless sensor networks was proposed using residual energy-based idle channels [11]. To ensure data delivery, vice-LEACH adopted the idea of two CHs [10]. In addition to the data overhead problem, additional uses of CH introduce new problems.

Using LEACH to reduce the average amount of energy each system consumes, recent work [14] is shown to improve energy efficiency. One-round LEACH with multi-hop networks was proposed [15]. The CH role was transferred to another SN when the current CH's Re wasn't enough for the next round of elections.

Table 1. **List of the previous surveys of the WSN protocols.**

Author & Year	Contributions	Limitations
(Lotf et al., 2010) [16]	Energy consumption and network lifetime were compared for six hierarchical routing protocols (HRPs).	One network lifetime parameter is used, and only six protocols are compared.
(Xu & Gao, 2011) [17]	In this study, twelve parameters were compared between six HRPs.	Proper parameters are not used, and the discussed protocol is outdated.
(Aslam et al., 2012) [18]	A comparison of LEACH energy consumption with M-LEACH, MHLEACH, and sLEACH was conducted.	Only four HRPs are analyzed under energy consumption parameters.
(Hani & Ijjeh, 2013) [19]	CH selection is compared to LEACH, as are improvements over LEACH and their disadvantages, in discussing various LEACH-related protocols.	A limited number of comparison parameters are taken.
(Madheswaran & Shanmugasun-daram, 2013) [20]	Based on how CH selection algorithms are optimized, modified, and energy-aware, it is possible to categorize LEACH variants into these three categories.	In comparison with some selected parameters, fewer HRPs are available.
(Rahayu et al., 2014) [21]	We present several variants of LEACH that are security-related.	Only security-related protocols and issues are discussed.
(Mahapatra & Yadav, 2015) [22]	We compare and discuss the successors of LEACH protocols alphabetically.	Only four parameters are considered and analyzed unless energy consumption parameters are considered.
(Arora (Research Scholar) et al., 2016) [23]	LEACH and other HRP protocols can be described using four parameters.	An analysis uses only four parameters and a limited number of HRPs.

3. WSN ROUTING PROTOCOLS

Implement routing protocols that define how message packets are transferred efficiently and with less energy consumed within a system. As a result, the network will consume less energy over time. WSN routing protocols are classified in Figure 2 [24, 25].

