LIFETIME ENHANCEMENT OF A HETEROGENEOUS WIRELESS SENSOR NETWORK USING CORRELATED LEACH AND MC- LEACH

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ABSTRACT

The successful operation of Wireless Sensor Network fully depends on the limited battery power of their nodes. Since large number of nodes are deployed in a small area thus leading to spatial correlation among data causing data redundancy. The transmission of redundant data causes unnecessary consumption of limited energy thus reducing the lifetime of the network. In order to enhance the lifetime of the network, a clustering algorithm named as 'Correlated LEACH' has been proposed in this paper by exploiting the correlation between cluster head and other nodes. This paper also includes the modification over Correlated LEACH named here MC-LEACH. It achieves longer lifetime by introducing a modification in cluster head selection criteria based on heterogeneity of nodes. Here, the preference to advanced nodes over normal nodes in cluster head selection process prolonging the lifetime of the network. The simulation model has been developed using Matlab software and first node die out metric has been used for lifetime calculations.

Keywords—clustering; correlation; heterogeneous; Wireless Sensor Network; LEACH

INTRODUCTION

The need of deploying a large number of low-cost, low-power, multifunctional nodes having sensing and computational capabilities in the small area, led to the establishment of Wireless Sensor Network (WSN) [1]. Depending upon the application for which WSN is designed, it addresses various challenges. The most important challenge is Physical resource Constraint. It includes limited battery power, limited memory size, and limited computational power. Fig. 1 shows the hardware of a sensor node. The sensor node mainly comprises of four units, sensing unit, processing unit, transceiver, and power unit. The sensing unit converts analog signals produced by sensing of nodes into digital by ADC and then fed to the processing unit. In order to carry on sensing task, the Processing unit consisting of Processor and Storage make the sensor node collaborate with other nodes. Transceiver basically connects nodes to the network by allowing nodes to send and receive data. The most important unit is power unit which supplies power to the other units. Depending upon the need of the

application, some other subunits may be used like Mobilizer, Power Generator, and location finding systems. There are many constraints in WSN like throughput, lifetime, and quality of service of the network which should be taken care of while designing a WSN.

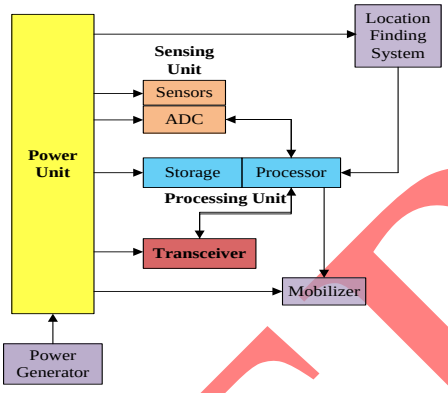

Fig. 1 Hardware of a Sensor node.

Deciding factors of the lifetime of a WSN may be energy aware MAC protocol, clustering techniques, energy efficient routing protocol, or using efficient energy models. Since nodes are deployed in difficult to access locations, so replacing the batteries of nodes is not feasible. Hence, minimizing energy consumption for maximizing lifetime becomes a key issue in designing a WSN.

One of the methods of clustering the sensor nodes into groups such that sensors send information to the cluster heads (CH) and then the CH transmits the aggregated information to the base stations, is a good method for minimizing energy consumption in WSN. Hence, many lifetime enhancing routing protocols are designed based on the clustering. Earlier clustering methods [2] were used where cluster head once elected, serves for entire lifetime. So cluster head node was overloaded with long range transmissions and extra processing for data aggregation. As a result, the cluster head node expires before other nodes. Hence, one new clustering method for energy dissipation called Low Energy Adaptive Clustering Hierarchy (LEACH) was proposed [3, 4], a clustering-based protocol which minimizes energy dissipation. LEACH balances the energy usage by random rotation of cluster heads such that the energy is equally distributed among all sensor nodes in the network. The algorithm also allows data-aggregation that can be used to reduce the amount of data transmission. The cluster head selection is random and is based on the probability of the node to become cluster head. The operation of LEACH is achieved by rounds. Hence, the network is reclustered periodically in order to select energy-abundant nodes to serve as CHs, thus distributing the load uniformly on all the nodes.

