COMPARATIVE ANALYSIS OF CLUSTER BASED ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

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Abstract : The prominence of Wireless Sensor Networks have expanded hugely because of the huge capability of the sensor systems to associate the physical world with the virtual world. Since these gadgets depend on battery and might be put in hostile environment so replacing them becomes a tedious job. In this manner, improving the energy of these networks becomes significant. This paper provides methods for clustering and cluster head selection to WSN to improve energy efficiency. In this paper, we develop, analyze and compare Low-energy adaptive clustering hierarchy (LEACH), Stable Election Protocol (SEP) and Zonal-Stable Election Protocol (Z-SEP) to achieve good performance in terms of stability period, network lifetime and throughput.

Keywords : Clustering, data aggregation, Probabilistic, sensor network, energy efficiency, Epoch.

1. INTRODUCTION

The Wireless Sensor Network (WSN) should be comprised of an extensive number of sensors and somewhere around one base station. The sensors are self-sufficient little gadgets with a few limitations like the battery control, calculation limit, correspondence range and memory. They additionally are provided with handsets to accumulate data from its condition and leave it behind to a specific base station, where the deliberate parameters can be put away and accessible for the end client.
Because of the arbitrary deployment of sensors, the Wireless Sensor Network has generally changing degree of density of node along its zone. These sensor networks are also energy restrained because the individual sensors from which the network is made with are immensely energy restrained too. The specialized gadgets on these sensors are little and have restricted power and range. Commonly, the system topology is ceaselessly and powerfully changing and it is not an ideal answer to recharge it by injecting new sensors rather the exhausted ones. A genuine and suitable answer for this issue is to execute routing protocols that perform proficiently and using the less measure of energy as workable for the nodes to communicate. The Wireless Sensor Networks comprises of two principal parts – Sensor Nodes and Base Station.

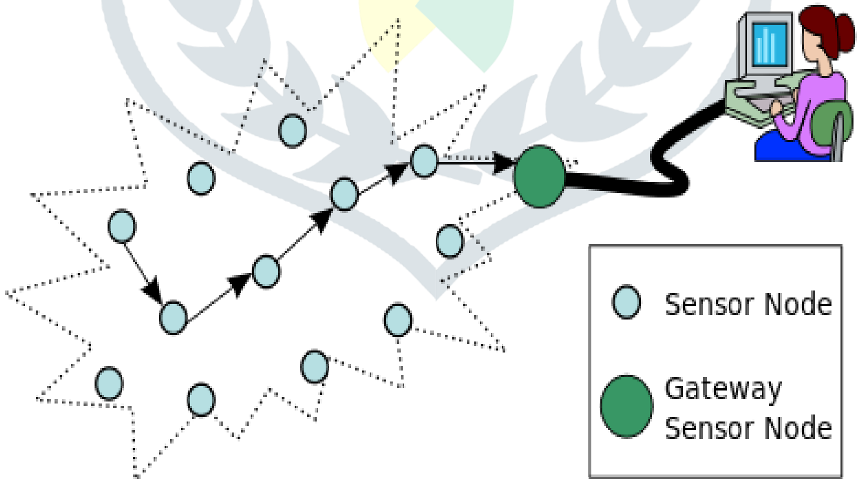

Figure 1.1: Wireless Sensor Networks

1.1 SENSOR NODES

The Sensor nodes are regularly made of couple of sensors and a mote unit as appeared in the figure. A sensor is a gadget which detects the data and pass it on to mote. Sensors are normally used to gauge the progressions in physical environmental parameters like temperature, humidity, pressure, sound, vibration and changes in the wellbeing parameter of individual. A mote comprises of processor, memory, battery, A/D convertor for interfacing with a sensor and a radio transceiver for constructing an ad hoc network system. A mote and sensor together structure a Sensor Node. A sensor network is a wireless ad-hoc network arrangement that consists of sensor nodes. Every sensor node can bolster a multi-hop routing algorithms as forwarder for transferring data packets to a base station.

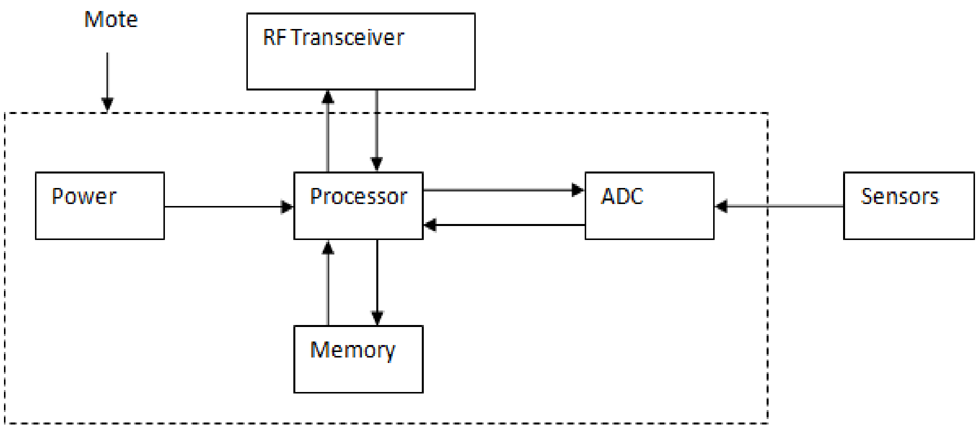

Figure 1.2: Block Diagram of Sensor Node

1.2 Base Station

A base station interfaces sensor network system to another sensor network system. It comprises of a processor, radio board, antenna and USB interface board. It is pre-customized with low-power mesh networking software for communication with wireless sensor nodes. Establishment of the base station in a wireless sensor network is significant as all the sensor nodes deliver their information to the base station for handling and making of decision. Energy preservation, coverage of sensor nodes and dependability issues are dealt with amid arrangement of base station in sensor network.

Figure 1.3: A Base Station Node

1.3 Energy-efficient Routing Algorithms

The Energy efficient routing algorithm can be classified as :

1. Data centric routing algorithm
2. Hierarchical routing algorithm
3. Location based routing algorithm

Data centric routing algorithm utilizes meta data to discover the path from source to goal before any real data transmission to remove unnecessary data transmission. The Hierarchical routing is utilized to perform energy efficient routing. It means higher energy nodes can be utilized to process and send data while lower energy nodes are utilized to execute sensing in the area of interest. The location based routing algorithm requires real location data for each sensor node. Location data can be acquired from GPS signals. Utilizing location data, an ideal path can be framed.

1.4 Heterogeneous WSN Model

In this segment we depict our wireless sensor network model with heterogeneous nodes. We especially show the setting, energy model and how the ideal no. of clusters can be processed. Let us suppose the scenario where a certain proportion of the sensor nodes is outfitted with more energy resources than the remainder of the nodes. Let us assume that m is the fraction of the total number of nodes n which are outfitted with α times more energy than the others. These nodes with more energy are known as advanced nodes, and the remaining $(1 - m) \times n$ as normal nodes.

