A Novel Static Clustering Scheme for Energy-efficient Routing in Wireless Sensor Network

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Abstract

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular distributed cluster-based routing protocols in wireless sensor networks. Clustering algorithm of the LEACH is simple but offers no guarantee about even distribution of cluster heads over the network. LEACH doesn't ensure even node-distribution among the clusters formed as per its provision. In this paper, we propose a New Clustering Scheme; the scheme must be designed to be extremely energy-efficient. Here the proposed scheme, a novel scheme, is supposed to achieve objective of being energy-efficient. In this paper, the modifications proposed in the existing scheme of LEACH which are assumed to improve the energy efficiency of the WSN.Furthermore, the scheme would be compared with LEACH to judge its relative performance over LEACH.

Keywords—Clustering methods, energy efficiency, LEACH protocol, wireless sensor networks.

1. Introduction

A Wireless sensor network is a collection of sensor nodes interconnected by wireless communication channels. Each sensor node is a small device that can collect data from its surrounding area, carry out simple Computations, and communicate with other sensors or with the base station (BS).Such networks have been realized due to recent advances in micro electromechanical systems and are expected to be widely used for applications such as environment monitoring, home security, and earthquake warning. Despite the infinite scopes of wireless sensor Networks, they are limited by the node battery lifetime. Once they are deployed, the network can keep operating while the battery power is adequate. This is critical point to be considered as it is almost impossible to replace the node battery once deployed over an inaccessible area. Such constraints combined with a typical deployment of large number of sensor nodes, have posed many challenges to the design and management of sensor networks and necessitate energy-awareness at all layers of networking protocol stack [1],[2].In this paper we assume a sensor network model with the following properties:

- All sensor nodes are immobile and homogeneous with a limited stored energy.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- None of the nodes know their location in the network.
- Each node senses the environment at a fixed rate and always has data to send to the base station.
- Base station is fixed and not located between sensor nodes.

In this paper, we propose A New Energy-Efficient Clustering Scheme, Which is a hierarchical static clustering Scheme, which eliminates the overhead of dynamic clustering and engages high power sensor nodes for power consuming tasks and as a result prolongs the network lifetime. In this Scheme The complete sensing-field is divided into four clusters, each having some member-nodes and two specifically designated responsible nodes-Temporary Cluster Head (TCH) and Cluster Head (CH) i.e. a total of four cluster-heads and four temporary-cluster-heads is elected provisionally.

New Energy-Efficient Clustering Scheme is a modified version of the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol [5].
In LEACH, cluster-heads are elected in randomized manner; and at the beginning of every round, clusters are formed also in randomized manner. Moreover, LEACH doesn't ensure even node distribution among the clusters formed as per its provision. The proposed scheme deals with these issues as follows:
Despite randomized cluster-formation, well-structured clusters with even node-distribution are supposed to increase network-longevity.

- Static clustering reduces the overhead while cluster-formation as compared to dynamic clustering.

The setup phase of the LEACH is broken into two sub-phases to be referred as setup phase and responsible node selection phase respectively. Here are the modifications proposed in the existing scheme of LEACH which are assumed to improve the energy efficiency of the WSN:

- Well-structured clusters would be formed with even node-distributed nodes among themselves ensuring even load-distribution among the nodes.

- Once the clusters are formed, they would remain static throughout the network lifetime to reduce the overhead of repeated cluster-formation at the beginning of every round.

- Cluster-head-election would be based on two parameters- residual energy and relative position on nodes within the respective cluster.

2. Proposed Scheme

The proposed scheme is a self-organizing, static clustering method that forms clusters only once during the network action. The complete sensing-field is divided into four clusters, each having some member-nodes and two specifically designated responsible nodes- Temporary Cluster Head (TCH) and Cluster Head (CH) i.e. a total of four cluster-heads and four temporary-cluster-heads is elected provisionally. The operation of the scheme is broken up into rounds, where each round consists of set-up phase, responsible node selection phase and steady-state phase.

