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Maximizing the Lifetime of Wireless Sensor Network Using Z-SEP

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Abstract— The Wireless Sensor Networks (WSNs) are comprised of thousands of sensor nodes, with restricted energy, that co-operate to accomplish a sensing task. Reducing the energy consumption of available resources is still a problem to be solved in Wireless Sensor Networks (WSNs). Many types of existing routing protocols are developed to save power consumption. In these protocols, cluster-based routing protocols are found to be more energy efficient. A cluster head is selected to aggregate the data received from root nodes and forwards these data to the base station in cluster-based routing. The selection of cluster heads should be efficient to save energy.

The proposed protocol is a hybrid routing protocol: Zonal-Stable Election Protocol (Z-SEP) for heterogeneous WSNs. In this protocol, some nodes transmit data directly to base station while some use clustering technique to send data to base station as in SEP. We implemented M-SEP and compared it with traditional Low Energy adaptive clustering hierarchy (LEACH) and SEP. Simulation results showed that Z-SEP enhanced the stability period and throughput than existing protocols like LEACH and SEP.

Keywords— Z-SEP, LEACH, Throughput, WSN, heterogeneity, Clusterhead

I. INTRODUCTION

In recent years, researchers have been attracted by Wireless Sensor Networks (WSNs) due to their potential use in a wide variety of applications. Initially WSNs were used only in the battlefields for military purposes but now their use is extended for monitoring and controlling the different processes in many other civilian areas. A WSN contains different types of autonomous sensor nodes that are used to sense and transfer the data wirelessly to the base station or the next receiver node. Typically hundreds or thousands of low cost sensors are used in WSNs . The technology advancements made it possible to reduce the cost and the size of the electronic devices. A wide range of sensors are available to monitor the different ambient conditions such as temperature, pressure, humidity, movement, and lightening conditions. Low cost and smaller size of sensor nodes does not allow the use of the large battery source. The required lower energy consumption restricts the sensor to use the limited resources such as less memory capacity, low transmit power, and less processing computations. Other than data communication, a periodic routing protocol transmission is required to update the sensor's routing table. The selection of a proper routing protocol can help to prevent the excessive use of routing updates. The goal of this research is to find an energy efficient routing protocol for Wireless Sensor Networks.

II. WIRELESS SENSOR NETWORKS

The challenges and characteristics of WSNs are different than the conventional Wireless Ad-hoc Networks (WANETs) due to their specific requirements. Therefore, the designing task of a routing protocol in WSNs requires more careful considerations than the other wireless ad-hoc networks (MANETs or WMNs). The issues to consider for an efficient and reliable communication in WSNs include network topology, data reporting methods, node and link heterogeneity, mobile adaptability, energy efficiency, coverage, data aggregation, and quality of service. Some of the protocols are as follows

A. LEACH

The LEACH protocol is the basic clustering-based energy-efficient routing protocol. The clustering techniques proved to be very useful to reduce the energy consumption and increase the network lifetime. The entire network is divided into clusters in the LEACH routing protocol. One sensor node in each cluster must act as a cluster head and all remaining sensor nodes are member nodes of that cluster. Communication between the member nodes and sink is only possible via the cluster head. From each cluster, only the cluster head can directly communicate with the sink. The cluster heads collect, aggregate, and forward the data from member nodes to the sink. The cluster head consumes more energy due to the additional functions and this node can die quickly if it continuously plays the role of a cluster head. LEACH resolved this problem by changing dynamically the role of nodes as cluster heads. LEACH works in rounds. The operations that are carried out in each round consist of two phases known as setup and steady state phases. The organization of clusters and selection of cluster heads (CHs) are done in the setup phase of the LEACH. The data are sent to the sink during the second or steady state phase. In the setup phase, the formation of clusters and the election process of cluster heads are performed. First of all, the whole network is divided into clusters. Now the cluster head election process starts in each cluster. There are many ways to elect the CH. Some of the wireless nodes in the network ignore the negotiation process with other nodes and elect themselves autonomously as CHs. The CH selection criteria of a member node are the recommended percentage P and the earlier record as a CH. If a node is not a CH in preceding 1/P rounds, it produces a number between zero and one (0-1). Only nodes with a generated number less than threshold T (n) are eligible to become CHs. The formula used to calculate the value of threshold is given in equation below.

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

$$=1 \qquad Otherwise$$

where
G = Group of nodes not selected as CHs in preceding 1/p rounds;
P = Recommended percentage of CH;
r = Current round.

