Optimal Overhead Energy Efficient Algorithm of Leach Protocol in Wireless Sensor Networks

Muhammad Khurram, Sellappan Palaniappan, Syed Imran Ali

Abstract : Future world will consist of smart devices that would basically dependent upon the sensory data from real world environments. In this way, inevitability of large scale remote sensors and IoT is unyielding in future. Wireless sensor nodes have limited resources, which comprised of spatially dispersed remote sensing nodes, which have some constrained issues among them the consumption of the power is the most significant one. WSN consumes hundreds to thousand times more energy in transmission of data as compared to the execution of instructions. The applications of the WSN are in wide spread fields, e.g. Military battle field, detection of forest fire, medical, and smart home/ city automations. So a big challenge for researchers for a large scale WSNs during the collection of data is the minimal amount of energy utilization. Lot of techniques used to diminish the utilization of energy in data gathering. Among all, small size data packets is one of the important aspect to conserve the energy, because sensor node dissipates less amount of power for information processing as compared to communication among the nodes. Reduce energy consumption and decreases the system delay is the prime target of cluster based sensor networks. For micro-sensor networks LEACH is a cluster based protocol which accomplishes low power, expandable routing and reasonable access of media for sensing nodes. Data collection with usage of a dynamic clustering method is possiblein different round. In every round, new set of clusters with different nodes comes into existence. The basic concept of LEACH is optimal set of CH according to the total nodes present in the network and the uniform dissemination of energy utilization among network nodes. This rest of the paper is organized as follows: Section I contains Introduction, Section II discussion about distributed clustering algorithms, Section III energy consumption in data collection rounds, Section IV proposed overhead energy calculation, Section V discussion about simulation model, Section VI performance analysis and results, Section VII Conclusion is based on the observation ofboth analysis and simulation.

Index Terms:WSN, TDMA, CSMA, LEACH

I. INTRODUCTION

Wireless Sensor Network (WSN) is a type of adhoc network. It contains thousandof sensing devices called sensors. These sensing nodes are ready for detecting distinctive activities either environmental or physical activities. In addition to sensing, these sensors collect, compute and communicate the sensed data withnearby sensors [1][3]. The communication among the nodes are not onlylimited to transmissions and receptions of the data but also able to route and forward the data to Base station. Base station is a central node. Base Station is also called Sink. The Base station either connected or not connected to some other Internet or Intranet. WSN is different from other adhoc networks because WSN have limited resources [2]. The prime resources exists in WSN are either battery (power supply) or memory (storage). There is a wide range of applications of WSN. E.g. Health care, military operations, industrial engineering, research and development (R&D), video surveillance, smart city, disaster prevention, and agricultureare various areas where WSN has significant benefits. In this paper, we survey conventional protocols directly related to overall energy dispersal in WSN networks[4]. Apart of that, based on our findings the conventional protocols required lesser transmission energy. Static clustering is not optimal for sensor networks [6]. So in this respect, we propose LEACH protocol which could be based on clustering protocol. In the WSN, LEACH utilizes random rotation of local cluster sink called cluster heads to equally distribute the energy requirement among the sensors in the network. LEACH utilizes local coordination to enable scalability and robustness for dynamic networks. LEACH also reduce the amount of information and incorporates data fusion in to the routing protocol that must be transmitted to the base station. Location of the CHs are not considered in the CH selection criteria for this there are several protocols are made like [3], [6], [5], [9], [11], [12] and [14]. Accordingly, in these protocols the selected CHs are not consistently dispersed in the area. After CH selections in LEACH protocol, minimal distance of nodes to their CHs play a vital role in formation of cluster. In a long distance transmission of data along the routing path the energy of a sensing node consumes; Routing protocol formed an efficient route that will have a significant effect on the energy consumption [2]. So the main goal for the WSN is to design a low power protocol which consumes an optimal energy during the transmissions [4].

II. DISTRIBUTED CLUSTERING ALGORITHMS

Distributed clustering algorithms is the most widely known algorithms because the data is stored and disseminate from different locations. LEACH is the basic foundation of the proposed cluster based protocol. In LEACH the data transmission rounds are comprises into two stages: i) Setting up the cluster phase ii) Data transmission and aggregation phase. Each sensor nodes usually synchronized by clocks so that these nodes know the starting of a new clock cycle in each

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round i.e called the starting of a new round. Without negotiating with other nodes the selection of CHs is done independently by the sensor nodes themselves.

