LEACH-GA: Genetic Algorithm-Based Energy-Efficient Adaptive Clustering Protocol for Wireless Sensor Networks

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***Abstract*—This study proposes a genetic algorithm-based (GA-based) adaptive clustering protocol with an optimal probability prediction to achieve good performance in terms of lifetime of network in wireless sensor networks. The proposed GA-based protocol is based on LEACH, called LEACH-GA herein, which basically has set-up and steady-state phases for each round in the protocol and an additional preparation phase before the beginning of the first round. In the period of preparation phase, all nodes initially perform cluster head selection process and then send their messages with statuses of being a candidate cluster head or not, node IDs, and geographical positions to the base station. As the base station received the messages from all nodes, it then searches for an optimal probability of nodes being cluster heads via a genetic algorithm by minimizing the total energy consumption required for completing one round in the sensor field. Thereafter, the base station broadcasts an advertisement message with the optimal value of probability to the all nodes in order to form clusters in the following set-up phase. The preparation phase is performed only once before the set-up phase of the first round. The processes of following set-up and steady-state phases in every round are the same as LEACH. Simulation results show that the proposed genetic-algorithm-based adaptive clustering protocol effectively produces optimal energy consumption for the wireless sensor networks, and resulting in an extension of lifetime for the network.**

***Index Terms*—Adaptive clustering protocol, clustering head, genetic algorithm, optimal probability, lifetime.**

I. Introduction

Wireless sensor networks (WSNs), which consist of a number of small battery-powered devices, are frequently to obtain various sorts of useful data from surroundings. These devices sense physical properties, such as sound, humidity, pressure, luminosity, temperature, or chemical concentration, and transmit the gathered data to a base station (BS) for further analysis and processing. WSNs have been effectively deployed in tactical combat situations, habitat monitoring, home security, and so on [1-5]. Since WSNs consist of many sensors with limited energy, an energy-efficient network protocol is an important consideration in WSN applications. Many routing protocols for WSNs have appeared in the literature. In applications using direct transmission (DT) protocols [6], sensor nodes transmit their sensed data directly to a BS. Thus, the nodes located far from the BS will die quickly since they dissipate much energy in transmitting data packets. DT protocols are inefficient since energy levels of nodes are drained rapidly when the BS is located far. On the other hand, minimum transmission energy (MTE) protocols [7, 8] transmit data packets to the BS by way of multi-hop relay. As a result, nodes located near the BS die quickly since they end up relaying lots of data on behalf of remote nodes. The results of simulations using the DT and MTE communication protocols are shown in Figs. 1(a)-(d), with the BS located at the point with coordinate (50, 200). Clearly, DT and MTE result in a poor distribution for energy consumption by nodes. Sensor nodes in some subregions have all died out, but nodes in other regions are still active. As a result, data for a part of the sensor field may not be detected.

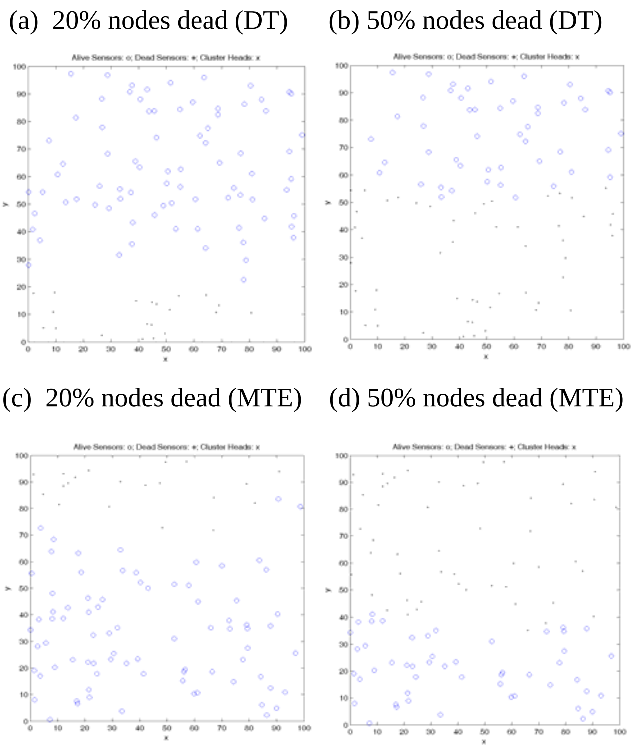

Figure 1. Survival statuses of sensor nodes using DT ((a) and (b)) and MTE ((c) and (d)) protocols.