Various techniques were proposed to improve the lifetime of a wireless sensor network by introducing some modifications in LEACH. Another improvement in LEACH includes LEACH-C [5], LEACH-F [6], LEACH-V [7], TL-LEACH [6], etc. Then the concept of applying LEACH in the heterogeneous network is introduced, which gave better result than homogeneous networks [8]. Heterogeneous networks consist of sensor nodes having different capabilities; energy level, sensing range and computational power. Hence, another way to prolong the lifetime of WSN is to insert a

percentage of sensor nodes equipped with additional energy resources i.e. making the WSN heterogeneous in terms of energy.

In order to exploit the heterogeneity of the nodes, a modification to LEACH is introduced [9]. Since cluster head is responsible for data processing and transmitting the data to the base station, so cluster head consumes more energy than the other node. Modified LEACH organizes the cluster head selection based on the energy of the nodes in a heterogeneous network. We have provided more energy to a fraction of nodes, which can become only cluster head.

Since the sensor nodes are densely deployed in WSN, transmissions of information from the nodes to the sink are spatially correlated [10]. Hence, redundant correlated data are observed because of the common sensing area between nodes. To avoid this unnecessary transmission of redundant data, a new algorithm named as Correlated LEACH based on the correlation between node and cluster head was proposed. Modifications to cluster head selection criteria of Correlated LEACH is applied based on heterogeneity of the nodes named as MC-LEACH to further enhance the lifetime of the nodes.

The outline of the paper is as follows. Section II describes the proposed algorithms based on Modified LEACH, Correlated LEACH, and MC-LEACH protocols. Simulation results and evaluation of proposed methods are shown in Section III. Finally the conclusion is given in Section IV.

PROPOSED ALGORITHMS

A. *Modified LEACH*

In order to prolong the lifetime of the network, a modification in cluster set-up is proposed. Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the famous clustering algorithms that elect cluster heads based on randomized rotation around sensor nodes. Modified LEACH [9] is used for minimizing energy dissipation. It uses a network which is heterogeneous in terms of energy level. The nodes having greater energy than the others are called advanced nodes. Often the energy of cluster heads is consumed much earlier as they have to collect the data from their cluster members and transmit it to the sink. Hence, a new algorithm of selecting cluster head based on their extra energy is proposed. The operation of Modified LEACH is achieved by rounds. Each round starts with set-up phase for cluster formation. The second phase is steady state phase, where data are transmitted to the sink.

a) Set-up Phase

The set-up phase consists of Advertisement phase and Cluster set-up phase. The advanced nodes only take part in the cluster head formation. They are given more priority than normal nodes to become cluster head i.e. the cluster heads may be advanced nodes, as well as normal nodes but cluster members are only normal nodes. Cluster head selection criteria are explained using flowchart shown in Fig. 2. Each node whether it is advanced or normal node decides independently if it wants to become a cluster head or not depending on the duration of the previous time the node has been cluster head. A node n chooses a random number between 0 and 1 and checks if it is less than a certain threshold value T(n), then it becomes cluster head, where the threshold function T(n) is defined as follows [3]:

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

(1)

where, p denotes the desired percentage of cluster head, r denotes the current round number and G denotes the set of nodes that have not been selected as cluster heads for last (1/p) rounds. Flow chart of set up phase after cluster head selection is shown in Fig. 3. In the advertisement phase, the cluster head declares its status to its neighboring nodes which are normal nodes by sending advertisement packet while, in LEACH CH announces its status to all other nodes. The advertisement packet is received by the non-cluster normal head node which is nearest to the corresponding cluster head. In cluster set-up phase, the nodes which want to associate with cluster head send a join packet request to it containing their IDs using CSMA. Hence, the cluster head has the knowledge of total number of member nodes as well as their IDs. Based on all messages received within a cluster, the cluster head assigns the time on which sensor node can send data to cluster heads based on the table of TDMA schedule. Then the cluster head randomly picks a CSMA code and broadcasts the TDMA table to all the cluster members.