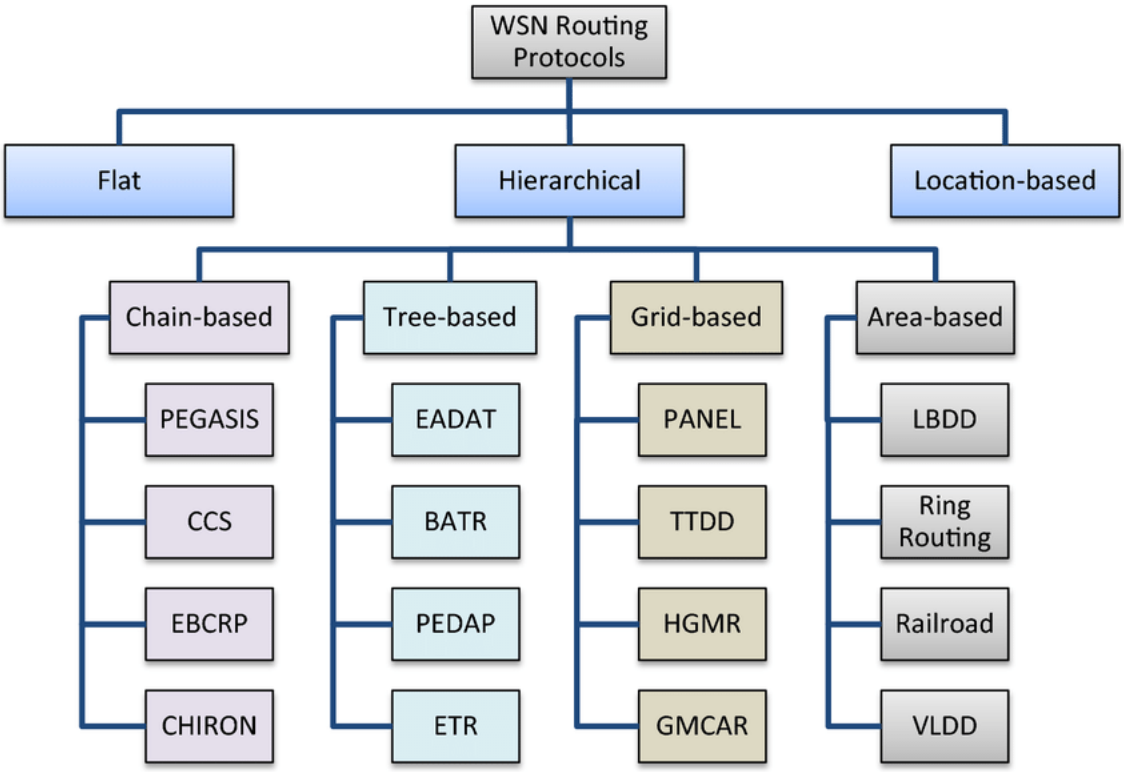

FIGURE 2. **Routing protocols classified by WSN**

- **Routing protocols based on flatness :** The same device node performs the sensing task on all other sensor nodes.
- **Protocols based on hierarchical structures :** Cluster heads (CH) serve as cluster heads (CH) for this type of routing, and lower-energy members (CM) collect data from the cluster heads. Members of the cluster send sensed data to cluster heads to reduce the number of messages sent to the sink. The rotation of cluster heads and clusters results in a more reliable and scalable clustered network.
- **Protocols for routing based on location :** Sensor nodes communicating with each other based on location are called this type of routing protocol. Estimating the distance between neighbouring nodes by analyzing the signal strength from the source or GPS (Global Positioning System) is possible.

4. METHODOLOGY

The LEACH [13] protocol aims to reduce wireless sensor network power consumption. Rotating CH selections is accomplished by using a random factor. There are two stages in the LEACH protocol: setup and steady state [10, 11]. First stage: Selection of CHs and clusters (groups of nodes). CHs announce themselves to other cluster members and assign each member a TDMA table [26]. An overview of LEACH's setup phase can be found in Figure 3.

The cluster's nodes determine the selected CH, which generates chance statistics from 0 to 1 during all rotund [27, 28]. The numbers created can be compared using a predefined reference number T(n). In the case where the reference number is greater than the random number, it is the CH that created the random number. Referencing number T(n) is calculated

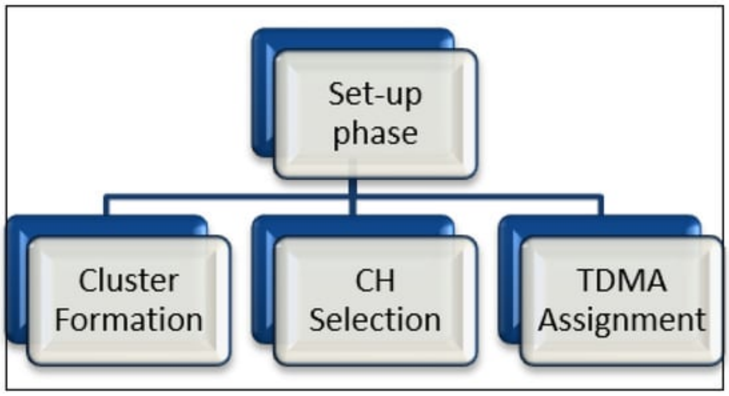

FIGURE 3. **During the setup phase.**

using equation 1 [26]:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times (r \, mod \dfrac{1}{p})} & : if\ n \in G \\ 0 & : otherwise \end{cases} \tag{1}$$

Although some G nodes were CHs during previous 1/p rounds, they are not now. In this way, the cluster receives equal energy from all nodes. When all CHs have been chosen, each node will determine which should be joined together to form a cluster [29]. A message is sent to all nodes by CH. Signal strength determines whether a node is connected to an advertising CH; the signal strength will be higher if it is close to the CH. The node must message the cluster leader to become a member. A timetable is then sent to other cluster members by the CH.

• **Z-SEP Operation**

Z-SEP transmits data to the base station using two different transmission techniques. Here are some techniques:

Direct Communication: Base stations receive data directly from Zone 0 nodes. The base station receives information about the environment directly from the sensor nodes.