Clustering communication protocols represent a superior approach, and result in more balanced patterns of energy use

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in WSNs [9]. The first low-energy adaptive clustering hierarchy was LEACH, proposed by Heinzelman *et al.* [10, 11]. It showed how energy loads could be well amortized by dynamically creating a small number of clusters based on a threshold function T(s) with a priori probability p (say, 5%), in a set-up phase. The technique uses cluster heads (CHs) to mediate data transmission. Simulation results in [10, 11] show that all node tend to dissipate the same level of energy over time since the CH roles are rotated among nodes. Although LEACH clearly outperforms the DT and MTE protocols, it retains several shortcomings. Thus several enhanced versions of LEACH have appeared in the literature [12]. LEACH uses a threshold function parameterized by a probability p input by user. However, the performance of sensor network is very sensitive to the value of p. When p is large, many clusters are formed and could result in high energy consumption since many CHs dissipate energy in transmitting to the BS. On the other hand, when p is small, only a few clusters are formed, which may increase energy dissipation when member nodes transmit to CHs. The literature suggests that the optimal p value p_{opt}, or the optimal cluster number k_{opt}, depends on parameters such as the total number of nodes distributed in the sensor field, the size of sensor field, the location of BS, and so on [13, 14]. Our work proposes a genetic algorithm-based (GA-based) adaptive clustering protocol, termed LEACH-GA, to predict the optimal values of probability effectively.

II. Energy-efficient Communication Protocols

We now briefly describe the LEACH protocol, and then present our genetic algorithm-based adaptive clustering protocol.

A. Clustering Hierarchy in LEACH

LEACH operates in several rounds, each consisting of a set-up and a steady-state phase. Each node transmits sensed data to its closest CH. The CH for each cluster receives and aggregates the data from cluster members and then transmits the aggregated data to the BS through a single-hop relay (shown in Fig. 2). LEACH creates a set-up phase for CHs' selection, and a steady-state phase for time slot scheduling and transmission. Each sensor node s decides independently of other senor nodes whether it will claim to be a CH or not, by picking a random r between 0 and 1 and comparing r with a threshold T(s) based on a user-specified probability p. The threshold is defined as follows [10]:

$$\mathrm{T}(s)=\begin{cases}\dfrac{p}{1-p\left(r \bmod \left(\dfrac{1}{p}\right)\right)} & \text{if } s\in G\\ 0 & \text{otherwise}\end{cases} \quad (1)$$

where G is the set of nodes that have not been CHs in the last $1/p$ rounds. When a node decides to be a CH, it broadcasts an advertisement message, with the node's ID and a header, using a non-persistent carrier-sense multiple access (CSMA) MAC protocol to ensure the elimination of collisions, to the entire sensor field. The size of the message is small, so that it can be efficiently broadcasted to reach all of the nodes in the network. Non-CH nodes (or member nodes) decide to join the cluster defined by the CH with the strongest received signal. Next, each non-CH sends a join-request containing their ID, to the closest CH using CSMA.

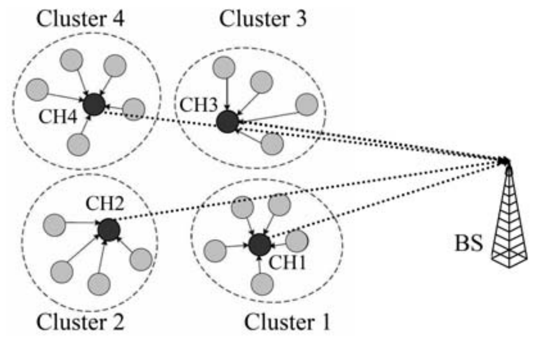


Figure 2. The LEACH clustering communication hierarchy for WSNs.

