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A Review Summary on Various Cluster-Head Selection Improvement Techniques for LEACH-Based Protocols in Wireless Sensor Networks

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Abstract

In present days, wireless sensor network (WSN) plays an important role in the domain of networks because of its vast applications in various fields. Sensor nodes (SNs) or nodes which are infinitesimally small in sizes are involved in the functioning of WSN for observing and monitoring the environmental phenomena by deploying these nodes in the region of interest. These tiny nodes are energy constrained and also have limited resources. Hence, various cluster-based routing techniques have been developed to optimise the energy utilisation of sensor nodes for extending network lifespan. LEACH is one of the most eminent cluster-based protocols where many derivative protocols have been proposed and still huge efforts are being contributed by many researchers to propose new algorithms based on the parent LEACH protocol. In this paper we represent a survey on LEACH based protocols related with the various modified techniques of cluster head selection. In cluster-based LEACH protocol cluster heads spend much more energy than that of energy by other nodes in the cluster. Therefore, proper selection of cluster heads is necessary in order to optimise the energy efficiency of a network. This paper reviews mainly the various modified election probability of cluster head selection and threshold condition based on LEACH protocol to provide a brief idea of these improvement techniques to the readers.

Keywords: cluster head, threshold condition, election probability, cluster-based, lifetime, energy

1. Introduction

Wireless sensor networks (WSNs) have recently contributed an important role in the networking domain and is the most attention seeking research area in the wireless networks. The uses of WSNs are increasing exponentially in various spots such as surveillance system, earthquake detection, home security, defence purpose, traffic speed control, monitoring of patients, monitoring of remote areas, etc which makes wireless sensor network (WSN) a highly demand necessities in day-to-day life. WSN comprises of a huge number of cheap, miniaturised, power constrained and bounded memory devices called sensor nodes (SNs) in which a non-chargeable battery acts as the power source of these nodes. Each sensor node (SN) has the capability of signal processing, local computation and communication to the base station (BS) or transmitting information to each other. Every SN will detect a particular event associated with the region under observation and transmit the detected events to the BS or will serve as the relay node for some other far away nodes from the BS or destination node or sink node as in the case of multi-hop transmission. Figure 1 shows the general overview of WSN layout [1].

It is necessary for WSN to design a protocol which provides maximum energy efficient to the system because of its limited battery power source. Cluster based hierarchical protocol such as LEACH (low energy adaptive clustering hierarchy) can be stated as a routing technique that falls under the category of energy efficient routing protocol [2]. Clustering based protocol is one of the vastly used energy efficient protocol in most of the WSN applications. Even though there are many other energy efficient cluster-based routing protocols such as HEED protocol, k means clustering algorithm, etc [3-8], this paper will focus mainly on LEACH cluster-based protocol. In WSNs, BS can be a mobile node according to the requirements of specific application where the user can access to the sensed data at any time through the mobile BS but this paper will give preference to the fixed BS routing protocols. In this paper, both the homogeneous (same initial nodes' energy) and heterogeneous (different initial nodes' energy) LEACH protocol-based sensor networks are taken into account. In heterogeneous network higher probabilities can be assigned directly to those nodes with higher initial energy and lower probabilities to other remaining nodes unlike homogeneous network so that death of nodes can be delayed to some extent [9]. In some proposed techniques initial energy of some nodes in the network are taken to be higher than the remaining nodes to observe its effects in terms of network lifetime and other network performance parameters [10-14]. LEACH is non centralized adaptive clustering protocol where cluster formation is completely distributed in nature and the intense energy consumption of being a cluster head (CH) or leader node is equally taken by every SN in the network so that the load of energy depletion is shared equally in the sensor network. LEACH is basically splitted into two stages (phases) namely set up and steady state stage. Both the stages are significant in performing LEACH operation. The first phase starts by self-arranging the SNs into local groups called clusters under the leadership (cluster heads) of a node in each cluster and the remaining nodes will join to one of the CHs which is nearest to those SNs. The CHs role will rotate among themselves to have equal energy load distribution in the overall networks for every clustering process (rounds). The CHs election process is a randomised process and energy consumption of CHs are higher than other ordinary nodes or cluster members (CMs) since they perform direct transmission of data to the BS which

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may be located at near or far distance from the observing area. Also, the CHs aggregate the received data before sending the sensed data to BS by SNs. Clusters are not fixed instead it varies from round-to-round process. The CHs selection depends on the random number generation of every node and threshold condition given by equation (1).

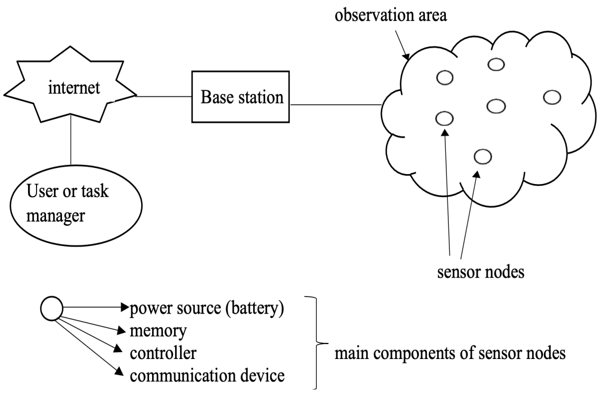

Fig. 1. Overview of WSN

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod 1/p)} & n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

where p = desired percentage of nodes to be CHs, r = present round and G are those nodes which have not taken the leadership role in recent 1/p rounds. If a lesser random number is generated by a node than the threshold value, then a leadership role will be given to that node and the chance of nodes to become CHs depend on the percentage value and the number of times the nodes have taken the leadership role. LEACH uses two types of radio propagation model i.e. free space and multipath radio propagation model depending on the distance between two nodes. Figure 2 represents the radio energy model deployed in LEACH protocol [2][15]. Figure 3 represents the cluster formation in LEACH.

The energy dissipation model are as follows [2]:

$$E_t(b,d) = \begin{cases} E_{te}(b) + b\epsilon_{fs}d^2, d < d_o \\ E_{te}(b) + b\epsilon_{mp}d^4, d < d_o \end{cases} \quad (2)$$

where $d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$ represents the threshold distance.

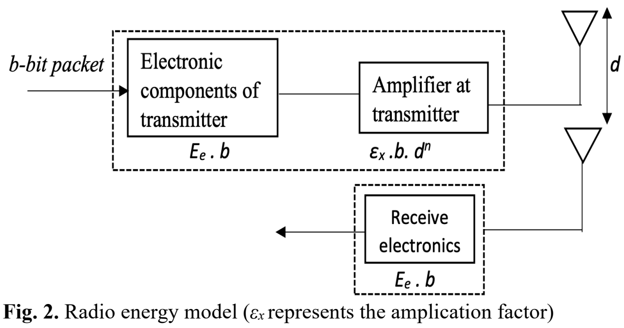

Fig. 2. Radio energy model (ε_x represents the amplication factor)

E_t denotes depletion in energy by the transmitter for transmitting b-bit data over *d* distance. E_e denotes energy depletion by electronic components based on factors like digital modulation, coding and filtering process. $E_{te}(b) = b.E_e = E_{re}(b)$ symbolises the energy depletion by electronic components for transmitting and accepting b-bit data over *d* distance which are taken to be 50 nJ/bit and 100 pJ/bit/m^2 respectively. ϵ_{fs} and ϵ_{mp} are the energy required for amplifying a single bit by the amplifier circuit.

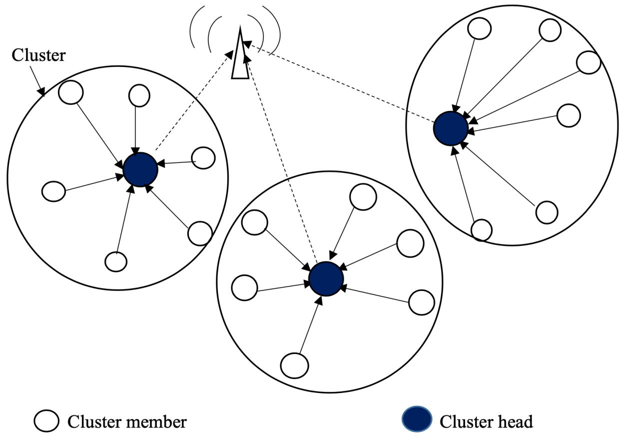

Fig. 3. Cluster formation in LEACH

The two states set up and steady state makes a complete round operation. The CHs selection is done at the set-up phase followed by advertising themselves as the CHs for the current round in the network. The SNs will decide to which CH they will join after acknowledging the maximum signal strength CH as the nearest node to them. The CHs broadcast the specific time period to member nodes to convey their sensed data to CH. In steady state, member nodes transfer their collected data to the concerned CH and the CHs send the gathered information to end user after data fusion process. The phase of steady state is considered to occupy longer time than the set-up phase since there is less overhead transmission and the main data passing process occurs during this phase. Many research works have been done focussing on the improvement process of wireless sensor network constraints such as node deployment, coverage, reliability, robustness, etc. Although some survey papers have been published by researchers on routing techniques [2-3][16-19] this paper specially covers the various improved LEACH derivative protocols which provides the summary of different improvement approaches based on cluster head selection process of LEACH. We try to cover maximum improved cluster head selection techniques specially those approaches based on threshold condition and election probability in our paper.

