



PERFORMANCE ANALYSIS OF ENERGY EFFICIENT SCALABLE HEIRARCHIAL PROTOCOL FOR HOMOGENEOUS NETWORK

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ABSTRACT

Wireless Sensor nodes connect the physical world to the digital world using smart, tiny and self configured stand alone devices. These small devices offer pack of brilliant opportunities to the digital world by capturing and revealing real time events which later used as data cloud in numerous applications. With impressive improvements in protocols, node level programming, simulation platforms and middleware developments sensor nodes have become promising options in the development of smart cities, gas and chemical industry, precision agriculture etc. However, these industrial application demands more lifetime and faster-secure data transmissions. In many applications it is recorded that with increase in network size LEACH routing protocol functioning degenerate. Further, designing of a promising routing protocol that can maintain less energy consumption during data gathering and propagation leads to use of variety of approaches. This work is based on the abstraction of equal distribution of energy among nodes with scalability. Experimental results show commendable improvement in network lifespan with residual energy of nodes to last for longer period. Throughput is also monitored considering scalability.

Key words: Energy Efficient Protocol modelling, Life Expectancy, Scalable, Propagation, Wireless networks.

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1. INTRODUCTION

With the advent of 5G, self configured node networks have become prospective area of research. These tiny node networks offers tremendous possibilities in the development of

technical applications for real time monitoring of any event [6][7]. However, life expectancy of these networks has been a topic of research for very long time. A wireless sensor network comprises many thousands number of nodes as per the requirement of area under observation [16]. So designing an energy efficient protocol becomes essential for longevity of network. In this paper, we have modified the classic LEACH protocol [15]. The modified version utilizes the idea of even distribution of energy among nodes. While the results are promising and they also offer trade off between network longevity and data speed. However it has been observed that many applications require long life of network with moderate data rate refer table 1. In future work it can be tested for mobile networks.

The main points of frame of work are:

- Improvement in life time of network.
- Reduction in energy consumption by each node during data propagation.
- Efficient utilization of bandwidth using various data aggregation techniques.

Heinzelman et al. [16] presented a LEACH protocol which optimizes performance of network and substantial increase in lifetime. It utilizes TDMA based MAC protocol for making schedules [11]. This version of LEACH is good for homogeneous networks considering inter-cluster communication cheaper in terms of energy maintaining required BER [].

2. ENERGY EFFICIENT ADAPTIVE CLUSTERING HIERARCHY ROUTING PROTOCOL

This work is mainly synthesised for hierarchy networks. The approach is applied in classic LEACH. This protocol works in two stages: Set-up phase and Steady-State phase [1] [13]. The complete deployed network further allocated to form small set of node which is known as clusters. These so formed Clusters are electing a head using probabilistic election method during first stage of operation [11].

Set-up: In first phase of operations the nodes take part in a distributed election algorithm to elect themselves cluster head based on selection criterion. The CH election is purely a probabilistic model defined by Eq. (1) and (2) [1] [7].

$$\sum_{i=1}^N S_i(t) = k \quad (1)$$

Here $P_i(t)$ = Likelihood of selecting a random node as cluster head

N = Total number of tiny nodes in network

k = Number of Desired CH

There are many ways to pick $S_i(t)$; here for instance one is mentioned. In this approach the value are lie between 0 and 1 as shown in Eq. (2)

$$S_i(t) = \begin{cases} \frac{k}{N - k * (r \bmod N/k)}, & P_i(t) = 1 \\ 0, & P_i(t) = 0 \end{cases} \quad (2)$$

Here $P_i(t)$ is used to find out that any node i has been a head in rotation $r \bmod (\frac{N}{k})$. This method uniformly divide the responsibility among all nodes of been head in the network, therefore it is good to be used in homogeneous network. After election of cluster head remaining nodes in the network will become cluster member. With electing cluster head the idea of even distribution of energy within network is attained up to some extent, which increases network expectancy in turn. However, real energy associated with each random

node is not considered in this model. Therefore, we have applied different approach as given in Eq. (3) to determine $S_i(t)$ [1] [17],

$$S_i(t) = \min \left\{ \frac{E_i(t)}{E_{total}(t)} k, 1 \right\} \quad (3)$$

Table 1 Various versions of LEACH Protocols

LEACH (Versions)	Advantages			
	Multiple Access	Data Forwarding within cluster	Data forwarding outside cluster	Aggregation of Data
LEACH	TDMA	One-Hop	One-Hop	At CH
ML-LEACH	TDMA	One-Hop	Multi-hop	At CH
WM -LEACH	TDMA	One-Hop	Multi-Hop	At CH
MMR-LEACH	TDMA	One-Hop	Multi-hop	At CH

Here $E_i(t)$ = Actual energy of any random node 'i'

$E_{total}(t)$ = Total energy of network i.e. sum of all energy components

After a node becomes CH, it will send information about its role to all the neighbouring nodes in advertisement messages, using non-persistent CSMA, CSMA –CD [4]. Other nodes in network join the nearest cluster head sending join in request (Join_REQ) and forms cluster. Received signal strength is used to select member nodes. Cluster head selection process ensures that the responsibility of being CH is shared by all nodes on rotation basis. This also helps in maintaining uniform energy distribution in network and clusters are created dynamically.