2. LEACH (Low Energy Adaptive Cluster Hierarchy)

W. Heinzelman [1], presented a hierarchical clustering algorithm for sensor networks called Low Energy Adaptive Clustering Hierarchy (LEACH). It organizes nodes of the network into clusters of small size and picks one as the cluster head (CH) from them. After that CH collects the data got from all nodes and forwards it to BS. The nodes picked as the CH looses more energy relative to other nodes because information is required to send to the BS which might be far found. Thus, LEACH utilizes random rotation of the nodes to become CH to uniformly distribute energy utilization in the network.

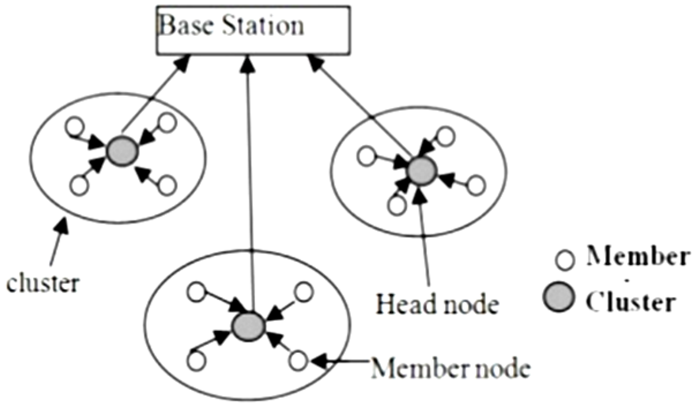

Figure 2.1: Clustering in LEACH Protocol

The operations of LEACH can be partitioned into two stages: - Setup Phase and Steady Phase.

During the setup stage, a node randomly selects a number between 0 to 1, and this number is compared to the threshold values T(n). If this number is lower than the threshold value T(n), then this node becomes CH for this round otherwise it remains as a common node. Threshold value T(n) is determined by the following:

T(n) = $\frac{p}{1-p[r\ mod(\frac{1}{p})]}$ if n ∈G

T(n) = 0 otherwise

here p denotes the percent of the CH nodes, r is the number of rounds, G is the accumulations of the nodes which have not become cluster head nodes in the initial 1/P rounds. Every elected CH broadcasts an advertisement message for invitation to the remainder of the nodes in the network so that they can join their clusters. On the basis of the strength of advertisement signal, the non-CH node choose to join the clusters. Then the non-CH nodes sends an acknowledgement message to their respective CH that they will be under their cluster. After receiving the acknowledgement message, the CH makes a TDMA (Time-division multiple access) schedule and allocates a time slot to every node so that they can transmit information in the given time slot. This TDMA schedule is broadcasted to each cluster members. The CH picked for the ongoing round can't again become the CH until all remaining nodes of the network have not become CH.

During the steady phase, the non-CH nodes begins detecting information and sends it to their CH in accordance with the TDMA schedule. After receiving data from all the member nodes, the CH collects it and after that transmits it to the BS. After a specific time, the network again returns into the setup phase and new CHs are picked.

3. SEP (Stable Election Protocol)

In SEP [4], nodes are treated differently on the basis of their initial level of energy. The nodes that has lower energy are known as normal nodes and a weighted election probability p_{nrm} is allocated which is less than p_{adv} i.e. the weighted election probability allocated to the nodes with higher energy levels (advanced nodes).

Nearly there are n×(1+α.m) nodes where n is the total no. of nodes, m is the proportion of advanced nodes and α is the extra energy factor between normal and advanced nodes. The weighed probabilities for normal and advanced nodes are :-

$$p_{nrm} = \frac{p_{opt}}{1+\alpha.m}$$

$$p_{adv} = \frac{p_{opt}}{1+\alpha.m}(1+\alpha)$$

The normal nodes have following threshold:-

T(s_{nrm}) = $\frac{p_{nrm}}{1-p_{nrm}[r\ mod(\frac{1}{p_{nrm}})]}$ if s_{nrm} ∈G'

T(s_{nrm}) = 0 otherwise

where r is the ongoing round, G' is the collection of nodes which have not been cluster head within the last $\frac{1}{p_{nrm}}$ rounds of the epoch, and T(s_{nrm}) is the threshold applied to a population of n.(1- m) (normal) nodes. Similarly, the advanced nodes have following threshold :-

T(s_{adv}) = $\frac{p_{adv}}{1-p_{adv}[r\ mod(\frac{1}{p_{adv}})]}$ if s_{adv} ∈G''

T(s_{adv}) = 0 otherwise

where G'' is the collection of nodes that have not been cluster head within the last $\frac{1}{p_{adv}}$ rounds of the epoch, and T(s_{adv}) is the threshold applied to a population of n.m (advanced) nodes.

4. Z-SEP (Zonal Stable Election Protocol)

Faisal, S., et al.[5] has proposed Zonal – Stable Election Protocol (Z-SEP). In Z-SEP, Network field is partitioned in three type of zones on the basis of energy levels. These are :-

1. Zone 0: Normal nodes are placed between 20<Y<=80.
2. Head zone 1: Half of the advance nodes are placed between 0<Y<=20.
3. Head zone 2: Another Half of the advance nodes are placed between 80<Y<=100.

The explanation for this type of arrangement is that advance nodes have higher level of energy than normal nodes. We have placed advanced nodes (higher energy nodes) in Head Zone 1 and Head Zone 2 because corners are more far places in the network so a node a node which is present at the corner need more energy for communication with base station.

Z-SEP uses two types of method for communication with BS. These methods are are direct communication and transmission via cluster head.

4.1 Direct Communication:-

The nodes which are present in Zone 0 sense environment, gathers data of interest and send data directly to BS.

4.2 Transmission via Cluster head:-

Firstly in Head Zone 1 and Head Zone 2, CH is selected among nodes. Then CH collect data from member nodes, aggregate it and transmit it to BS. Cluster is formed only in advance nodes. Probability for advance nodes to become cluster head is

$$p_{adv} = \frac{p_{opt}}{1 + \alpha.m}(1 + \alpha)$$

Accordingly the threshold for advance nodes is

$$T(s_{adv}) = \frac{p_{adv}}{1 - p_{adv}[r \bmod (\frac{1}{p_{adv}})]} \text{ if } s_{adv} \in G''$$

$T(s_{adv})$ = 0 otherwise

where G'' is the collection of nodes that have not been cluster head within the last $\frac{1}{p_{adv}}$ rounds.