(a) Setup Phase

In this phase, after node-deployment, a randomly elected node declares as well as broadcasts its status as $\mathrm{Initiator-cum-TCH_1}$.This $\mathrm{Initiator/TCH_1}$takes the job of getting other responsible elected. Based on received-signal strength, nodes which are approximately at a distance of twice of sensing range i.e. $2*\mathrm{Rs}$ from $\mathrm{Initiator}$, acknowledge $\mathrm{Initiator}$ to be considered as candidates for $\mathrm{TCH_2}$. Now, $\mathrm{Initiator}$ confirms the node as $\mathrm{TCH_2}$ which it finds at the most approximate distance of $2*\mathrm{Rs}$ from itself. In turn, both, $\mathrm{TCH_1}$& $\mathrm{TCH_2}$ advertise their status and search for $\mathrm{TCH_i}, i=3,4$, following the same previous process; care is taken to ensure that the nodes elected as $\mathrm{TCH_i}$ must be distant by approximately $2*\mathrm{Rs}$ from one another. Once $\mathrm{TCH_i}, 1\leq i\leq 4$ are elected, they advertise their respective status asking for the tentative member of $\mathrm{Cluster_i}, 1\leq i\leq 4$.

Each node determines its cluster by choosing the temporary-cluster- head that requires the minimum communication energy, based on the received signal strength of the advertisement from each temporary-cluster-head. After each node has decided to which cluster it belongs, it must inform the temporary-cluster-head node that it will be a member of the cluster. Each node transmits a join-request message (Join-REQ) back to the chosen temporary-cluster-head using a no persistent CSMA MAC protocol. Once the clusters are formed, they remain fixed throughout the network-lifetime. Afterwards, mean position of the node-distribution in every cluster is computed by the respective TCH and distance of each node in every cluster from this mean position along with the TDMA schedule for the cluster is transmitted back to the node by the concerned temporary-cluster-head.

(b) Responsible Node Selection Phase

At the beginning of each round, all the nodes in the cluster send their residual energy level and their distances from the mean position of the concerned cluster to temporary-CH in their respective time-slot. Afterward, temporary-CH choose the sensor node with utmost value of $\mathrm{E_n/d_n}$, as CH for the current round; and the node with lowest energy level is selected as temporary-CH for the next round and sends a round-start packet including the new responsible sensor ID for the current round. This packet also indicates the beginning of round to other nodes. Care is also taken that no node can regain the

Cluster-Head status till a definite number of rounds are passed.

$E_n =$ Residual Energy of the concerned node

d_n =Distance of the concerned node from the corresponding cluster's mean-position of node distribution

(c) Steady-State Phase

The steady-state phase is broken into frames where nodes send their data to CH during pre-allocated time slots. These data contain node ID and sensed parameters. In this scheme the Direct Transmission approach is made for the communication between CH and base station.

The duration of each slot in which a node transmit data is constant, so the time to send a frame of data depends on the number of nodes in the cluster. To reduce energy dissipation, the radio of each non-cluster head node is turned off until its allocated transmission time, but the CHs must be awake to receive all the data from nodes to the cluster.

