CHAPTER 4
MODIFIED MOBILE SINK
ASSISTED LEACH
ALGORITHM
CHAPTER 4
MODIFIED MOBILE SINK ASSISTED LEACH ALGORITHM

4.1 Introduction

Mobile Sinks (MSs) have a major role in prolonging lifetime of the WSNs. As the nodes near the Static Sink (SS) is prone to earlier energy depletion because of their constant utilization, the use of MSs can overcome this issue, by providing a uniform load among the sensor nodes (Khan et al. 2013). The use of MS will reduce the hops to reach the BS which further reduces energy consumption. This chapter describes the Modified Mobile Sink Assisted LEACH in which the sink mobility concept with multiple sinks is incorporated.

4.1.1 Network Model

The energy model used is the simple first order radio model (Heinzelman et al. 2000). The radio dissipates $E_{\text{elec}} = 50 \text{ nJ/bit}$ for running the transmitter or receiver circuitry and the transmit amplifier uses $\varepsilon_{\text{amp}} = 100\text{ pJ/bit/m}^2$. According to this model, for transmitting a k-bit message over a distance d, the radio expends:

$$E_{\text{TX}}(k, d) = E_{\text{TX-elec}}(k) + E_{\text{TX-amp}}(k, d)$$ (4.1)

$$E_{\text{TX}}(k, d) = E_{\text{elec}} \times k + \varepsilon_{\text{amp}} \times k \times d^2$$ (4.2)

To receive a message, the radio expends:

$$E_{\text{RX}}(k) = E_{\text{RX-elec}}(k)$$ (4.3)

$$E_{\text{RX}}(k) = E_{\text{elec}} \times k$$ (4.4)

$E_{\text{TX}}$ and $E_{\text{RX}}$ is the transmitting energy and receiving energy in Joules.
4.1.2 Assumptions for Mobile Sink Assisted LEACH

- Sensor nodes are arbitrarily dispersed within a sensing field.
- There is only one Base Station (BS).
- Sensor nodes and the BS are static after deployment. The location of the BS is known by each node and they have the capability of communicating directly with the BS in certain situations.
- Sensor nodes can use power control to vary the amount of transmit power depending on the distance to the receiver. For simplicity it is assumed that the power level is continuous. The process of sensing is also continuous.
- Based on RSS, sensor nodes can compute their relative distance to BS and communication is symmetric.
- Sensor nodes are homogeneous.
- Four MSs are used for data gathering. The MSs are having higher range than that of the normal nodes and are rechargeable.

4.2 Description of the Modified Mobile Sink Assisted LEACH Algorithm

Consider Figure 4.1 and Figure 4.2. The area of deployment is assumed to be square region. Let ‘s’ be the length of each side and v be the uniform velocity. In Figure 4.1 the time required by the sink to move from A to B can be calculated as;

\[ t = \frac{s}{v} \]  \hspace{1cm} (4.5)
Where $v$ is the velocity or speed in m/s, $s$ is the linear distance travelled in meters and $t$ is the time in seconds. The total time required to cover the four sides will be;

$$t_2 = 4 \times \frac{s}{v} = 4t \quad (4.6)$$

From the above equation it is clear that the time taken to cover all the sides based on the mobility pattern represented in Figure 4.1 is $4t$. In Figure 4.2 the length of the diagonal is $\sqrt{2}s$. Therefore, distance from the centre to B can be calculated as;

$$d = \frac{\sqrt{2}s}{2} \quad (4.7)$$

$$d = \frac{s}{\sqrt{2}} \quad (4.8)$$

Figure 4.1: Single Mobile Sink Movement Path
The time taken to move from \( C_1 \) to \( C \) will be;

\[
T = \frac{s}{v} \times 4 \\
(4.9)
\]

\[
T = \left( \frac{s}{\sqrt{2}v} \right) \\
(4.10)
\]

Therefore, the total time taken by all the four sinks to reach the vertices can be calculated as;

\[
T_1 = \left( \frac{s}{\sqrt{2}v} \right) \times 4 = 2\sqrt{2} \times t \\
(4.11)
\]

From the equation 4.6 and equation 4.11, it can be seen that \( t_1 > T_2 \)

\[
t_1 = \sqrt{2}T_1 \\
(4.12)
\]

The mobility pattern of the MS as shown in Figure 4.1 takes \( \sqrt{2} \) times the time required by the mobility pattern of MSs exhibited in Figure 4.2 which indicates that using multiple MSs is better than using a single MS to cover a
particular region. Based on this, the concept of sink mobility was introduced to Modified LEACH algorithm where in four mobile sinks are incorporated. The two conditions were considered for the movement of MSs; one is giving pause times in between, and the other of continuous movement of the MSs. Consider the Figure 4.3. Let OA=OB=OC=OD=d, where d is the half diagonal length.