The following sections of the chapter is arranged as given here. Section 2 discusses the various enhancement techniques based on LEACH protocol which is further splitted into sub sections. Sub section 2.1 describes the different approaches based on cluster head selection process with more priority to election probability and threshold condition of cluster head selection since these two factors play the main role in network performance parameters specially lifetime. Conclusion has been discussed in section 3.

2. Cluster based protocols enhancement

LEACH shows analysis results in network parameters like lifetime, throughput, CHs selection per round, total energy dissipation in system comparing to other routing protocols. Various modified LEACH derivatives have been proposed to improve the network performance in some or the other parameters in which most of the cluster head selection improvement techniques have shown better results in network lifetime [14]. Section 2 and sub sections of it represents the brief description of those improved approaches based on LEACH protocol.

2.1 Based on cluster head (CH) selection

Clustering protocols are used to conserve the energy of SNs and to decrease the length of data packets that is being transmitted to the BS. For cluster-based protocols to be energy efficient, selection of CHs is one of the important functions to be considered since heavy energy is consumed by CHs. Many research works have been done based on LEACH by considering some additional parameters for CHs selection as an improved technique.

In conventional LEACH, the selection of a cluster head at a particular round depends on its election probability and threshold condition as given in equation (1). This election probability of a node to elect itself as a cluster head depends upon the number of nodes that can become cluster head in each round process which is a predetermined value and the current round number [15] as given in equation (3).

$$p_i(t) = \begin{cases} \frac{C}{n-C\left(r \bmod \frac{n}{C}\right)} & ; \forall\, s_i(t) \in n \\ 0 & ; \forall\, s_j(t) \in n \end{cases} \quad (3)$$

where C is the number of nodes that can become cluster heads per round, n is the total number of nodes in the network, r is the present round number, $s_i(t)$ are nodes that are eligible for becoming cluster heads i.e. which has not been cluster head in the recent rounds $\left(r \bmod \frac{n}{C}\right)$ and $s_j(t)$ are nodes that have been cluster heads in the recent rounds $\left(r \bmod \frac{n}{C}\right)$. This method of cluster head selection leads to faster death of nodes since it does not consider unconsumed energy of nodes which further leads to 'hot spots' in the network [18] and shorter stability period (First node dead). In addition to this, consideration of distance of nodes from base station is an important factor to take into account since energy dissipation is more for nodes far away from base station in comparison with that of closer nodes which is also not considered in the conventional LEACH. This consideration is necessary to avoid early death of nodes which further results in shorter network lifespan. Hence, various techniques have been proposed by many researchers incorporating energy and distance factors in cluster head selection process in different way to enhance the network lifetime and other network performance metrics based on the proposed techniques. Most of these techniques have given priority in improving network lifetime because battery replacement in sensor network is a hot challenging issue in the current scenario. The following sub sections categorised the various improvement techniques.

2.1.1 Based on cluster size

In [4] the authors proposed an energy efficient derivative of cluster-based LEACH protocol called balancing energy consumption using cluster-based approach (BECUCBA named for convenience) for extending network lifetime and to maintain uniform energy consumption of all nodes throughout the network. The authors have considered different cluster size for every clustering process based on the distance of cluster heads from base station. They have taken three cases namely when all nodes' distances from BS are below d_o (cross over distance) in the first case, all nodes are lying above d_o in the second case and in the third case some nodes below d_o and some nodes above d_o. The BS will assign average nodes to the cluster heads lying at the centre of the network and will decide the number of nodes for other cluster heads according to equation (4). The proposed protocol results in extended lifetime and better leftover energy of all nodes at the time of first node dead (FND) showing a gain of 7.7049% and 144.61% respectively over LEACH.

$$g_1 - g_2 = \frac{C\epsilon_{mp} d_{g2}^4 - C\epsilon_{fs} d_{g1}^2}{2E_e + E_{da} + \frac{\epsilon_{fs} M^2}{2\pi C}} \quad (4)$$

where g_1 and g_2 are the number of nodes under cluster head 1 (CH1) and cluster head 2 (CH2) respectively, d_{g1}^2 and d_{g2}^4 are the distances of CH1 and CH2 from base station, E_{da} is the energy required for data aggregation per bit (J) and M is the maximum dimension of the network.

In [10] the authors proposed a uniform cluster size LEACH called C-LEACH where each cluster has almost similar number of member nodes (consistent cluster size) in addition to modified threshold condition which is given by equation (5). Equal cluster size is obtained by maintaining a threshold value for minimum and maximum cluster size. This protocol allows equal sharing of load among the cluster heads as compared to LEACH protocol.

$$T(n) = \begin{cases} \frac{p * \frac{E_p}{E_i}}{1-p(r \bmod 1/p)} ; n \in G \\ 0 \quad ; otherwise \end{cases} \quad (5)$$

where E_p= present nodes' energy

2.1.2 Based on threshold condition with energy factor

In [5] the authors put forward an improved LEACH called Balanced Energy Consumption and Cluster-Based Routing Protocol (BECCRP) to lessen energy depletion of sensor nodes, enhance its lifetime and to balance distribution of energy load in the network. This proposed protocol consists of five levels namely gateway selection level, CHs election level, cluster formation level, transmission path estimation level and data transmission level. Also, the sensor nodes in the improved protocol have six ranks namely UNDECIDED, TEMP_CH, CH, TEMP_GW, GW and CM. Higher energy nodes are elected as gateways since data transmission to BS is carried out by them. Election process of CH is done using the threshold condition as presented in [20]. The gateway and CH advertisement is broadcast to reach upto some threshold distance. The transmission path is constructed by taking into account gateway ID, hops count to the BS and its energy status. The proposed work has exhibited improved lifetime than LEACH for different network size.

In [8] the authors suggested an improvement in the LEACH protocol with the consideration of consumed energy of nodes in the threshold condition as the deterministic factor to extend the lifespan of network for different density of network nodes and different base station location. The threshold condition is given as follows:

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod 1/p)} * \tan\left(\frac{E_{con}}{E_i}\right) ; n \in G \\ 0 \quad ; otherwise \end{cases} \quad (6)$$

where E_{con}=consumed energy
E_i= initial energy of nodes

In [9] authors considers ratio of current energy and initial energy in addition to percentage of clusters in the network in the threshold condition as given in (7) and named it as A-

LEACH. The result shows better lifetime, throughput and better message delivery with alive nodes.

$$T(n) = \begin{cases} \frac{k}{N-k*(rmodN/k)} + S; \text{n} \in \text{G} \\ 0 \quad ; otherwise \end{cases} \tag{7}$$

where
$S = \frac{E_{cur}}{E_{res}} * \frac{k}{N}$
E_{cur}= current node energy
E_{res}= residual energy
k= number of clusters
N= total network nodes

In [10] Ma X. et al. proposed a balanced energy consumption for clustering algorithm (BECC) for heterogeneous network to extend network lifespan, stability period and throughput of the network. The authors used polarized energy factor which is estimated using unused energy of each node and mean relative energy in the network so that nodes with higher unused energy can become CHs for the current round. The comparison is performed for different heterogeneous energy levels and different percentage of heterogeneity. The new threshold of being CHs is given as:

$$T(n) = p_{opt} * q_{pol}(n) \tag{8}$$

where
p_{opt} = optimal percentage of CHs [2]
$q_{pol}(n)$ = polarized energy factor

In [15] the authors proposed an updated LEACH called PE-LEACH (named for convenience) to extend network's lifespan and to remove unnecessary energy consumption while communicating among the nodes in cluster. An improved threshold condition is proposed considering the current energy of node and average network energy as given in equation (10) and for the nodes whose present energy is higher than average residual energy, the additional factor Q in (10) will be used else Q in (11) will be used. This protocol also uses the layer concept for far away CHs to pass the aggregated data to the BS.

