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An Enhanced Stable Election Protocol for Wireless Sensor Networks

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ABSTRACT

With the advancement in technology wired communication is becoming wireless. Wireless communication is sometimes runs through sensors and defined as wireless sensor network. Wireless sensor network is created using battery operated nodes known as motes. Thus it becomes important to preserve battery power, and to do so various protocols are proposed in past. These protocols can be used in various applications like: military applications, agriculture, humidity, temperature etc..

In WSNs different nodes sensed data and gathered information is send to the sink. In sensor nodes energy is dissipated in sensing, transmission and reception. In WSN practically it is not possible to replace batteries once nodes are deployed. Thus to save battery power various routing protocols are proposed. In this work, further enhancement is proposed in Stable Election Protocol. Recently Zonal Stable Election Protocol was proposed, where normal and advance nodes are distributed in different zones. In this work, we optimized the size of zones to obtain better stability period, network lifetime and throughput. We further propose to use intermediate nodes and more number of zones to enhance the performance further. Results are obtained through computer simulations using MATLAB.

Keywords: *Throughput, Stability period and SEP etc...*

1. INTRODUCTION

Latest developments in micro-electro-mechanical systems, highly integrated digital electronics and low power have guided us to the development of micro-sensors [1–5]. These kinds of sensors are normally has capabilities of data processing and communication. The sensing circuitry estimates ambient conditions concerned with the environment around the sensor and changes them them into an electric signal. Processing such kind of signal uncovers certain characteristics about objects situated and/or events going on in the region of the sensor. The sensor transmits such collected data, more often through radio transmitter, to a command center (sink) either by means of a data concentration center (a gateway) or directly. The reduction in the cost and size of sensors, resulting from these sorts of technological developments, has energized interest in the possible application of vast set of disposable unattended sensors. This interest has encouraged intensive research in the previous couple of years addressing the potential of collaboration among sensors in data collection, processing and the coordination and management of the sensing activity and flow of data to the sink. A characteristic architecture for such collaborative distributed sensors is a network with wireless links that can be developed among the sensors in a specially patterned way.

It is expected that networking unattended sensor nodes have noteworthy effect on the effectiveness of numerous military and common applications for example combat field security, surveillance, and disaster management. In these systems, the collected data is processed from various sensors to monitor occasions in an area of interest. Let use assume that in a setup of disaster management, a great number of sensors can be placed with the help of a helicopter. With the Networking of these sensors, we can have a great assistance in rescue operations by discovering survivors, distinguishing unsafe areas and making the rescue crew more mindful of the whole circumstance. These kinds of utilization of sensor networks not just can enhance the effectiveness of rescue operations additionally makes sure the safety of the rescue crew. As far as the military side is concerned, uses of sensor networks are various. Moreover, sensor networks can empower a more general use of landmines by making them remotely controllable and target particular keeping in mind the end goal to avoid harming animals and human beings. Security applications of sensor networks incorporate intrusion detection and criminal hunting.

2. RELATED WORK

LEACH is a progressive clustering algorithm for sensible utilization of energy in the network. The randomized rotation of the local cluster head is used by LEACH [4]. It works quite effectively in homogeneous conditions. In LEACH each node contains same likelihood to turn out a cluster head. Though, it is not effective for heterogeneous conditions.

As far as SEP is concerned, it is a two stage heterogeneous protocol presenting two kinds of nodes [5]. These nodes are advance nodes and normal nodes. The energy of advance nodes exceeds as compared to normal nodes. Both nodes (normal and advance nodes) in SEP have weighted probability to transform into cluster head. Advance nodes contain high chances to be turned out as cluster head in comparison to normal nodes. SEP doesn’t ensure proficient deployment of nodes. For Distributed Energy-Efficient Clustering Protocol (DEEC) indicates multilevel heterogeneity [6]. In this, formation of the cluster head is on the basis of the node’s residual energy and average energy of the network. In addition, in DEEC, it is more likely that the high energy node turns out to be cluster head as compared to low energy node. Normal nodes and advance nodes in SEP are deployed in a random way. In the event a major number of normal nodes are

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deployed at a great distance from base station, more energy will be consumed during the transmission of data which consequently shorten the stability period and diminishing in throughput. Therefore, efficiency of SEP decreases. In order to overcome these defects, we classify network field in zones. Due to the fact that corners are highest inaccessible areas in the field where more energy is required by nodes for the transmission of data to base station, normal nodes are put closer to the base station and in this way they can transmit their data to base station directly. Still, advance nodes are deployed at far distance from base station because they have more energy. In the case data is transmitted directly by the advance nodes to base station more energy is consumed. Therefore in order to save energy of advance nodes, clustering process is used just for advance nodes.

In a great number of routing protocols, nodes are being deployed in a random manner in network field and energy of nodes in network is not utilized in an efficient manner. Theme is modified in zonal stable protocol: network field is classified in three zones [7]. These are zone 0, Head zone 1 and Head zone 2, and this is classified on the basis of level of energy and Y co-ordinate of network field.

We take the assumption that a small measure of the whole nodes is equipped with greater energy. Suppose *m* as that small measure of the total nodes *which* consist of α time more energy in comparison of other nodes. We allude these nodes as advance nodes, $(1\text{-}m)\times n$ 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.

This kind of deployment is because the advance nodes are equipped with high energy than normal nodes. Due to the fact that corners are greatest distant places as far as the field is concerned, thus if a node is placed at corner then it needs more energy in order to communicate with base station hence we need to deploy high energy nodes (advance nodes) in Head zone 1 and Head zone 2.

