EHE-LEACH: Enhanced heterogeneous LEACH protocol for lifetime enhancement of wireless SNs

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Abstract— **Wireless Sensor Network (WSNs) are collection of small Sensor Nodes (SNs) which are capable of performing multiple tasks such as data aggregation, processing and communication either to other SNs or to the Base Station (BS). As SNs are battery operated, so efficient utilization of energy during various operations in WSNs is one of the major issues which requires special attention. It has been observed in literature that Hierarchical clustering and the node heterogeneity are the two parameters by which the lifetime of WSNs can be enhanced. Keeping in view of the above, in this paper, we propose an Enhanced Heterogeneous LEACH (EHE-LEACH) Protocol for Lifetime Enhancement of SNs. A fixed distance based threshold is used for the bifurcation of direct communication and cluster based communication in the proposed scheme. SNs near to the BS communicate directly and those which are far away from the BS use cluster based communication. To evaluate the performance of the proposed scheme two key parameters known as: Half Nodes Alive (HNA) and Last Node Alive (LNA) are selected. By selecting the distance based threshold with the ratio of 1:9 between direct communication and cluster based communication it has been observed that EHE-LEACH has better network lifetime with respect to various parameters in comparison to the other well known proposals such as LEACH and SEP.**

Keywords— Sensor network; clustering; network lifetime; heterogeneous

I. INTRODUCTION

Now days wireless sensor networks (WSNs) attract the researchers more due to their potential applications in environment monitoring, radiation and nuclear-threat detection systems; weapon sensors for ships; battlefield reconnaissance and surveillance; military command, control, communications, intelligence, and targeting systems and biomedical applications. In addition to this military sensing, physical security, process control, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, weather sensing, environment monitoring, and building and structure monitoring will also be the major areas where WSNs are very helpful [1-2]. In such networks, each sensor node not only serves as a host to generate sensed data and to process the collected data, but also works as a gateway to transmit messages and receive messages from other sensors within its transmission range. Therefore deployment of sensor nodes will also depend upon the application.

The small components of WSN, sensor nodes sense the data from the environment, perform the desired computation on the collected data and communicate easily to the excess point, base station (BS). Computed data can be communicated either by predefined route or simultaneously defined route. From the literature [3] it is come across that routing in WSNs has specific requirements such as to enable reliable communication, consider the limited bandwidth, variable capacity of radio links and most important issue is energy efficiency. Real-time communications with given delay limits is also interesting since some applications required immediate action to sensor inputs. Practical algorithms should provide robustness against link failures, by any means, and track changes in the network topology if sensor nodes are mobile. This indicates that the selection of appropriate routing protocol is the key challenge in WSN environment. Mostly sensor nodes are battery operated, almost impossible to replace or recharge the battery, and they perform the complex task too, therefore the main objective of this work is to design energy efficient routing protocol for the WSN that prolong the network lifetime and stability.

The major problem of the sensor node is the limited energy. Therefore, energy efficiency in the design of routing protocols for sensor networks is of principal requirement. Here we proposed an enhanced heterogeneous low energy adaptive cluster based hierarchical protocol (EHE-LEACH). EHE-LEACH is based on the fixed distance threshold, which is used to bifurcate the coverage area, used two separate mechanism direct diffusion and clustering. From the literature survey it is observed that minimum two hop data transmission is required for the cluster based communication, from source to BS even though the distance between source and BS is very small. This consumes extra execution time for the completion of a round. Further in the clustering approach, data

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transmission from single source, there is an energy loss of at least two sensor nodes (if multihop communication is not being used). Here we are focusing the constraints on the energy of individual sensor node and the complete network both. Therefore in the proposed model two parameters are considered: firstly- minimize the execution time of a round to some extent by using direct diffusion. Secondly- maximizes the lifetime and stability of the network by using the combination of two techniques simultaneously direct diffusion and clustering. The half nodes alive (HNA) & last node alive (LNA) are the key parameters used for the measurement of lifetime and the stability of the system.