$$T(n) = \begin{cases} \frac{p}{1-p(rmod1/p)} * Q; n \in G \\ 0 \quad ; otherwise \end{cases} \tag{9}$$

Where

$$Q = P\left(\frac{E_{avg}}{E_{cur}}\right) = \begin{cases} \frac{E_{cur}-E_{avg}}{E_{cur}}; E_{avg} < E_{cur} \\ 0 \quad ; else \end{cases} \tag{10}$$

$$Q = \begin{cases} p + (r_s mod1/p)(1-p); \; n \in G \\ 0 \quad ; otherwise \end{cases} \tag{11}$$

In [17] Azim A. et al. put forward an upgraded LEACH called H-LEACH to improve network lifetime, reduce packet loss and to reduce energy consumption of nodes. They have considered some extra relay nodes that can become as CHs if their probability of becoming CH is more than the threshold value and the threshold condition for ordinary nodes is given as:

$$T(n) = \begin{cases} \frac{k}{N-k*(rmodN/k)} * \frac{E_{cur}-E_i}{E_{cur}}; n\epsilon G \\ 0 \quad ; otherwise \end{cases} \tag{12}$$

In [18] authors. presented an enhanced LEACH called LEACH-N which considers unused energy of sensor nodes to give better performance in terms of network lifespan, data transmission to BS and energy depletion of nodes with rounds. The new threshold condition is given as:

$$T(n) = \begin{cases} \frac{p}{1-p*(rmod1/p)} * \frac{E_i-E_{cur}}{E_i}; n\epsilon G \\ 0 \quad ; otherwise \end{cases} \tag{13}$$

In [19] the authors proposed an improved LEACH called R-LEACH (named for convenience) which provide new threshold condition for extending lifetime, throughput and to have more acceptable residual energy of nodes which is given as follows:

$$T(n) = \begin{cases} \frac{p}{1-p*\left(\frac{rmod1}{p}\right)} * \frac{E_{res}}{E_i} * k_{opt} \\ 0 \quad ; otherwise \end{cases} \tag{14}$$

where $k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \frac{\sqrt{\varepsilon_{fs}}}{\sqrt{\varepsilon_{mp}}} \frac{M}{d^2}$ (15)

In [21] the authors proposed a new method of CH selection based on LEACH called W-LEACH where they consider average moving energy consumption instead of considering the current energy of sensor nodes with moving energy window size E_{mov} and threshold as given in (16)

$$T(n) = \begin{cases} \frac{p}{1-p*(rmod1/p)} * \frac{E_{mov}}{E_i} * k_{opt} \\ 0 \quad ; otherwise \end{cases} \tag{16}$$

where $E_{mov} = \frac{E_{r-w} + \ldots\ldots E_{r-1} + E_r}{w}$ and w is the window energy size taken as 10 in the proposed protocol. This protocol provides better results in terms of lifetime and system energy consumption.

In [22] the authors provide modification in W-LEACH by considering CH selection probability over the moving energy window average in the threshold condition as in (17) to extend the network lifetime.

$$T(n) = \begin{cases} \frac{p}{1-p*(rmod1/p)} * E_{map} * k_{opt} \\ 0 \quad ; otherwise \end{cases} \tag{17}$$

Where,

$$E_{map} = 1 - \frac{E_{mov}-E_{cur}}{E_{mov}}$$

In [23] the authors developed an improved protocol based on W-LEACH and MAP LEACH having adaptive moving average called as smoothing factor ($E_{a\text{-}mov}$) to adjust the appropriate number of CHs in every round and to achieve efficient system energy dissipation with improvement in network lifetime. The improved threshold condition is:

$$T(n) = \begin{cases} \frac{p*k_{opt}}{1-(p*k_{opt})(rmod1/p*k_{opt})} * E_{A-Map}; n \in G \\ 0 \quad ; otherwise \end{cases} \tag{18}$$

Where,

$$E_{map} = 1 - \frac{E_{a-mov} - E_{cur}}{E_{a-mov}}$$

In [24] Handy M. J. proposed LEACH with deterministic cluster head selection for extending stability period for different BS locations. The new threshold is given as:

$$T(n) = \frac{p}{1-p(rmod1/p)} \begin{bmatrix} \frac{E_{cur}}{E_i} + (r_s div1/p) * \\ \left(1 - \frac{E_{cur}}{E_i}\right) \end{bmatrix} \quad (19)$$

where r_s represents consecutive rounds where nodes have not taken CH role.

In [11] authors proposed an energy efficient protocol based on heterogeneous LEACH for maximising network lifetime, throughput, stability period and to reduce network energy consumption for wireless sensor networks. This algorithm consists of single hop and multihop communication according to the distance of CHs from the BS. The modified threshold condition is given in equation (20). In the given equation E_{avg} is the average network energy and p_i is the probability of nodes according to their energy category which they belong. The network nodes are divided into normal nodes (ordinary energy level), advanced nodes (high energy) and intermediate nodes (energy level between normal and advanced nodes).

$$T(n) = \begin{cases} \frac{p_i}{1-p_i(rmod1/p_i)} \begin{bmatrix} \frac{E_{cur}}{E_{avg}} + (r_s div1/p) * \\ \left(1 - \frac{E_{cur}}{E_{avg}}\right) \end{bmatrix}, & n \in G \\ 0, & otherwise \end{cases} \quad (20)$$

In [25] the authors proposed modified threshold condition as given in (21) for LEACH protocol to extend network lifetime. Also, it employs modified TDMA scheme to lessen energy consumption. We will not cover much about the modified TDMA scheme in our paper. For larger networks the authors consider multi-hop communication between cluster head and base station instead of single hop transmission. This algorithm outperforms LEACH by 25% in network lifetime.

$$T(n) = \begin{cases} \frac{p}{1-p*rmod1/p} * \frac{E_{re}}{E_{t_n}}; & n \in G \\ 0 & ; otherwise \end{cases} \quad (21)$$

where E_{re} represents remaining energy of node n at current round and E_{t_n} represents network overall energy at current round.

In [26] the authors proposed an improved threshold condition in order to avoid frequent selection of lower energy nodes as cluster head and the simulation result shows great improvement in the network lifetime.

$$T(n) = \begin{cases} \frac{p}{1-p*(rmod\ 1/p)} \left[\alpha p + (1-\alpha p)\frac{E_{resi}}{E_o}\right], & n \in G \\ 0 & otherwise \end{cases} \quad (22)$$

where E_{resi} is current residual energy of node, E_o is the energy of a node at the beginning of clustering process and α is the number of consecutive rounds in which a node has not been cluster head so far. In this proposed approach, the authors also consider selecting specific node among the cluster heads to act as relay node for other cluster heads. This new approach is named as LEACH-R protocol and the result shows that it can save upto 20% energy of sensor network comparing to that of conventional LEACH.

In [27] the authors proposed an improved threshold condition to extend the network lifespan which may be stated as follows:

$$T(n) = \begin{cases} \frac{k}{N-k*(rmod\frac{N}{k})} * \left[\frac{E_i}{E_S}\right], n \in G \\ 0 & else \end{cases} \quad (23)$$

where k is the probability of cluster heads, r is current round, $\frac{E_i}{E_S}$ is the ratio of node's present energy and initial energy of node. This proposed approach enhanced the network lifetime and have better stability in different number of deployed nodes and initial energy.

In [28] the authors described an improved threshold condition by considering residual energy and the degeneration rate of energy in a node and the result shows better data transmission to BS, delayed FND, better average residual energy and also the randomness in selecting CH is reduced.

$$T(n) = \begin{cases} \frac{p}{1-p(rmod\frac{1}{p})} * [X], n \in G \\ 0 & else \end{cases} \quad (24)$$

where $X = \frac{R_r - R_D}{aR_r - aR_D}$ (25)

R_r is residual energy of node, R_D is degeneration rate of node energy, aR_r is average residual energy, aR_D average degeneration rate.

In [29] the authors proposed two modified threshold conditions based on LEACH protocol called as mLEACH1 and mLEACH2 for improving network lifespan, FND and HNA (Half node alive) which are given in equation (26) and (27) respectively as follows:

$$T(n) = \begin{cases} \frac{p}{1-p(rmod\frac{1}{p})} * \frac{S(i).e}{Eie}; & if\ n \epsilon G \\ 0 & otherwise \end{cases} \quad (26)$$

$$T(n) = \begin{cases} \frac{p}{1-p(rmod\frac{1}{p})} * \frac{E_{ie}}{E_{ie}*n}; & if\ n \epsilon G \\ 0 & otherwise \end{cases} \quad (27)$$

where E_{ie} is energy of node at the beginning of round process, n is total nodes in the network, $S(i).e$ is present energy of i[th] node and $E_{io} * n$ total initial network energy. The authors compared the simulation results of mLEACH1 and mLEACH2 with original LEACH.