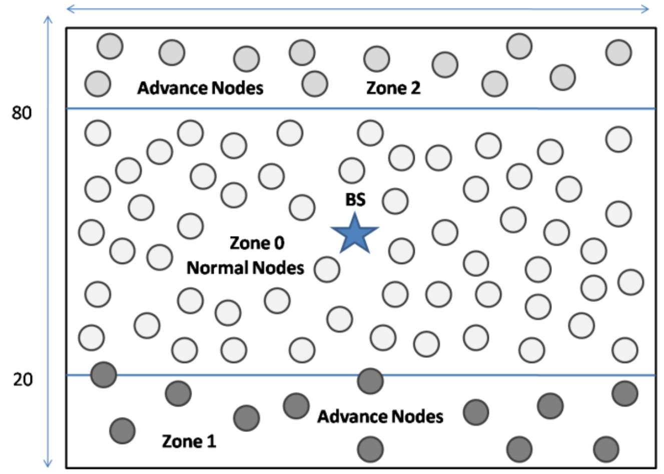

Figure 1 Network Architecture

Z-SEP Operation

Z-SEP makes use of two methods to transmit data to base station. Methods are:

• Direct communication.

• Transmission via Cluster head.

Direct Communication:

Nodes in Zone 0 transfer their data to base station directly. Normal nodes sense conditions, collects data of interest and transfer it directly to base station.

Transmission via Cluster head:

Nodes that lie in Head zone 1 and Head zone 2 transmit information to base station by means of clustering algorithm. Among nodes of Head zone 1 and Head zone 2, Cluster head is chosen. Cluster head gather data from member nodes collect it and send it to base station. The selection of Cluster head is quite vital. Fig.1 shows the deployment of advance nodes in random way in Head zone 1 and Head zone 2. The formation of Cluster is possible only in advance nodes. Let us take an optimal number of clusters *Kopt* and *n* as the quantity of advance nodes. As per the SEP optimal probability of cluster head is

$$P_{opt} = \frac{K_{opt}}{n} \qquad (1)$$

Each node makes the decision whether to turn out as a cluster head in present round or not. For node, a random number is developed between 0 and 1. In the case of this random number is equal or less than threshold *T(n)* for node at that stage it is chosen as cluster head. Threshold *T(n)* is given by

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

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

Probability for advance nodes to turn out to be cluster head is proposed in [33] which is

$$P_{adv} = \frac{P_{opt}}{1+\alpha.m}(1+\alpha) \qquad (3)$$

As per the threshold for advance nodes is

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

G' is the set of advance nodes that have not been cluster head in the last 1/Padv rounds.

After the selection of the cluster head, the cluster head shoots a message to the nodes. The message is received by the nodes and they makes the decision to which cluster head it will go for the present round. This stage or phase is known as *cluster formation phase.*

According to the strength of received signal, nodes give response to cluster head and join cluster head as a member. Cluster head at this moment assign a TDMA format for the nodes at the time in which nodes can transfer data to cluster head. After the formation of clusters of each node data, transfer the data to the cluster head within the time slot fixed by the cluster head to the node. Fig. 2 illustrates this phase.

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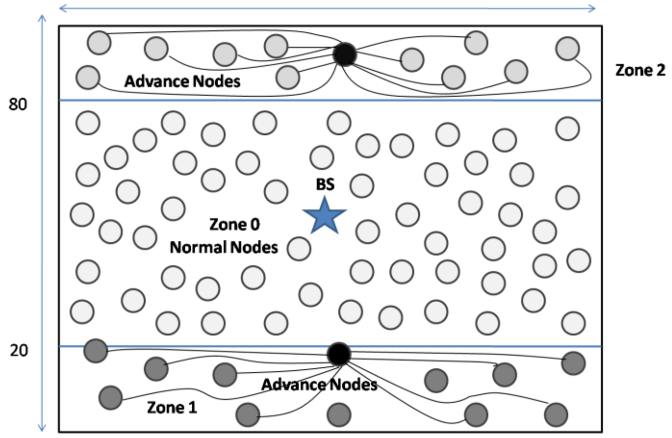

Figure 2 Data transmission to cluster head by various nodes

At the moment, data reached from nodes, Cluster head collects this data and transmit it to the base station. Now this phase is termed as *transmission phase as shown by* Fig.3.