B. Stable Election Protocol

Most of the hierarchical routing protocols such as LEACH consider the homogeneous nodes with respect to their energy in the WSNs. The nodes selected as CH consumes more energy due to performing additional functions that results in early death of these nodes. The stability region, time interval before the death of first node, is low in these protocols. SEP provides a mechanism for using the heterogeneous nodes, a percentage of nodes with higher initial energies, in WSNs which increases the stability region. The nodes with higher initial energies are called advanced nodes. SEP considers the weighted election probabilities of the nodes in which the advanced as well as normal nodes are selected as cluster heads to ensure the balanced energy consumption. The residual energy is used as a parameter for the selection of the cluster heads. The additional energy of the advanced node helps to prolong the network lifetime. As compare to other protocols, the death of first node in SEP occurs after more rounds which results in higher stability region.

III. ZONAL STABLE ELECTION PROTOCOL(Z-SEP)

A. Network Architecture

In most routing protocols, nodes are deployed randomly in network field and energy of nodes in network is not utilized efficiently. A modification is made to this theme: network field is divided in three zones: zone 0, Head zone 1 and Head zone 2, on the basis of energy levels and Y co-ordinate of network field.

It's been that a fraction of the total nodes are equipped with more energy. Let m be fraction of the total nodes n, which are equipped with α time more energy than the other nodes. We refer these nodes as advance nodes, (1-m)×n are normal nodes.

Zone 0: Normal nodes are deployed randomly in Zone 0, lying between $20<Y<=80$.
Head zone 1: Half of advance nodes are deployed randomly in this zone, lying between $0<Y<=20$.
Head zone 2: Half of advance nodes are deployed randomly in Head Zone 2, lying between $80<Y<=100$.

The reason behind this type of deployment is that advance nodes have high energy than normal nodes. As corners are most distant places in the field, so if a node is at corner then it requires more energy to communicate with base station so we have deployed high energy nodes (advance nodes) in Head zone 1 and Head zone 2.

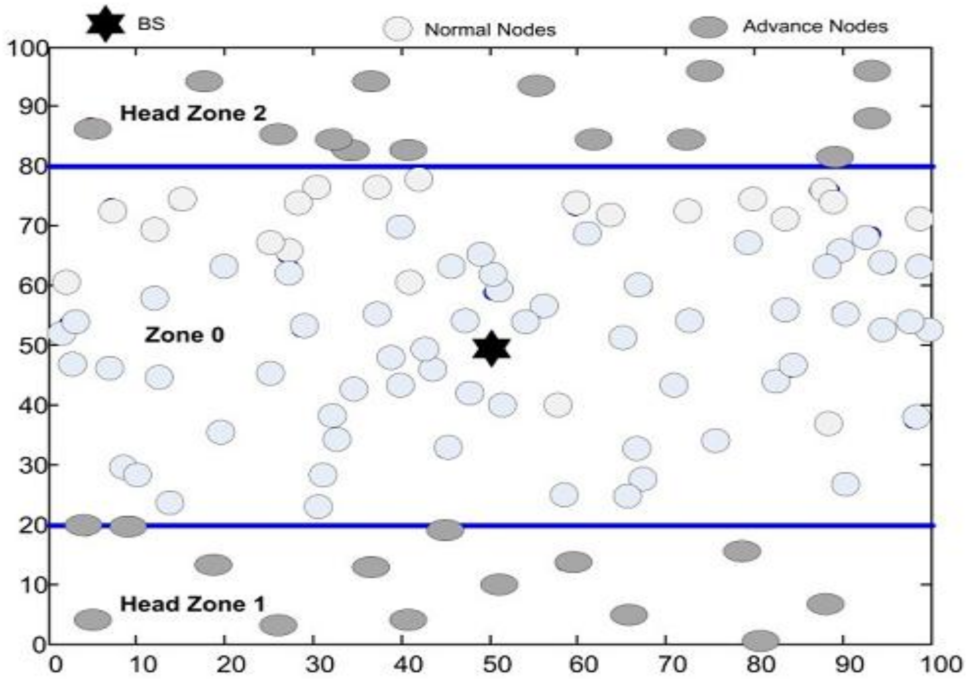

Fig 1: Network Architecture

B. Operation

Z-SEP uses two techniques to transmit data to base station. Techniques are:

- Direct communication.
- Transmission via Cluster head.

Direct Communication:

Nodes in Zone 0 send their data directly to base station. Normal nodes sense environment, gathers data of interest and send it data directly to base station.