The LEACH based protocol called as M-LEACH with a new threshold condition which is given by the equation:

$$T(n) = \begin{cases} \frac{p}{1-p(rmod\frac{1}{p})} * \frac{E_k}{E_{ag}} * \frac{E_{pcn}}{E_{cn}}; & if\ n \epsilon G \\ 0 & otherwise \end{cases} \quad (28)$$

where is E_k energy of node before the upcoming round, E_{ag} is average energy consumed by whole network before the succeeding round, E_{pcn} is average energy consumed by whole network in the previous round and E_{cn} is energy consumed by a node in the previous round. This new approach results to better lifetime, throughput and lesser energy consumption.

2.1.3 Based on overhead energy of cluster head

In [7] authors made a study based on the effect of overhead energy of different optimum cluster head on network lifetime and the optimum CHs (5-10% of total nodes in this study) is considered for different network areas and different density of nodes. The overhead energy is calculated considering two radio energy dissipation models such as free space and multipath radio propagation models with cross over distance as 87m. This study shows that the network lifespan decreases with increase in network area and also found that the nodes dead are slow in small network area comparing to the larger area network. The result shows that the network lifetime is increased upto 20% if the overhead energy consumed by extra random cluster heads is reduced.

2.1.4 Based on threshold condition with distance factor

In [24] authors. developed a clustering algorithm ANCH (Avoid near cluster head) based on LEACH to manage consumption of energy to a lesser amount and to extend network lifespan by optimising CH distribution in the network. A fix distance *D* (closeness value) is taken based on network size, node density and number of CHs in the network. If the range between any two nearby CHs has value lesser than *D* then the later chosen CH will drop the role of CH in the current round. This protocol outperforms LEACH protocol in terms of network lifetime and efficient energy consumption. To assure optimum CHs in every round a new threshold is developed which is given as:

$$T'(n) = T(n) + \left(1 - T(n)\right) * a \tag{29}$$

where,
a is add-on co-efficient which is a constant value and its value depend on the network layout and the closeness value *D*.

2.1.5 Based on election probability with distance and energy factor

In [28] authors proposed an energy efficient distance-based clustering for wireless sensor network based on LEACH to extend network lifetime and to maintain uniform energy dissipation. The author implemented this protocol by dividing the network into groups which is having their own independent clusters and cluster members. A new probability is assigned for CHs selection as given below:

$$P_i(t) = \begin{cases} \frac{k_j}{N_j - k_j * (r mod N_j/k_j)}; & C_i(t) = 1 \\ 0 & ; \ C_i(t) = 0 \end{cases} \tag{30}$$

Where,
N_j are the number of nodes, k_j is calculated based on distance of nodes from sink (BS) and number of clusters in each group [28] and $C_i(t) = 1$ represents those nodes which have not been CH in the recent rounds or have acted as cluster member [2]. The proposed approach results in better lifetime with balanced energy consumption.

In [30] Amini N. et al. proposed an energy efficient clustering protocol with distance-based segmentation for WSNs. This protocol includes division of whole network into similar area segments and each segment has independent clustering techniques to lessen the energy consumption thereby extending network lifetime and to obtain better stability period. This protocol deprives the unnecessary energy consumption by unrequired CHs as shown in figure 4 and figure 5 represents segmentation of random network with BS inside the network [30].

The probability of a node **i** to become CH in segment **j** at round **r** assuming the innermost segment to be of lowest index is given as:

$$p_{i,j}(t) = \begin{cases} \frac{k_{segmentj}}{\frac{N}{m} - k_{segmentj} * \left(r mod \frac{N/m}{k_{segmentj}}\right)}; & C_{i,j}(t) = 1 \\ 0 & ; \ C_{i,j}(t) = 0 \end{cases} \tag{31a}$$

$$p_{i,j}(t) = \begin{cases} \frac{p_{segmentj}}{1 - p_{segmentj} * \left(r mod \frac{1}{p_{segmentj}}\right)}; & C_{i,j}(t) = 1 \\ 0 & ; \ C_{i,j}(t) = 0 \end{cases} \tag{31b}$$

where

m represents segments number,
i is node in segment j,
N denotes total nodes in the network,
N/m is the average per segment,
$k_{segmentj}$ is the expected number of cluster heads in segment j and
$p_{segmentj} = \frac{k_{segmentj}}{N/m}$ as defined in [30].

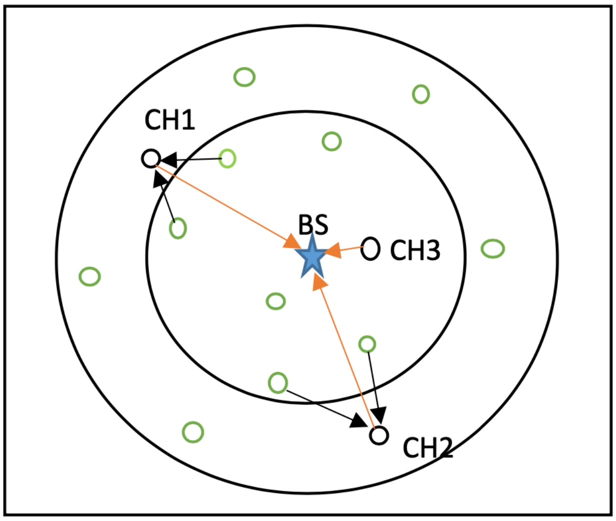

Fig. 4. Wasteful transmission by CH1 and CH2

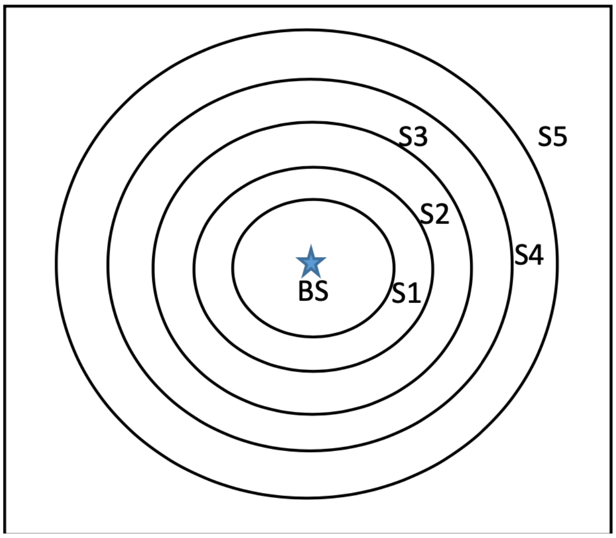

Fig. 5. Demonstration of segmentation (5 segments) in a random Network with base station (BS) inside the network (S1, S2, S3, S4, S5 represents segments 1,2,3,4,5 respectively)

In [31] the author proposed distance dependent threshold for selecting cluster head called as LEACH-DT by taking into account the separation of sensor nodes from BS in election probability of CH. This algorithm extends the network stability period leading to overall lifetime increment by 10% from LEACH. For CHs whose distance is far away from BS employs multi-hop transmission. Considering nodes d and j take their turns as CHs with chances p_d and p_j respectively, p_d in terms of p_j and energy consumption can be represented as

$$p_d = \frac{p_j(e_{CH}(d_j) - e_{non-CH})}{e_{CH}(d_d) - e_{non-CH}} \quad (32)$$

where $e_{CH}(d_j)$ nd $e_{CH}(d_d)$ are energy spend by 'CH node j' at distance 'd' from BS and 'CH node d' at distance 'd' from BS.

In [14] the authors proposed an improved LEACH by performing optimal cluster head selection with the consideration of leftover energy and the present position of nodes. They employ the principle of election probability of SEP protocol as the authors consider heterogeneous LEACH network (advanced nodes with greater energy level and ordinary nodes with smaller energy level). The optimum cluster head selection [2] is given as:

$$p_{opt} = \frac{1}{\sqrt{2\pi N}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d_{BS}^2} \quad (33)$$

where N is overall sum of nodes in the network, M denotes the largest network dimension and d_{BS}^2 represents space between nodes and base station. Election probabilities of advanced and ordinary nodes are taken as follows:

$$p_{ad} = \frac{P_{opt}}{1+\partial n} \quad (34)$$

$$p_{nr} = \frac{(1+\partial)P_{opt}}{1+\partial n} \quad (35)$$

where n represent the ratio of advanced to ordinary nodes and ∂ indicates the times of advanced nodes' initial energy exceeds the ordinary nodes. The nodes whose distance from cluster head is more than the distance from base station will directly transmit the data else it will transmit to cluster head for the data transmission process. The result shows that the proposed algorithm has extended the network lifetime to a great extent and also the leftover average network energy is increased.