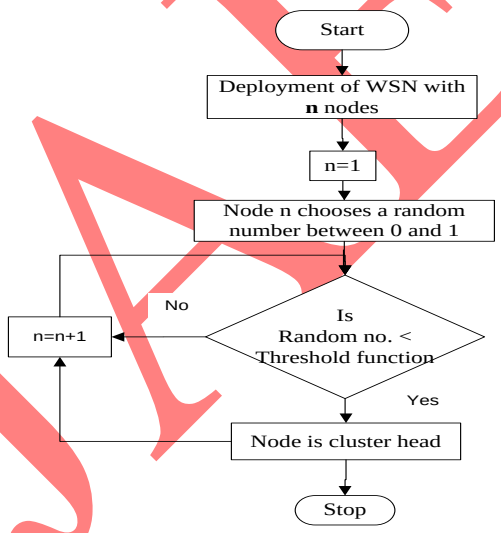

Fig. 2 Cluster head selection of Modified LEACH

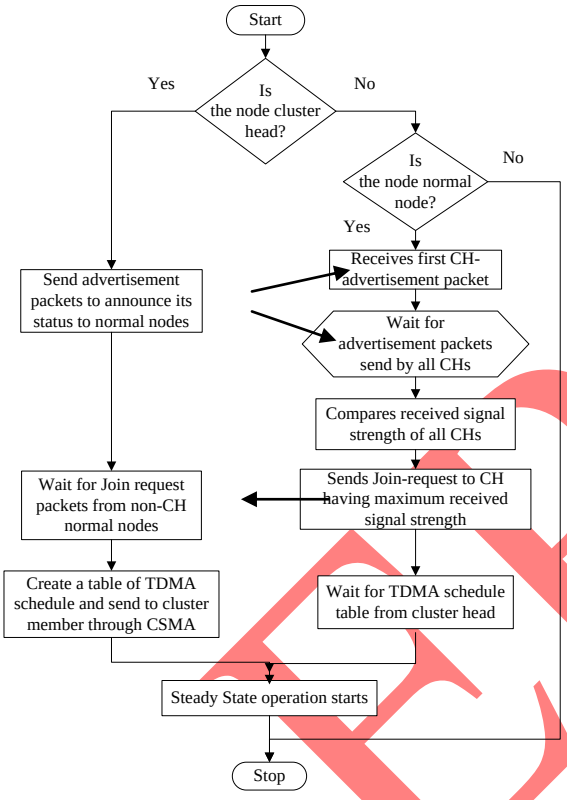

Fig. 3 Set-up Phase of Modified LEACH

b) Steady State Phase

Nodes begin sensing and transmitting data during their allocated TDMA slot to the cluster head. When all the data has been received, the cluster head aggregate these data and send it to the sink. Thus, LEACH is able to aggregate the data in each cluster to reduce the amount of data transmitted to the sink.

Proposed technique of Modified LEACH has been explained in *Algorithm 1*, where *N* denotes the heterogeneous network assumed for proposed algorithm, *n* is the total number of nodes in the network, *m* is the fraction of nodes which have energy greater than rest of the nodes, $E_{nor,}$, E_{adv} are initial energy of normal nodes and advanced nodes respectively, *random* is a random number between 0 and 1, *T(n)* is the threshold value, d_{min} is the distance between a cluster head and node that is minimum in its surrounding.

Algorithm 1: *Formation of Cluster using efficient energy distribution in a heterogeneous network*

Input: *A heterogeneous network* $N(n,m,E_{nor,}E_{adv})$

Initial condition:

Output: *Cluster head selection and cluster formation for energy efficient WSN*

Steps:

1. *Initialization of heterogeneous network*

2. *Assignment of energy to nodes(advanced nodes and normal nodes):*

for each node i ∈(1……n)do

if

set $E(i)=E_{nor}$

set node i_type= 'Normal'

else

set $E(i)=E_{adv}$

set node i_type= 'Advanced'

end if

end for

for each round r ∈(1……RND)