Transmission via Cluster head:

Nodes in Head zone 1 and Head zone 2 transmit data to base station through clustering algorithm. Cluster head is selected among nodes in Head zone 1 and Head zone 2. Cluster head collect data from member nodes, aggregate it and transmit it to base station. Cluster head selection is most important. As shown in Fig.1 advance nodes are deployed randomly in Head zone 1 and Head zone 2. Cluster is formed only in advance nodes. Assume an optimal number of clusters Kopt and n is the number of advance nodes. According to SEP optimal probability of cluster head is

$$P_{opt} = \frac{K_{opt}}{n} \qquad (2)$$

Every node decides whether to become cluster head in current round or not. A random number between 0 and 1 is generated for node. If this random number is less than or equal threshold T(n) for node then it is selected as cluster head. Threshold T(n) is given by

$$T(n) = \frac{P_{opt}}{1 - P_{opt}(r * mod \frac{1}{P_{opt}})} \qquad If\ n \in G \qquad (3)$$

$$= 0 \qquad Otherwise$$

Where,

G is the set of nodes which have not been cluster heads in the last 1/Popt rounds.

Probability for advance nodes to become cluster head is

$$P_{adv} = \frac{P_{opt}}{1 + \alpha * m} * (1 + \alpha) \qquad (4)$$

Accordingly the threshold for advance nodes is,

$$T(adv) = \frac{P_{adv}}{1 - P_{adv}(r * mod \frac{1}{P_{adv}})} \qquad If\ n \in G$$

$$= \quad 0 \qquad Otherwise$$

G' is the set of advance nodes that have not been cluster head in the last 1/Padv rounds. Once the cluster head is selected then the cluster head broadcasts an advertisement message to the nodes. The nodes receive the message and decide to which cluster head it will belong for the current round. This phase is called as cluster formation phase. On the basis of received signal strength, nodes respond to cluster head and become member of cluster head. Cluster head then assign a TDMA schedule for the nodes during which nodes can send data to cluster head. After the clusters formation, every node data and sends it to the cluster head in the time slot allocated by the cluster head to the node. This phase is shown in Fig.

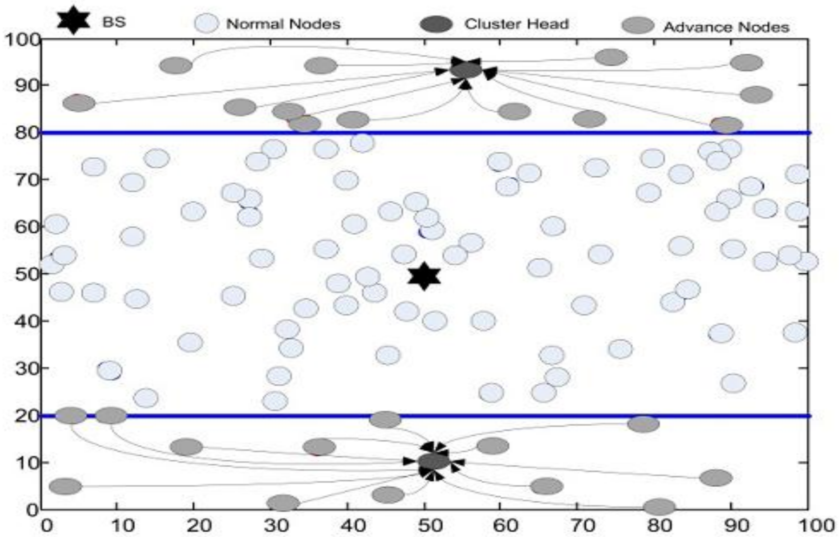

Fig. 2: Nodes sending data to cluster

When data is received from nodes, Cluster head then aggregates this data and send it to the base station this phase is called as transmission phase. Fig.3 illustrates this phase.