An unexhausted energy-based cluster head selection by considering optimum number of cluster heads (36) in the original threshold condition of LEACH for improving network lifetime, FND (first node dead) and LND (last node dead).

$$p_{op} = \sqrt{\frac{N_A}{2*\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \left(\frac{DM}{d_s^2}\right) \quad (36)$$

where is p_{op} the optimum number of cluster heads, N_A number of active nodes, N_A is the maximum dimension and d_s^2 is distance of nodes to base station.

2.1.6 Hybrid based CH selection

Hybrid based CH selection in this paper, basically refers to those techniques which utilises either energy and distance factors or energy and density or distance and cluster size or energy and round time or energy, distance and density etc.

In [12] the authors implemented an algorithm for enhancing network lifetime and to improve coverage for cluster-based heterogeneous wireless sensor networks with mobility capacity of nodes. Initiation and coverage preservation phases are the types of phases in this algorithm. The initialisation phase is again divided into three sub phases finding sensing neighbours, finding redundant neighbours and determining intersection points. Two nodes are said to be neighbours if their distance is less than or equal to the sum of their sensing radius. The coverage redundancy of sensor nodes is decided by their sensing area. After calculating the intersection points [12], each node maintains the list of neighbour nodes and intersecting points. If the remaining energy of nodes is low, then the node is expected to cause a coverage hole and a node that can move towards the coverage hole is elected to be cluster head after considering three factors sensing radius, moving distance and unconsumed energy of nodes. The energy-distance factor [12] is calculated as:

$$ED(s_i) = \frac{s_i.E - e_d}{d_i} \quad (37)$$

where $s_i.E$ is the remaining energy of node s_i and e_d is the energy required for the node to travel the distance d_i. If the equation (37) is greater than $ED_{threshold}$ (energy-distance factor threshold) and $s_i.r_s \geq r_{sec}$ then the node is considered to be the most appropriate candidate to be CH considering r_s as the sensing radius and r_{sec} as the required radius.

In [11] the authors introduce an improvement in the existing LEACH protocol called E-LEACH by inserting the remaining energy of nodes in the threshold condition and using variable round time on the basis of cluster size to enhance networks' lifespan, better stability period and throughput.

$$T(n) = \begin{cases} \frac{p_{head}}{1 - p_{head}*(r mod 1/p_{head})} * \frac{E_{cur}}{E_i}; n\epsilon G \\ 0 \qquad ; otherwise \end{cases} \quad (38)$$

where

$p_{head} = \sqrt{\frac{N}{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d^2 * N}$

M= maximum dimension of network area

d= average distance between nodes and BS.

In [32] the authors proposed RED-LEACH which employs residual energy and remoteness of nodes from base station as an additional factor in the threshold condition. A node can become cluster head only if it has lesser distance than the mean distance of all nodes from BS and the random number should be less than the threshold as stated below:

$$T(n) = \begin{cases} \frac{p}{1 - p*(r mod\ 1/p)} * E_{ri}, n \in G \\ 0 \qquad otherwise \end{cases} \quad (39)$$

where E_{ri} is the node's residual energy in the current round. This technique increases network lifetime by two times from that of LEACH and lessen energy consumption by three times.

In [20] a clustering algorithm with consideration of distance and energy LEACH based called EDL-LEACH is developed by Hon R. et al. In this approach, a distance threshold is maintained to be the cluster member of a cluster to enhance the lifespan of network for different number of nodes in network. If the separation range between CH and cluster member has value more than the threshold, then it declares itself as another CH and the threshold associated with this algorithm is:

$$T(n) = \begin{cases} \frac{p}{1-p*(rmod1/p)} * \frac{E_t}{E_{tot(t)}} \\ 0 \quad ; otherwise \end{cases} \quad (40)$$

In [33] Sharma R. et al. proposed an energy efficient distance-based cluster head (DBCH) selection algorithm to have longer network lifetime than LEACH and to have balance energy depletion of nodes. The proposed protocol considers ranges between nodes and BS for CH selection and also considers selecting nearer nodes as CHs more often than the farther nodes to achieve uniform energy load distribution in the network. The new threshold is given as:

$$T(n) = \begin{cases} \frac{p}{1-p\left(rmod\frac{1}{p}\right)} + (1-p)\frac{D_{max}-D_{i\ to\ BS}}{D_{max}-D_{min}}\left(\frac{E_{res}}{E_i}\right), \\ \quad n\epsilon G \\ 0, \quad otherwise \end{cases} \quad (41)$$

where D_{max} indicates maximum distance between nodes and BS, D_{min} indicates minimum distance between nodes and BS and $D_{i\ to\ BS}$ symbolises distance between a node and BS.

In [34] authors proposed an advanced algorithm for LEACH protocol to enhance network lifetime with proper CH selection. A new threshold has been developed in this work by including remaining energy of a node and mean energy of network which is presented in (42). $E_{rest}(r)$ represents current unused energy of a node at the existing round and $E_{average}(r)$ represents average remaining energy of cluster members in the current round. Here, either multi-hop or one-hop communication is used for forwarding the message to BS depending on the ranges between cluster head and BS. The new threshold condition is given as:

$$T(n) = \begin{cases} \frac{p}{1-p\left(rmod\frac{1}{p}\right)} * E(n), \quad n \in G \\ 0, \quad otherwise \end{cases} \quad (42)$$

The multi-hop communication depends on optimal choice of number of hops (γ_{opt}) and forwarding nodes.

$$E(n) = \frac{E_{rest}(r)}{E_{average}(r)} \quad (43)$$

$$\gamma_{opt} = \frac{D}{d_o} \quad (44)$$

where D represents the range of separation between cluster head nodes and BS and d_o represents crossover distance.

In [35] authors implemented a cluster routing protocol with distance-based threshold called as LEACHDistance and LEACHDistance-M for static and mobile networks respectively to improve network lifetime, throughput and balance energy consumption for different number of nodes in network (scalability). This protocol aims to overcome the energy wastage by cluster heads which are lying at a distant location from base station and also by those cluster heads which are at a close position to base station by selecting eligible nodes for cluster heads. This eligibility of nodes depends on pre-determined threshold distance value. Lower threshold distance is taken as 20m and upper threshold distance as 60.8m. Those nodes whose distance (calculated by using Euclidean distance) from base station lies between these two threshold values are eligible to become cluster heads for static networks. In mobile networks, nodes with higher velocity are rejected from the eligible nodes.

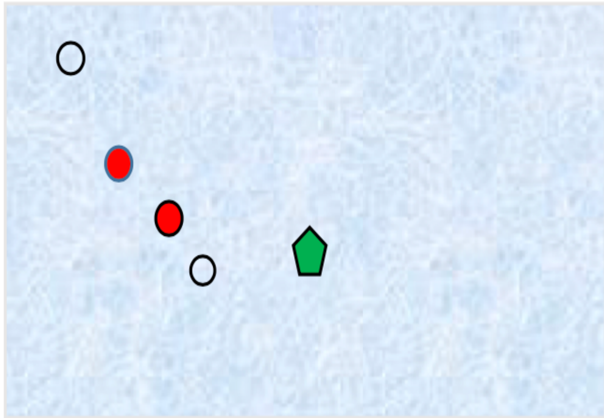

Fig. 6. Selection of eligible nodes for cluster heads in network of size (100x100) m^2
Represents eligible nodes for cluster heads
Represents nodes that can be a member node
Represents base station (50,50)

Cluster heads from the eligible nodes are elected based on the threshold condition as given in (45)

$$T(n) = \begin{cases} \frac{p}{1-p*\left(rmod\frac{1}{p}\right)} \times \frac{E_{n_{curr}}}{E_{n_{ini}}} \quad if\ n \in G \\ 0 \quad otherwise \end{cases} \quad (45)$$

where
$E_{n_{curr}}$ represents energy of node in the ongoing round and
$E_{n_{ini}}$ is the initial energy of nodes and
G is the eligible set of nodes for cluster heads.

Figure 6 [35] shows the process of electing cluster heads from the eligible nodes based on pre-determined threshold distance.