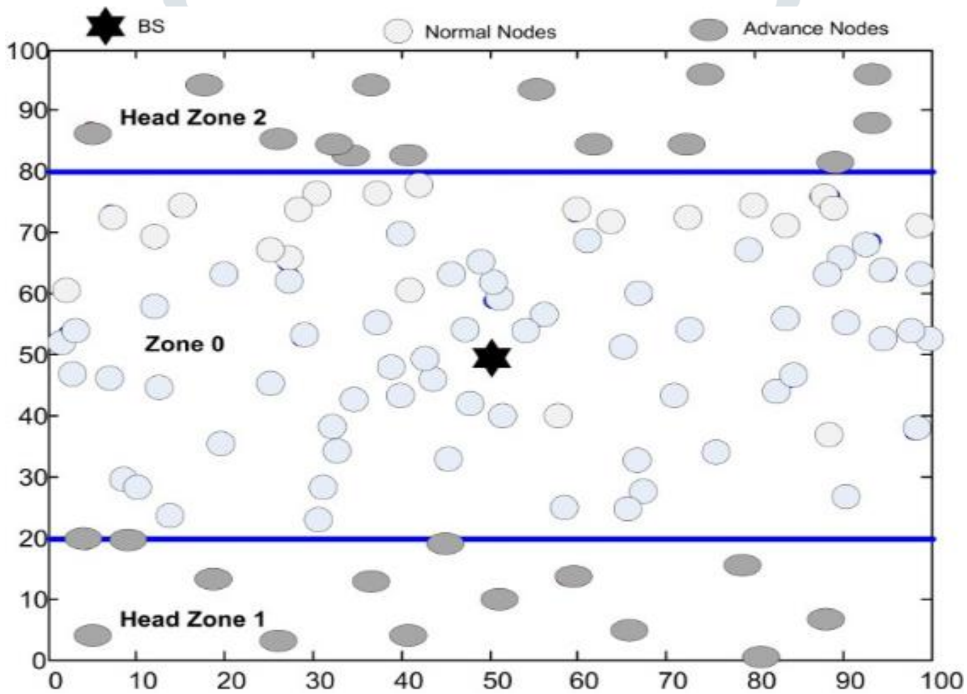

Figure 4.1: Network Architecture of Z-SEP

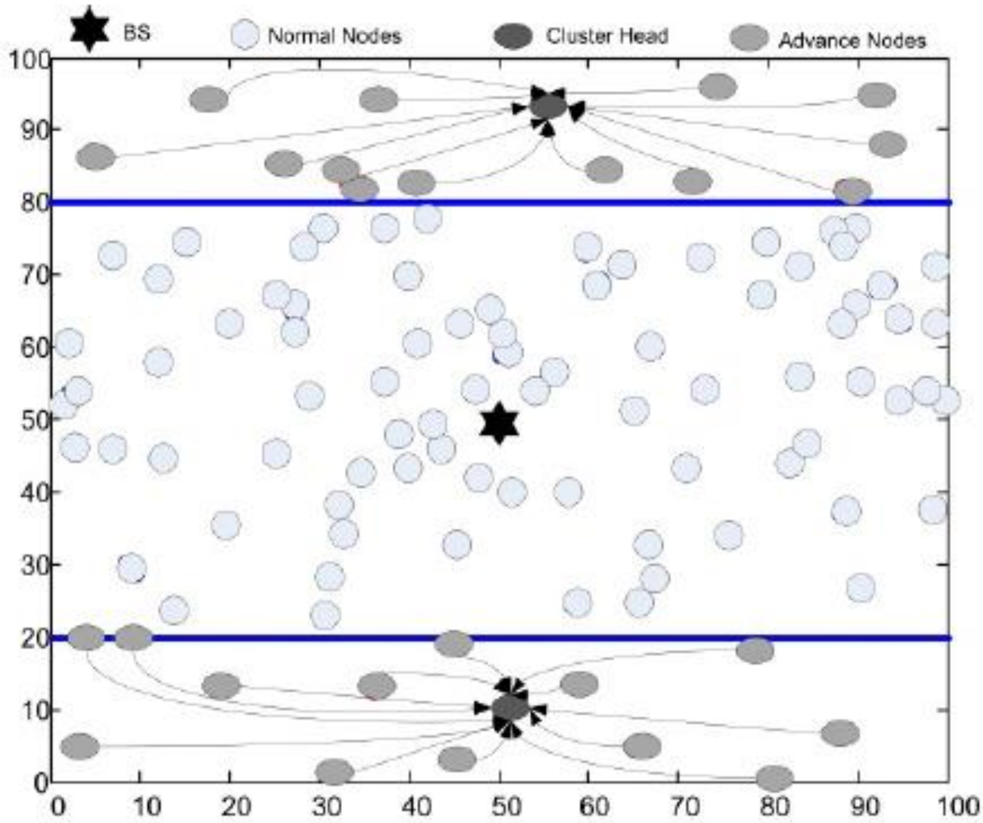

Figure 4.2: Nodes sending data to CH

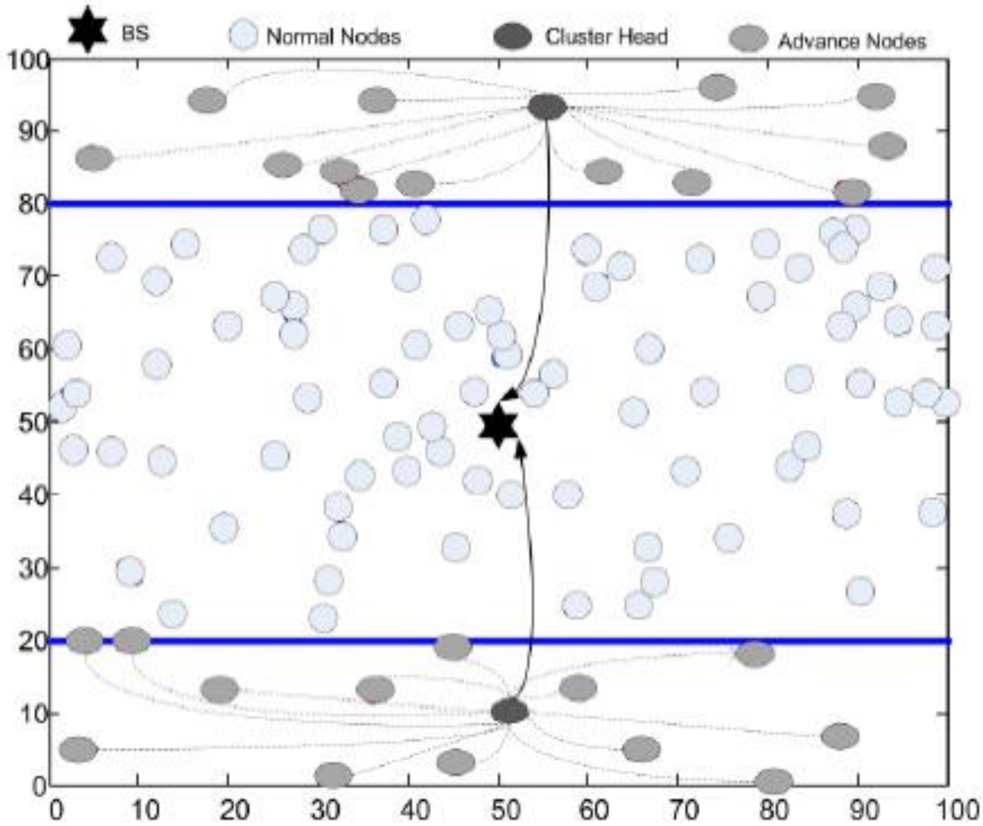

Figure 4.3: CH transmitting data to BS

5. FUNCTIONAL REQUIREMENT

Functional requirements define a function of a software system or its component. Some of the functional Requirements are:

- Input
  - No. of nodes
  - Optimal election probability of a node to become cluster head
  - Percentage of nodes that are advanced
  - Value of alpha (i.e. alpha times advance nodes have energy greater than normal nodes)
  - Maximum no. of rounds
- Output
  - The system should predict no. of alive nodes vs rounds.
  - The system should predict no. of dead nodes vs rounds.
  - The system should predict no. of packets to Base station vs rounds.

6. PERFORMANCE MEASURES

We define here the measures we use in this paper to evaluate the performance of clustering protocols.

- **Stability period:** is the time interval from the start of network operation until the death of the first sensor node. We also refer to this period as “stable region”.
- **Instability period:** is the time interval from death of the first node until the death of the last sensor node. We also refer to this period as “unstable region”.
- **Network lifetime:** is the time interval from the start of operation(as of the sensor network) until the death of the last alive node.
- **Number of cluster heads per round:** This instantaneous measure reflects the number of nodes which would send directly to the sink information aggregated from their cluster members.
- **Number of alive nodes per round:** This instantaneous measure reflects the total number of nodes and that of each type that have not yet expended all of their energy.

7. FINDINGS AND RESULTS

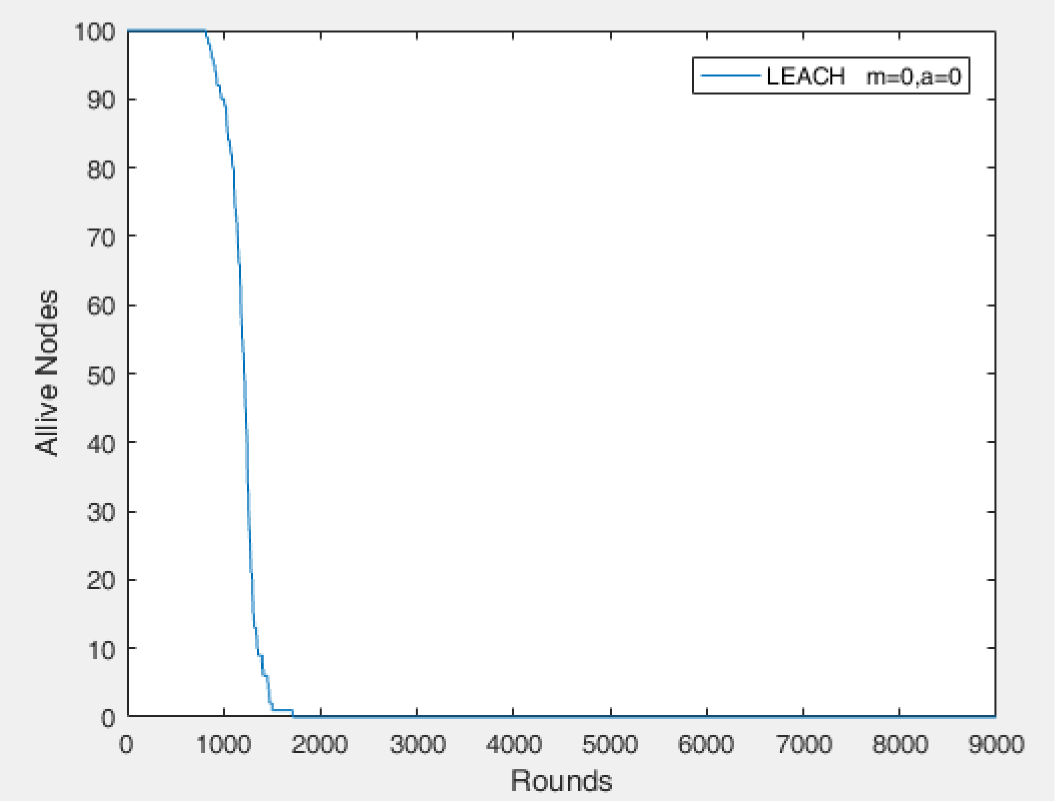

Figure 7.1: No. of alive nodes in Homogeneous LEACH (m=0, a=0)