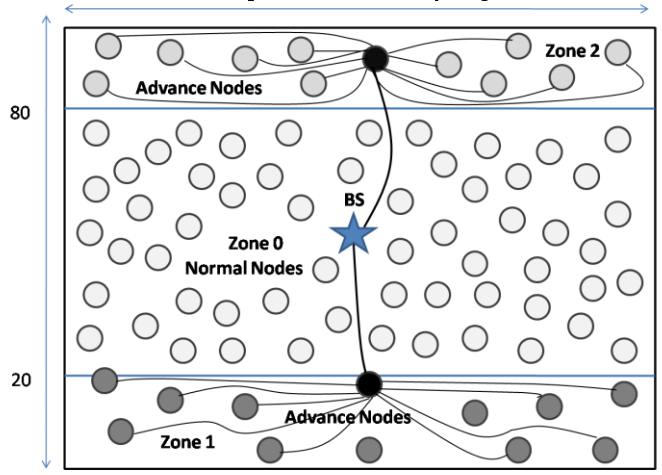

Figure 3 Data transmission for cluster head to base station

3 RADIO MODEL

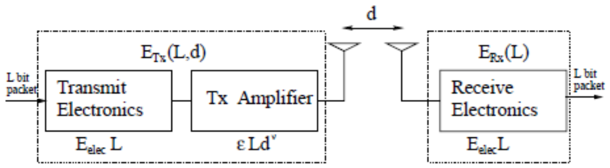

Figure 4 Radio Model representation

In this work the simulation setup has 100-nodes network where nodes were randomly distributed between (*x*=0, *y*=0) and (*x*=100, *y*=100) with the Base Station at location (*x*=50, *y*=50). Each data message is 500 bytes long. The power attenuation is dependent on the distance between the transmitter and receiver. For relatively short distances, the propagation loss can be modeled as inversely proportional to d^2, whereas for longer distances, the propagation loss can be modeled as inversely proportional to d^4. Power control can be used to invert this loss by setting the power amplifier to ensure a certain power at the receiver. For the experiment described here, both the free space and the multipath fading channel models were used, depending on the distance between the transmitter and receiver.

As per the radio energy dissipation model as shown in the Figure 1, in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an $L-$bit message over a distance *d*, the energy expended by the radio is provided by [8]:

$$E_{TX}(l,d)=\begin{cases} L.E_{elec}+L.\varepsilon_{fs}.d^2 & \text{if } d<d_0 \\ L.E_{elec}+L.\varepsilon_{mp}.d^4 & \text{if } d\geq d_0 \end{cases} \quad (5)$$

the parameter in the above equation *Eelec* is the energy dissipated per bit to carry out the transmitter or the receiver circuit, ε_{fs} and ε_{mp} rely on the transmitter amplifier model we applied, and the parameter *d* is the distance between the sender and the receiver. By equating the two expressions at $d=d_0$, we will get $d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$. To receive an $L-$bit message the radio expends

$$E_{RX}=L.E_{elec}. \quad (6)$$

Let us assume an area $A = M\times M$ m^2, and *n* the nodes number that are being distributed uniformly over that area. To make it simple, let the sink is positioned at the center of the field, and that the greatest distance of any node to the sink is $\leq d_0$. Hence, the energy dissipated in the cluster head node at the time of a round is given by the undermentioned formula:

$$E_{CH}=L.E_{elec}\left(\frac{n}{k}-1\right)+L.E_{DA}\frac{n}{k}+L.E_{elec}+L.\varepsilon_{fs}d_{toBS}^2 \quad (7)$$

In the above equation, paramet *k* represents the clusters number, and the distance between the cluster head and the sink is represented by parameter dt_{oBS} while E_{DA} is the processing (data aggregation) price of a bit per signal. The energy utilized in a noncluster head node is given by:

$$E_{nonCH}=L.E_{elec}+L.\varepsilon_{fs}d_{toCH}^2 \quad (8)$$

The parameter *dtoCH* represents the distance between a cluster head and its member. With the assumption that the nodes are distributed uniformly, it can be illustrated that:

$$E\left[d_{toCH}^2\right]=\iint(x^2+y^2)\rho(x,y)dxdy=\frac{M^2}{2.\pi.k}$$

here $\rho(x, y)$ is the node distribution

The whole energy dissipated in the network is given by:

$$E_{Cluster}\approx E_{CH}+\frac{n}{k}E_{nonCH} \quad (9)$$

The measure of total energy dissipated in the network is:

$$E_{tot}=L.\left[2nE_{elec}+n.E_{DA}+\varepsilon_{fs}\left(k.d_{toBS}^2+n\frac{M^2}{2.\pi.k}\right)\right]$$

We can get the optimal number of constructed clusters with the differentiation of *Etot* in respect of *k* and equating to zero:

$$k_{opt}=\sqrt{\frac{n}{2\pi}}\frac{M}{d_{toBS}}=\sqrt{\frac{n}{2\pi}}\frac{2}{0.765} \quad (10)$$

Due to the fact that the average distance to the sink from a cluster head is provided by [33]:

$$E\left[d_{toBS}\right]=\iint(x^2+y^2)\rho(x,y)\frac{1}{A}dA=0.765\frac{M}{2} \quad (11)$$

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We can compute the optimal probability of a node to turn out to be a cluster head, P_{opt} as:

$$P_{opt} = \frac{k_{opt}}{n} \quad (12)$$

Table 1: Simulation Parameters [6]

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

4. PROPOSED PROTOCOL

In Z-SEP, two zones of 20 m each and one zone of 60 m is chosen. However, how these zones are selected is not detailed. The purpose of this work is twofold, first is to design the length of zones in Z-SEP such that throughput can be maximized. In the second part of the work number of zones has been increased from 4 to 5, and concept of intermediate nodes has been introduced.

First Work:

Let *p* be the normal nodes and *q* are the advanced nodes and *n* is the total number of nodes then

$$p+q=n \quad (13)$$

Let the length of zones in *y* direction are y_1, y_2 and y_3 respectively. Let the field length in y direction is *L*.

$$y_1+y_2+y_3=L \quad (14)$$

In the first part of the work lengths y_1, y_2 and y_3 are optimized such that throughput can be maximized.