The remaining part of the paper is organized as follows: related work is briefly discussed in Section II. In Section III we discuss the network and radio models used. Section IV describes EHE-LEACH routing protocol in detail. In Section V, we simulate the EHE-LEACH protocol by using MATLAB and compare its performance with other established routing protocols. Finally, we conclude with future scope in Section VI.

II. Related Work

As WSNs have been used in wide areas of applications, so routing is important and need a special attention. Lot of research proposals have been reported in the literature addressing this issue. In this section we cover some existing protocols for the issue we have discussed earlier.

C. Intanagonwiwat et al [4] suggested direct diffusion (DD) to construct the route between sensor nodes and BS. It consists of four stages out of which interested stage is direct data communication. Sensor nodes away from the BS dies quickly in DD due to the large distance data transmission, indicating that some portion is now uncovered. But for small field DD is still better option.

W. R. Heinzelman et al [5-6] suggested low energy adaptive clustering hierarchy (LEACH) and centralized LEACH protocol for the data communication from source nodes to the BS through gateways, usually known as cluster heads (CHs). LEACH protocol performs the grouping of nodes in to clusters, here local interactions among the cluster members (CMs) is controlled by CH. In addition to this CH have several responsibilities like local data reception, aggregation and fusion, this process controlled the energy of sensor nodes and effectively prolong the lifetime of network field. CHs are most relying sensor nodes as these are taking the responsibility of data transmission to the BS, consume more energy. Therefore the role of CH is dynamically changed such that the high-energy consumption in data transmission to the BS is distributed to all the sensor nodes in the network. LEACH-C used centralized approach and considers the remaining energy. The operation of LEACH and LEACH-C is controlled by rounds, which consist of two phase setup phase and steady state phase. CHs are selected in setup phase and allocate the TDMA schedule to the respective CMs. While in the steady state phase, data communication between the CMs and the CH is performed. A CM in a cluster is active only during its allocated time slot, while CHs are active all the time in steady state phase. LEACH performs periodic CH selection, the energy consumption burden of the CHs is also shared. The duration of the steady state phase is longer than the duration of the setup phase. Observations shows that LEACH provides a factor of 4–8 reduction in energy consumption compared to a flat-architecture routing protocol. Major drawback of this protocol is that they do not consider the residual energy of sensor nodes and assume zero energy consumption for the formation of cluster.

S. Lindsey et al [7-8] suggested power efficient gathering in sensor information systems (PEGASIS) for the data communication from source node to the BS. This protocol is based on the chain, CH is selected randomly from the dedicated chain and responsible for data transmission to the BS. Major drawback of this algorithm is that it required the global knowledge of the network, based on which chain can be constructed using greedy algorithm. There is a proper load balancing as a sensor node receive the data from its neighbour, available in the chain, aggregate the same with own data and transmit to the another neighbour which is the part of chain. Chain will be reconstructed when a node die, now it exclude the die node. Observation shows that PEGASIS provides 100–300% lifetime enhancement over LEACH. Another drawback of PEGASIS is the significant delay, since the data have to be sequentially transmitted in the chain and the CH waits until all the messages are received before transmitting to the BS.

A. Manjeshwar et al [9-10] suggested threshold-sensitive energy efficient sensor network (TEEN) and adaptive threshold-sensitive energy efficient sensor network (APTEEN) to provide event based data transmission. Two types of thresholds are used in TEEN hard threshold (HT) and soft threshold (ST). Here sensor nodes are programmed in such a way that it will respond to sensed-attribute changes, by comparing the measured value to the HT, if HT exceeded, the sensor node sends its observed data to the CH. ST is used to reduce the redundancy in the transmission. Whenever the HT exceeded, the sensor node also checks the ST for consequent observations. Sensor node does not transmit this information, if the difference between consecutive observations does not exceed the ST. Major drawback of LEACH and PEGASIS is that these protocols periodically transmit the sensed information, and are not suitable for the event based data transmission. TEEN is designed to work effectively only for event based data transmission. APTEEN is the enhancement in TEEN and support for the responding periodically. APTEEN provides a TDMA-based structure for the transmission of sensed information to the cluster and each sensor node transmits its information periodically to the respective CH. However major drawback of TEEN and APTEEN, there is some situation where data is not transmitted.