/* Algorithm of our Scheme */

1. BEGIN
   /* setup-phase */
2. Selects a node in random fashion as $initiator\ (or\ TCH_1)$ and informs that node of its selection /* By Base Station */
3. $i = 1$ /* To start with */
4. $while\ (i < 4)$
5. Broadcast respective status of $temporary - cluster - head\ (TCH)$ $/*\ By\ every\ TCH_i\ */$
6. $for\ j = 1{:}n$ /* $n \rightarrow total\ no.of\ nodes$ */
7. $if\ Node_j \notin \{TCH\}\ \&\ distance(i,j) \cong 2 * R_s$
8. $Acknowledge\ TCH_i$ about its *candidature*
9. *end*
10. *end*
11. Confirm most suitable candidate node say *k* (such that $d(i,k) \approx 2 * R_s, \forall\ TCH_i$)
    $i.e. TCH = [TCH, Node(k)]$
    $/*\ by\ initiator\ (or\ TCH_1)\ */$
12. $i = i + 1$
13. *end*
14. Advertise the respective status of $temporary - cluster - head\ (TCH)$
    $/*\ by\ every\ TCH_i\ */$
15. $for\ j = 1{:}n$
16. $if\ Node(j) \notin \{TCH\}$
17. Join appropriate TCH_i based on *received-signal-strength* of every TCH_i
18. *end*
19. *end*
20. $for\ r = 1{:}round$
    **** responsible node selection-phase */***
21. $for\ j = 1{:}n$
22. $if\ Node_j \notin \{TCH\}$
23. send *2-tuple* information, $< location_j, residual - energy_j >$ to the concerned TCH
    $/*\ by\ every\ Node_j\ */$
24. *end*
25. *end*
26. $for\ i = 1{:}4$ */* for every cluster */*
27. $for\ j = 1{:}m_i$
    / $m_i \rightarrow$ no. of member nodes */*
28. $compute\ Eresidual_j^i / d_j^i$
    where $d_j^i = distance\ (Node_j^i, Mean\_Position_i)$
    and $Mean\_Position_i = (\sum x_j^i / m_i, \sum y_j^i / m_i)$
29. *end*
30. *declare node with value,* $max\ (Eresidual_j^i / d_j^i)$ *as* $cluster - head_i (CH_i)$ *for current round r /* by* TCH_i **/*
31. *declare node with* $\min\ (Eresidual_j^i)$ *as* TCH_i *for next round,* $r = r + 1$ */* by* TCH_i **/*
32. *advertise status of* CH_i *along with the TDMA-schedule for* $Cluster_i$ */* by* CH_i **/*
33. *end*
    /* Steady-State Phase */
34. *For i←1 to k*
35. *For Alive_node ← 1 to* m_i
36. *Send data to* CH_i */*Data transmission by Alive_node(s) */*

37. End For

38. Send aggregated data to the base station

/ Data transmission by CH_i */*

39. End For

40. End For / End of rounds */*

41. END / End of Algorithm*/*

3. Simulation Results

To validate the performance of Our Scheme, we simulate Our Scheme and utilize a network with 100 nodes randomly deployed between (x=0, y=0) and (x=100, y=100) and base station at (50,175). The bandwidth of channel is set to 1 Mb/s, each data message is 500 bytes long, and the packet header for each type of packet is 25 bytes long. The initial power of all nodes is considered to be 2J and duration of each round is 20s[5].

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics as shown in Figure 1. For the experiments described here, both the free space (d^2 power loss) and the multipath fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and receiver. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used [6],[7].

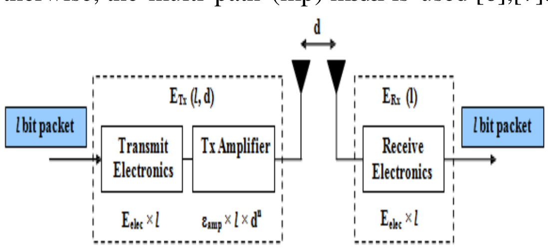

Figure1. Radio energy dissipation model

Where

- $\mathbf{E_{elec}}$ is the amount of energy spent to run the circuit(of receiver or sender) for 1-bit data
- $\mathbf{E_{fs}}$ and $\mathbf{E_{mp}}$ are the transmitter constants and depend upon the type of transmitter use

To transmit an *l*-bit message a distance *d*, the radio expends:

$$E_{Tx}(l, d) = E_{Tx\text{-}elec}(l) + E_{Tx\text{--}amp}(l, d)$$

If $d<d_0$

$$lE_{elec} + lE_{fs}d^2$$

If $d>d_0$

$$lE_{elec} + lE_{mp}d^4$$

To receive this message, the radio expends:

$$E_{Rx}(l) = E_{Rx}\text{-elec}(l)$$

To evaluate the performance of New Clustering Scheme, MATLAB 2009 is used as a simulation tool. We consider that the sensor nodes are deployed randomly across a plain area. Each node is equipped with equal amount of energy at the beginning of the simulation. Further, we assume that WSN is working in continuous data flow application domain. Table 1 represents various parameters and their values used in simulation [5].