Second Work:

Let *p* be the normal nodes and *q* are the advanced nodes, *r* are the number of intermediate nodes and *n* is the total number of nodes then

$$p+q+r=n \quad (15)$$

Let the length of zones in *y* direction are y_1, y_2, y_3, y_4 and y_5 respectively. Let the field length in y direction is *L*

$$y_1+y_2+y_3+y_4+y_5=L \quad (16)$$

In the second part of the work lengths y_1, y_2, y_3, y_4 and y_5 are considered to be equal and effect of intermediate nodes on throughput is observed.

5 RESULTS

In figure 5, Alive Nodes vs. Rounds for Z-SEP and A-SEP is plotted. In Z-SEP, advanced nodes are uniformly distributed in two zones of 10 m each and in left over 80 m, normal nodes are distributed. In A-SEP, two zones of 25 m each and in left over 50 m, normal nodes are distributed. Here, 90% nodes are normal nodes, and rest 10% are advanced nodes. The energy of advanced nodes is 4 times higher than normal nodes. In Z-SEP, 90% nodes die out till 6133 rounds, while in A-SEP it take 7080 rounds. In Z-SEP, all the nodes die out after 8605 rounds, while in A-SEP, it takes 9544 rounds

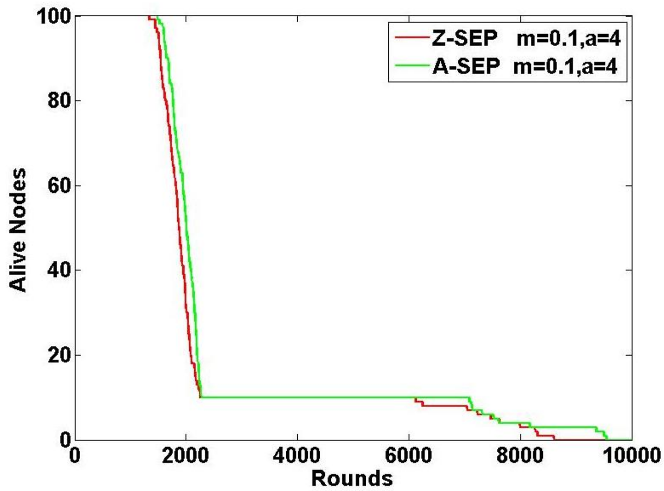

Figure 5 Alive Nodes vs. Rounds for Z-SEP and A-SEP

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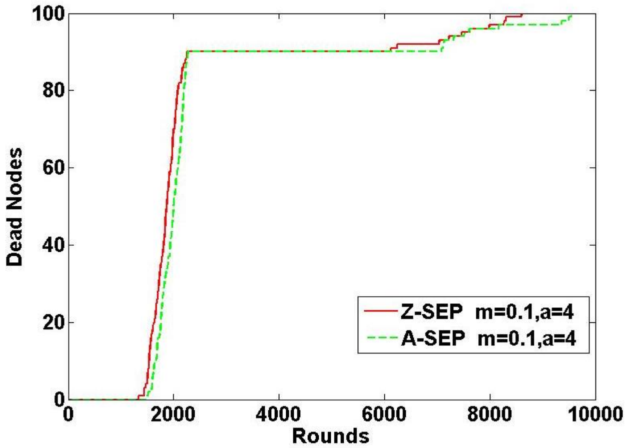

Figure 6 Dead Nodes vs. Rounds for Z-SEP and A-SEP

In figure 6, Dead Nodes vs. Rounds for Z-SEP and A-SEP is plotted.

In figure 7, packets to BS vs. rounds are plotted for both the combinations. The performance of both the combination is exactly same for nearly 2000 rounds. Thereafter a significant difference can be observed in the results. The maximum throughput for Z-SEP is 2.395×10^5 and for A-SEP throughput is 2.557×10^5. thus, an improvement of 6.76% is observed.

In figure 8 Alive Nodes vs. Rounds for Z-SEP and A-SEP is plotted. In Z-SEP, advanced nodes are uniformly distributed in two zones of 20 m each and in left over 60 m, normal nodes are distributed. In A-SEP, two zones of 33.33 m each and in left over 33.33 m, normal nodes are distributed. Here, 90% nodes are normal nodes, and rest 10% are advanced nodes. The energy of advanced nodes is 4 times higher than normal nodes. In Z-SEP, 90% nodes die out till 6133 rounds, while in A-SEP it take 7080 rounds. In Z-SEP, all the nodes die out after 8386 rounds, while in A-SEP, it takes 9962 rounds.

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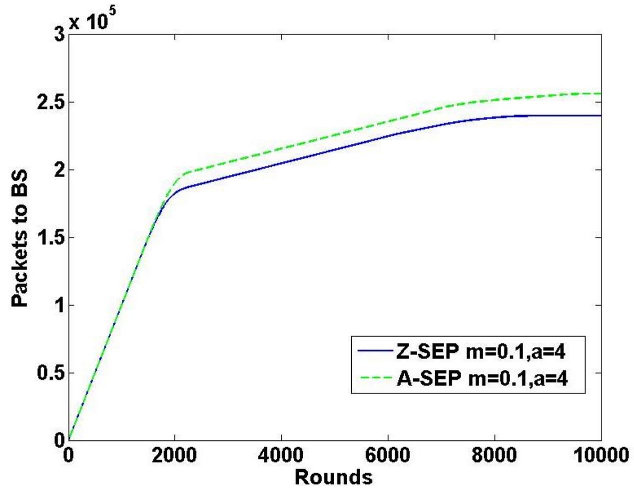