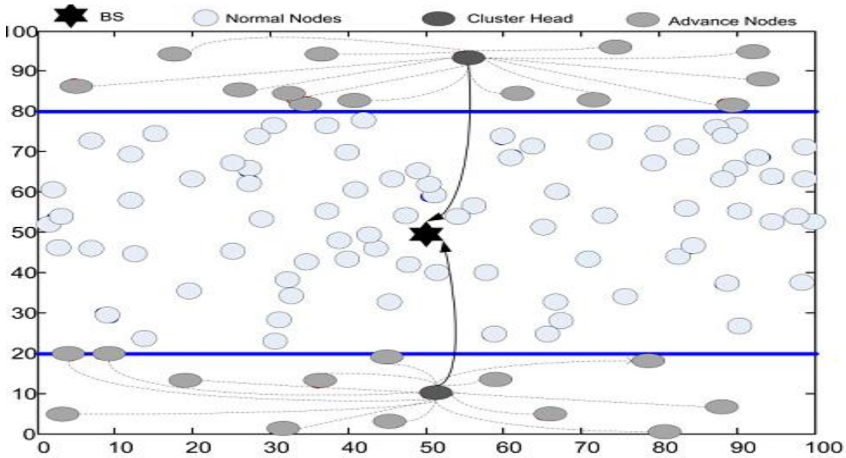

Fig. 3: Cluster head Sending Data to Base Station

The reason why normal nodes (deployed in Zone 0) do not form cluster is because energy of normal node is less than advance node, and cluster head consumes more energy than cluster members in receiving data from cluster members. If we allow normal nodes to become cluster head they die soon resulting in the shortening of stability period. Fig.4 illustrates Z-SEP operation.

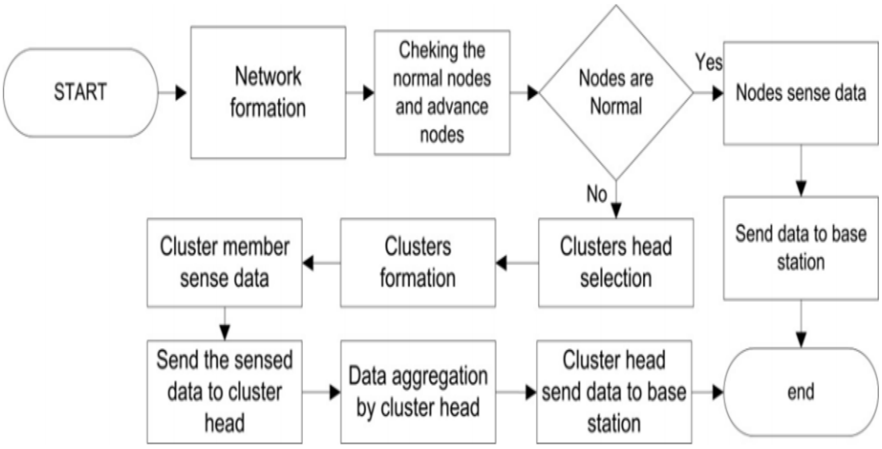

Fig 4: Flowchart of Z-SEP

IV. SIMULATIONS AND RESULTS

The protocol is simulated in a field with dimensions 100m×100m and 100 nodes deployed in specific zones with respect to their energy. Base station is placed in the center of the network field. The first order radio model as used in SEP is used. MATLAB is used to implement the simulations. Some of the assumptions are as followed.

Let 20% of nodes are advance nodes and half of them are deployed in Head zone 1 and half in Head zone 2.since Popt is 0.1 so there are 2 cluster heads per round. One cluster head in Head zone 1 and one in Head zone 2 per round.

Other simulation parameters are shown in Table 1

TABLE I
SIMULATION PARAMETERS

Parameters	***Value***
Initial Energy E_0	0.5*J*
Initial energy of advanced nodes	$E_0(1+\alpha)$
Energy for data aggregation E_{DA}	5*nJ/bit/signal*
Transmitting and receiving energy	5*nJ/bit*
Amplification energy for short distance	$10pJ/bit/m^2$
Amplification energy for long distance E	$0.013pJ/bit/m^4$
Probability P_{opt}	0.1

Here, the results of Z-SEP with SEP and LEACH are compared. Heterogeneity is introduced in LEACH, with the same setting as in proposed protocol, so as to access the performance of all the protocol in presence of heterogeneity. The goals in conducting simulation are

- To examine the stability period of LEACH, SEP and Z-SEP.
- Also the throughput of LEACH, SEP and Z-SEP.

Fig.5 and Fig.6 shows result for the case when m=0.2 and α=1.

This means that there are 20 advance nodes out of total nodes which are 100. According to the implemented protocol 10 advance nodes will be deployed randomly in Head zone 1 and 10 advance nodes are placed in Head zone 2. Fig.5 shows the number of alive nodes against rounds. Fig.5 clearly shows that Z-SEP protocol is enhanced from SEP and LEACH in terms of stability. As LEACH is very sensitive to heterogeneity so nodes die at a faster rate.