T(n) = k / 1-k x (rmode(i/k)) for n ϵ G Eq. 1
0 otherwise

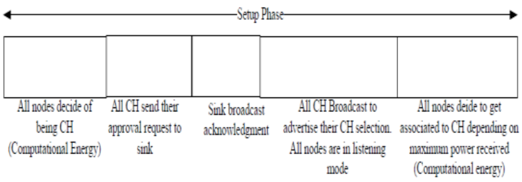
All sensor nodes want to become CH this happens at the beginning of each round(r) and the set of senors that have not become a CH in the past 1/k rounds this all depends on the required percentage of CHs in the network.Each node generate a random number at the start of each round which is compare with a threshold vlaue R(n). On sensor node n if the random number generated is less than R(n), then n becomes CH for the current round. each node is calculates its own threshold value R(n), which is mention in equation number 1.C is the set of previous CHs they were selected in last 1/k. CSMA protocol is used to broadcast the status of the all selected CHs. During this process all non-cluster head nodes receivers must keep ON to hear this announcement [8]. The remaining nodes select their CHs after hearing the CH announcement.

TDMA schedule is given by every CH to its cluster members after clusters are formed. Cluster node is permitted to send its data to its CH because of the TDMA schedule mechanism. Significant power savings are happen due to the TDMA schedule mechanism, the sensor nodes turn ON only when they have permission to transmit [10]. Selection and rotation of CHs in LEACH protocol give an equal opportunity to all nodes to become a CH.

III. ENERGY CONSUMPTION IN DATA COLLECTION ROUNDS

LEACH is an acronym for low energy adaptive clustering hierarchy. LEACH divides communication process in different rounds, every round includes: i) initiate the setup Phase, ii) A stable and steady state phase and iii) sink phase for data transmission. These phases are shown in Fig. 1. Now the commencement of a new cycle or the start of a new round we are supposed to have that the sensor nodes are to be synchronized with clock. So the LEACH is our basic protocol which estimates the amount of energy utilizes in cluster setups in dynamic cluster based WSNs.

Fig.1: Setup Phase of LEACH



A. *Setup Phase*

1. During the setup phase the computational energy is consumed. In dynamic cluster based protocols the selection criteria may differ in different protocols.
(a) What is the node energy level at the time of selection?
(b) Previously how many times this node has been selected as a CH.
(c) Random variable is also used to randomize the selection, besides the above two criteria's.
2. CHs remain in idle listening modes.
3. All CHs receives an acknowledgement from the sink.
4. All elected CHs broadcast to advertise their CH-selections.
5. Nodes associated to CH based on their signal strength. They can estimate their nearest CH based on this signal, hence as a CH choose the nearest one.

B. Steady State Phase

1. Closest CH receives the replies before association with these nodes.
2. CHs broadcast all acknowledgements. Each associated node is to allot time slots through TDMA schedule.
3. In these assigned time slots the data transmission is happen between sensor nodes andCHs. Eachframe is made of N data slots as shown in Fig. 2.

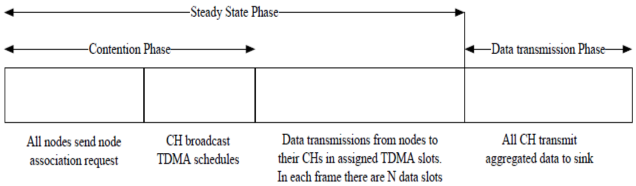


Fig. 2: Steady State Phase and Data Transmission Phase

C. Data Transmission to Sink Phase

1. In this phase a computational energy is consumed. All CH aggregate the received data.
2. Aggregated data forwarded from all CH to sink.
First two phases are considered as an overhead and the power utilization in these phases treated as overhead energy (OHE).

D. Overhead Energy Calculation

The following are the equations 3.1 to 3.4 that describe the basic energy model which is use to evaluate the power utilization in various phases of transmission of control and data messages.

$$E_{Trans} = E_{elec} \times n + E_{p\text{-}mp} \times n \times d^2 \quad (3.1)$$
$$E_{Trans} = E_{elec} \times n + E_{tp} \times n \times d^4 \quad (3.2)$$
$$E_{Recv} = E_{elec} \times n \quad (3.3)$$
$$E_{Idle} = \beta \times E_{elec} \times n \quad (3.4)$$

Where,
E_{Trans}:utilization of the energy for n bits transmission.
E_{Recv}: utilization of energy during the reception of data.
E_{idle}: utilization of energy during in idle listening phase.
E_{elec}: utilization of energy for receiving or transmitting a 1-bit data. Unit is J/b.
$E_{p\text{-}amp}$: utilization of energy for free space model in power amplifier. Unit is $J/b/m^2$.
E_{tp}: utilization of energy of power amplifier. Unit is $J/b/m^4$.
N: total bits transferred from transmitter to receiver.
B: ratio between the reception and idle listening energy mode.
D: distance between transmitter and receiver.