After the cluster-setup sub-phase, the CH recognizes the number of member nodes and IDs of the nodes. Based on all join-request messages received within the cluster, the CH creates a TDMA schedule in addition to a unique spreading code, and transmits them to cluster members at the beginning of steady-state phase. Thereafter, all nodes in the cluster transmit their data packets to their CHs in the pre-specified TDMA time slot, using this code. As we known that TDMA-based protocols are naturally energy preserving, because they have time slots built-in, and do not suffer from collisions. Also, each member node can situate in a sleep mode at all times except during its corresponding time slots in order to decrease node's energy dissipation. When the data packets sent by a node have been received by a CH, the CH aggregates and forwards them to the BS. These actions are repeated in each round. The plots of simulation results by LEACH are shown in Figs. 3(a) and (b), for the BS located at coordinate (50, 200). It is clearly shown that the nodes dead obtained using LEACH are more uniform than that of DT and MTE protocols.

(a) 20% nodes dead (b) 50% nodes dead

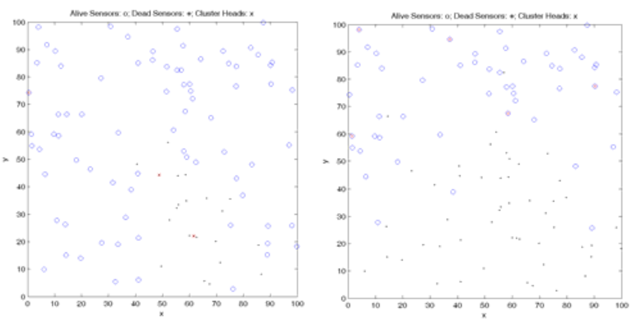


Figure 3. Survival status of sensor nodes under LEACH.

B. Our Proposed Genetic Algorithm-based Adaptive Clustering Protocol

Our work introduces a genetic algorithm-based variant of LEACH to determine the optimal value of p for various base station placements. The GA-based optimization procedure is performed only once, before the set-up phase of the first round. The pseudo-code of the proposed protocol is described as follows.

Pseudo-code of the Proposed LEACH-GA Protocol:

```
BEGIN
Specify the probability (p_set), number of nodes (n);
E_init(s)=E_0,  s=1,2, …, n;
(I) PREPARATION PHASE
if (E_init(s)>0 & rmod(1/p_set)≠0)  then  //p_set can set≥0.5
  r←random(0,1) and compute T(s);  //given by (1)
  if (r < T(s))  then
    CCH{s}=TRUE; //node s be a candidate CH
  else
    CCH{s}=FALSE; //node s not be a candidate CH
  end if
end if
SendToBS(ID_u, (x_u,y_u), CCH(u)) ← All nodes send
    messages to BS;
GAinBS(p_opt) ← Optimal probability is determined;
BC (p_opt) ← BS broadcasts a message back to all nodes;
(II) SET-UP PHASE
  do {                        //repeat for r rounds
  r←random(0,1);
  if (E_init(s)>0 & rmod(1/p_opt)≠0)  then
    compute T(s);             //given by (1)
    if (r < T(s))  then
      CH{s}=TRUE; //node s be a CH
    else
      CH{s}=FALSE; //node s not be a CH
    end if
  end if
  if  (CH{s}=TRUE) then
      BC (ADV) ← broadcast an advertisement message;
      Join(ID_i);    //non-cluster head node i join
                            into the closest CH
      Cluster(c);             //form a cluster c;
  end if
(III) STEADY-STATE PHASE
  If (CH(s)=TRUE) then
     Receive(ID_i, DataPCK) //receive data from members;
     Aggregate(ID_i, DataPCK) //aggregate received data;
     TansToBS(ID_i, DataPCK); //transmit received data;
  else
     If (MyTimeSlot=TRUE) then
        TansToCH(ID_i, DataPCK); //transmit sensed data;
     else
        SleepMode(i)=TRUE;       //node i at a sleep state
     end if
  end if
  }                // one round is completed
END
```

