# Super Cluster based Modified LEACH Protocol for Wireless Sensor Networks

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## Abstract

Achieving both energy efficiency and quality of data at the same time is a challenging task in wireless sensor networks (WSN). This is very crucial to ensure that the system operates at minimum energy in a WSN. Main objective of this research is to minimize the energy consumption and thereby enhance the network life-time. Energy consumption is very much dependent upon the efficiency of routing protocols. In this paper, a Super Cluster based modified LEACH (Low Energy Adaptive Clustering Hierarchy) protocol has been proposed where an elected Super Cluster head (SCH) takes the charge of routing the gathered data to the base station. The super cluster head is elected among the existing clusters depending upon some weight factors. Weight factors are evaluated based on distance and remaining energy considerations. Simulation results show that the proposed Super Cluster-Head based Modified LEACH protocol effectively produces optimal energy consumption for the wireless sensor networks and thereby results in an extension of life time for the network. In the proposed model, the preparation phase is performed only once before the set-up phase of the first round and the processes of following set-up and steady-state phases in every round are the same as LEACH. The proposed model is compared with an existing LEACH based model and it is found to produce much better result than the existing in terms of energy consumption.

## Keywords

Energy efficiency, network life-time, super cluster, WSN, SCH, weight factor, modified LEACH

## 1. INTRODUCTION

During the operation of a wireless sensor network energy dissipation by the system is of major concern. The energy of each sensor node is constrained by the battery-life. In conventional routing algorithms such as direct transmission or MTE (minimum transmission energy) lead to non-uniform dissipation of energy across the sensor nodes leading to uneven die-out time of nodes and lower system lifetime. In contrast, LEACH (Low Energy Adaptive Clustering Hierarchy) provides a balancing of energy usage by random rotation of cluster-heads, consequently enhancing energy-dissipation and system lifetime. The compression of data can be used to reduce the amount of transmission data. In super-cluster head based protocol each of the elected cluster-head select a super-cluster head among themselves and transmit their compressed data to it, which further compresses the data and transmits to the base station.

## 2. LEACH PROTOCOL

In order to evenly distribute the energy dissipation across the wireless sensor network [3, 8] of sensor nodes, LEACH [2, 4] uses random rotation of cluster-heads. Based on a desired number (percentage) of cluster-heads equal number of clusters are formed, and each non-cluster head node decides which cluster-head's cluster to join based on which would lead to minimum dissipation in energy [7] when it transmits its data to that cluster-head. After joining of appropriate cluster each non-cluster head node sends its data to its cluster-head node which compresses all the received data by some compression algorithm and then sends the resulting data-packet to the base station. The use of spreading codes such as CDMA (Code Division Multiple Access) prevents inter-cluster data transfer. Each cluster-head selects its unique code. The entire protocol is divided into rounds and each round being divided into two phases [1] - the set-up phase and the steady-phase (Transmission phase).

### *A. Setup Phase*

In the setup phase, each node decides whether or not to become a cluster head for current round. The selection depends on decision made by the node by choosing a random number between *0* and *1*. If the number is less than the threshold $T(n)$, the node becomes a cluster head for the current round. The threshold is set as:

$$T(n) = \frac{p}{F(n)};$$

$$F(n) = \begin{cases} 1 - p \times (r \times \mathrm{mod}(1/p)), & if\ n \in G \\ 0, & else \end{cases}$$

Where $p$ is the probability of the node being selected as a cluster-head node, $r$ is the current round, and $G$ is the set of nodes that have not been cluster-heads in the last $1/p$ rounds, *mod* denotes modulo operator. Nodes that are cluster-heads in round 0 shall not be selected in the next $1/p$ rounds. Then each elected CH broadcasts an advertisement message to the rest of the nodes in the network to invite them to join their clusters. Based upon the strength of the advertisement signal, the non-cluster head nodes decide to join the clusters. In the set-up phase, the cluster head nodes are randomly selected from all the sensor nodes and several clusters are constructed dynamically.

### *B. Steady Phase*

The non-cluster head nodes send their data to their respective cluster-head nodes. The cluster-head nodes after receiving all the data compress the data-packets into a single bigger packet using some compression algorithm. A control packet is concatenated with this packet and transmitted to the base-station. The total time of a round is the sum of the time involved in setup-phase and the time involved in the entire transmission process. The energy dissipated is broken down into phases. The summation of energy spent in all the processes in these two phases give the amount of energy dissipated in that round.