Transmission via Cluster H ead: Clustering algorithms transmit data from headzones 1 and 2. Head Zone 1 contains cluster nodes, Head Zone 2 contains cluster nodes, and Head Zone 3 consists of cluster heads in Head Zone 2. Data is gathered, consolidated, and transmitted between cluster heads and base stations. Cluster heads should be selected carefully. As shown in Figure 1, there are two zones in the head. Clusters are only formed by nodes that have been pre-assigned. In the case of n advanced nodes, K_{opt} is clustering optimally. 80% is the expected probability for cluster heads, according to SEP

$$P_{opt} = \frac{K_{opt}}{n} \tag{2}$$

Each node decides the current round's cluster head. Node numbers are generated among 0 and 1. The cluster head should be selected if T(n) equals or is less than this random number. Assume that T(n) is equal to

$$T(n) = \begin{cases} \dfrac{P_{opt}}{1 - P_{opt}(r \times mod \dfrac{1}{P_{opt}}} & if\ n \in G \\ 0 & otherwise \end{cases} \tag{3}$$

In the last $1/P_{opt}$ round, which nodes did not serve as cluster heads. An algorithm is proposed for calculating the probability that advance nodes will become cluster heads.

$$p_{adv} = \frac{P_{opt}}{1 + (\propto .m)} \times (1 + \propto) \tag{4}$$

Therefore, advance nodes must meet the following threshold

$$T(adv) = \begin{cases} \dfrac{Padv}{1 - Padv\left(r \times \text{mod} \dfrac{1}{Padv}\right.} & \text{if } n \in G' \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

During the last $\frac{1}{Padv}$ Round, there have not been any advance nodes referred to as G' as cluster head.

Cluster heads broadcast advertisement messages once they are selected. The cluster head assigns nodes that receive a migration around it. Cluster formation is the term used to describe this phase. A node's signal strength depends on whether it is included in the cluster head. The cluster head assigns nodes a TDMA period once the schedule is determined. Data is transmitted from nodes to the cluster head during their assigned timeslots. Sensor nodes are demonstrated in Figure 4 in the square. A normal node is blue, while an advanced node is green.

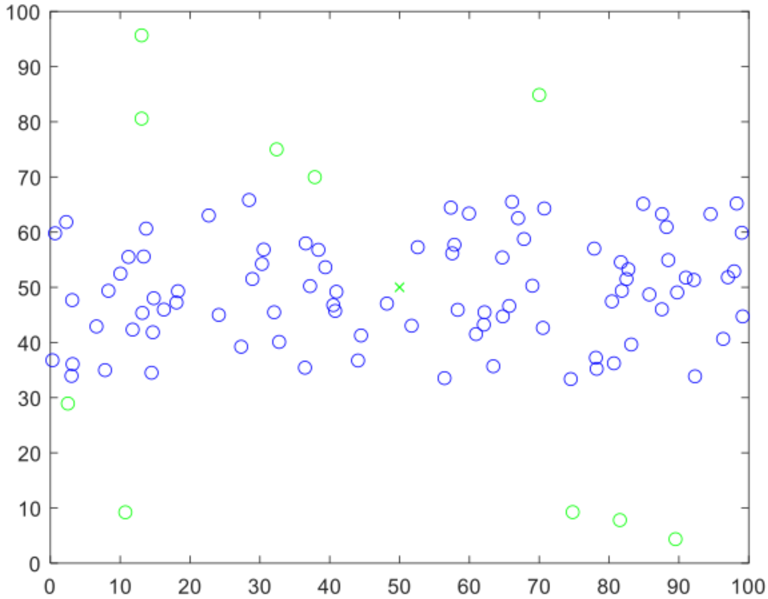

FIGURE 4. Sensor nodes deployment randomly in the 100 X 100 square areas.

As data is transmitted, a cluster head collects and aggregates it. In Zone 0, normal nodes have less energy, while cluster heads consume more energy gathering data from cluster members, so nodes not in Zone 0 cannot form clusters. It shortens the stability period of nodes that are not cluster heads. Figure 5 illustrates Z-SEP's operation.

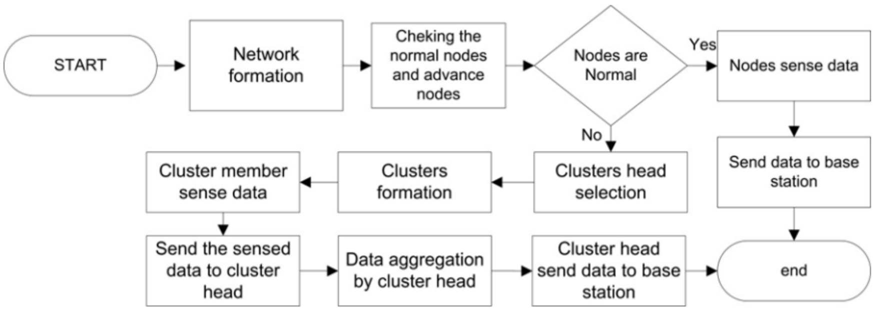

FIGURE 5. Flowchart of Z-SEP routing protocols.