In [36] authors implemented an enhanced approach based on LEACH for wireless sensor networks to get better network lifespan, throughput, lesser energy consumption and less randomness in electing cluster heads. They modified the threshold condition for selecting cluster head and also the TDMA (time division multiple access) scheme for each member in a cluster. However, this paper will not discuss about the modified TDMA schedule since our paper mainly focuses on improved cluster head selection techniques. The authors have considered unconsumed energy of nodes, space between nodes and base station and density of neighbours of a node in the threshold condition and is given by

$$T(n) = \begin{cases} T(n)' \times (1 - log_{10}d) \times CH_t \times NH_n \\ \quad if\ n \in G \\ 0 \quad otherwise \end{cases} \quad (46)$$

Where,

$T(n)'$ is the threshold after considering the leftover energy and separation of nodes from base station [36],
CH_t is the time for selecting cluster head,
NH_n denotes number of neighbours of n nodes,
d indicates distance among each other nodes.

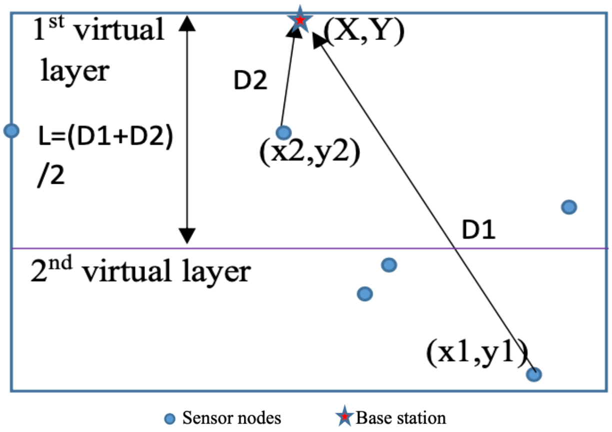

Fig. 7. Division of sensor network into virtual layers

In [13] the authors proposed an updated LEACH which involves dividing the whole network (100x100)m^2 into two virtual layers based on the mean distance between nearest node and farthest sensor node from the base station as shown in Figure 7.

In Figure 7 D2 is the least distance between sensor nodes and base station given by D2=Y-y2 and D1 is the largest distance between sensor nodes and base station given by D1=Y-y1. L is the mean distance of D1 and D2. The author takes into account leftover energy and distance of sensor nodes in the threshold condition of cluster head selection as follows:
For sensor nodes within D2,

$$T(n) = \frac{p}{1-p.(rmod\frac{1}{p})} * \frac{E}{E_i} * (\frac{D2}{D})^2 \quad (47)$$

For sensor nodes within D1,

$$T(n) = \frac{p}{1-p.(rmod\frac{1}{p})} * \frac{E}{E_i} * (\frac{D1}{D})^2 \quad (48)$$

where E is the residual energy and E_i is elementary energy of sensor nodes and D indicates range between sensor nodes and base station. The authors compared the performance of LEACH and E-LEACH in both homogeneous and heterogeneous condition and concluded that the proposed algorithm outperforms the existing method in terms of network lifetime, stability period and lesser overall energy consumption.

In [37] the authors proposed an extended LEACH called as xLEACH to extend the network lifetime and to improve efficiency of energy consumption. The authors make use of distance of nodes from base station in the threshold condition in order to reduce energy consumption in the network. This inclusion of distance factor leads to non-uniform cluster head selection which makes the closer nodes to base station to get more chance to be the cluster head. The new threshold condition is as follows:

$$T(n) = \frac{p}{1-p(rmod1/p)} * \left[\frac{E_{i\,current}}{E_{i\,max}} + (r_{is}div(1/p))\left(1 - \frac{E_{i\,current}}{E_{i\,max}}\right)\right] \quad (49)$$

where $E_{i\,current}$ is residual energy of i^{th} node, $E_{i\,max}$ is the initial energy of i^{th} node and r_{is} is the consecutive rounds that i is not cluster head, r is the number of rounds and p is probability of cluster head selection which is same for all nodes except for the nodes which are far away from base station and is given as follows:

$$p_n = p(1-\propto\left(\frac{d_i-d_M}{d_{ma}-d_M}\right) \quad (50)$$

where d_i is distance of i^{th} node from base station, d_{mi} is the minimum distance, d_{ma} is the largest distance and d_M is mean distance.

$$d_M = \frac{d_{mi}+d_{ma}}{2} \text{ and } \propto = \frac{d_{ma}-d_{mi}}{d_{ma}} \quad (51)$$

$\propto$ decides influence of distances in election probability. The results show that the throughput remains almost unchanged for different p_n values.

In [38] the authors proposed an unequal clustering scheme-based LEACH for improving network lifetime. The new threshold condition is set as follows:

$$T(n) = \begin{cases} \frac{p}{1-p\left[rmod\left(\frac{1}{p}\right)\right]}.\left(\beta.\frac{E_i}{E_o} + (1-\beta).D_s\right), \beta \in [0,1], & n \in G \\ 0, & else \end{cases} \quad (52)$$

where β is weight factor, E_i is the present unused energy of nodes, E_o is energy at the initial round, D_s is competition value of distance (CVD) which is given as $D_s = \frac{L-D_{ni}}{L-D_o}$ where L is the network area radius, D_{ni} is the separation range of n^{th} node from base station, D_o is the space between closest node and base station. The insertion of $\frac{E_i}{E_o}$ helps the proposed protocol to select higher energy nodes as leaders with greater number of times comparing to other nodes. The lifetime increases by 30% from that of LEACH protocol.

In [39] authors proposed LEACH-D protocol, the authors inserted the density of nodes around a node in the threshold condition for improving network lifetime and stability period. Also, they have shown that with this technique the energy consumption is lesser for transmitting the same amount of information in comparison to that of LEACH. Secondly, they also consider the cluster radius and its connectivity with other nodes based on the distance from base station. The improved threshold condition is set as follows:

$$T(n) = \frac{p}{1-p(rmod1/p)}.\frac{E_{i-res}}{E_o}.\frac{D_i}{D_{av}} \quad (53)$$

where E_{i-res} indicates unconsumed energy of nodes in the present round, E_o is the preliminary energy of nodes, D_i is the degree of connection with other nodes within the range of communications, D_{av} represents the network's average degree.

In [40] the authors proposed an improved LEACH named as LEACH-H which considers energy of nodes, number of neighbours of each node and separation between nodes and base station. The improved threshold is given as:

$$T(n) = [w_1T_1(n) + w_2T_2(n) + w_3T_3(n)] * p \quad (54)$$

where w is the weight factor ranging from 0 to 1, w_1 is the weight value of leftover energy of nodes, w_2 is the weight of length between nodes and base station, w_3 is the node's neighbours weight value and $\sum_{t=1}^{3} w_t = 1$.

$$T_1(n) = \begin{cases} S(i).\frac{E}{E_{av}} & S(i).E > E_{av} \\ 0 & S\,(i).E > E_{av} \end{cases} \quad (55)$$

where $S(i).E$ is the residual energy of node i in present round, E_{av} is the average energy of all nodes.

$$T_2(n) = \begin{cases} S(i).dis/D_{am} & S(i).dis > D_{am} \\ 0 & S\,(i).dis > D_{am} \end{cases} \quad (56)$$

where $S(i).dis$ is the range between node i and base station, D_{am} is the mean distance of nodes.

$$T_3(n) = \begin{cases} S(i).Node/N_{av} & S(i).Node > N_{av} \\ 0 & S\,(i).Node > N_{av} \end{cases} \quad (57)$$

where $S(i).Node$ are the nodes surrounding node i, N_{av} is the average neighbour nodes of all nodes. This algorithm increases the lifetime to considerable extent and also extends the period of FND and HND (half node dead).

In [41] the authors proposed two improved LEACH called LEACH-E and LEACH-ED which takes into account the node's current energy in the threshold condition as given in (58) and nodes' distance from BS respectively.

$$T(n) = \frac{p}{1-p(r mod \frac{1}{p})} * \frac{E_{n\_c}}{E_{n\_i}} \quad (58)$$

where E_{n_c} is the node's current energy and E_{n_i} is the node's initial energy. This method helps in selecting higher energy nodes as cluster head more often than nodes with lower energy and nodes closer to BS are given preference to become candidate for CH. This technique avoids non uniform death of nodes in network and also it improves network lifetime.

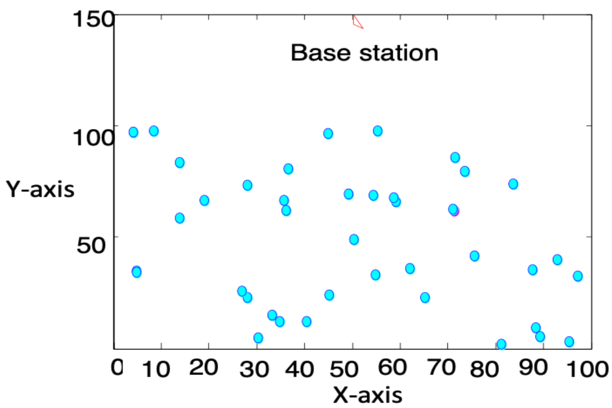

Fig. 8. Random number of nodes distribution in random network

Figure. 8 shows how the nodes are distributed in random network (LEACH protocol).