# 3. PROPOSED MODEL (SUPER CLUSTER BASED MODIFIED LEACH)

The energy dissipated during transmission and reception is given as mentioned in [1]:

$E_{Tx}(k, d) = E_{elec}*k + \mathcal{E}_{amp}*k*d^2$

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

Here '*k*' is the message length and'*d*' is the transmission distance. Thus energy dissipation varies linearly with message length and as a square for transmission distance.

The modification suggested in the existing LEACH protocol is to include a 'Super Cluster Head' or SCH. As the name suggests the SCH will be a node from chosen cluster heads which will be at an optimum distance and energy consideration from the base station.

Thus by super-clustering we may be increasing the length of the final transmitted message but by using only one node for transmitting to the base station a lot of energy is saved, since distance factor is reduced.

In the LEACH protocol [5] the transmission depends on the energy remaining of the node and square of the distance between the cluster-head node and the base station. The suggested modification takes into consideration both the factors but on a weighted basis.

$T_c = W_1 * D + W_2 * E_f$

Here $T_c$ is transmission criterion. $W_1$ and $W_2$ are the weight factors. *D* is the proximity factor given by the sum of the distances of other cluster-head nodes from the cluster-head node whose $T_c$ is to be evaluated. $E_f$ is the energy factor and is defined by the difference of the energy required to transmit to the base-station from this cluster-head node and the current energy level of the node. A cluster-head node able to transmit will have a non-positive value. A cluster-head node being unable to transmit will always have a positive value. The weight factors will be calculated as per the requirements of the transmission. The ratio of the weight factors will indicate the transmission grading.

## C. Election of Super Cluster Head

Once the Cluster Heads (CH's) [6] are selected according to the LEACH protocol, then each CH calculates its transmission criterion ($T_c$).

$T_c = W_1 * D + W_2 * E_f$

Where,

*D* = Sum of the distances of all the CH nodes with each other (Proximity factor).

$E_f$ = Energy required in a transmission to base station from this CH – Current energy of this CH node (Energy factor).

$W_1$, $W_2$ = Weight factors that determine the transmission grading.

Now, each CH multicasts it's $T_c$ to all the CH's. The CH with minimum $T_c$ gets elected as *SCH* for the current round. The remaining CH's send their data to the *SCH* following a TDMA protocol. *SCH* runs a compression algorithm in order to compress the size of data to be sent over network.

During the selection of *SCH* the weight factors plays a critical role. Depending on the quality of transmission required and various other factors like size of network and distance of *SCH* to the base station we select the values of $W_1$ and $W_2$ accordingly.

## D. Significance of weights W1 and W2

As mentioned earlier the weight factors $W_1$ and $W_2$ play a pivotal role in the selection of *SCH*. $W_1$ is used to give preference to energy dissipation in the process of transmission. $W_2$ is to give more preference to the network throughput. Non-positive values of $E_f$ imply that the corresponding node is capable of transmitting to base station directly.

In any transmission, let us consider

$W_1 = W_2 = 1$

For any two cluster-head nodes $CH_1$ and $CH_2$ let ($D$, $E_f$) pairs be (1, -2) and (2, -4) respectively

Let, $T_c = W_1*D + W_2*E_f$

$CH_1$: $1*1 + 1*(-2) = -1$

$CH_2$: $1*2 + 1*(-4) = -2$ (Elected)

In the above case $CH_2$ gets elected as the super cluster head due to its lower $T_c$ value. Note that sign is taken into consideration.

Now, let us consider

$W_1 = 10$, $W_2 = 1$

$CH_1$: $10*1 + 1*(-2) = 8$ (Elected)

$CH_2$: $10*2 + 1*(-4) = 16$

Now, $CH_1$ gets elected due to the $W_1$ consideration. Since the sum of inter *CH* distances is greater in $CH_2$ than in $CH_1$ therefore to minimize the energy dissipated in the network we elect $CH_1$ as the *SCH*.

Again let,

$W_1=1$ and $W_2=10$

$CH_1$: $1*1 + 10*(-2) = -18$

$CH_2$: $1*2 + 10*(-4) = -38$ (Elected)

Now, $CH_2$ gets elected as the *SCH* due to $W_2$ consideration. Since the energy required in the transmission is less in $CH_2$ than in $CH_1$.