3. *Cluster head(CH) selection:*

for each node i ∈(1……n)

if $E(i) \geq E_{nor}$ && $random < T(n)$

set node i_type= 'CH'

end if

end for

4. *Associating the nodes to CH (during cluster formation):*

for each node i ∈(1……n)

if $d=d_{min}$

if $E(i) > 0$ && $E(i) \leq E_{nor}$

set node i_type= 'member'

end if

end if

end for

end for

B. *Proposed Algorithm: Correlated LEACH*

Data sensed by the sensor nodes deployed in smaller area are spatially correlated. Hence, unnecessary energy is consumed in redundant data transmission. To avoid this problem, a new algorithm called Correlated LEACH is proposed similar to LEACH but clusters are formed based on the correlation among cluster head and node. Cluster head selection criteria are same as LEACH protocol. After the formation of cluster head, nodes send join-request to only that cluster head with which has maximum correlation with it. Its operation is divided into rounds. Each round begins with set-up phase and ends with steady-state phase.

a) Set-up phase

The set-up phase consists of advertisement phase and cluster set-up phase. Advertisement Phase starts with the election of cluster head and then advertising its status to other nodes. The cluster head selection phase is same as Modified LEACH. In the advertisement phase, the cluster head sends advertisement packets to their neighboring normal nodes stating that it has become cluster head. The non-cluster head nodes check its correlation with all the cluster heads and picks the advertisement packet of that cluster head which has the maximum correlation with it. The correlation *Kv* between nodes is calculated by [10]:

$$K_v(i,j) = \frac{2\frac{d(i,j)}{v}}{\pi} - \frac{2d(i,j)}{\pi v^2}\sqrt{v^2 - d(i,j)^2} \quad (2)$$

where d(i,j) is the distance between nodes i and j, and v is the sensing range of the node. In cluster set-up phase, the member nodes send the join packet to its cluster head containing their IDs using CSMA. Hence, the cluster head has advertisement packet of that cluster head with which it has maximum correlation based on the formula of Correlated LEACH. In cluster set-up phase, the member nodes send the join packet to its cluster head containing their IDs using CSMA. Hence, the cluster head has the knowledge of number the knowledge of number of member nodes along with their IDs. Based on all messages received within a cluster, the cluster head assigns the time based on TDMA schedule on which sensor node can send data to cluster heads. Then the cluster head picks a CSMA code randomly and broadcasts the TDMA table to cluster members. The advertisement phase and cluster set-up phase is explained by the flowchart shown in Fig. 4.

a) Steady State Phase

Nodes begin sensing and transmitting data during their allocated TDMA slot to the cluster head. Firstly nodes calculate their correlation with the cluster head and thus send only uncorrelated data in order to reduce redundancy. When all the data has been received, the cluster head aggregate those data and send it to the sink. Thus, data is aggregated in each cluster to reduce the amount of data transmitted to the sink.