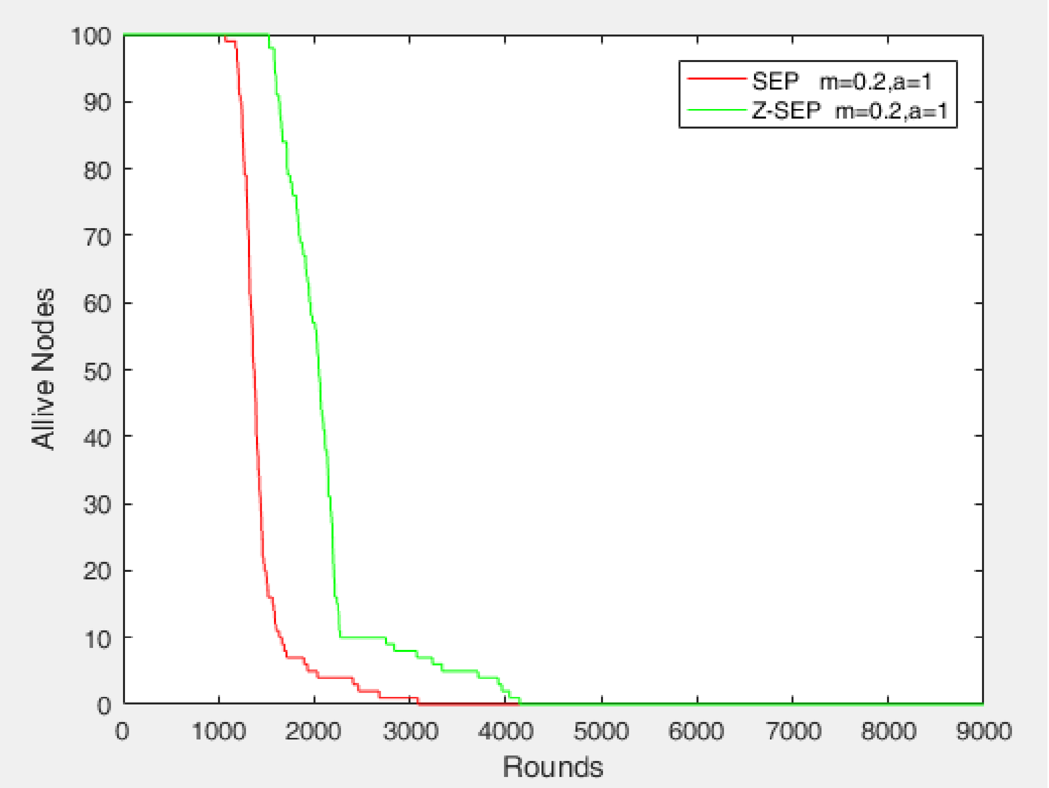

Figure 7.2: No. of alive nodes in SEP, Z-SEP for m=0.2, a=1

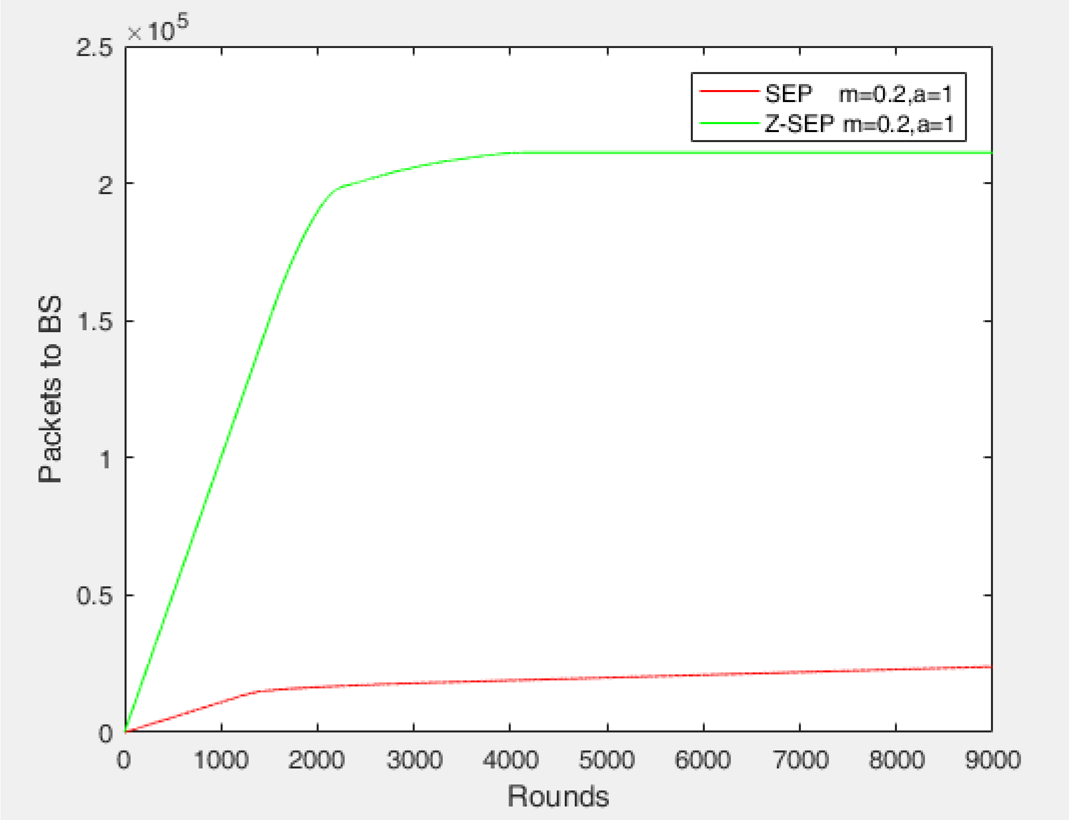

Figure 7.3: Throughput of SEP, Z-SEP for m=0.2, a=1

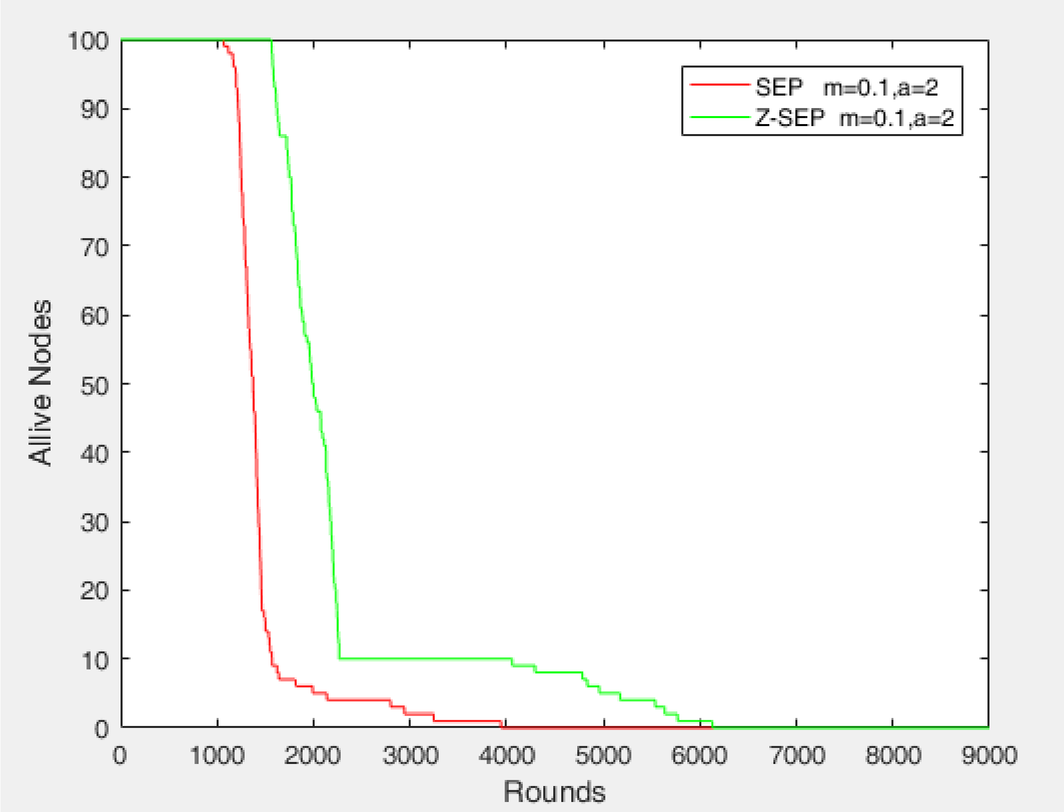

Figure 7.4: No. of alive nodes in Heterogeneous SEP, Z-SEP for m=0.1, a=2

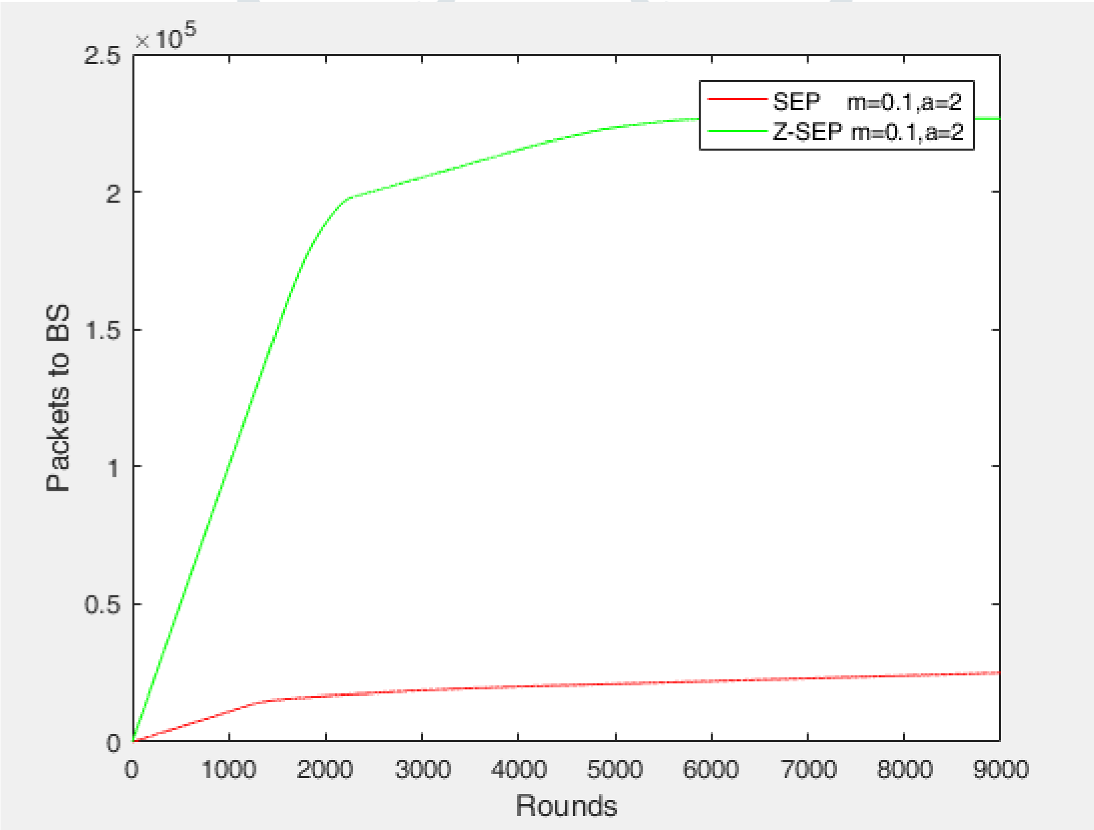

Figure 7.5: Throughput of SEP, Z-SEP for m=0.1, a=2