SEP performs better than LEACH in two level heterogeneity, because SEP has weighted probability for selection of cluster head for both normal nodes and advance nodes. Z-SEP performs better than LEACH and SEP, because nodes in Zone 0 (normal nodes) communicates directly to base station while nodes in head zone 1 and head zone 2 communicates via cluster head to base station: As in clustering technique, cluster head consumes energy in the form of data aggregation and also by receiving data from nodes in the cluster. So this energy is conserved in normal nodes as they do not have to aggregate data and receive data from other nodes, so energy is not dissipated as that of cluster head, resulting in the increase of stability period. In Fig.5, it can be seen that network lifetime is also increased because of the advance node. Advance nodes have α time more energy than normal nodes so advance nodes die later than normal nodes. So this increases the instability period.

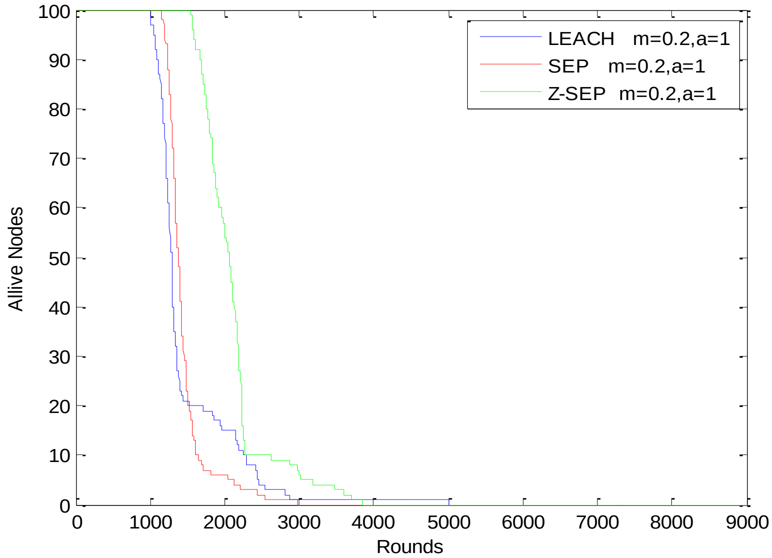

Fig 5: Alive nodes in LEACH, SEP and Z-SEP

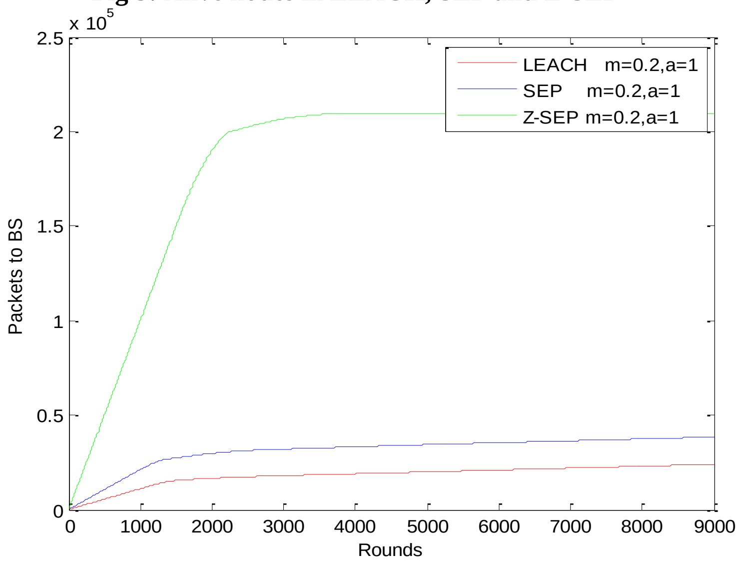

Fig 6: Throughput of LEACH, SEP and Z-SEP

Fig.6 shows that the throughput of Z-SEP is far better than LEACH and SEP because every normal directly send data to base station. Throughput of LEACH and SEP is less than Z-SEP because only cluster head send data to base station.Fig.7 and Fig.8 shows result for the case when m=0.1 and α=2. There are total 10 advance nodes in the field, 5 nodes in Head zone 1 and 5 nodes in Head zone 2. However there energy is increased i.e. α=2.