In [42] an improved LEACH (IDE-LEACH) has been proposed for increasing network lifetime whose threshold condition is based on energy and distance of nodes. The new threshold is set as:

$$T(n) = \begin{cases} \frac{p_r}{1-p_r*(r mod \frac{1}{p_r})} * (\rho\left(\frac{d_{av}}{d_b}\right))(\tau(\frac{E_{rm}}{E_{or}})) \\ 0 \qquad otherwise \end{cases} \quad (59)$$

where p_r denotes probability election of cluster head, d_{av} indicates mean distance between nodes and base station, d_b indicates range of a node from base station, E_{rm} indicates remaining node's energy in the ongoing round, E_{or} represents original energy of a node, ρ and τ are weighted constants which are taken to be 0.1 and 1- ρ. This technique increases the lifetime to some extent.

In [43] authors considers energy and density factors of nodes in the threshold condition and also engages unequal clustering in the network i.e. smaller cluster size is formed for cluster heads located near to base station and larger cluster size is formed for those far away from base station. This unequal clustering helps in solving the problem of 'hot spots' in the network. This method brings fair energy dissipation in the network and also lengthens network lifespan. The improved threshold condition is designated as:

$$T(n) = \begin{cases} \frac{p}{1-p\left(r mod \frac{1}{p}\right)}\left(q_1 E_r + q_2 r_f\right), & n \in G \\ 0 & else \end{cases} \quad (60)$$

where q_1 and q_2 are weighted constant which are taken to be 0.6 and 0.4 respectively, E_r represents ratio between nodes' unconsumed energy and mean unconsumed energy of alive nodes distributed inside the average ideal cluster radius [43] in the ongoing round, r_f is the ratio of nodes distributed in the area bounded by ideal average cluster radius to the nodes in the initial cluster radius of the node [43].

In [44] Lin and Ying proposed an energy efficient algorithm for LEACH protocol for wireless sensor networks which takes into consideration the position and node's energy in the threshold condition to reduce randomness in cluster head selection and optimize the transmission mode of data. Cluster heads which are at distant location from base station select some of their neighbouring nodes as relay nodes which are closer to base station to counterbalance the energy consumption in data transmission. This new algorithm increases data throughput, balances energy dissipation as well as enhance the network lifetime. The new threshold condition is designated as:

$$T(n) = \begin{cases} \frac{p}{1-p(r mod \frac{1}{p})}\left[\frac{E_{icur}}{E_{ag}} * \frac{d_{bs}}{d_{mx}-d_{mn}}\right], n \in G \\ 0 \qquad else \end{cases} \quad (61)$$

Where,
E_{icur} is node's present energy for the concerned round,
E_{ag} is average energy of the network,
d_{bs} is separation of a node from base station,
d_{mx} symbolises the highest range between nodes and base station and
d_{mn} symbolises the least range between node and base station.

In [45] authors proposed an improved LEACH with modified threshold condition to lengthen the network lifetime, to provide better throughput and to obtain better residual energy in the network and is given by

$$T(n) = \begin{cases} X(n) if\ E(v) \geq \varphi * \frac{1}{R}\sum_{s=1}^{R} E(s) \\ 0 \quad else\ E(v) < \varphi * \frac{1}{R}\sum_{s=1}^{R} E(s) \end{cases} \quad (62)$$

Where,
$X(n) = a_1 T_1(n) + a_2 T_2(n) + a_3 T_3(n) + a_4 T_4(n);$
a_1, a_2, a_3, a_4 are weighing constants that lie between 0 and 1;
φ lies between 0 and 2;
R represents alive nodes in network and

$E(v)$ indicates residual energy of currently surviving nodes. $T_1(n)$, $T_2(n)$, $T_3(n)$, $T_4(n)$ are sub threshold values as given in [45].

In [46] the authors proposed an improved threshold condition of LEACH called as WM-LEACH by considering the factors like RSSI (radio signal strength indicator), distance between BS and sensor nodes, nodes residual energy and node density within the transmission range to elongate network lifetime.

$$T(n) = \begin{cases} C(n); & if\ n\epsilon G \\ 0 & otherwise \end{cases} \quad (63)$$

where,

$C(n)$=$\frac{\partial E_{r(i)}+\tau N_{r(i)}+\emptyset RSSI(i)}{\gamma d(i)}$;
$E_{r(i)}$ is start up energy,
$N_{r(i)}$ neighbour nodes of a node i,
$d(i)$ is distance of node from BS, $\partial, \tau, \varphi, \gamma$ are weighing constants [0,1].

In [47] Yuan Minglan proposed an improved LEACH by taking into account distance and energy factors in the threshold condition of cluster head selection to achieve longer network lifetime and to have better performance in average residual energy which can be stated as follows:

$$Tnew(n) = \begin{cases} (1-P) * T(n) + P * ED(n); & if\ n\epsilon G \\ 0 & otherwise \end{cases} \quad (64)$$

Where,
P is percentage of nodes that can become as cluster heads out of the total nodes,
T(n) is threshold condition of original LEACH protocol and ED is energy distance probability which is given as:

$$ED(n) = \frac{E_s(n)}{\frac{E_m(n)}{E_o}} - P * \frac{f_b}{f_{mb}} \quad (65)$$

Where,
$E_o, E_s(n), E_m(n)$ represent energy at the beginning of round process of node *n*, standard deviation of remaining energy and average residual energy of nodes respectively,
f_b is distance between node and base station and
f_{mb} is the maximum distance between all alive nodes and base station.

In [48] the authors proposed an improved threshold condition for LEACH called as SILEACH by inco-operating residual energy and distance of nodes to the original threshold condition to get better network lifespan. The new threshold is:

$$T(n) = \begin{cases} \frac{p}{1-p(rmod\frac{1}{p})} * \cos(t)\ ; & if\ n\epsilon G \\ 0 & otherwise \end{cases} \quad (66)$$

Where
$\mu E_n + \pi / d_n$,
E_n is current remaining energy of node *n* and d_n is separation between node and base station.
$\mu\ and\ \pi$ are weighing constants for remaining energy and distance of node to base station whose value is decided experimentally using simulation process (0.4 and 0.6 respectively in the proposed protocol). This algorithm outperforms in lifetime than other LEACH derivatives like ELEACH AND ILEACH.

2.1.7 CH selection based on rounds

In [41] Jiman Hong et al. proposed T-LEACH where cluster head replacing process in a clustering protocol is based on some pre-defined threshold value to get rid of unwanted wastage of energy consumption required for overhead transmission by the cluster heads. Even though the energy expenditure in overhead transmission is very low comparing to that of energy required for data transmission and reception, this amount of energy becomes a huge wastage if it is counted for overall rounds (every cluster head replacement). This threshold value is generated based on the energy consumption of cluster head nodes and is given by

$$P_{Th} = Count_{RND}.(pk_{Tx} + pk_{Rx})P_{Tx} \quad (67)$$

where,
$Count_{RND}$ represents rounds after which the cluster head replacement will take place,
pk_{Tx} is transmit packet size,
pk_{Rx} is receive packet size and
P_{Tx} indicates the energy required for transmitting data of 1 byte. This proposed approach not only improves the network lifetime but also balances the interval between first node dead (FND) and last node dead (LND).

In [43] authors proposed improved LEACH by considering variable round time rather than performing cluster head replacement in fixed round time to increase the lifetime of network and named it as VR-LEACH. This round time depends on the length of time slot of member nodes, number of clusters per round, initial energy of nodes, cluster head energy expenditure in every frame and a constant λ.

In [49] the authors mainly focus on reducing the energy depletion by cluster heads for the sake of having longer network lifespan and to have better energy consumption. In conventional LEACH protocol, the cluster heads broadcast to ordinary nodes after their selection advertising themselves as cluster heads for the current round with their node id so that the ordinary nodes can join them. In this process, cluster heads exhaust some of its energy. Even though this energy lost is very less in comparison with energy lost by data processing and transmission, this depletion of energy becomes higher as the round proceeds. To save this unnecessary depletion of energy, reappointment of cluster heads is done with new threshold condition which is set as follows:

$$T(n) = \begin{cases} \frac{k}{[N-k\left(\left(floor\left(\frac{r_1}{T}\right)\right)mod\frac{N}{k}\right]}, & n \in G \\ 0 & otherwise \end{cases} \quad (68)$$

Where,
N represents sum of nodes in the network,
k is the cluster heads number and T is the reappointment times which is taken to be 3-6 in the proposed protocol. For every new round of reappointment, r_1 resets to zero.