• **Communication Model**

Here, we use a homogeneous environment model instead of a heterogeneous one [30]. In our proposal, data communication [31] comprises hierarchical clustering [32] and combined into a hybrid protocol. Cluster members are selected based on the received signal strength. Our radio model was the same as in [30]. In the proposed protocol, Figure 6 shows a communication module.

The free-space model will be considered whenever distances between cluster heads and associated nodes are short. In contrast, the multipath fading model will be considered when distances between cluster heads and associated nodes are longer [33]. Remote sensor nodes can be connected using a power formula [4, 5]:

$$E_{TX}(k,d) = E_{TX_{elec}}(k) + E_{TX_{amp}}(k,d) \tag{6}$$

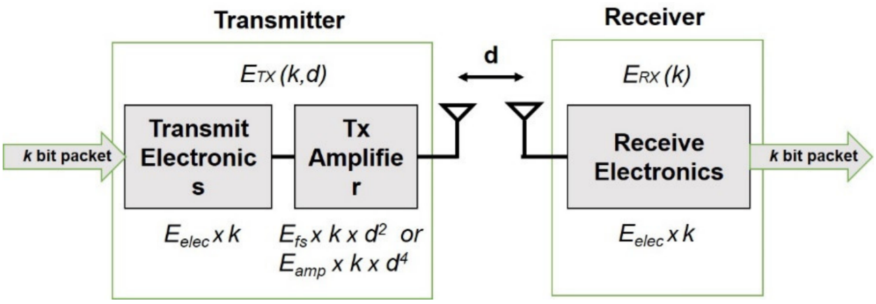

FIGURE 6. **Radio communication model.**

$$E_{TX} = \begin{Bmatrix} E_{elec} * k + E_{fs} * k * d^2, & d \leq d_0 \\ E_{elec} * k + E_{amp} * k * d^4 & d > d_0 \end{Bmatrix} \tag{7}$$

$$E_{RX}(K) = E_{RX_{elec}}(K) + KE_{elec} \tag{8}$$

$$d_0 = \sqrt{\frac{E_{fs}}{E_{amp}}} \tag{9}$$

As a result of this equation, the Euclidian distance is the distance between the sender and the receiver. E_{elec} . To receive k bits of data, the receiver must consume energy per bit, and radio modules consume a lot of power E_{elec}. Multipath fading amplifiers' energy output, as well as the amount of free space, respectively, are E_{f_s} and E_{amp}.

5. RESULT ANALYSIS & DISCUSSION

Based on MATLAB 2015a simulations, the Z-SEP, SEP and LEACH protocols have been simulated. Table 2 identifies the parameters for each protocol. Furthermore, we tested the presentation of these protocols on small networks with a small number of nodes and large networks with many nodes. A Packet-to-BS test was conducted, as well as tests on Dead nodes and Alive nodes. Here are the initial values for the SEP, LEACH, and Z-SEP parameters in Table 2. Table 2 provides the initial values for the SEP, LEACH, and Z-SEP parameters.

Table 2. **Simulation Parameters.**

Parameters	**Value**
$No.\ of\ round\ (R)$	2500
P	0.2
m	0.1, 0.2
a	1, 2
$E_{TX}\ or\ E_{RX}$	50nj/bit
ϵ_f	10pj/bit/m^2
E_{elec}	5nj/bit/message
ϵ_m	0.0013pj/bit/4
No. of Sensor (N)	200
Packet Size	4000 bits

An experimental wireless sensor network clustered in an area of (100 100) m^2 has been simulated. A total of 100 sensors are connected to the network. Over the field, nodes are distributed randomly. A far distance was maintained between all nodes and the BS. As close as possible to the closest sensor node, the BS should be at least 50m away.