Figure 7 Packets to BS vs. Rounds for Z-SEP and A-SEP

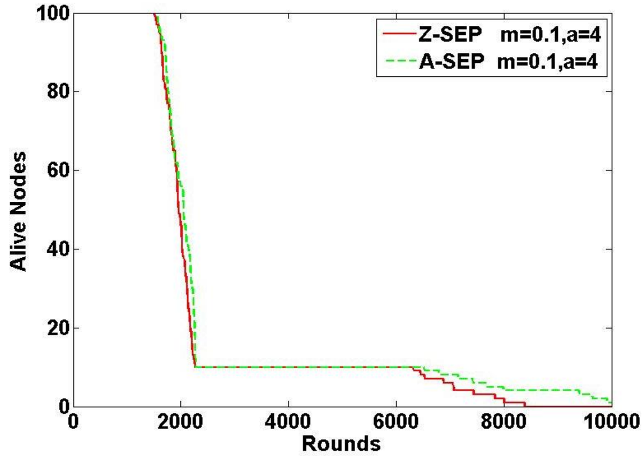

Figure 8 Alive Nodes vs. Rounds for Z-SEP and A-SEP

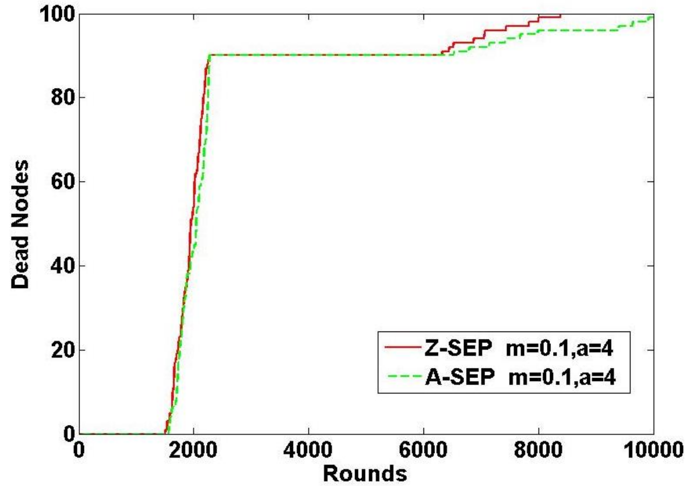

Figure 9 Dead Nodes vs. Rounds for Z-SEP and A-SEP

In figure 9 Dead Nodes vs. Rounds for Z-SEP and A-SEP is plotted. This figure is very much similar to figure 5.4.

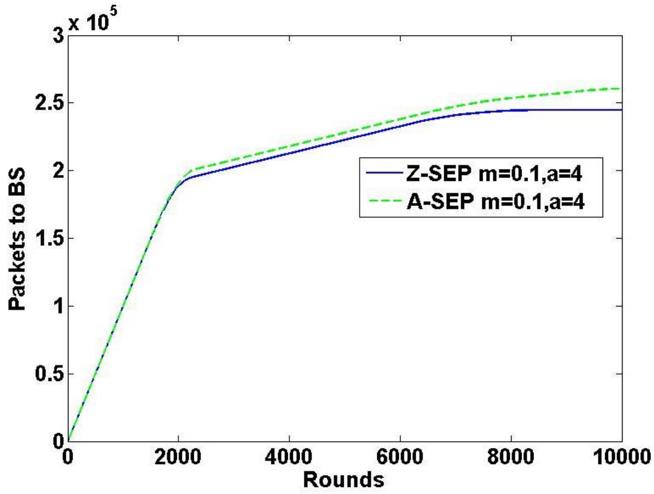

Figure 10 Packets to BS vs. Rounds for Z-SEP and A-SEP

In figure 10, packets to BS vs. rounds is plotted for both the combinations. The performance of both the combination is exactly same for nearly 2000 rounds. Thereafter a significant difference can be observed in the results. The maximum throughput for Z-SEP is 2.447×10^5 and for A-SEP throughput is 2.504×10^5.

In the second part of the work, we have increased number of zones from 3 to 5. In zone 1, normal nodes are placed whose energy is E_0 in zone 2 and 3, intermediate nodes whose energy is $E_0(1+a/2)$ and in zone 4 and 5 advanced nodes with energy $E_0(1+a)$ is placed.