In [50] an improved threshold for LEACH has been proposed which is named as Modified Threshold-based Cluster Head Replacement (MT-CHR) LEACH to enhance the network lifespan and the threshold is given as:

$$T(VRC) = \begin{cases} \frac{p}{1-p*(VRCmod\ 1/p)}, if\ node\ is\ eligible \\ 0 \qquad else \end{cases} \quad (69)$$

where VRC represents the actual number of reformation of clusters which are carried out by each node.

Table 1. Summarisation of the improvement techniques related with the reference number of this paper

S.No.	LEACH derivative according to reference number in the paper	Parameters studied/improved	Improved techniques
1.	([4][10])	[10]-Balance load distribution among CHs [4]- network lifetime and network residual energy increases by 7.7049% and 144.69% respectively over LEACH	Based on cluster size
2.	([5][8][9][10][15][17][18][19] [21][22][23][20][11][25][26] [27][28][51][29])	[29]- network lifetime, stability period [51]- network lifetime, throughput, lesser energy consumption [28]- throughput, randomness of CH selection is reduced, residual energy [27]- network lifetime, stability period for different number of nodes and initial energy [26]- save upto 20% of sensor network [25]- network lifetime increase by 20% [11]- network lifetime, throughput, stability period, lesser energy consumption [20]- stability period for different BS locations [23]- network lifetime, efficient energy dissipation [22]- network lifetime [21]- network lifetime, efficient system energy dissipation [19]- network lifetime, throughput, residual energy [18]- network lifetime, throughput, efficient energy dissipation [17]- network lifetime, throughput, lesser energy consumption [[15]- network lifetime, balance energy consumption [10]- network lifetime, throughput, stability period [9]- network lifetime, throughput [8]- network lifetime for different BS locations and number of nodes [5]- network lifetime, balance energy consumption	Based on threshold condition with energy factor
3.	([7])	Network lifetime increases by 20% after saving energy from overhead bits	Based on overhead energy of cluster head
4.	([24])	Network lifetime, efficient energy consumption	Based threshold condition with distance factor
5.	([28][31][31][14][52])	[52]- network lifetime, stability period [14]- network lifetime, residual energy [31]- network lifetime increases by 10% [30]- network lifetime, stability period	Based on election probability with energy and distance factor

		[28]- network lifetime, balance energy consumption	
6.	([12][11][32][20][33][34][35][36][13] [37][38][39][40][41][42][43][44][45] [46][47][48])	[48]- network lifetime [47]- network lifetime and residual average network energy [46]- network lifetime [45]- network lifetime, throughput, residual energy [44]- network lifetime, balance energy dissipation, throughput [43]- network lifetime, fair energy dissipation [42]- network lifetime [41]- network lifetime, overcomes non uniform distribution of CHs [40]- network lifetime, stability period [39]- network lifetime, stability period, balance energy consumption [38]- network lifetime [37]- network, efficient energy consumption [13]- network lifetime, stability period, lesser overall energy consumption [36]- network lifetime, lesser energy consumption and randomness in cluster head election, throughput [35]- network lifetime, throughput, balance energy consumption for different number of nodes (scalability) [34]- network lifetime, proper CH selection [33]- network lifetime, balance energy consumption [20]- network lifetime (scalability) [32]- network lifetime, lesser energy consumption [11]- network lifetime, stability period, throughput [12]- network lifetime and coverage	Hybrid based cluster head selection
7.	([41][43][49][50])	[50]- network lifetime [49]- network lifetime, balance energy consumption [43]- network lifetime [41]- network lifetime, balances interval between FND and LND	CH selection based on rounds

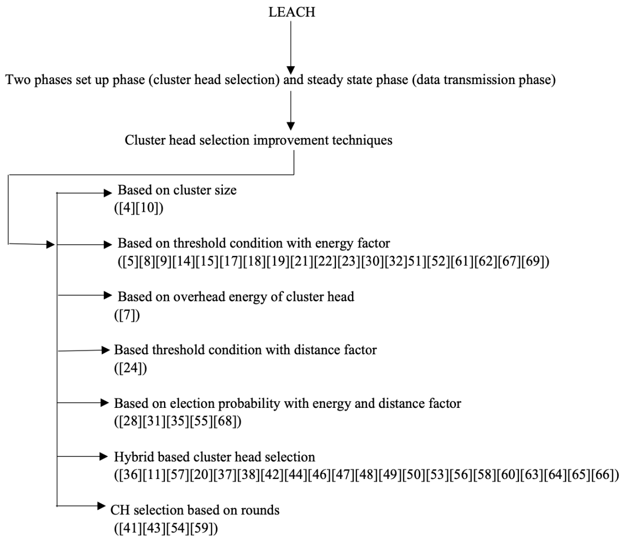

Fig. 9. Classification of cluster head selection improvement techniques (related with reference number of this paper)

Figure 9 represents the classification of cluster head selection improvement techniques in LEACH based protocol.

3. Discussion

Table 1 shows a summary of the improvement techniques and the corresponding parameters studied by the authors. From the proposed techniques in [30][37][38][39][41][46][48] we can observe that the network lifetime decreases with increase in network size or area since the CHs have to send the aggregated data a longer distance to reach BS. Hence, 'hot spots' (area where there is no coverage by sensor nodes due to early death of nodes) happened early due to the fast exhaustion of sensor node energy. A similar case happens if the BS is located far away from the area where the sensor nodes are being deployed. Hence, it can be stated that the longer the distance between sensor nodes and BS, the shorter the network lifespan. Similarly, considering the case of energy consumption by nodes, CHs spend a huge amount of energy compared to other nodes since the process of sending, receiving and aggregating data is done by CHs. If a node is continuously acting as CHs for the consecutive rounds, it may lead to fast depletion of its energy ultimately making the network lifespan shorter [5][8][15][17][18][19][21][22][23][20]. Therefore, it becomes necessary to consider both energy and distance when selecting CHs to increase their lifetime. The faster the energy consumption or the higher the energy consumption the shorter the network lifetime.

Other factors like cluster size and density of nodes are also important parameters to be considered [4][10]. The more cluster members, the greater the energy expenditure by CHs since it has to receive data from all the members. The larger the density of a network, the shorter the network lifespan for the same amount of initial network energy. In [24][36][39][43][46] the authors have taken into account density of a network or number of neighbour nodes surrounding a node for the proper selection of CHs. Lastly, we need to pay importance to round time if the network size is large. CHs spend a small amount of energy transmitting overhead bits. Hence, it is mostly neglected in many proposed approaches. But if the network size is large and a node is acting as CH for a longer period of time then it may lead to early death of nodes again. Some authors [41][43][49][50] have considered round time for improving network lifetime to avoid unnecessary consumption of energy in replacing CHs and advertising (overhead bits) themselves as CHs for the current round to cluster members. It may also be noted that heterogeneous networks are more desirable than homogeneous network because they are more suitable in real world applications than the homogeneous network [11][10] and with marginal cost increment they can provide better stability and improved lifetime.

4. Conclusion

Recently cluster-based routing protocols have got a lot of attention and introduced special challenges with other types of routing protocols in wireless sensor networks (WSNs). Optimising the efficiency of energy utilisation is a hot issue to be dealt with by many researchers since WSN is characterised by batteries with limited power sources. Cluster heads consume energy intensively in processes like data transmission, data aggregation, receiving data etc. Hence, immense supervision has to be given in selecting cluster head in order to intensify network performance, especially network lifetime. Energy and distance of nodes are the two factors that are generously considered for proper selection of cluster heads. In a few papers, many authors have introduced these two factors in different ways in the cluster head selection process to increase network lifetime and throughput. In this review paper, we have analysed various modified threshold conditions, election probabilities for cluster head selection and improvement techniques based on round time, cluster size etc. With all these techniques discussed in this paper, we can say that researchers have given more considerations to threshold condition improvement techniques than election probability or any other additional factors in extending network lifetime.

Although this paper has discussed the different ways of considering distance and energy factors by different authors for cluster head selection in cluster-based LEACH protocol, there are still other open issues where more accurate research may be taken up, like introducing network security since wireless sensor networks are mostly used in unsecure environments, establishing mechanism for accurate data collection, latency tolerance of a network, etc without utilising much energy resources as the nodes have limited battery power supply. Even though different standard techniques are available for the wired and fixed networks, it is still a deep concern for ad-hoc networks like WSNs which have limited resources.

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