## E. Effect of D on energy dissipation of the network

*D* is the sum of distances of the *CH*'s from *SCH*. When a *SCH* is selected all the rest *CH*'s transmit their data to the *SCH* to be forwarded to the base station. If *D* is large then the energy dissipated in the *CH* to *SCH* transmission is quite high resulting in a low energy saving whereas if *D* is small, the energy dissipation is less and the nodes can save more energy. Depending on the value of *D*, the weight factor is chosen appropriately and the energy dissipated in the network is minimized.

## F. Effect of Ef on throughput of the network

$E_f$ is the energy difference between the current energy of the node and the energy required in transmission to the base station. Throughput of the network is defined as the total amount of data transmitted from the network in a unit time. If we select any node to be the *CH* without considering its $E_f$ value and if the node is also selected as the *SCH* then there might be case that its $E_f > 0$, in that case if the energy of the *SCH* is not sufficient to transmit to the base station, and the current round goes wasted. As a result the throughput of the network decreases.

So it is necessary to check the $E_f$ value of the node before every round. This will minimize any chances of a round being wasted. Therefore the throughput of the network is optimized.

# 4. PERFORMANCE EVALUATION AND COMPARISON

A program for simulation of the proposed Super-Cluster based LEACH protocol was built using C/C++ language. The energy-dissipation and throughput of the proposed model were compared with the existing one [1].

## *G. Simulation assumptions and parameters*

There were certain assumptions made while running the simulation program. They are listed as:

The area under consideration is considered to be *60 x 60 m²* square fields with *100* sensors placed inside randomly.

A rectangular coordinate system is chosen, with coordinates of vertices of square field being *(0, 0), (0, 60), (60, 60) & (60, 0)*. The coordinates of base station being *(50,175)*.

An upper bound of '*n*' is placed on the number of received messages by each cluster-head from non-cluster head nodes, where *n* is the number of desirable cluster-heads to be formed.

The relay nature of transmission of messages among non-cluster head nodes is not taken into consideration in order to decrease the complexity of the simulator program.

After the advertisement phase, the non-cluster head nodes choose their cluster on the basis of distance rather than signal energy level. The non-cluster head node chooses the cluster-head which is closest to it.

The electronics energy, $E_{elec}$ of both transmitter and receiver circuits is assumed to be equal.

TABLE I. PARAMETERS USED IN SIMULATION

| Sl no. | Parameters/Constants | Value |
|---|---|---|
| 1 | Monitored Area Dimension | 60 X 60 m² |
| 2 | Number of nodes | 100 |
| 3 | Electronics Energy ($E_{elec}$) | 100 nJ/bit |
| 4 | Amplifier Energy ($\varepsilon_{amp}$) | 100pJ/bit/m² |
| 5 | Initial energy of each node | 3J |
| 6 | Control packet size | 50 bytes |
| 7 | Data packet size | 100 bytes |
| 8 | Channel Type | Wireless |
| 9 | Energy model | Battery |
| 10 | Simulation time | 200 secs |

# 5. RESULTS OBTAINED

The result of the simulation was obtained in form of a plot:

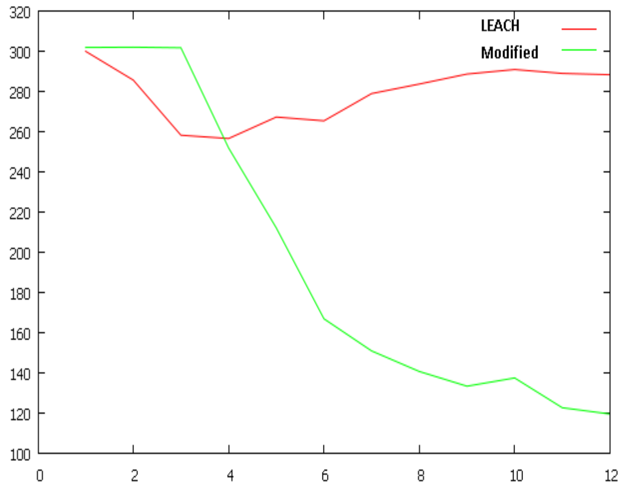


Fig. 1. Net-Energy dissipation ($W_1=W_2=1$), energy dissipated (in joules) v/s % of cluster-heads