The zone are defined in Y directions, the various zones are defined as

Zone 1: $0 < x < 100$ and $40 < y < 60$

Zone 2: $0 < x < 100$ and $20 < y < 40$

Zone 3: $0 < x < 100$ and $60 < y < 80$

Zone 4: $0 < x < 100$ and $0 < y < 20$

Zone 5: $0 < x < 100$ and $80 < y < 100$

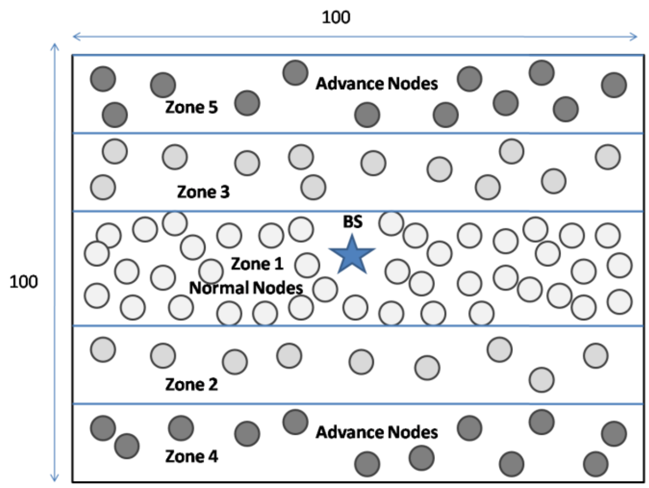

Figure 11 Sectorial division of field

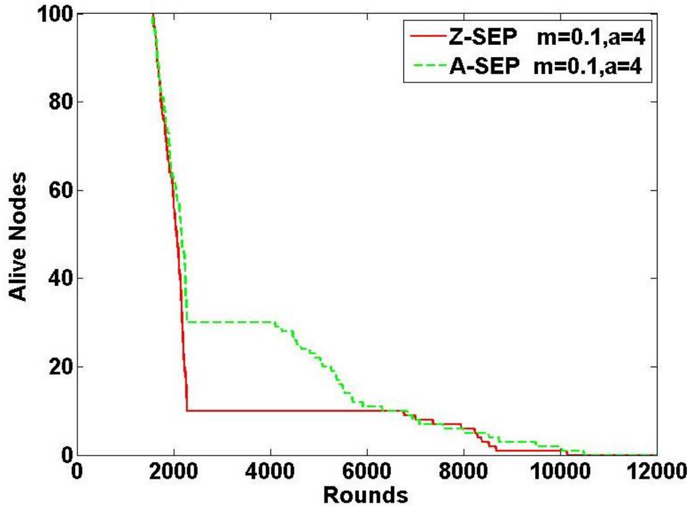

Figure 12 Alive Nodes vs. Rounds for Z-SEP and A-SEP

In figure 12 Alive Nodes vs. Rounds for Z-SEP and A-SEP is plotted. In Z-SEP, two zones of 33.33 m each and in left over 33.33 m, normal nodes are distributed. While the distribution of A-SEP is defined above. Here, 70% nodes are normal nodes, 20% nodes are intermediate nodes and rest 10% are advanced nodes. The energy of advanced nodes is 4 times higher than normal nodes while the energy of intermediate nodes is thrice of normal nodes. In Z-SEP, 90% nodes die out till 2271 rounds, while in A-SEP it take 6698 rounds. In both Z-SEP and A-SEP, all the nodes die out nearly at the same time 10490 rounds.

In figure 13 Dead Nodes vs. Rounds for Z-SEP and A-SEP is plotted. Here, A-SEP more number of nodes remain alive for longer duration. Thus the use of intermediate node improves the throughput. However, it does not increases stability period and network life time.

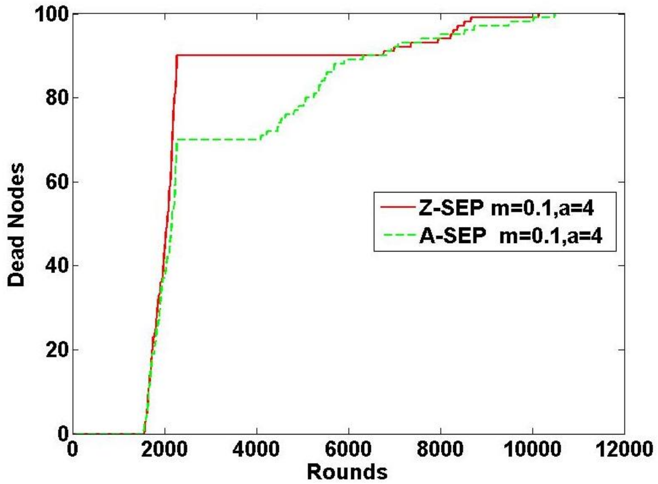

Figure 13 Dead Nodes vs. Rounds for Z-SEP and A-SEP

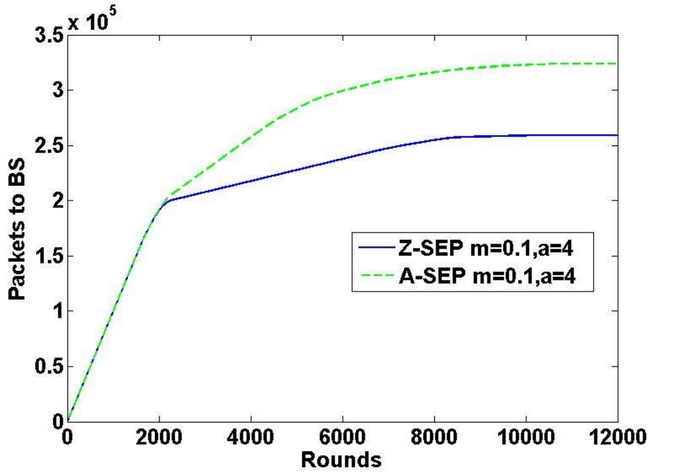

Figure 14 Packets to BS vs. Rounds for Z-SEP and A-SEP

In figure 14, packets to BS vs. rounds is plotted for both the combinations. The performance of both the combination is exactly same for nearly 2000 rounds. Thereafter a significant difference can be observed in the results. The maximum throughput for Z-SEP is 2.590×10^5 and for A-SEP throughput is 3.234×10^5. Thus an improvement of nearly 20% is observed.