III. Optimal Clustering Analysis

We evaluate our protocol using the first-order radio model of [10]. The parameter settings used in the simulation for the model are listed in TABLE I. According to the radio energy dissipation model of Fig. 4, the energy required by the transmit amplifier $E_{Tx}(l,d)$ to transmit an l-bit message over a distance d between a transmitter and receiver is

$$E_{Tx}(l,d)=\begin{cases} l\times E_{elec}+l\times\varepsilon_{fs}\times d^2 & if\ d\le d_0 \\ l\times E_{elec}+l\times\varepsilon_{mp}\times d^4 & if\ d\ge d_0 \end{cases} \quad (2)$$

where $d_0=\sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$ denotes the threshold distance, E_{elec} represents the energy consumption in the electronics for sending or receiving one bit, and $\varepsilon_{fs}d^2$ and $\varepsilon_{mp}d^4$ represent amplifier energy consumptions for a short- and long-distance transmissions, respectively. To receive an l-bit message, the energy $E_{Rx}(l)$ required by the receiver is given by

$$E_{Rx}(l)=l\times E_{elec} \quad (3)$$

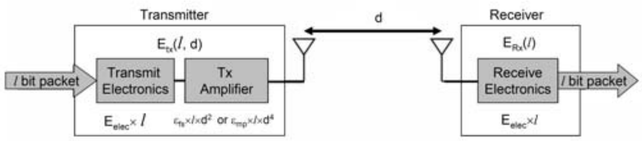


Figure 4. First-order radio model.

TABLE I. Parameter settings of the first-order radio model

Parameters	Values
Initial energy (E_0)	0.5 J/node
Transmitter Electronics (E_{elec})	50 nJ/bit
Receiver Electronics (E_{elec})	50 nJ/bit
Data Packet Size (l)	2000 bits
Transmitter Amplifier (ε_{fs}) if $d\le d_0$	10 or 100 pJ/bit/m^2
Transmitter Amplifier (ε_{mp}) if $d\ge d_0$	0.0013 pJ/bit/m^4

Let a total of n sensor nodes be distributed uniformly in the sensor field of size $M\times M$ meters, and be grouped into k clusters. The energy required per round for a CH to receive data packets from member nodes, and aggregate and forward them a distance d_{toBS} to the BS is

$$E_{CH}(l,d)=\begin{cases} l\times\left[E_{elec}(\frac{n}{k}-1)+E_{DA}\frac{n}{k}+E_{elec}+\varepsilon_{fs}\times d_{toBS}^2\right] & if\ d_{toBS}<d_0 \\ l\times\left[E_{elec}(\frac{n}{k}-1)+E_{DA}\frac{n}{k}+E_{elec}+\varepsilon_{mp}\times d_{toBS}^4\right] & if\ d_{toBS}\ge d_0 \end{cases} \quad (4)$$

where E_{DA} represents the energy dissipation for aggregating data. The energy dissipation for a non-cluster head node is

$$E_{non-CH}(l,d)=l\times E_{elec}+l\times\varepsilon_{fs}\times d_{toCH}^2 \quad (5)$$

where d_{toCH} represents the distance between a cluster member and its CH. Since the nodes are assumed to be uniformly distributed in the sensor field, the expected value of squared distance from a member nodes to its CH, which located at the point (a, b), is given by

$$E\left[d_{toCH}^2\right] = \frac{1}{A}\iint (x-a)^2 + (y-b)^2 dxdy \qquad (6)$$

Assuming the shape of clusters is a circle, thus (6) becomes

$$\begin{aligned} E\left[d_{toCH}^2\right] &= \frac{2}{A}\iint (x^2+y^2)dxdy \\ &= \frac{1}{\pi}\frac{M^2}{k} \end{aligned} \qquad (7)$$

The value of d_{toCH}^2 in (7) is twice that of Heinzelman *et al.*, who assumed that the CH is placed at the center of cluster. Moreover, the energy dissipated in a cluster is obtained as

$$E_{total} = k \times \left(E_{CH} + (\frac{n}{k} - 1)E_{non-CH} \right) \approx k \times \left(E_{CH} + \frac{n}{k} E_{non-CH} \right) \qquad (8)$$