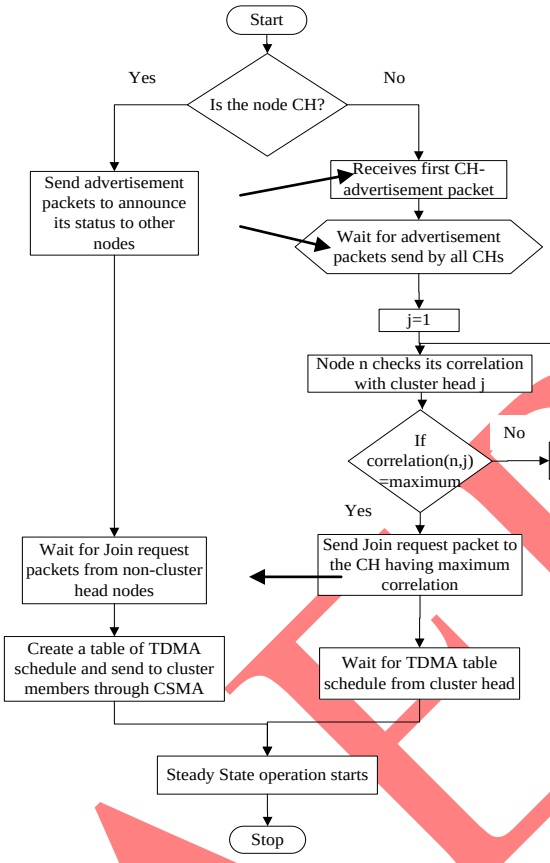

Fig. 4 Set-up Phase of Correlated LEACH

Cluster formation process of Correlated LEACH has been explained in *Algorithm 2*, where *N* denotes the WSN assumed for Correlated LEACH, *n* is the total number of nodes in the network, E_o is initial energy of nodes, *random* is a random number between 0 and 1, *T(n)* is the threshold value, *corr(i,j)* is the correlation between nodes i and j, C_k is the kth cluster of the network, *b* is the total cluster heads in each round and d_{min} is the distance between a cluster head and node that is minimum in its surrounding.

Algorithm2: *Cluster head selection and formation of cluster*

Input: *A heterogeneous network* $N(n,m,E_{nor}, E_{adv})$

Initial condition:

Output: *Cluster head and cluster for WSN*

Steps:

1. *Initialization of WSN*
2. *Assignment of energy to nodes:*
   for each node $i \in (1 \ldots\ldots n)$*do*
   if $i \geq (m \times n + 1)$

set E(i)=E_{nor}
set node i_type= 'Normal'
else
set E(i)=E_{adv}
set node i_type= 'Advanced'
end if
end for
for each round r ∈(1……RND)

3. *Cluster head(CH) selection:*
   for each node i ∈(1…….n)
   if $E(i) \geq 0$ && $random < T(n)$
   set node i_type= 'CH'
   end if
   end for
4. *Associating the nodes to cluster head (during cluster formation):*
   for each node i ∈(1……n)
   for each cluster head a ∈(1……b)
   if corr(i,b)=maximum
   if $E(i) > 0$
   set node i_type= 'member'
   end if
   end if
   end for
   end for
   end for

C. *Modified Proposed Algorithm: MC-LEACH*

Since cluster heads are mainly responsible for energy consumption due to data aggregation as well as the overhead of data transmission. Hence, same modification as Modified LEACH is applied in Set-up Phase of MC-LEACH in order to prolong the lifetime of the network. MC-LEACH is Modification in Correlated LEACH based on advanced nodes of heterogeneous network. Here also the operation is achieved by rounds. The set-up phase consists of advertisement phase and cluster set-up phase. Advertisement Phase includes the selection of cluster head and then advertising its status to other nodes. The cluster head selection phase is same as Modified LEACH. The advanced nodes only take part in the cluster head formation. They are given more priority than normal nodes to become cluster head i.e. the cluster heads may be advanced nodes, as well as normal nodes but cluster members are only normal nodes.

In the advertisement phase, the cluster head sends advertisement packets only to their neighboring normal nodes not to the advanced nodes stating that it has become cluster head. Only the non-cluster head normal nodes check its correlation with the entire cluster heads and pick the of member nodes

along with their IDs. Based on all messages received within a cluster, the cluster head assigns the time based on TDMA schedule on which sensor node can send data to cluster heads. Then the cluster head picks a CSMA code randomly and broadcasts the TDMA table to cluster members. The advertisement phase and cluster set-up phase is explained by the flowchart shown in Fig. 5. Steady state phase is same as Correlated LEACH.

Cluster formation process of MC-LEACH has been explained in *Algorithm 3*, where *N* denotes the WSN assumed for the Proposed Algorithm, *n* is the total number of nodes in the network, E_o is initial energy of nodes, *random* is a random number between 0 and 1, *T(n)* is the threshold value, *corr(i,j)* is the correlation between nodes i and j, and *b* is the total cluster heads in each round.