In figure 15, Alive Nodes vs. Rounds for Z-SEP and A-SEP is plotted. In Z-SEP, two zones of 33.33 m each and in left over 33.33 m, normal nodes are distributed. While the distribution of A-SEP is defined above. Here, 70% nodes are normal nodes, 20% nodes are intermediate nodes and rest 10% are advanced nodes. The energy of advanced nodes is 2 times higher than normal nodes while the energy of intermediate nodes is twice of normal nodes. In Z-SEP, 90% nodes die out till 2288 rounds, while in A-SEP it take 4447 rounds. In both Z-SEP and A-SEP, all the nodes die out nearly at the same time 6554 rounds.

In figure 16 Dead Nodes vs. Rounds for Z-SEP and A-SEP is plotted. Here, A-SEP more number of nodes remain alive for longer duration. Thus the use of intermediate node improves the throughput. However, again it does not increase stability period and network life time.

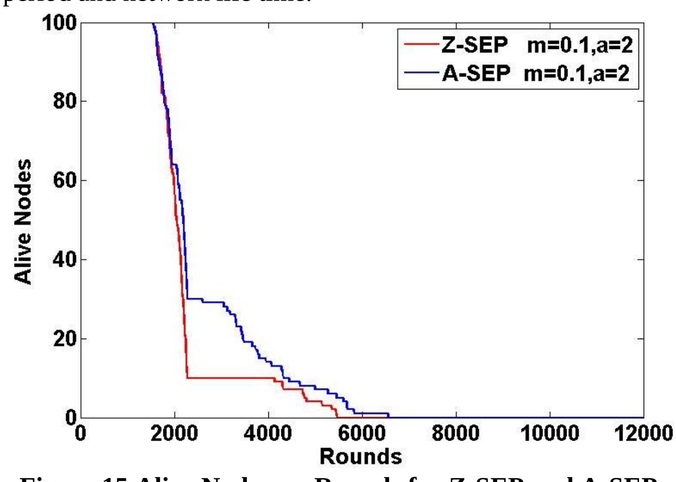

Figure 15 Alive Nodes vs. Rounds for Z-SEP and A-SEP (a=2)

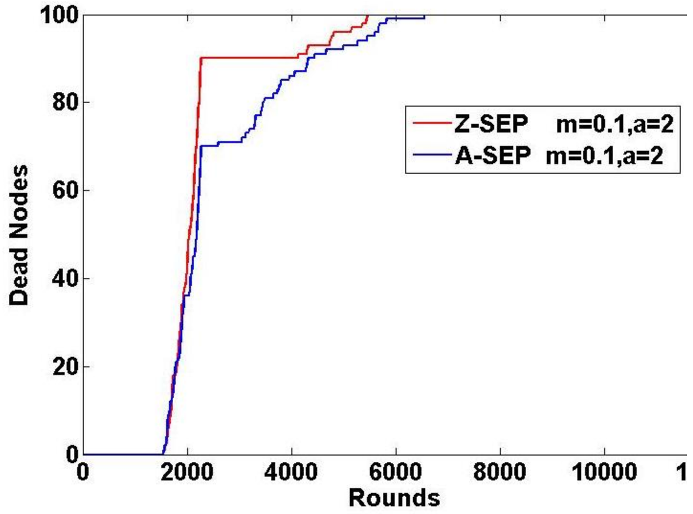

Figure 16 Dead Nodes vs. Rounds for Z-SEP and A-SEP (a=2)

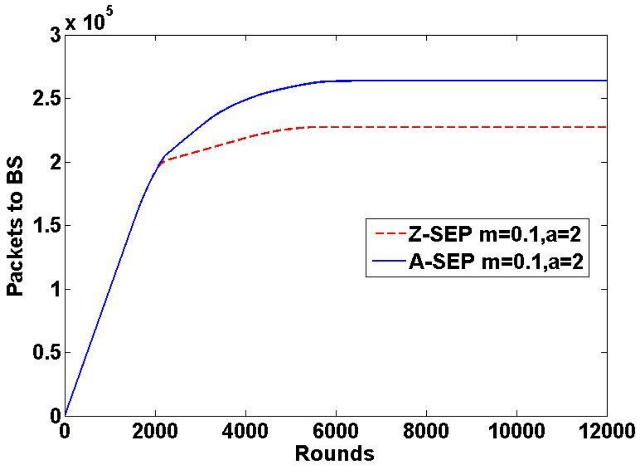

Figure 17 Packets to BS vs. Rounds for Z-SEP and A-SEP (a=2)

In figure 17, packets to BS vs. rounds is plotted for both the combinations. The performance of both the combination is exactly same for nearly 2000 rounds. Thereafter a significant difference can be observed in the results. The maximum throughput for Z-SEP is 2.272×10^5 and for A-SEP throughput is 2.639×10^5. Thus an improvement of nearly 16% is observed.

In figure 18 Alive Nodes vs. Rounds for Z-SEP and A-SEP is plotted. In Z-SEP, two zones of 33.33 m each and in left over 33.33 m, normal nodes are distributed. While the distribution of A-SEP is defined above. Here, 70% nodes are normal nodes, 20% nodes are intermediate nodes and rest 10% are advanced nodes. The energy of advanced nodes is 2 times the normal nodes while the energy of intermediate nodes is 1.5 times of normal nodes. In Z-SEP, 90% nodes die out till 1570 rounds, while in A-SEP it take 1583 rounds. In both Z-SEP and A-SEP, all the nodes die out nearly at the same time 4181 rounds.