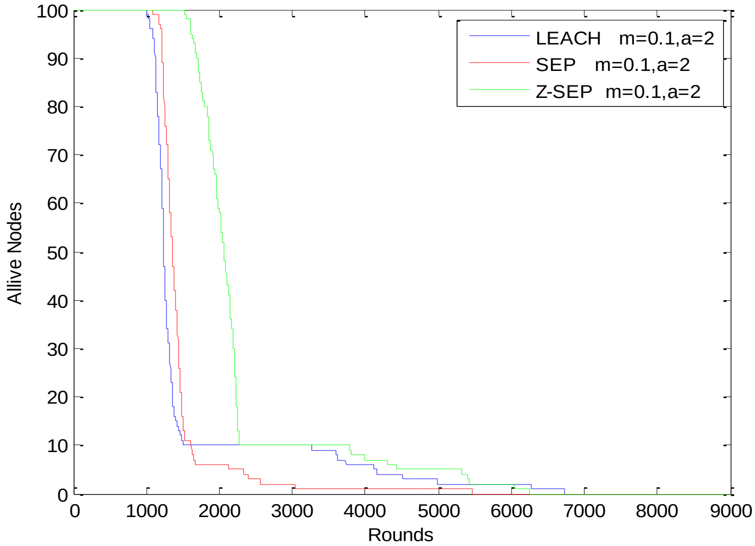

Fig. 7: Alive nodes in LEACH, SEP and Z-SEP

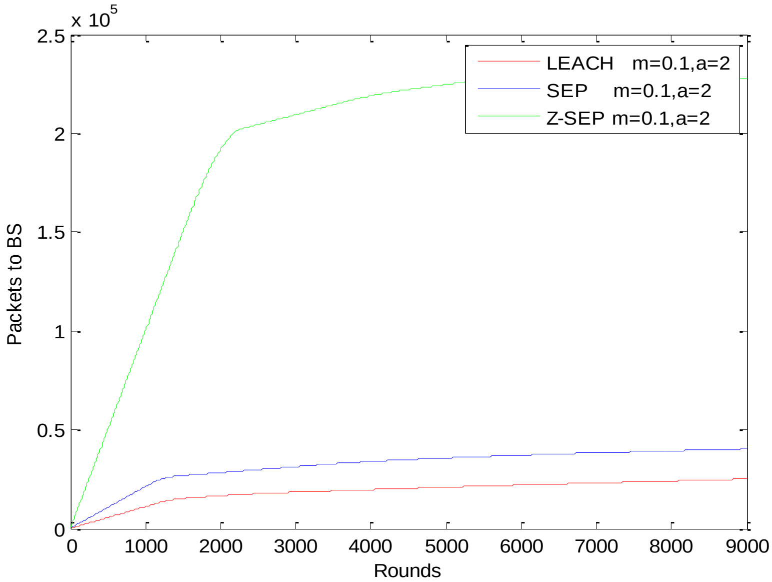

Fig. 8 Throughput of LEACH, SEP and Z-SEP

From Fig.7, it can be seen that stability period of Z-SEP is almost same for both cases i.e. (m=0.2, α=1 and m=0.1, α=2). The reason behind is that normal nodes have same amount of energy, they consume same amount of energy and they die almost at the same time as before, however network lifetime is increased because of the extra energy of advance nodes. Stability period of LEACH is decreased because LEACH is very sensitive to heterogeneity. LEACH does not have weighted probability as in SEP for even distribution of extra energy. In LEACH every node has equal chance to become cluster head so normal nodes die sooner than advance nodes.

Fig.8 shows the throughput of LEACH, SEP and Z-SEP. Throughput of Z-SEP is greater than LEACH and SEP although energy of advance node has been increased.

TABLE III
Comaprison Table when m=0.2 and α=1

Protocol	Stability period(Rounds)	Network Lifetime(Rounds)	Throughput (Packets)
LEACH	1018	4685	1.99×10^4
SEP	1089	3005	3.43×10^4
Z-SEP	1531	4119	2.21×10^5

TABLE IIIII
Comaprison Table when m=0.1 and α=2

Protocol	**Stability period(Rounds)**	**Network Lifetime(Rounds)**	**Throughput (Packets)**
LEACH	899	5583	2.44×10^4
SEP	1150	5078	4.02×10^4
Z-SEP	1584	5966	2.26×10^5

V. CONCLUSIONS

The In this paper, I implemented Z-SEP for heterogeneous environment: two level heterogeneity. The field is divided in to three zones: Zone 0, Head Zone 1 and Head Zone 2. Normal nodes are only deployed in zone 0 to reduce the energy consumption and they transmit data directly to base station. Half of advanced nodes are deployed in Head zone 1 and half in Head zone 2 and they use clustering technique to transmit data to base station. Results have shown that the stability period is increased approximately 50%, by just altering the deployment of the different type of nodes in different zones according to their energy requirement. Throughput of Z-SEP is also increased compared with LEACH and SEP.

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