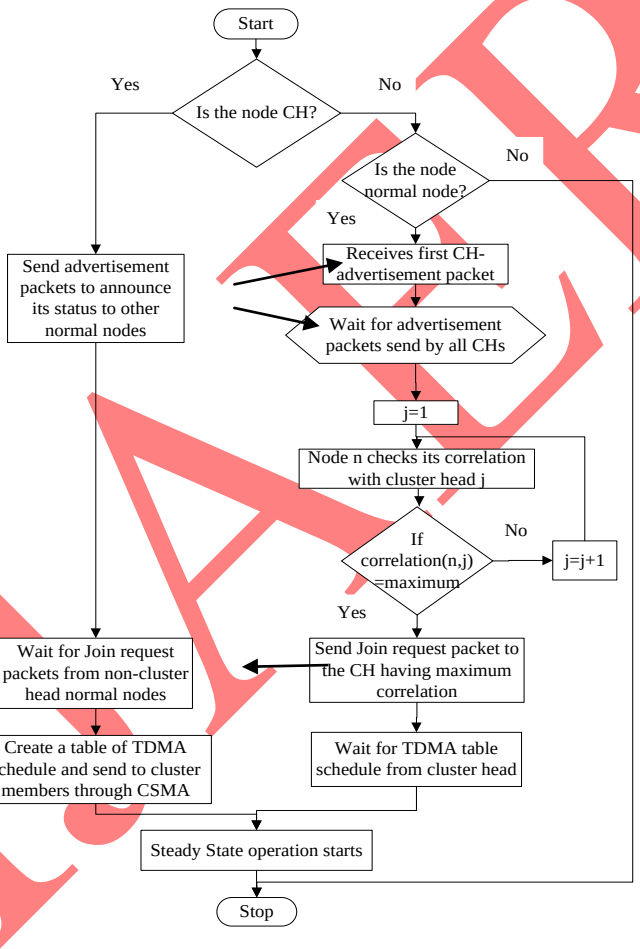

Fig. 5 Set-up phase of MC-LEACH

Algorithm3: *Cluster head selection and formation of cluster*
Input: *A heterogeneous network* $N(n,m,E_{nor}, E_{adv})$
Initial condition:
Output: *Cluster head and cluster for WSN*
Steps:

1. *Initialization of WSN*
2. *Assignment of energy to nodes:*

for each node i ∈(1……n)do

if $i \geq (m \times n + 1)$

set E(i)=E_{nor}

set node i_type= 'Normal'

else

set E(i)=E_{adv}

set node i_type= 'Advanced'

end if

end for

for each round r ∈(1……RND)

3. *Cluster head(CH) selection:*

for each node i ∈(1……n)

if $E(i) \geq E_{nor}$ && $random < T(n)$

set node i_type= 'CH'

end if

end for

4. *Associating the nodes to cluster head (during cluster formation):*

for each node i ∈(1……n)

for each cluster head a ∈(1……b)

if corr(i,b)=maximum

if $E(i) > 0$ && $E(i) \leq E_{nor}$

set node i_type= 'member'

end if

end if

end for

end for

end for

SIMULATION RESULT

The physical constraint considered here for obtaining simulation result is the lifetime of the network. Since large number of nodes is deployed within small area hence due to data redundancy lifetime can be decreased. So, protocols have been proposed to exploit spatial correlation of nodes. There are various metrics for calculating lifetime like first node die out round, half node die out round, last node die out round, the average energy of nodes etc. In this paper, different parameters are considered for calculating the lifetime in terms of First node die out round of the network like different heterogeneity conditions and different number of nodes in different areas. The simulation parameters used for simulation in shown in Table 4.1 and in each case, lifetime is averaged up to 5 times. Scenario for described parameters is shown in Fig. 6 showing heterogeneous sensor network in area of 100x100 m^2 having the heterogeneity of 10% in terms of the energy of nodes i.e. 10% of the nodes are having twice

energy than the others. 'o' denotes the normal nodes while '+' denotes the advanced node. Sink 'X' is located at the center of the network.