Protocol	Stability Period (Rounds)	Network Lifetime (Rounds)
LEACH	831	1498
SEP	1078	3040
Z-SEP	1538	4132

Table 7.1 : Comparison table between Homogeneous LEACH (m=0, a=0), SEP (m=0.2, a=1) and Z-SEP (m=0.2, a=1) on the basis of Stability period and Network Lifetime.

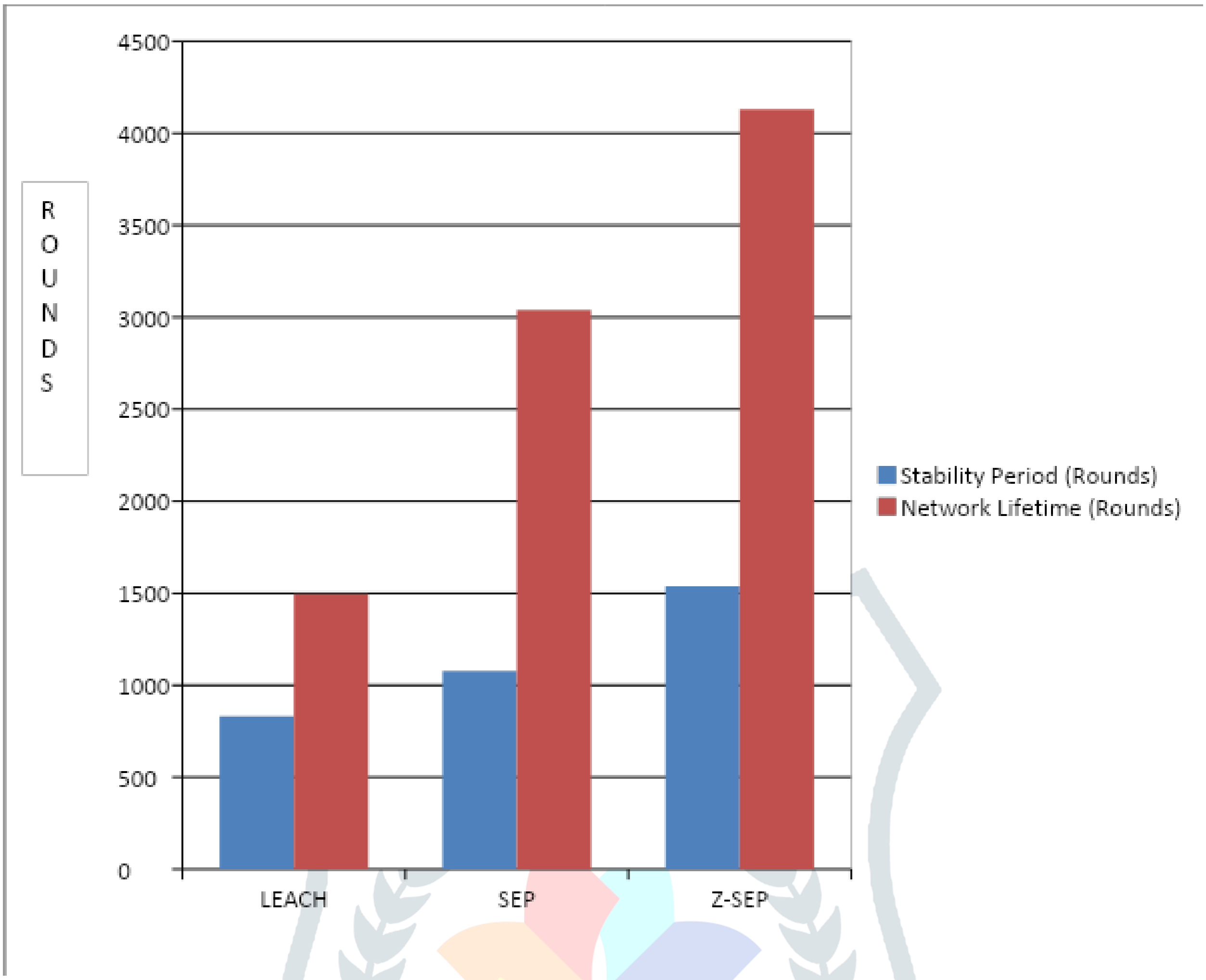

Figure 7.6: Comparison bar chart of LEACH (m=0, a=0), SEP (m=0.2, a=1) and Z-SEP (m=0.2, a=1) on the basis of Stability period and Network Lifetime .