Thus, the total energy dissipation for a round is given by

$$E_{Total} = \begin{cases} l \times \left[2nE_{elec} + nE_{DA} + k\varepsilon_{fs}E[d_{toBS}^2] + \varepsilon_{fs}\frac{nM^2}{\pi k} \right] & if\ d_{toBS} < d_0 \\ l \times \left[2nE_{elec} + nE_{DA} + k\varepsilon_{mp}E[d_{toBS}^4] + \varepsilon_{fs}\frac{nM^2}{\pi k} \right] & if\ d_{toBS} \geq d_0 \end{cases} \qquad (9)$$

From (9), the analytical optimal solutions for k_{opt} and p_{opt} are obtained.

$$k_{opt} = \begin{cases} \sqrt{\frac{n}{\pi}} \frac{M}{\sqrt{E[d_{toBS}^2]}} & \text{if } d_{toBS} < d_0 \\ \sqrt{\frac{n}{\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \frac{M}{\sqrt{E[d_{toBS}^4]}} & \text{if } d_{toBS} \geq d_0 \end{cases} \qquad (10)$$

and

$$p_{opt} = \frac{k_{opt}}{n} = \begin{cases} \sqrt{\frac{1}{n\pi}} \frac{M}{\sqrt{E[d_{toBS}^2]}} & \text{if } d_{toBS} < d_0 \\ \sqrt{\frac{1}{n\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \frac{M}{\sqrt{E[d_{toBS}^4]}} & \text{if } d_{toBS} \geq d_0 \end{cases} \qquad (11)$$

We assume the coordinates of the BS to be $(0.5M, 0.5M+B)$, and calculate the values of $E[d_{toBS}^2]$ and $E[d_{toBS}^4]$ to be

$$E[d_{toBS}^2] = \frac{M^2}{6} + B^2; \quad E[d_{toBS}^4] = \frac{7M^4}{180} + \frac{2}{3}B^2M^2 + B^4 \qquad (12)$$

Therefore the values of k_{opt} and p_{opt} are related to the total number of sensor nodes, domain size of sensor field, and the location of BS. In addition, Heinzelman *et al.* assumed the BS is far from the nodes, so the energy dissipation follows the multipath model. Thus, their formula for k_{opt} is only the lower part of (10). The original formula, denoted as original form in this work, for k_{opt} from Heinzelman *et al.* is [11]

$$k_{opt} = \sqrt{\frac{n}{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \frac{M}{d_{toBS}^2} \qquad (13)$$

Therefore, the p_{opt} can be formulated as

$$p_{opt} = \frac{k_{opt}}{n} = \sqrt{\frac{1}{2\pi n}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \frac{M}{d_{toBS}^2} \qquad (14)$$

In this work, (10) and (11) are used as the corrected forms of analytical solution for k_{opt} and p_{opt} without assuming the positions of BS located near or far from the sensor field.

IV. Genetic Algorithm-based Clustering

At the beginning of preparation phase, each node initially determines whether or not it should be a candidate cluster head (CCH), using the following cluster head selection procedure. First, every sensor node selects a random number r from the interval [0, 1]. If r is smaller than T(s), based on a prescribed probability p_{set}, then the node is a CCH. The value of p_{set} can be a large value in our protocol, p_{set}=0.5, say. Thereafter, each node sends its ID, location information, and whether or not it is a CCH to the BS. As the BS receives messages sent by all nodes, it performs GA operations to determine the optimal probability, $p_{opt} = k_{opt}/n$, by minimizing the total amount of energy consumption in each round. Therefore, the objective function used in the GA can be formulated as

$$\begin{aligned} f(\vec{x}) = &\sum_{c=1}^{k}\sum_{i=1}^{q}(E_{elec} + \varepsilon d^{\alpha}[i, CCH(c)]) \times x_c + \\ &\sum_{c=1}^{k}(E_{elec} + E_{DA} + E_{elec} + \varepsilon d^{\alpha}[CCH(c), BS]) \times x_c \end{aligned} \qquad (15)$$

where $\vec{x} = [x_1, x_2, \ldots, x_c, \ldots, x_k]$. The values of x_c are one for our binary-GA when it is a CCH, otherwise, it is zero. The parameters $\varepsilon = \varepsilon_{fs}$ and α=2 were used for $d \leq d_0$; while, $\varepsilon = \varepsilon_{mp}$ and α=4 were set for $d \geq d_0$. The symbol q represents the number of member nodes in a CCH. The optimal probability p_{opt} is determined by the GA by searching the solution space through an evolutionary optimization process incorporating probabilistic transitions and non-deterministic rules, and applying selection, crossover and mutation operators. Once the optimal probability p_{opt} is found, the BS broadcasts the value of p_{opt} to all nodes. The set-up and steady-state phases begin. The procedures of set-up and steady-state phase are the same as in LEACH.