![Figure 4.3: Mobile Sink Path Movement](image)

For the triangle OAB,

\[ d^2 + d^2 = L^2 \]  \hspace{1cm} (4.13)

\[ d = \frac{L}{\sqrt{2}} \]  \hspace{1cm} (4.14)

Let T be the time for continuous motion. Speed at continuous motion is

\[ v = \frac{L}{\sqrt{2T}} \]  \hspace{1cm} (4.15)

Considering the pause time of MSs for \( \tau \) seconds and \( n \) number of pause times, the total time taken would be \( T+n\tau \). Speed for \( n \) pause times for \( \tau \) second duration,

\[ v = \frac{L}{\sqrt{2(T+n\tau)}} \]  \hspace{1cm} (4.16)
where $v$ is the speed to be determined in meter/second, $L$ is the length of each square side in meters, $T$ is the time taken in seconds for continuous motion, $\tau$ is the duration of pause time in seconds and $n$ is the number of pause times along distance ‘d’. The pause times and the number of pause time were randomly varied to decide the speed of MS’s mobility.

Modified Mobile Sink Assisted Routing algorithm consists of three major phases namely; Network clustering phase, Mobile sink navigation phase, Data collection phase/Routing. Clustering is carried out as same as that of the Modified LEACH algorithm. The movement of the MSs is designed with a uniform velocity in a particular path so as to have maximum coverage within a limited time. The nodes will communicate to the CHs and the CH will communicate to the MS within its range. MSs will aggregate the data and transfers to the static sink (SS).

The initial phase is the Network Clustering Phase. The network is partitioned to clusters using clustering algorithm of Modified LEACH with fewer number of CHs possible. Once CH nodes are chosen, they broadcast beacon to advertise their presence within their communication range. Based on the RSS each non cluster nodes choose their CHs to which they belong to. The CH nodes send their information to the MS and BS. Because of this arrangement sensor node need only low power for data transmission to CHs. CHs will aggregate this information and wait for MSs to deliver the data.

The next phase is the Mobile Sink Navigation Phase. The path for the MSs is predefined. Initially the four MSs are positioned at the centre of the deployed square region. They will be moving towards its corners and back to the centre throughout the simulation period. Half the diagonal length will be covered by each MS.
The CH’s within the coverage area of the MSs will send the aggregated data from their respective clusters to the MSs. The MSs are assumed to have better range compared to the sensor nodes. Two types of MS mobility pattern are considered; the first in which the MSs move continuously in the predefined path and the second one where MSs will have a pause time of two seconds at different points on its path movement. The CH’s sends their data to the MSs during this time of MS navigation. The routing of the data happens from the cluster members to the CHs and from the CHs to the respective MSs. MSs will further aggregate the information and routes it to the SS/BS.

The procedure of the Modified Mobile Sink Assisted LEACH algorithm is given below. [ BS is the base station, CH is the cluster head, MS is the mobile sink, RSS is the received signal strength, N is number of nodes deployed, A is the area of deployment, max_count is taken as 5%of N, t is the time limit and R is the sensor range which is application dependent.]

- Initially all nodes send their information to the BS as well as to the immediate neighbours.
- Each node maintains a count and max_count information.
- Within time ‘t’ each node identifies its neighbours within ‘R’.
- Elect node with the count=max_count within the limited time ‘t’ as CH; CH sends advertisement messages to its immediate neighbours to confirm it as CH for then the time ‘t’ stops.
- Based on RSS each node sends back the information to its respective CH and forms the clusters.
- CHs send the TDMA schedule to all the members in which they can communicate the sensed data to their CHs.
- Path planning for the MS is done and duty cycling for the different clusters is performed.
CHs maintain information about the residual energy of all its members and their relative distance to the MS. Data aggregated from the cluster members will be forwarded to the MS by the CHs. MSs will aggregate this and further forward to the BS.