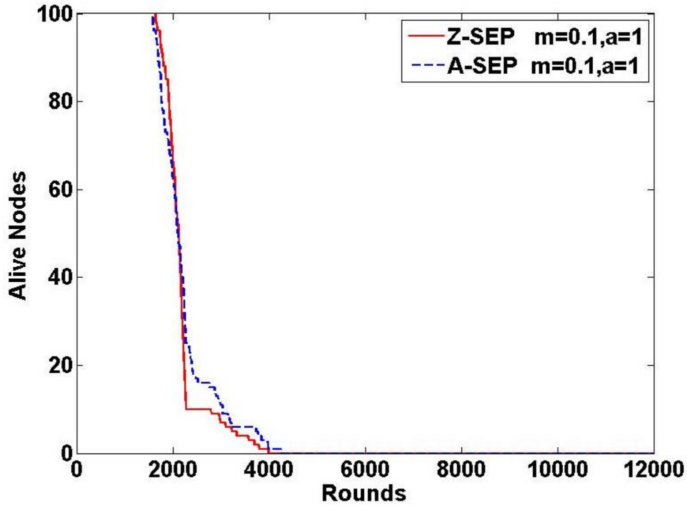

Figure 18 Alive Nodes vs. Rounds for Z-SEP and A-SEP (a=1)

In figure 19 Dead Nodes vs. Rounds for Z-SEP and A-SEP is plotted. Here, A-SEP more number of nodes remain alive for longer duration. Thus the use of intermediate node improves the throughput. However, again it does not increase stability period and network life time.

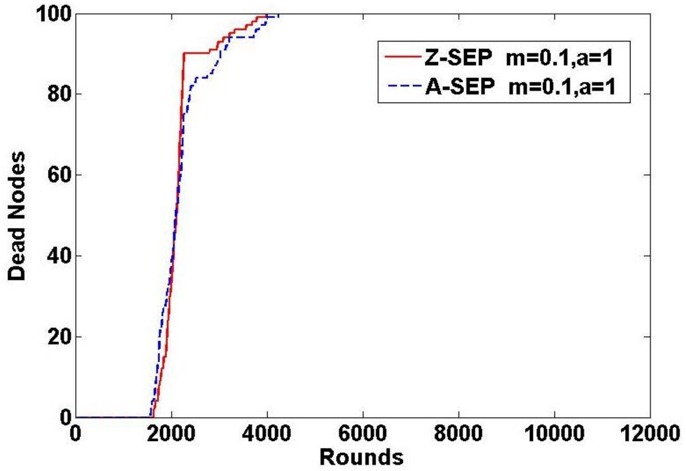

Figure 19 Dead Nodes vs. Rounds for Z-SEP and A-SEP (a=1)

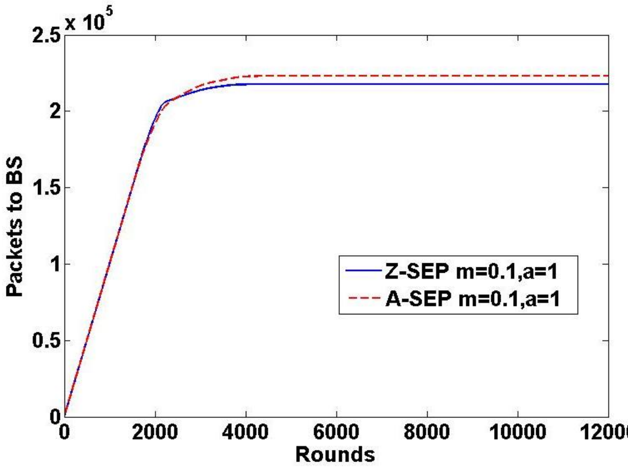

Figure 20 Packets to BS vs. Rounds for Z-SEP and A-SEP (a=1)

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In figure 20, packets to BS vs. rounds is plotted for both the combinations. The performance of both the combination is exactly same for nearly 2000 rounds. Thereafter a significant difference can be observed in the results. The maximum throughput for Z-SEP is 2.175×10^5 and for A-SEP throughput is 2.230×10^5. Thus an improvement of nearly 2.5% is observed.

Table 2: Throughput comparison at different energy for Z-SEP

Protocol	Energy Advanced Nodes	Throughput (Packets)
Z-SEP	2 E_0	2.590×10^5
	3 E_0	2.232×10^5
	5 E_0	2.175×10^5

Table 3: Throughput comparison at different energy for A-SEP

Protocol	Energy Intermediate Nodes	Energy Advanced Nodes	Throughput (Packets)
A-SEP	1.5E_0	2 E_0	2.230×10^5
	2 E_0	3 E_0	2.639×10^5
	3 E_0	5 E_0	3.234×10^5

The results for Z-SEP protocol is detailed in Table 5.1. Results for A-SEP protocol are tabulated in Table 5.2. It is clear from the table that, as the energy increases the throughput increases. The inclusion of intermediate nodes further improves the results.

6 CONCLUSIONS

This work aims for the designing and performance evaluation of wireless sensor network protocol. In first two chapters foundation is laid down for WSN.

On the basis of the obtained results following conclusions can be made:

1. The performance of A-SEP is better in comparison to above two protocols.
2. The numbers of alive nodes have an impact on the packet transferred to BS.
3. The energy of advance nodes have an impact on the packet transferred to BS.
4. Careful selection of geometry is very important for the placement of the advance nodes.
5. The performance of A-SEP is best among the considered protocols.
6. The performance of A-SEP in terms of throughput is much better.

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