In Figures 7-9, we can see that the Z-SEP stability period is almost identical for 99 nodes in the number of sensor networks than for 99 nodes in the number of sensor networks for SEP and LEACH with 100 nodes in the number of sensor networks. Advance nodes have more energy, which lengthens the network's lifetime even though they have the

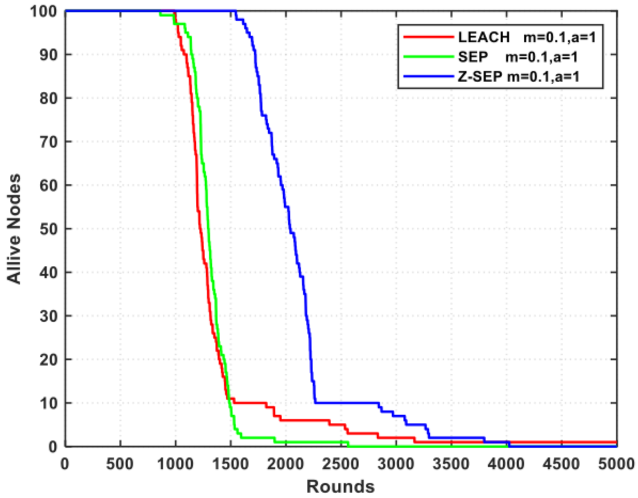

FIGURE 7. Alive sensor nodes versus number of rounds at m=0.1 and a=1.

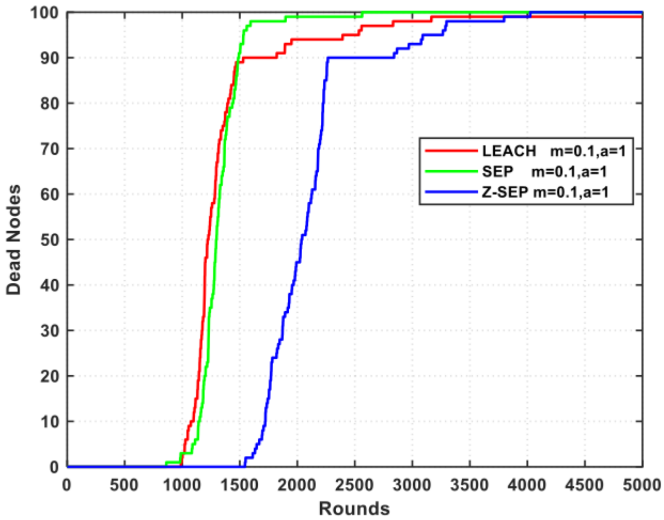

FIGURE 8. Graph showing dead sensor nodes at m=0.1 and a=1 compared to the number of rounds.

same energy as normal nodes. LEACH's instability period is shortened because of its sensitivity to heterogeneity. In LEACH, more energy was not distributed evenly like in SEP because there were no weighted probabilities. There is an equal chance for every node to become a cluster head in LEACH, so standard nodes die earlier than advanced ones.

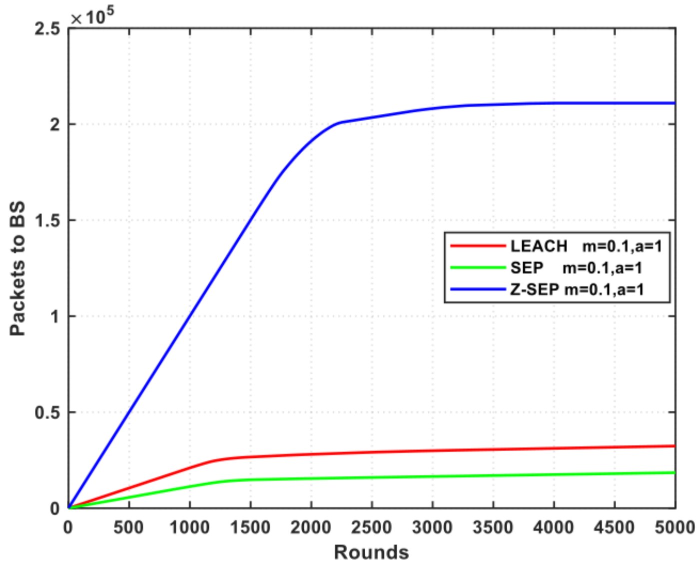

FIGURE 9. **A curve plotting packets to BS against rounds with a value of 1 and m=0.1.**

According to Figures 10-12, the Z-SEP stability period is nearly the same for cases with 100 nodes in the number of sensor networks (m=0.2, a=2) as it is for cases with SEP and LEACH. This recreation analyses LEACH and Z-SEP reliability time and their system lifetime. Nodes have developed within the head-boosted zone 1 and zone 2 as well as within the head-boosted zone 3. Compared with LEACH and SEP, Z-SEP is indisputably more accurate.