Protocol	Stability Period (Rounds)	Network Lifetime (Rounds)
LEACH	831	1498
SEP	1159	4986
Z-SEP	1589	6075

Table 7.2 : Comparison table between LEACH (m=0, a=0), SEP (m=0.1, a=2) and Z-SEP (m=0.1, a=2) on the basis of Stability period and Network Lifetime.

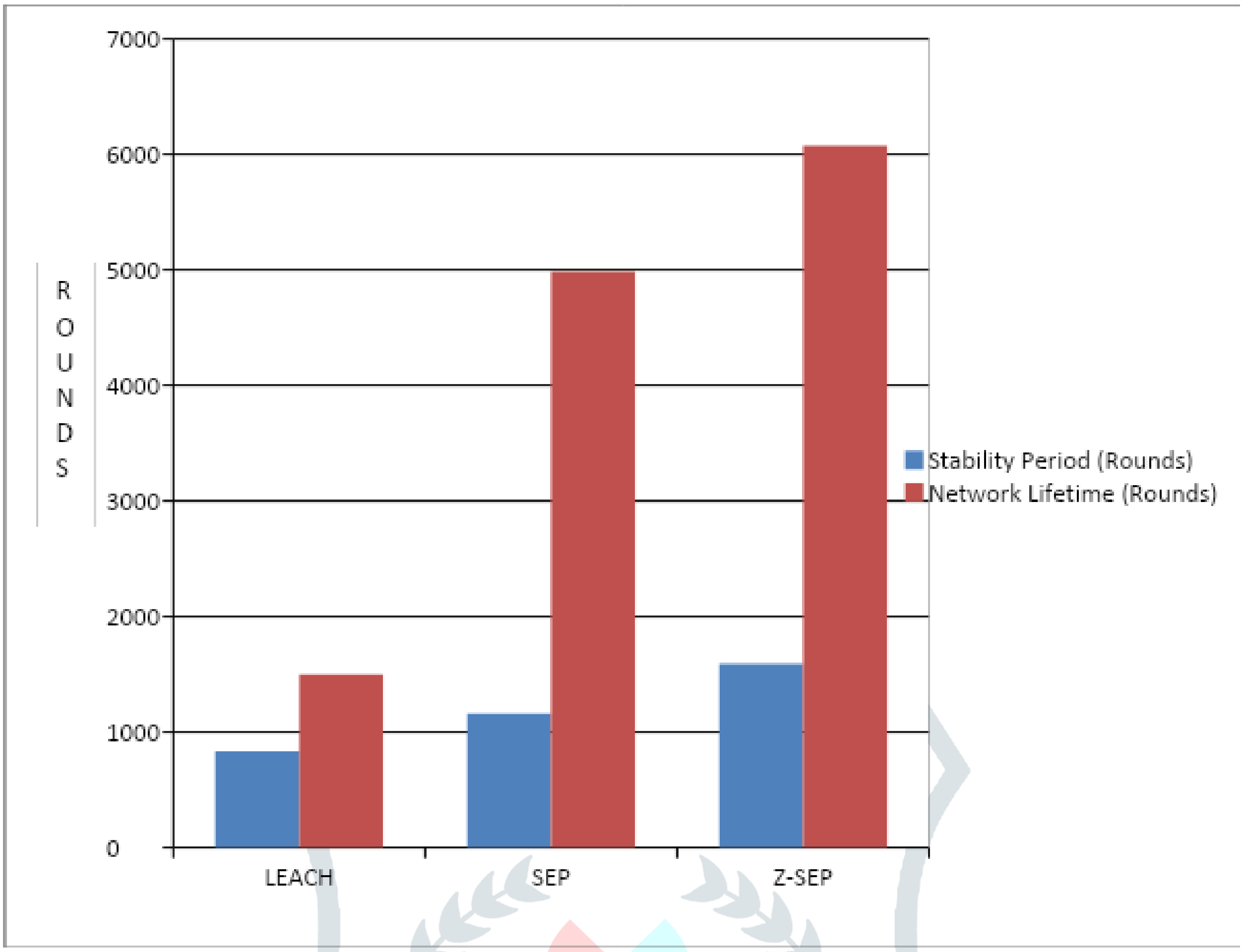

Figure 7.7: Comparison bar chart of LEACH (m=0, a=0), SEP (m=0.1, a=2) and Z-SEP (m=0.1, a=2) on the basis of Stability period and Network Lifetime.

Protocol	Packets To BS / Throughput
LEACH	33200
SEP	38800
Z-SEP	209100

Table 7.3 : Comparison table between LEACH(m=0, a=0), SEP(m=0.2, a=1) and Z-SEP(m=0.2, a=1) on the basis of Throughput.