Smaragdakis et al. [11] developed stable election protocol (SEP) for the two level heterogeneous networks, which includes two types of nodes, normal and advanced nodes. In SEP election probabilities are weighted by the initial energy of a node relative to that of other nodes in the network.

This prolongs the time interval of FND that must be crucial reliable communication. Further SEP is dynamic therefore it does not assume any prior distribution of the different levels of energy in sensor nodes. Finally SEP is scalable as it does not require any knowledge of the exact position of each node in the field. Disadvantage of SEP is that it performs poorly in terms of stability for multi-level heterogeneous WSNs.

III. Energy Model

For wireless communication system, the radio model used here is same as used in [6] as shown in fig. 1. If communication distance is less than distance d_0 free space channel model is used otherwise multipath model is used. So the transmission energy of transmitting a *k*-bit message over a distance *d* using this radio model is:

$$E_{Tx}\left(k,d\right)=k*E_{elec}+\mathrm{k}*\varepsilon_{amp}*\mathrm{d}^{\mathrm{n}} \tag{1}$$

Where pathloss component n (2 or 4) and amplification factor $\varepsilon_{amp}(\varepsilon_{fs} or \varepsilon_{mp})$ are defined in equation set (2) for free and multipath environment respectively.

$$E_{Tx}\left(k,d\right)=\begin{cases}k*E_{elec}+\mathrm{k}*\varepsilon_{\mathrm{fs}}*\mathrm{d}^2,(d<d_0)\\ k*E_{elec}+k*\varepsilon_{mp}*d^4,(d\geq d_0)\end{cases} \tag{2}$$

E_{elec} is the transmitter circuitry dissipation per bit and $d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$.

The receiving cost is $E_{Rx}\left(k\right)=E_{elec}*k$ (3)

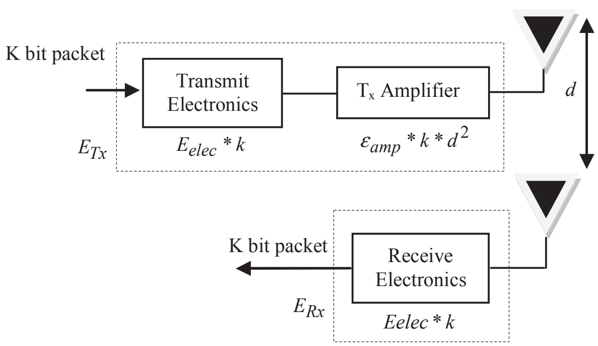

Fig. 1. Radio Model

IV. Proposed Model

For small scale network field direct diffusion approach is always better while for medium to large scale field cluster based approach is preferred, from the literature overview [3]. Therefore we are suggesting enhanced heterogeneous LEACH protocol that utilizes the facilities of both approaches as discussed above. We used a fixed distance based threshold which divides the network field in to two portions. We assume that BS is located at the one of the corner of network field and is stationary. Therefore with the fixed distance based threshold, region near to the BS is used direct communication approach while the region away from the BS used cluster based approach. In LEACH protocol it is assumed that the consumption of energy is almost zero for the formation of cluster, practically it is not possible. In our approach as we are using the combination of DD [4] and LEACH [5-6] based on the fixed distance based threshold $T_n(d)$, we can save the energy for the region over which clustering is not being used. Consequently the overall life time and stability of the network field increases. Motivation of proposed scheme is taken from the shortfalls of stable enable protocol suggested by Smaragdakis et al. in [11]. In the next section we discuss the major filling areas in the SEP protocol.