IV. PARAMETERS OF OVERHEAD ENERGY COMPUTATION

Overhead energy utilization was carefully calculated in each step of each round by considering the data and control packets sent. In the cluster setup phase the percentage and the level of energy is being utilize which is calculated for networks size and number of nodes. The power dissipation of nodes during the transmission considering the transmission ranges which means the distance between the transmitter and receiver and the size of data bits that can be seen in equations 3.1 to 3.4In a free space model the direct line of sight is considered and two ray ground propagation model consider ground refracted signals. Usually free space model is used if the distance is not greater than a threshold distance $d_{crossover}$. The $d_{crossover}$, here is taken as 85 meters [10]. Equation 3.1 for transmission state in two way ground propagation model and equation 3.2 energy equation is for transmission state in free-state model and equations 3.3 and 3.4 are used for the reception and idle states respectively. Transmission ranges means the distance between transmitter and receiver.

d_{max}= maximum Cluster head (CH) distance.
d_{ANtoCH} =Distance of node to its Cluster Head (CH)
$d_{CHtoSink}$=Distance of Cluster Head (CH) to the sink.

According to the requirement the packet sizes considered and the data size $N_d$is taken 300 bytes, Nc =30 bytes the control packets and N_t=(N_c + K) where K number nodes exist in each cluster and m represents the number of frames per round in each cluster. The communication between the rest of the nodes and the cluster heads are happen by using the non-persistent CSMA, during the contention period. For better throughput use a 1-persistent CSMA was chosen it gives the better performance as compared to non-persistence CSMA.

For non-persistent CSMA ***a***is the throughput which shown in the following equation:

$$\propto = N_c \times e^{(-\propto x N_c)} / N_c \times (1 + 2a) + e^{(-\propto \times N_c)}$$

Here,*a* is the ratio of transmission delay and propagation delay, taken as 0.001. For control packet size of 30 Bytes, αis 0.916. Different commercial transceivers radio parameters are available on internet [16].In this simulation,E_{elec} is 60 nJ/bit and for E_{p-amp} and $E_{tp}$is 12pJ/bit/m^2 and 0.0014pJ/bit/m^4 respectively [12]. Initial energy E_o given to eachnode is taken as 2.7 Joules. βis 0.6 which is the ratio of energies in between in reception and idle listening mode [13].

V. SIMULATION MODEL

Here we present and discuss the results obtained from the simulation which could be based upon a simulation model that uses a method for calculating the overhead energy.

We prepare an energy model for the dynamic cluster selection in wireless sensor networks (WSN) in MATLAB. Initially we consider a 50, 100 and 150 nodes with area sizes of 100m^2, 200m^2 and 300m^2 respectively.

Assumptions are made as follows:

1. Nodes are randomly deployed in a static order
2. Initially all nodes having equal energy.
3. Transmitting node depending upon the power level of the received signal. Receiving nodes can evaluate the distance between them.
4. According the distance between the nodes the radio powers of the nodes are adjusted properly.

After considering these assumptions we can calculate the overhead energy on network lifetime through with the simulation in MATLAB. The cluster head percentage value find it optimally with multiple parameters, for example number of nodes deployed in the cluster, size of a network or area, and the percentage of cluster heads. We could define the network energy and the network lifetime on the basis of when the first node was dead in the network. The variables are used in simulations which are summarized in Table 5.1. Two MAC modes namely non-persistent CSMA (for broadcasting the advertisements)and TDMA (To transfer the data packets) are considered. During the contention periodthe communication between all other nodes and the cluster-head is achieved by using non-persistent CSMA.Retransmitted packet collisions are lesser in non-persistent CSMA [16].