The procedure for clustering and duty cycling is given below; [nodetype is the type of node, nodeenergy is the node’s energy level, RSS is the received signal strength, T is the threshold energy, n is the number of nodes, m is the time limit, neigh [ ] is the array of neighbour nodes, Mindist is the minimum distance, Mobsinkpos is the position of the mobile sink and CHpos is the position of the cluster head]

//Clustering procedure
for all node i=1 to n
   if nodetype==2 and RSS==high then form cluster
      if nodeenergy>T and nodetype==1
         elect as CH
      end
   end
end

//Duty cycling procedure
for all node cycletime= 1 to m
   for all node to n
      pos=mobsinkpos-CHpos
      if nodedist < range/ 2
         if pos<Tdist
            CH sends data to MS end
         end
      end
   end
end
The data aggregation and routing procedure is mentioned below.

//Data aggregation algorithm
RSS is the received signal strength
T is the threshold energy
n is the number of nodes
m is the time limit
neigh [] is the array of neighbour nodes

for all node i=1 to n
    if data[neigh[i]] == data[j] then
        data= data[i]
        flag=1
    else
        flag=0
    end
if flag==1
    send data to MS
        data= MSdata
    end
end
//Routing algorithm
for all node i=1 to n
    if flag==1
        Nodes sends data to CH
        CH sends data to MS
        MS sends data to Static Sink
    end
end

The flowchart of the proposed Mobile Sink Assisted LEACH is given in Figure 4.4.
Figure 4.4: Flowchart of Mobile Sink Assisted LEACH
4.2.1 Simulation Results and Performance Analysis

The simulation is performed using MATLAB in different scenarios by varying the simulation parameters. Different cases were considered by keeping the area of deployment constant and varying the number of nodes. Randomly changing the area of simulation as well the numbers of nodes were also carried out. The speed of the MSs is arranged in such a way as it is possible to cover the area up to 500m×500m with in a specific time of fifty seconds. The simulation parameters are given in Table 4.2. The Modified Mobile Sink Assisted Routing algorithm is compared with the LEACH protocol and the M-LEACH protocol (Nguyen et al. 2008). M-LEACH allows the mobility of the nodes both the cluster members as well as CH during the setup and steady state phase. M-LEACH considers the remaining energy of node while selecting the CH. But due to the mobility of nodes overheads are more.

Table 4.1: Simulation Parameters for Mobile Sink Assisted LEACH Protocol

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Description</th>
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<td>Simulation Area</td>
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<td>Nodes power range</td>
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<td>Maximum Speed</td>
<td>24 m/s</td>
<td>Movement</td>
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<td>Mobility interval</td>
<td>0s, 2 s</td>
<td>Pause time of node</td>
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<td>Transmission Energy</td>
<td>$2 \times 10^{-1}$ joules / pkt</td>
<td>Energy to transmit a packet</td>
</tr>
<tr>
<td>Receiving Energy</td>
<td>$1 \times 10^{-1}$ joules / pkt</td>
<td>Energy to receive a packet</td>
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Three different scenarios are taken where in the area of deployment is varied with different number of sensor nodes. The different parameters used for performance analysis are delay, packet delivery ratio and the average energy of the network at various simulation periods. Based on different cases the performance evaluation of the Modified Mobile Sink Assisted LEACH using various parameters are discussed below. Tables 4.2, 4.3 and 4.4 shows the simulation results under various scenarios of sink mobility, where the results based on the simulation time till fifty percent of the nodes are alive in all the protocols considered.

- **Delay**
  In terms of delay the performance of Modified Mobile Sink Assisted LEACH is compared with LEACH and M-LEACH under different simulation parameters as mentioned below.

  **Case i: A=100m×100m, N=50**
  Figure 4.5 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the delay over the simulation period with 50 nodes.

  **Case ii: A=100m×100m, N=100**
  The performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the delay over the simulation period of 500 rounds with 100 nodes deployed in a 100m×100m square area is given in Figure 4.6.