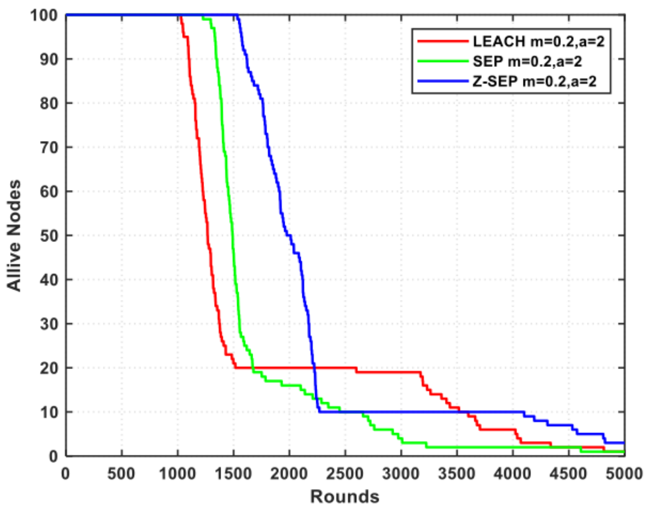

FIGURE 10. **At m=0.2 and a=2, live sensor nodes versus number of rounds.**

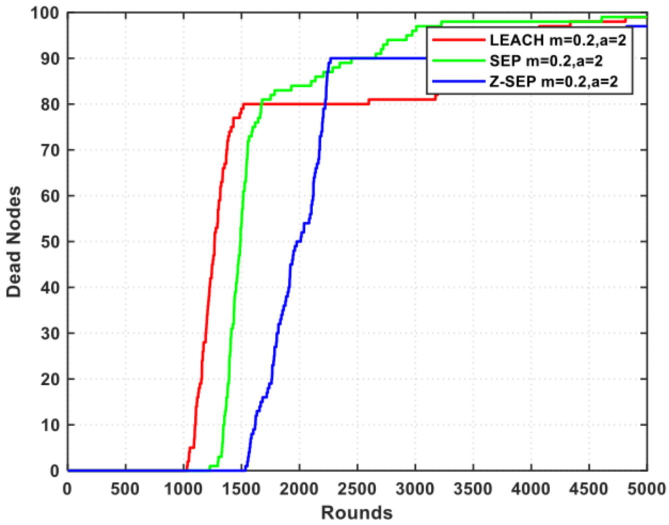

FIGURE 11. **Using m=0.2 and a=2, the number of dead sensors is compared with the number of rounds.**

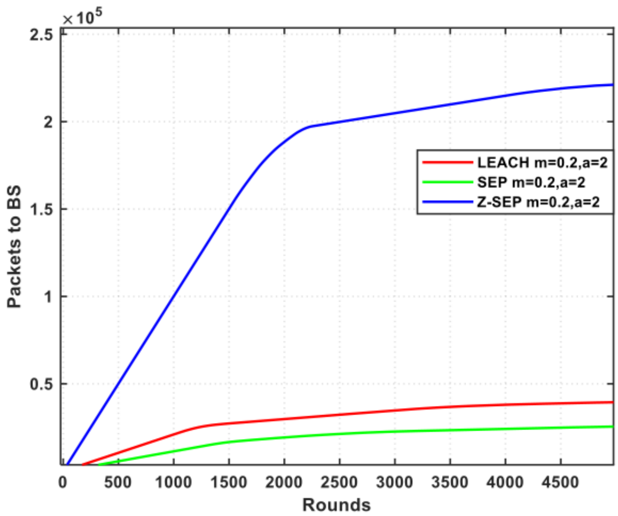

FIGURE 12. **With m=0.2 and a=2, BS packets correlate with rounds.**

6. CONCLUSION

An innovative protocol for introducing heterogeneous nodes into networks is proposed in this paper. In our protocol, we propose two regions for sensing. Normal or advanced nodes are contained in each region. A low-energy node near the base station receives the signal. Data is then transmitted directly from these nodes to the BS. The network's edge is home to advanced nodes. CHs must transmit BS data in this region. The Z-SEP protocol is a hierarchical cluster-based heterogeneous routing protocol using zonal stabilization election protocols (Z-SEPs). According to Z-SEP, nodes communicate directly with the BS rather than sending their data through clustering. Comparing Z-SEP with LEACH, its throughput is much higher. In the future, our new transmission control protocol Z-SEP can also extend to support more rounds to provide more energy efficiency and lifetime for WSN scenarios.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

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