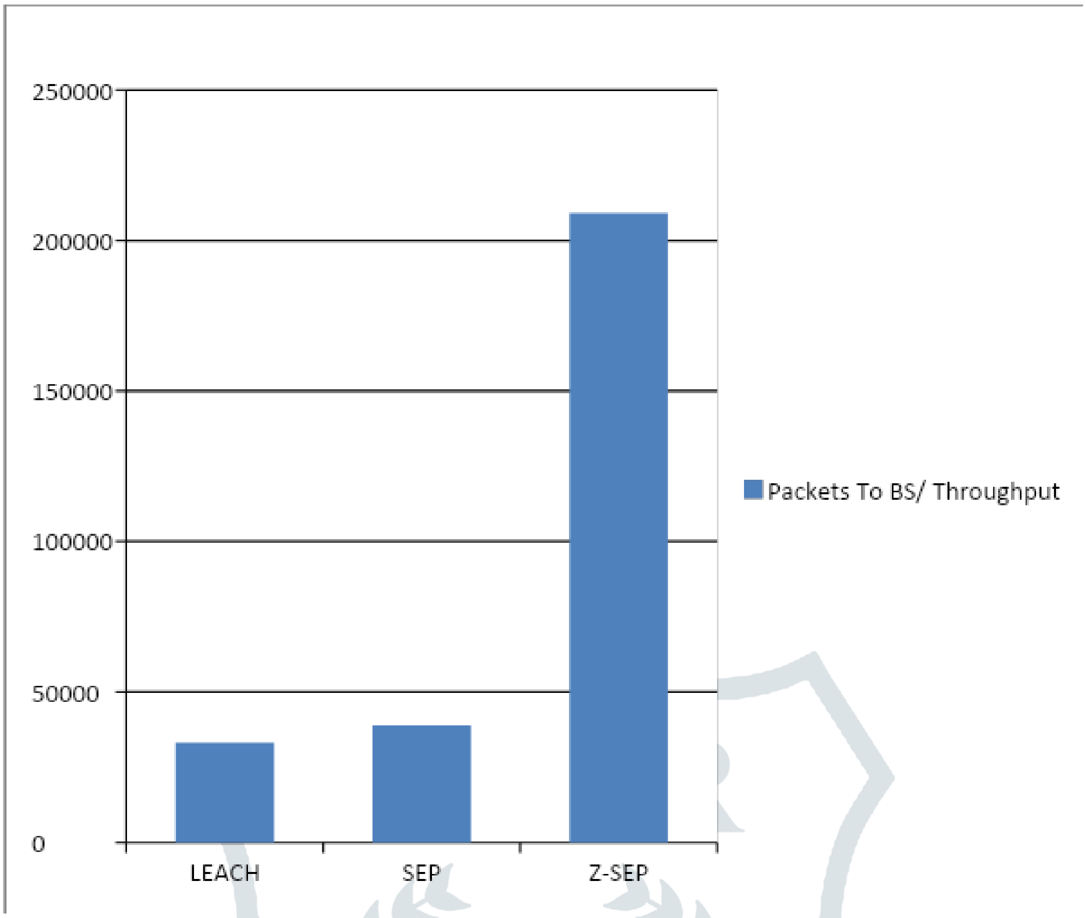

Figure 7.8: Comparison bar chart between LEACH(m=0, a=0), SEP(m=0.2, a=1) and Z-SEP(m=0.2, a=1) on the basis of Throughput.

Protocol	Packets To BS / Throughput
LEACH	33200
SEP	40500
Z-SEP	226500

Table 7.4 : Comparison table between LEACH(m=0, a=0), SEP(m=0.1, a=2) and Z-SEP(m=0.1, a=2) on the basis of Throughput.

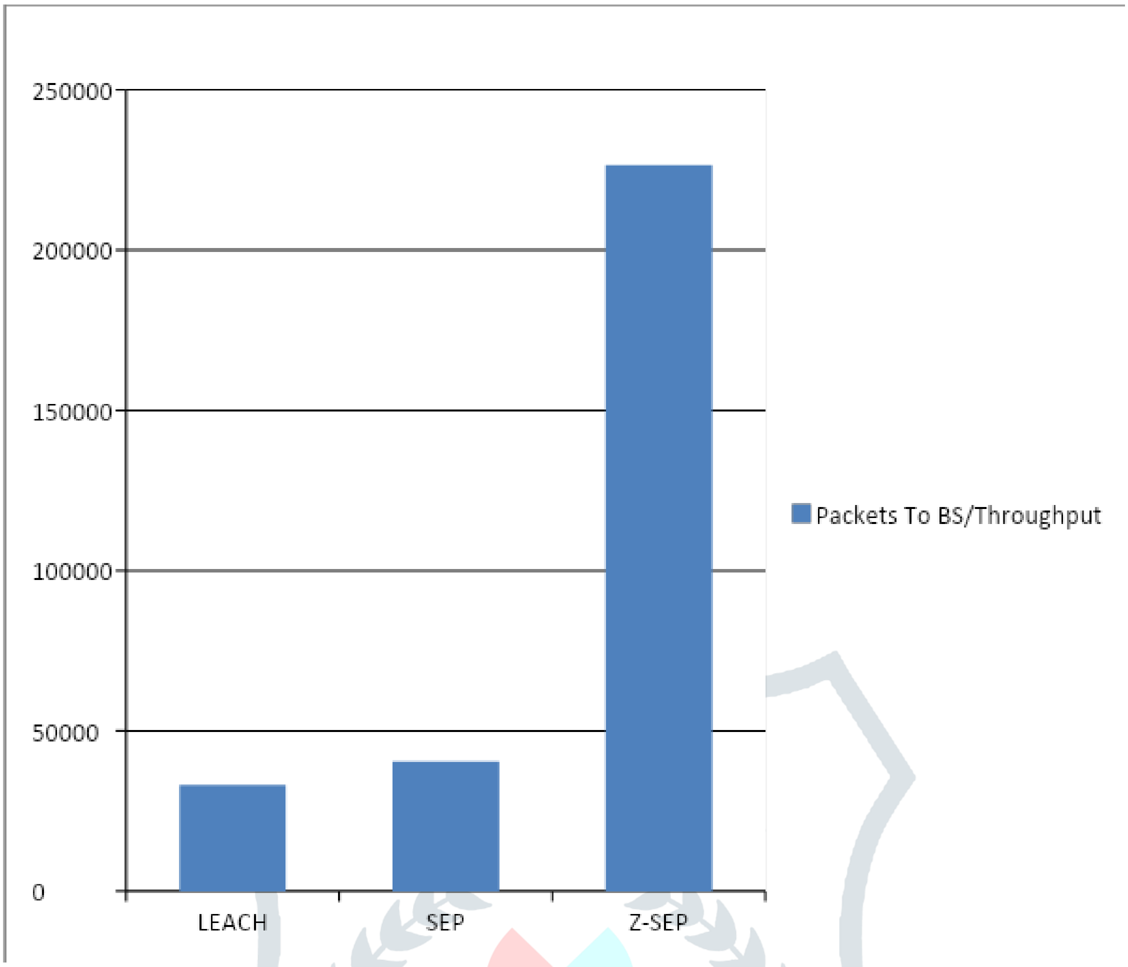

Figure 7.9: Comparison bar chart between LEACH(m=0, a=0), SEP(m=0.1, a=2) and Z-SEP(m=0.1, a=2) on the basis of Throughput.

8. CONCLUSION

In this paper, we studied and analysed cluster based routing protocols in WSN. Simulations are performed using MATLAB(R2016A). We compare the performance of LEACH, Stable Election Protocol(SEP) and Z-SEP(Zonal Stable Election Protocol) in terms of stability period, network lifetime and throughput for different values of m (fraction of nodes that have more energy) and a (extra energy factor b/w normal and advanced nodes). Results shows that Z-SEP is much better protocol than LEACH and SEP in terms of stability period, network lifetime and throughput because of homogeneity i.e. advanced nodes dies after a certain higher no. of rounds and because of weighted probability.

9. REFERENCES

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