  **Case iii: A=100m×100m, N=150**
  Figure 4.7 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the delay over the simulation period of 500 rounds.
Figure 4.5: Delay Vs Rounds for Modified Mobile Sink Assisted LEACH (N=50, A=100m×100m)

Figure 4.6: Delay Vs Rounds for Modified Mobile Sink Assisted LEACH (N=100, A=100m×100m)
In all the three cases, it can be observed that the Mobile Sink Assisted LEACH gives better performance based on the delay factor. It shows comparatively less delay and maintains stability throughout the simulation period. But it can also be observed that there is a change in the delay due to sink mobility at times during different rounds.

- **Packet Delivery Ratio**

Packet delivery ratio is another metric used to assess the performance which indicates the number of packets that have successfully reached the destination. Three different scenarios are illustrated based on this performance measure.

*Case i: $A=100m \times 100m$, $N=50$*
Figure 4.8 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the packet delivery ratio over the simulation period of 500 rounds.

**Case ii: A=100m×100m, N=100**

Figure 4.9 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the packet delivery ratio over the simulation period of 500 rounds.

**Case iii: A=100m×100m, N=150**

Figure 4.10 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the packet delivery ratio over the simulation period of 500 ms.

It can be observed that the proposed Mobile Sink Assisted approach attains higher packet delivery ratio in all the cases compared to LEACH and M-LEACH. But due to impact of sink mobility there is a sudden change in the packet delivery ratio at different times.
Figure 4.8: Packet Delivery Ratio Vs Rounds for Modified Mobile Sink Assisted LEACH (N=50, A=100m×100m)

Figure 4.9: Packet Delivery Ratio Vs Rounds for Modified Mobile Sink Assisted LEACH (N=100, A=100m×100m)
Figure 4.10: Packet Delivery Ratio Vs Rounds for Modified Mobile Sink Assisted LEACH
(N=150, A=100m×100m)

- **Average Residual Energy**

Average residual energy of the network indicates the energy efficiency of the network. Based on the average residual energy of the node in different simulation periods, the performance of the different protocols was compared. The different scenarios are illustrated below.

**Case i: A=100m×100m, N=50**

Figure 4.11 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the average energy consumed over the simulation period of 500 rounds.
Figure 4.11: Average Energy Vs Rounds for Modified Mobile Sink Assisted LEACH (N=50, A=100m×100m)

Case ii: A=100m×100m, N=100

Figure 4.12 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the average energy consumed over the simulation period of 500 rounds.

Case iii: A=100m×100m, N=150

Figure 4.13 gives the performance analysis of the Modified Mobile Sink Assisted LEACH Algorithm with the LEACH protocol and M-LEACH based on the average energy consumed over the simulation period of 500 rounds.
Figure 4.12: Average Energy Vs Rounds for Modified Mobile Sink Assisted LEACH (N=100, A=100m×100m)

Figure 4.13: Average Energy Vs Rounds for Modified Mobile Sink Assisted LEACH (N=150, A=100m×100m)
Table 4.2: Performance Comparison of LEACH and Modified Mobile Sink Assisted LEACH (120m×120m)

<table>
<thead>
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Table 4.3: Performance Comparison of LEACH and Modified Mobile Sink Assisted LEACH (300 m×300m)

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Table 4.4: Performance Comparison of LEACH and Modified Mobile Sink Assisted LEACH (600m×600m)

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4.2.2 Summary

From the simulation results, it is evident that by using MSs, there is considerable amount of saving in the energy. Reduced energy consumption of individual nodes is attained by multi hop transmission through the CH and then by the MSs, directed to the BS. Duty cycling introduced avoids the energy wastage to a good extend. Proper selection of CHs eliminates the energy hole problem that can terminate the network lifetime. Improved reliability can be achieved as there is less contention and collisions within the wireless medium because data can now be collected directly through single or limited hop transmissions since the MSs are involved. Reduced reliance on nodes located close to a static sink to route messages to the sink, resulting in increased energy efficiency and network lifetime is another advantage. Overall the modified method satisfies the objective of the research intended.

The Modified Mobile Sink Assisted Protocol is path constrained and the speed of the mobile sink affects the delay in packet delivery. It is showing better performance in lifetime enhancement in all the cases. But even though it is showing better performance in delay and packet delivery ratio compared to LEACH and M-LEACH, at different times there is large difference in the performance which can be a disadvantage for delay intolerant or emergency applications. The speed of sink mobility and the number and duration of pause times is application dependent and can be customised.