Major drawback of SEP protocol was the poor stability, as they found the decrement for LNA in comparison to LEACH. Whereas Smaragdakis et al. [11] achieved the very good lifetime enhancement over LEACH by using node heterogeneity. Therefore according to SEP better lifetime of the network field could be achieved by compromising the system stability. To overcome the above mentioned issue we proposed EHE-LEACH, principle of this protocol is discussed in theorem1.

Theorem1:If the distance between BS and sensor node is sufficiently small then consumption of energy is small for direct communication in comparison to cluster based.

Proof: For the proof consider the network field as shown in figure 2. Where parameters are:

d_1 - Distance between base station and sensor node.

d_2 - Distance between sensor node and cluster head.

d_3 - Distance between cluster head and base station.

$T_n(d)$ - Fixes distance based threshold.

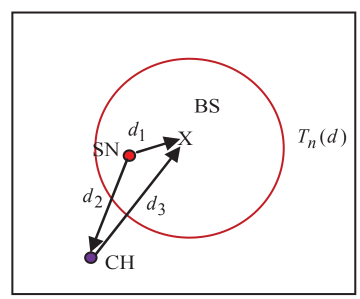

Fig. 2. Network Model

From fig. 2 it is clear that $d_3>d_2>d_1$. With the condition of $T_n(d)$ nodes will exist in the region where direct communication can be used therefore single hop communication is possible. While for LEACH protocol single hop communication is not possible for the data transmission from the source to BS, minimum two hope communication is required. Now we are calculating the cost of energy for both cases:

Cost of energy for direct communication is: $k*E_{elec}+\mathrm{k}*\varepsilon_{\mathrm{amp}}*\mathrm{d}_1^2$

Cost of energy for cluster based communication is: $3*k*E_{elec} + k*\varepsilon_{amp}*d_2^2 + k*E_{DA} + k*\varepsilon_{amp}*d_3^2$

All terms are defined above in the energy model, cost of energy for cluster based communication is high as compared to the direct communication. Therefore it is proved that if distance between BS and sensor node is sufficiently small then consumption of energy is small for direct communication in comparison to cluster based communication.

Further we are using two level of node heterogeneity, nodes under first level are known as normal nodes, second levels are advanced node. Advanced nodes have more initial energy in comparison to the normal nodes. Also assume that 'm' be the fraction of the total number of nodes N, which are equipped with 'a' times more energy than the normal nodes, these nodes are advanced nodes and remaining $N\times(1-m)$ are normal nodes. It is also assumed that all nodes are distributed uniformly over the network field. Now the total energy of the network changes, as it consists of two different categories of SNs. Let us consider that E_0 is the initial energy of each normal node then the initial energy of each advanced node will be $E_0\times(1+a)$. Heterogeneity model used here is similar to that of SEP discussed in [11]. Therefore total initial energy of the new heterogeneous network is $N\times E_0\times(1+a\times m)$ hence, the total energy of the system is increased by $(1+a\times m)$ Cluster heads are selected on the bases of weighted probabilities, for the normal and advanced node, it can be defined as follows:

$$p_{nrm} = \frac{p_{opt}}{(1+a\times m)} \tag{4}$$

$$p_{adv} = \frac{p_{opt}}{(1+a\times m)}\times(1+a) \tag{5}$$

Based on the weighted probabilities discussed above respective threshold can suggested:

$$T(S_{nrm}) = \begin{cases} \dfrac{p_{nrm}}{1-p_{nrm}\times\left(r \bmod \dfrac{1}{p_{nrm}}\right)}, if S_{nrm}\in G \\ 0, Otherwise \end{cases} \tag{6}$$

Here 'r' is the current round, G is the set of normal nodes that have not become CHs within the last $\frac{1}{p_{nrm}}$ rounds of the epoch, and $T(S_{nrm})$ is the threshold for a set of $N\times(1-m)$ normal nodes. In the similar fashion the threshold for advanced node can also be set.