TABLE 1: PARAMETERS USED IN SIMULATION

Parameter	Parameter's Value
Network Area	100m*100m
Base Station's Position	x=50m, and y=175m
Initial Energy for Nodes	2 Joule
Number of Deployed Nodes	100
Size of Data Message	4000 bits
Energy Consumed in Data Aggregation ($\mathbf{E_{DA}}$)	5nj/bit/signal
Energy Consumed by Transceiver's Circuitry ($\mathbf{E_{elec}}$)	50nj/bit
Energy Expenditure in Transmit-Amplification in Free-space model ($\mathbf{E_{fs}}$)	10pJ/bit/m^2
Energy Expenditure in Transmit-Amplification in Multipath fading model ($\mathbf{E_{mp}}$)	0.0013pJ/bit/m^4

The performance of the scheme is evaluated considering network lifetime as a parameter which is defined as the time until the last node dies in the network. Network lifetime is measured using two different yard-sticks:

- Number of nodes alive in the network—more number of nodes alive implies network lifetime lasts longer.
- Number of messages received at BS—more number of messages received at BS implies more

number of nodes is alive in the network leading to longer network lifetime.

A set of experiments is conducted to show the performance of present New Clustering Scheme:

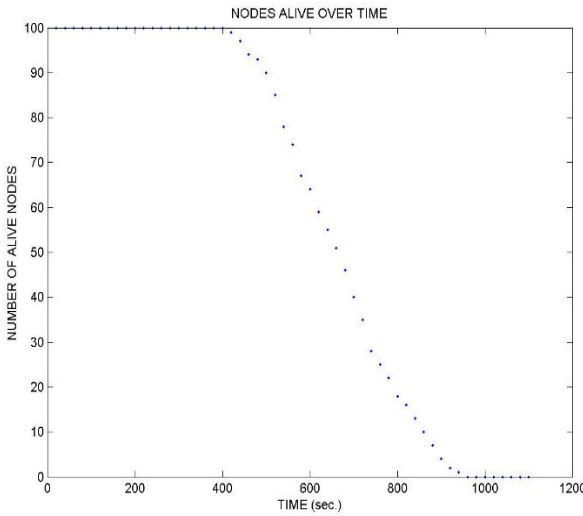

Figure 2. Number of nodes alive over time

According to the plot in Figure 2, it is observed that there are number of nodes alive over time, there are more nodes alive in our scheme as compare to LEACH simulation Result that is in [5].there is no nodes dead about in 430 Second, so we can say that there is more nodes transmit data to base station as compare to LEACH [5].

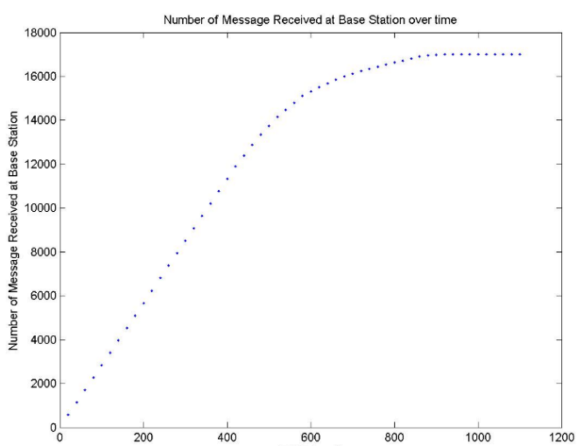

Figure 3 Number of data messages received at base station over time

Figure 3 shows the total number of data signals received at the BS over time and the total data received at the BS for a given amount of energy. In figure 3 shows that Our Scheme sends much more data to the BS in the simulation time as compare to other clustering scheme. In Our Scheme, each message is transmitted over a single hop to the cluster head, where data aggregation occurs. The aggregate signals are sent To the BS, greatly reducing the amount of data transmitted.