V. Simulation Results

Our work assumes that all sensor nodes are homogeneous and distributed uniformly over the sensor field with limited energy that the links between nodes are symmetric, and that messages from all nodes can reach the BS. The nodes are distributed randomly in a square of size $M \times M$. Each simulation is repeated for 30 independent runs. In addition, control packet sizes for broadcasting packet and packet header were 50 bits long, and the energy dissipation for aggregating data was 5 and 10 nJ/bit/signal.

A. Comparison of Optimal Probability of Cluster Heads

In this section, the energy dissipation for aggregating data and the parameter ε_{fs} were specified as 5 nJ/bit/signal and 10 pJ/bit/m^2, respectively. The total number of sensor nodes was 100. Figures 5(a) and (b) show the comparison of optimal probability obtained from model analysis and GA-based computation for a variety of locations of BS for the sensor fields of 50m×50m and 100m×100m. The comparison of solutions depicts that the distribution of present p_{opt} quite agreed with the corrected form using our analytical formulas of (11), whereas Heinzelman *et al.*'s results displayed a large discrepancy when compared to the data by using the GA and present modified analytical formulas. Moreover, the results show that the optimal probability, p_{opt}, is clearly affected by the locations of BS. When the BS is located near the sensor field, the values of p_{opt} are large. On the contrary, the values of optimal probability decrease as the BS moves farther from the sensor field. When the BS located at the center of sensor field, the values of $\sqrt{E[d_{toBS}^2]}$ is given by [15, 16]

$$\sqrt{E\left[d_{toBS}^2\right]} = \frac{1}{A}\int\sqrt{x^2+y^2}\,dA = 0.765\frac{M}{2} \tag{16}$$

and the form of p_{opt} can be simplified as

$$p_{opt} = \sqrt{\frac{1}{n\pi}}\,\frac{2}{0.765} \tag{17}$$

Equation (17) states that the parameter p_{opt} is just function of the total number of sensor nodes only when the BS located at the center of sensor field. Namely, the value of probability at the center of sensor field is independent of the domain size.

(a) 50*m*×50*m* sensor field (b) 100*m*×100*m* sensor field

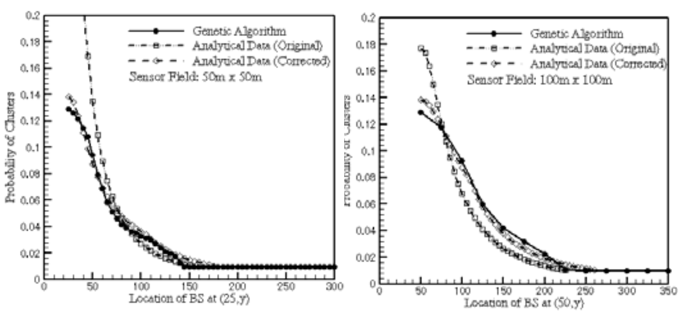


Figure 5. Comparison of optimal probability between analytical analyses and genetic algorithm optimzation for the sensor fields of (a) 50m×50m and (b) 100m×100m using ε_{fs}=10 pJ/bit/m and n=100.

Moreover, the values of p_{opt} are clearly dependent of the total number of sensor nodes (n) from the expression of (11). When the number of sensor nodes increases, the values of optimal probability will decrease based on (11). Two cases are conducted using n=200 and n=400 to study the effect of n to the value of p_{opt}. The simulation results for n=200 and n=400 are displayed in Figs. 6 and 7, respectively. Figures 6(a) and (b) show that the predicted distributions of optimal probability by present GA were as well as the present corrected form governed by (11) for BS located at different positions. In these two figures, the values of optimal probability at the center of sensor field were independent of the domain size of sensor field based on (17). This work also performed the simulation of the case with n=400, and the results are shown in Figs. 7(a) and (b). From the results shown in Figs. 5 and 7, the values of optimal probability at the center of sensor field for the case of n=400 were equal to the half of that of the case for n=100.