In EHE-LEACH we focused on the open issue of SEP protocol as discussed above, through the simulations in forthcoming session, we suggested that EHE-LEACH provides very good improvement on the network lifetime without any compromise in the system stability. Detail execution of our approach is discussed in the table 1.

TABLE I. PSEUDO CODE

Pseudo code of EHE-LEACH
1. Initialize the parameters
2. Identification of normal nodes: $if(temp\_rand \geq m\times n+1)$
3. $S(i).E = E_0$
4. end if
5. Identification of advanced nodes: $if(temp\_rand < m\times n+1)$
6. $S(i).E = E_0\times(1+a)$
7. end if
8. $if(d \geq T_n(d))$
9. Direct communication system is used.
10. Else, go to next step.
11. Weighted election probabilities for normal and advanced nodes
12. $p_{nrm} = \frac{p_{opt}}{(1+a\times m)}$ and $p_{adv} = \frac{p_{opt}}{(1+a\times m)}\times(1+a)$
13. Election of CHs based upon weighted election probabilities
14. Elected CH broadcast the message to SNs
15. CH allocate TDMA schedule to CMs
16. for CH, for CMs
17. Data transmitted from CMs to CH as per TDMA schedule
18. Data aggregation by CH
19. end for CMs
20. data transmitted from CH to BS
21. end for CH
22. end of code

V. RESULTS

The proposed algorithm is tested by using MATLAB. For the simulation we have considered 100 × 100 square network field, where 100 SNs are deployed randomly. All sensor nodes are stationary, remaining assumptions and parameters are same as used in [4-5]. Further we assume the location of BS is 100 × 100. Lifetime analysis is shown in Fig. 3, the comparison of LEACH, SEP and EHE-LEACH is given on the basis of HNA and LNA for different node heterogeneity level and initial energy $E_0 = 0.25J$. The average number of rounds for fifteen iterations in LEACH and SEP are less than over the EHE-LEACH, this can be easily seen from figure 3(a) and 3(b). On the bases of HNA and LNA we can observe that the lifetime of network field is significantly enhanced. This enhancement in

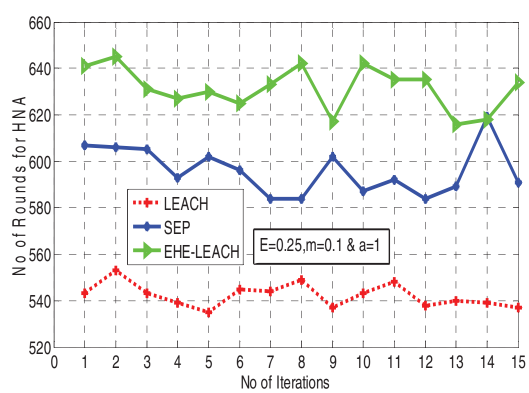

Fig. 3. a (i)

the lifetime is achieved by using the fixed distance threshold. Fig. 3(a), shows that the system lifetime of our protocol is better than LEACH and SEP as a function of HNA.Text heads organize the topics on a relational, hierarchical basis.

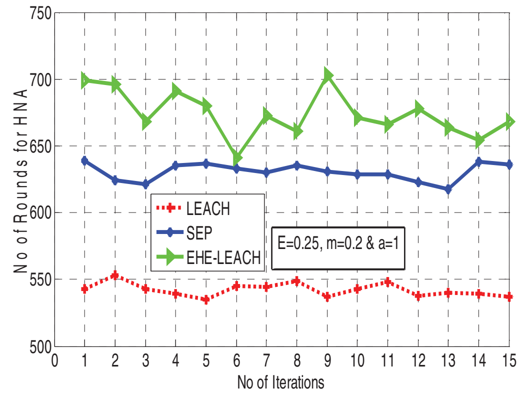

Fig. 3. a (ii)