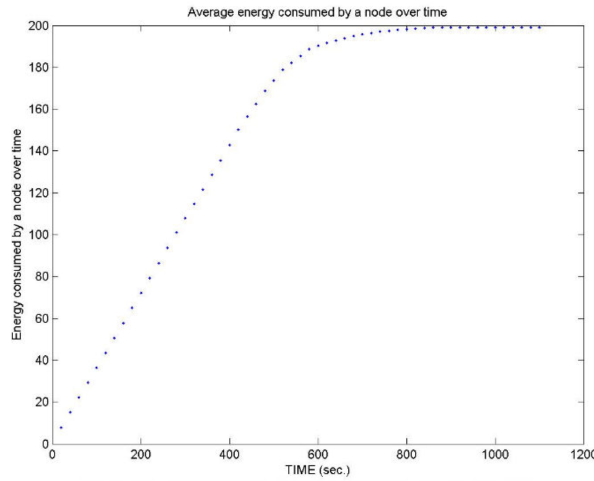

Figure 4 Number of data messages received at base station over energy

Figure 4 shows the total data received at the BS for a given amount of energy. This graph shows that Our Scheme which deliver the most data per unit energy, achieving both energy and latency efficiency. A routing protocol such as LEACH does not enable local computation to reduce the amount of data that needs to be transmitted to the BS.According to the plot in Figure 2 and Figure 3; it is observed that Our Scheme is efficient that delivers more data per unit energy as compare to LEACH that is simulated in [5].

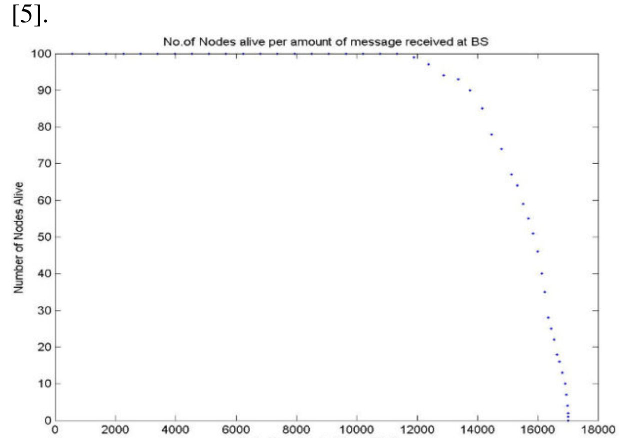

Figure 5 Number of nodes alive per amount of message received at BS

According to the plot in Figure 5, it is observed that there are number of nodes alive per amount of message received at base station. Similar to plotting in figure 2, there is more number of nodes alive for sending message to the base station as compare to LEACH [5] and EEPSC [10].so in other words we can say that our scheme provide better performance as compare to other clustering scheme. Our scheme is more energy efficient as compare to LEACH [5] and EEPSC [10].Our Scheme achieve a longer lifetime than Dynamic clustering.

4. Conclusion and Future Work

The proposed scheme is a self-organizing, static clustering method that forms clusters only once during the network action. The complete sensing-field is divided into four clusters, each having some member-nodes and two specifically designated responsible nodes- Temporary Cluster Head (TCH) and Cluster Head (CH).Total of four cluster-heads and four temporary-cluster-heads is elected provisionally. The operation of the scheme is broken up into rounds, where each round consists of set-up phase, responsible node selection phase and steady-state phase. This Scheme increase the network life time more as compare to other cluster technique. Simulation results show that our scheme offers a better performance than the LEACH protocol in terms of network lifetime. The energy efficiency and ease of deployment make New Clustering Scheme a desirable and robust protocol for wireless sensor networks. For future work, a model with heterogeneous sensor nodes may be investigated.

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