Variables	Description	Calculated Values
n	Total number of nodes in the cluster	100
Eo	All node having an initial energy	2.7 Joules
Eelec	The total dissipation of energy for a 1-bit transmission and reception	60 nJ/bit
Ep-amp	Energy dissipated by power amplifier	12pJ/bit/m^2
Etp	In two ray propagation model the energy consumed in power amplifier	0.0014pJ/bit/m^4
Nd	Size of Data Packet	300bytes
Nc	Size Control packet	30bytes
Nt	Packet size of TDMA schedule	(K+N) x Bytes
a	Non-persistent CSMA Throughput	0.916
dcrossover	Measuring the distance after which LoS does not work properly	90 m
m	In each cluster number of data frames per round	10

Table 5.1

VI. RESULTS AND FINDINGS

First we have to analyze the effect of different area sizes on the network and calculating energy utilization, then calculating the amount of overhead energy calculation in WSN.Network life time decreases if we increases the area of a network with initial energy Eo=2.7 Joules for the same number of nodes, Fig.3 and 4 shows the relationship among those entities.The transmit energy of each node depends on the distance between the transmitter and receiver which shown in equations 3.3 and 3.4, therefore the lifetime of the network reduced if the size of the network expands resulting it also consumes more energy. Fig.3 and 4comparing the results which shows that the nodes start expiring the raise the level of network energy also starts reducing. No energy being utilize because throughout the network the transmission of data is not being done successfully. Also for area of 50 x 50m^2 the rate of expiration of nodes are steadyand slow as compared to two other cases where network area is taken as 100 x 100m^{2}and 150x150m^2. Through simulation, we have obtained the amount of Overhead energy (OHE)utilization. Then the result of the overhead energy on network lifetime is taken under consideration. In this case the optimal value of a CH percentage is 5 to 10 percent.

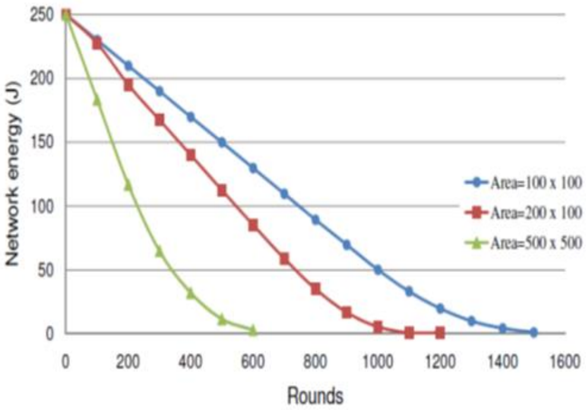


Fig. 3: Network Energy versus Rounds

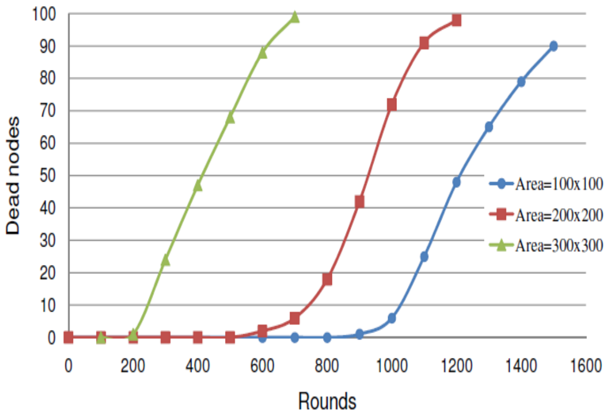


Fig.4: Dead Nodes versus Round

Here we propose a modification to the cluster head selection criteria to reduce the energy usage in micro sensor networks, this we are motivated from the original LEACH and LEACH-C and other improvement protocols [9, 10]

VII. CONCLUSION

In this paper we discussed the different stages of dynamic cluster based WSNs which consumed the approximate amount of energy. Percentage of cluster heads (CHs), network area with different measurements and the nodes available in the network that we are used for this investigation.Through with simulations we could be found the cluster setup phase utilizes 23% energy of the network due to the broadcast of control packets. The actual reasons of these broadcasts are the advertisements perform by cluster heads, node association requests made by a non- cluster head nodes and the TDMA schedule assignments by the cluster heads [15].In wireless communications, the main reason of substantial amount of energy dissipation is not only for the transmission of data bits but it's also depends upon the reception of data and in idle listening mode.We also found that a substantial amount of energy is consumed in cluster formations of these protocols then we investigate these states collectively so, the amount of power dissipated by each node it effects the network lifetime. Therefore if we design a low power algorithm for cluster setup phase to decrease the transmission of control packets which considerably increases the network life time for dynamic cluster based networks.

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