(a) 50*m*×50*m* sensor field (b) 100*m*×100*m* sensor field

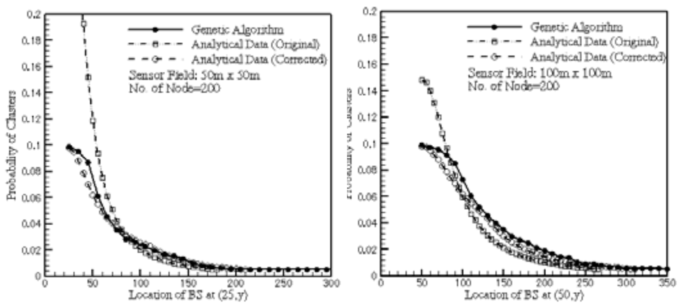


Figure 6. Comparison of optimal probability between analytical analyses and genetic algorithm optimzation for the sensor fields of (a) 50m×50m and (b) 100m×100m using ε_{fs}=10 pJ/bit/m and n=200..

(a) 50*m*×50*m* sensor field (b) 100*m*×100*m* sensor field

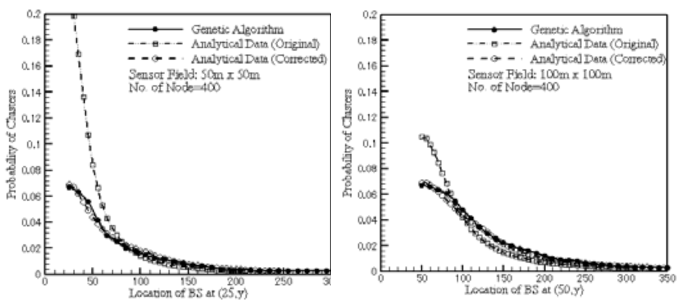


Figure 7. Comparison of optimal probability between analytical analyses and genetic algorithm optimzation for the sensor fields of (a) 50m×50m and (b) 100m×100m using ε_{fs}=10 pJ/bit/m and n=400.

B. Comparison of the Presented LEACH-GA and LEACH

In this section, the nodes with 100 are distributed randomly in the *M*×*M* sensor field with 50m×50m. Each simulation is also repeated for 30 independent runs, and solutions are obtained from the average of the runs. In addition, control packet sizes for broadcasting packet and packet header were 50 bits length for the present computations, and the energy dissipation for aggregating data and the parameter ε_{fs} were specified as 10 nJ/bit/signal and 100 pJ/bit/m^2 [11], respectively. Figure 8 is the solution distribution of p_{opt} predicted by using the presented LACH-GA for BS located at different positions. The comparison of the values of p_{opt} computed by LEACH-GA and corrected formula is agreeable, whereas, the data using Heinzelman *et al.*'s formula shown in (14) were clearly discrepant compared to LEACH-GA and our corrected form. Especially, there are large errors performed using the original form when the BS located near to the center of sensor field.

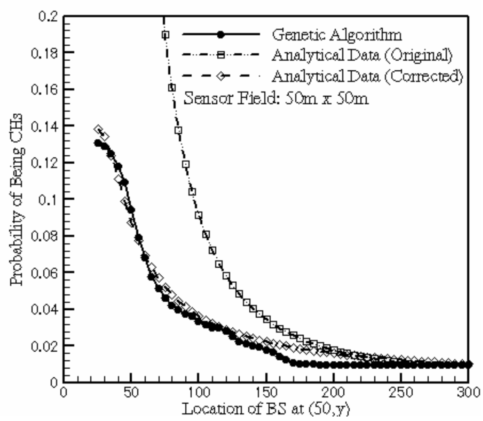


Figure 8. Comparison of optimal probability between analytical analyses and genetic algorithm optimzation..