TABLE 1. SIMULATION PARAMETERS

Sl.No.	**Simulation Parameters and their Values**	
	Parameters	***Scenario 1***
1.	Coverage area	100x100 m^2
2.	Number of nodes	100
3.	Location of sink	50x50 m^2
5.	Election Probability value of CHs (p)	0.1
6.	Number of rounds	1999
7.	Initial energy of normal nodes (E_{nor})	0.05 J
8.	Initial energy of normal nodes (E_{nor})	0.1 J

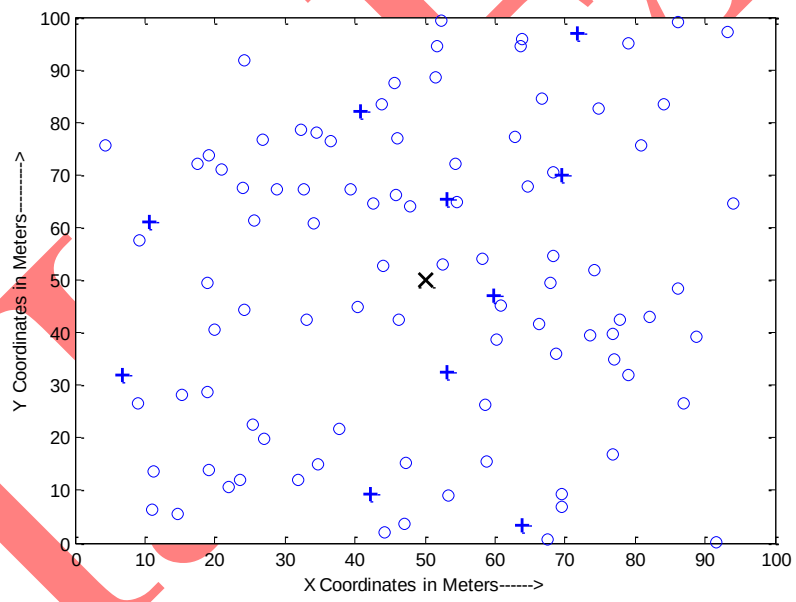

Fig. 6 Heterogeneous sensor network (where, 'o' indicates normal nodes, '+' indicates advance nodes and 'x' indicates the sink).

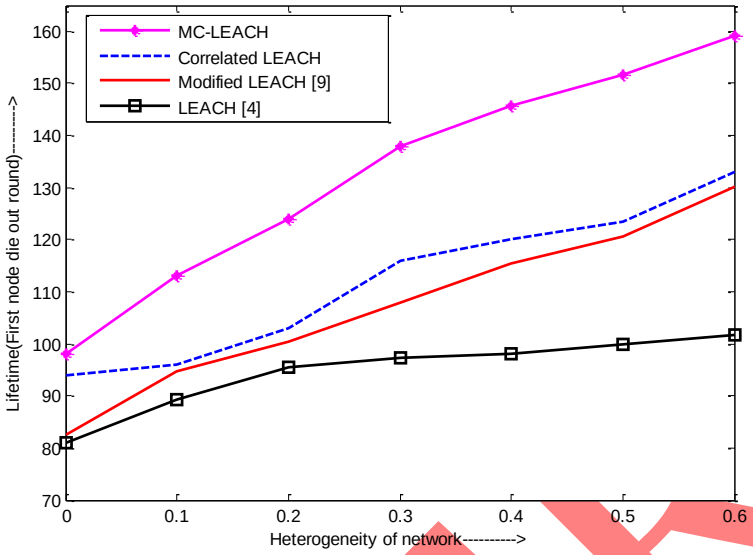

Fig. 7 Effect of heterogeneity on lifetime of the network

Fig. 7 shows the effect of heterogeneity on the Proposed Algorithms. From reported paper [9], it is known that with the increase in heterogeneity of the network, the lifetime in terms of first node die out increases. While Modified LEACH gives 30% longer lifetime than LEACH protocol [4] for 60% heterogeneous network, Correlated LEACH gives slightly longer lifetime than Modified

LEACH protocol. But MC- LEACH outperforms other protocols giving 22% longer lifetime than Modified LEACH protocol and 20% longer lifetime than Correlated LEACH. In homogeneous case also same order of MC-LEACH outperforms other protocols.