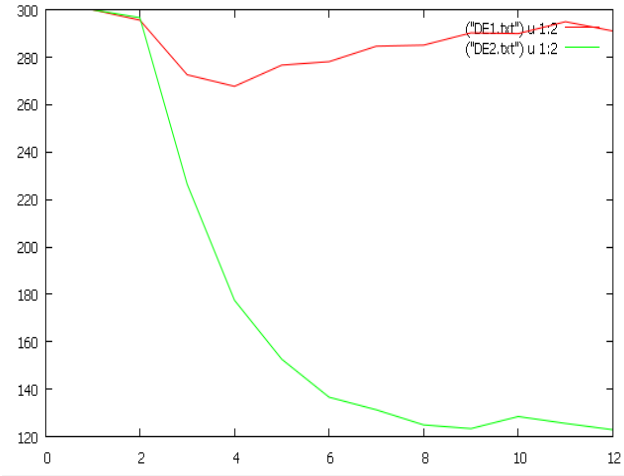


Fig. 2. Net Energy-dissipation ($W_1=100$, $W_2=1$) v/s % of cluster-heads

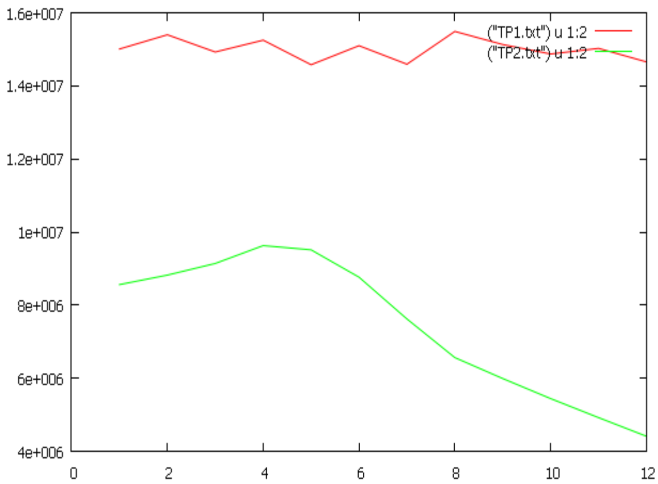


Fig. 3. Throughput ($W_1=W_2=1$), number of bytes transferred v/s % of cluster-heads

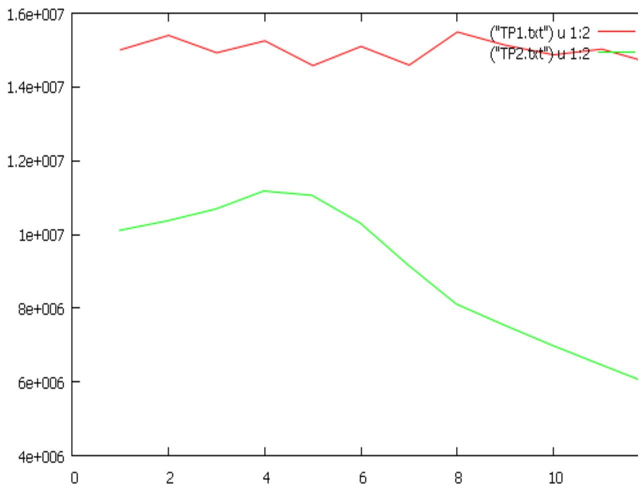


Fig. 4. Throughput (W1=1, W2=100) v/s % of cluster-heads

Fig. 1 shows net energy dissipation when $W_1$=$W_2$=1. Energy dissipation is computed against the number of cluster heads. Proposed model shows much energy saving than the existing [1] when number of cluster heads is greater than 4. Fig. 2 shows the above mentioned comparison in terms for $W_1$=100, $W_2$=1. In this case also, proposed model overpowers the existing one [1]. Fig. 3 depicts the throughput measurement against the number of cluster heads when $W_1$=$W_2$=1 and Fig. 4 shows the same computation when $W_1$=1, $W_2$=100. Obtained results show good performance in terms of network life time but throughput scenario needs to be optimized which is a part of the future work.

## 6. CONCLUSION AND FUTURE WORK

In the proposed Super Cluster based Modified LEACH model, we have introduced weight factors which show much better result in terms of net energy dissipation and network throughput in the WSN. Our future work will be optimizing the energy dissipation and network throughput by making weight factor evaluation much more distinct and definite.

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