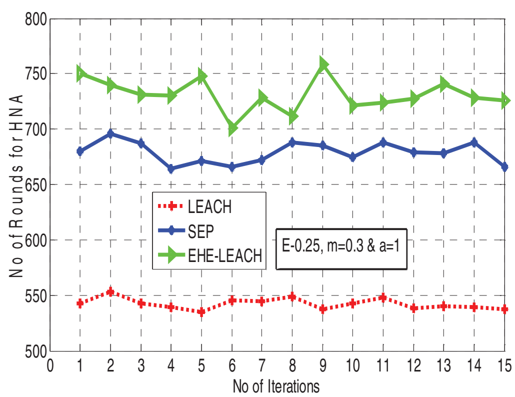

Fig. 3. a (iii)

Fig. 3. a Comparison of lifetime as HNA for different protocol at initial energy $E_0 = 0.25J$ and heterogeneity parameters (i) $m = 0.1$ & $a = 1$ (ii) $m = 0.2$ & $a = 1$ and (iii) $m = 0.3$ & $a = 1$

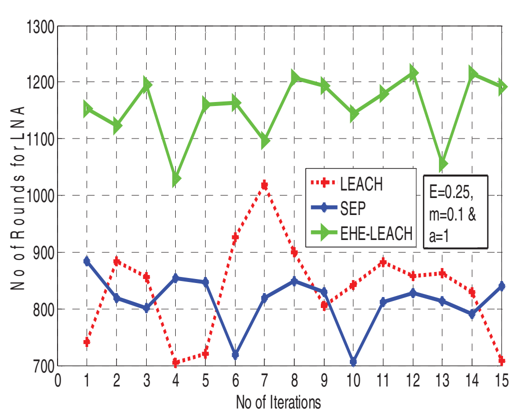

Fig. 3. b (i)

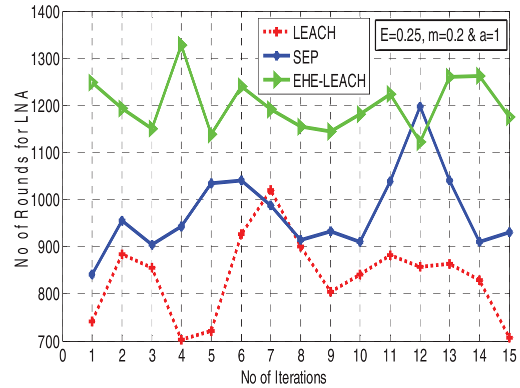

Fig. 3. b (ii)

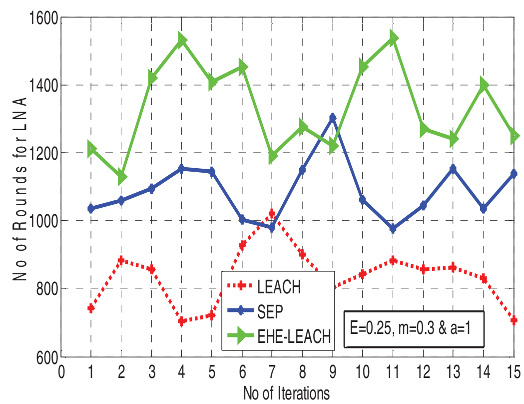

Fig. 3. b (iii)

Fig. 3. b Comparison of lifetime as LNA for different protocol at initial energy $E_0 = 0.25J$ and heterogeneity parameters (i) $m = 0.1$ & $a = 1$ (ii) $m = 0.2$ & $a = 1$ and (iii) $m = 0.3$ & $a = 1$