Fig. 8 shows the effect of variation of nodes on the lifetime in terms of first node die out round of the network having 10% heterogeneity. Less the number of nodes more will be the distance between nodes. Hence, a large amount of energy will be consumed in data transmission. As shown in fig. 8, with increase in number of nodes, lifetime of the network increases and MC-LEACH outperforms rest of the protocols. In case of Modified LEACH and LEACH, after 200 nodes there comes a saturation point and lifetime goes on decreasing on further increasing the nodes. But in case of Correlated LEACH and MC-LEACH, There is no saturation point up to 300 nodes and lifetime goes on increasing.

The bar chart in fig. 9 shows the lifetimes in terms of first node die out for different network areas. As network area increases, distance between nodes increases causing more energy consumption in data transmission. As shown in the bar chart, lifetime of network decreases with the increase in the network area and in case of network area, MC-LEACH gives longer lifetime than Correlated LEACH.

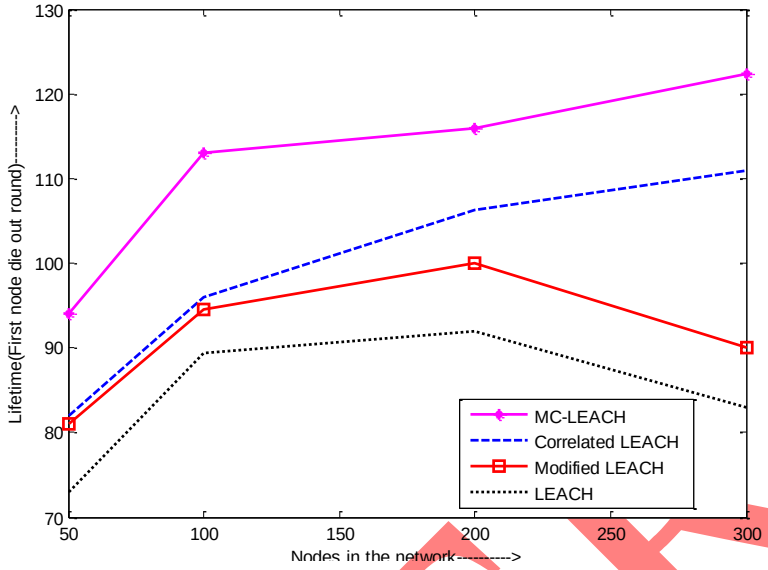

Fig. 8 Effect of variation of nodes on lifetime of the network.

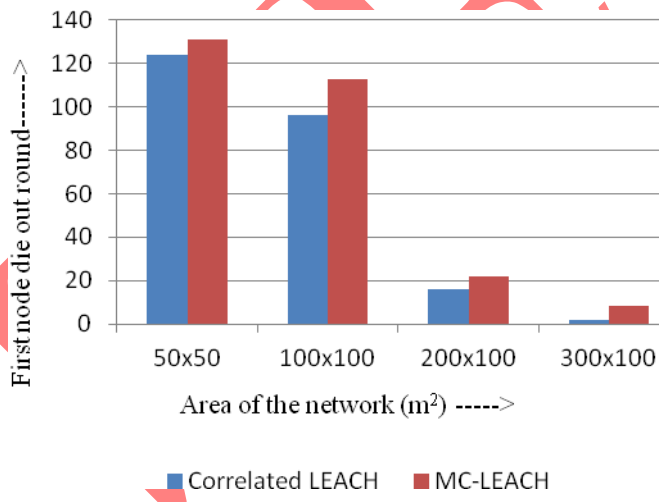

Fig. 9 Effect of area on lifetime of the network.

CONCLUSION

Since lifetime is a crucial factor for WSN performance, hence using an efficient cluster formation algorithm 'Correlated LEACH' exploiting the correlation between node and cluster head. It minimizes the energy requirement by removing the redundant data gathered at sensor nodes. Further it prolong the lifetime of the sensor network. In order to extend the lifetime, a modification in cluster head selection criteria is proposed in Correlated LEACH based on advanced node. Simulation result shows that MC-LEACH based on heterogeneity of network achieves minimum energy consumption with respect to Correlated LEACH and Modified LEACH. It increases the lifetime of the network by 20% than the Correlated LEACH.

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