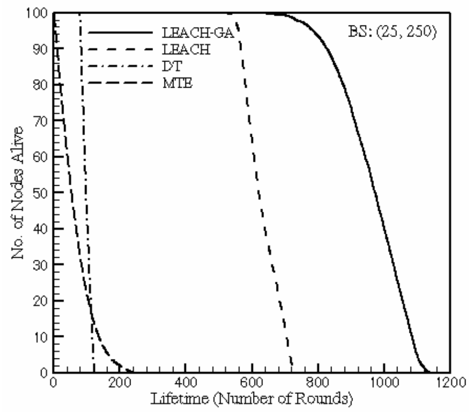
TABLE II lists the simulation results obtained using LEACH and presented LEACH-GA protocols for BS located at different positions. The initial energy for all nodes was 0.5(J) and the probability *p* used in LEACH is 5%, same as the settings in [10, 11]. The number of rounds required when the number dead of nodes is 1%, 20%, 50%, and 100% are recorded during simulations. From our results, the values of p_{opt} clearly depend on the positions of BS. The value of optimal probability is the largest when the BS is at the center of sensor field, and it decreases when the BS moves outward. Moreover, the proposed LEACH-GA outperforms LEACH in terms of lifetime of network.

TABLE II. COMPARISON OF NETWORK LIFETIMES (NUMBER OF ROUNDS) BETWEEN LEACH AND PROPOSED LEACH-GA PROTOCOLS

BS (25, y)	Protocol	Prob.	Nodes Dead			
			1%	20%	50%	100%
25	LEACH	0.05	1467	1618	1691	1850
	LEACH-GA	0.1307	1610	1732	1818	2040
50	LEACH	0.05	1438	1583	1661	1874
	LEACH-GA	0.0946	1512	1663	1717	2078
100	LEACH	0.05	1346	1473	1543	1787
	LEACH-GA	0.0334	1356	1482	1554	1815
150	LEACH	0.05	951	1027	1098	1298
	LEACH-GA	0.0181	927	1108	1205	1357
250	LEACH	0.05	540	576	616	718
	LEACH-GA	0.010	686	874	971	1106
350	LEACH	0.05	220	247	283	360
	LEACH-GA	0.010	407	574	660	757

Figures 9(a) and (b) compare the performance of four protocols with the BS located at two coordinates of (25, 250) and (25, 350), respectively. Our protocol clearly has excellent performance as compared with other protocols. When the location of BS is far from the sensor field, presented protocol prolongs the lifetime of network significantly since it uses an optimal probability in forming clusters. The gains achieved are as high as 54% and 110%, compared to LEACH with the BS located at (25, 250) and (25, 350), respectively.

(a)



(b)

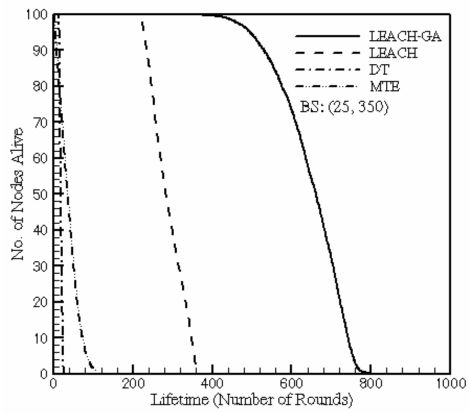


Figure 9. Performance comparisons of network lifetime for the BS located at points of (a) (25, 250) and (b) (25, 350).

VI. CONCLUSIONS

This work proposed a GA-based adaptive clustering protocol to determine the optimal thresholding probability for cluster formation in WSNs. The LEACH protocol requires the user to specify this probability for use with the threshold function in determining whether a node becomes a CH or not. However, the network performance is extremely sensitive to this probability, and it is very hard to obtain an optimum setting from available prior knowledge. Hence, our approach uses a preparation phase prior to the set-up phase of the first round to gather information about node status, IDs, and location and sends it to the BS, which determines the optimal probability to use in the CH selection mechanism. Our simulation results show that the optimum distribution of probability matched the analytical results proposed by our corrected formulas well. Moreover, our proposed LEACH-GA method outperforms MTE, DT, and LEACH in terms of network lifetime, since the use of the optimal probability yields optimal energy-efficient clustering.

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