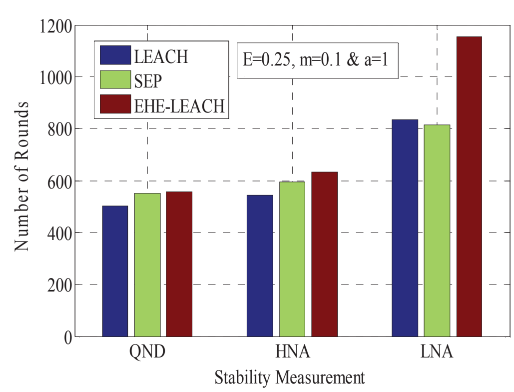

Fig. 4. (i)

Stability analysis is shown in Fig. 4, the comparison of LEACH, SEP and EHE-LEACH is given on the basis of histograms for different heterogeneity level and at $E_0 = 0.25J$ initial energy. The average numbers of round we have taken in our simulation are fifteen iterations, this shows that LEACH and SEP are less stable as compare to the EHE-LEACH. Stability analysis details are shown in figure 4(i), 4(ii) and 4(iii) at different node heterogeneity. On the bases of QND (quarter node die) suggested by us, HNA and LNA performances we can observe that the stability of our system is more as compared to LEACH and SEP.

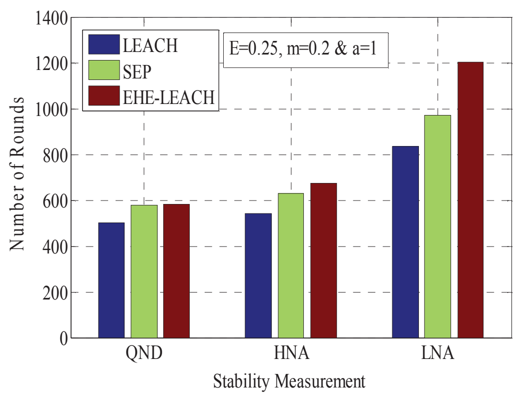

Fig. 4. (ii)

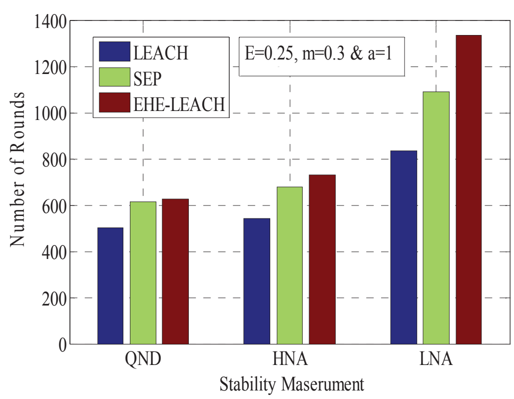

Fig. 4. (iii)

Fig. 4. Comparison for stability for different protocol at initial energy $E_0 = 0.25J$ and heterogeneity parameters (i) $m = 0.1 \,\&\, a = 1$ (ii) $m = 0.2 \,\&\, a = 1$ and (iii) $m = 0.3 \,\&\, a = 1$

VI. CONCLUSION

The wireless sensor networks are using in various monitoring applications and not limited to this domain only. Life time enhancement of the network field is primary requirement by using an appropriate mechanism. Generally there is not any proper definition of life time, depends upon the application, here we used QND, HNA and LNA as the key parameters for the lifetime measurement and stability. Major drawback of node heterogeneity is the poor system stability in comparison to the homogeneous clustering protocol. In this paper, we have proposed an extended heterogeneous LEACH protocol for wireless SNs. The energy efficiency, extended life time and improved system stability make EHE-LEACH an attractive protocol for wireless SNs. In order to improve the stability of the network system and lifetime, this paper utilise the fixed distance based threshold for clustering based communication and the direct communication of nodes to the BS. Observations show that EHE-LEACH has better lifetime and stability of the system as compared with LEACH and SEP for same energy level. We compared EHE-LEACH with LEACH and SEP, but due to the presence of various clustering algorithms that we need to evaluate and in future other factors can have an effect on the network lifetime.

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