Steady-State Phase: In this part of operations transmission schedules are created and followed by data transmission for further processing. So the complete phase contains two parts as shown in Fig (1),

- MAC schedule creation
- Information Forwarding

After clusters are formed, member nodes may join the cluster head as per their residual energy for the current round.

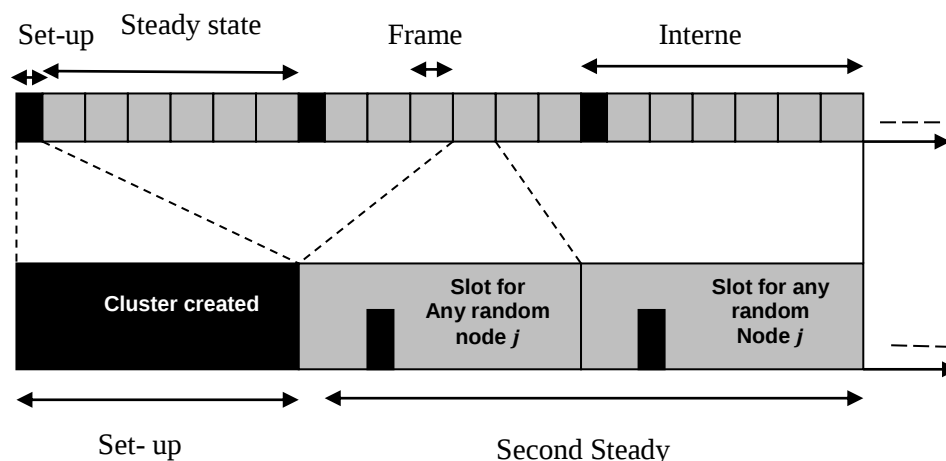


Figure 1 LEACH Protocol Setup and Steady State structure during data communication

It is achieved by using non persistent CSMA_CA multiple access technique [17]. This small message contains information about node identifier and a overheads that makes it different than any other information message in the network. Any random node that is near to cluster head requiring less transmission energy to establish data communication then that node sends Join_Req_msg to the Cluster head. Later on after schedule creation sub phase, the data transmission phase begins and nodes send data in their allotted TDMA slot to CH which they receive after schedule creation. However the nodes which are in idle mode go to sleep and save their energy. The energy required by any node is minimal in LEACH. Figure (1) shows slot formation in LEACH.

3. ANALYSIS OF MODIFIED ENERGY MODEL USED WITH SCALABILITY

Scalability is very important issue associated to designing of routing protocol for sensor network [2]. Any protocol is considered to be scalable if it can withstand changes in network topology time to time. As need grows to add more number of tiny nodes in later stages to already deployed network does not cause any short of deterioration in protocol performance metrics [4]. This protocol model shows network lifespan enhancement and also observe improvement in residual energy.

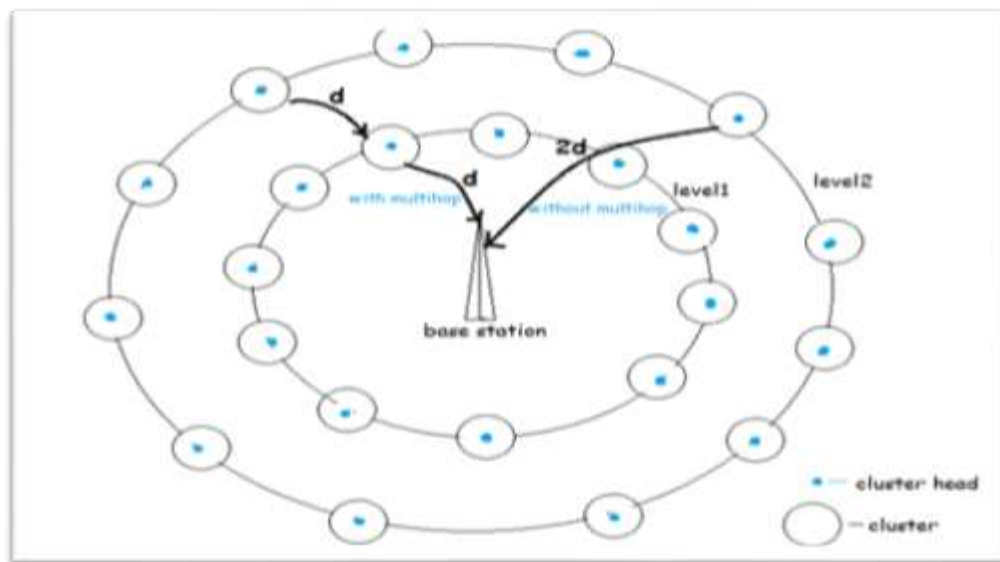


Figure 2 Strategic partitioning of Network

In presented work the nodes are deployment uniformly (as shown in Fig 2) into 100m*100m or 250 m *250 m area. It is assumed that all clusters formed are circular in shape, and the deployment is uniform in nature, so we can calculate 'd' as a function of network diameter. Using this average value of 'd²' is computed as in eq. (4). It is also considered that 'd' is the distance of any transmit and receive digital circuit in network. Total number of nodes deployed are 'n', and out of these 'k' clusters are formed after set up phase then 'm' number of nodes will become head set nodes. Head set nodes will in turn forward data to next higher level. Assuming M is total diameter of network. Then we can compute 'd²' as:

$$d^2 = \frac{M^2}{2*\pi*k} \quad (4)$$

Using this value, we have calculated E_{nonCH} as the energy for transmitting 'l' bits by a non CH node:

$$E_{nonCH} = l * E_e + l * E_s * \left(\frac{M^2}{\pi * k}\right) \quad (5)$$

Given that:

E_e = Energy consumed by transmitter / receiver circuit per bit.

E_s = Energy consumed in sensing the event per bit.

Definition of energy 'E' can be defined as:

$$E = \int_{-\infty}^{+\infty} |x(t)|^2 dt \quad (6)$$

Similarly, energy used by any CH is calculated by given equation:

$$E_{CH} = E_e * l * Q + E_l * l * d^4 + E_e * l + (1 + Q) * l * E_{DA} \quad (7)$$

Here, E_{DA} the energy is used in data aggregation techniques.

Given that: $Q = \frac{n}{k} - m$ and $R = n - m * k$

The start energy is calculated at each level separately starting from 1st to Lth

$$E_{T \text{ for level } 1} = E_{T \text{ for level } 1_CH/node} + \left(\frac{n}{k * m} - 1\right) E_{T \text{ for level } 1_nonCH/node} \quad (8)$$

$E_{T \text{ for level } 1}$

$$= \left\{ l * E_e \left[P + \frac{f_1 * N_f * (Q + 1)}{k} + (k + 1) + \frac{f_2 * N_f}{k} \right] + \left[\frac{f_1 * N_f * (l * E_l * d^4)}{k} \right] + l * E_s * d^2 \left[2 + \frac{f_2 * N_f}{k} \right] + \frac{f_1 * N_f * (Q + 1) * l * E_{DA}}{k} \right\} / m$$

(9)

Here f_1, f_2 frames transmitted by cluster head and non cluster head respectively. Hence, the complete energy drawn in transmitting and aggregating information to base station from any single level, created within the given network is found after aggregating all energy components associated like from sensing event to forwarding sensed information to the cluster head. The 'E' used can be calculated as:

$$E = \left(\frac{k}{2}\right) * \{ E_{CH} + Q * E_{nonCH} \}$$

$$E = \left\{ (2 * R + k) * l * E_e + \left(\frac{17}{2}\right) * (k * l) * E_l * d^4 + \{R + k\} * (l * E_{DA}) + (l) * E_s * R * \left(\frac{M^2}{\pi * k}\right) \right\} \quad (10)$$

Calculating the optimum value of 'k':

$$k = M \left\{ \frac{n * E_s}{\pi * \left((-2m + 1) E_e + \left(\frac{17}{2}\right) * E_l d^4 + (-m + 1) * E_{DA} \right)} \right\}^{\frac{1}{2}}$$

Now the ' E_{Total} ' can be computed as for entire network considering number of levels the network could have without deteriorating performances is 'L'

$$E_{Total} = (k/L) * l * \{L * (2Q + 2L) * E_e - \sum_{j=1}^{Lth} (2j - 1) * E_e + L * Q * E_s * d^2 + L(Q + 1) * E_{DA} + E_l * \sum_{j=1}^{L-1} (L - j) * d_{j+1}^4\} \quad (11)$$

Total amount of energy utilized in sensing the event, sending, receiving and aggregating the information at various levels starting from node level to reaching the sink in network. Like classic LEACH this modified version is developed for immobile nodes and Sink. Simulation parameters used in synthesising model are given in Table (2).

Table 2 Simulation Parameters:

Network Metrics	Metrics Value
Network area	100 m × 100 m, 250 m × 250 m
Random nodes deployed	100, 200, 300, 400, 500
Number of Bits in packet	6400 bits
Start Energy of node	0.5
Data Aggregation Energy	5.0 pJoule/bit/m ⁴
E_{fs}	10 pJoule/bits/m ²
E_{mp}	0.0013 pJoule/bit/m ⁴
E_{Tx}	50 nJoule/bits
E_{Rx}	50 nJoule/bits
Number of Rounds	1000, 2000, 2500, 3000, 3500, 4000
Radius of network	10 m, 25 m

4. SIMULATION RESULTS

To estimate the performance of this energy model, it is simulated on MATLAB R2020a. Results clearly indicates enhancement in lifespan of network in comparison of classic LEACH [1]. It is found that in proposed LEACH model the expectancy of network has increased by 42.18%, 46.28% , 50.23%, 56.16% and 78.18% for 100-,200-,300-,400-,500-nodes respectively.

Figure (3) –Figure (10) shows nodes distribution in 100m *100m field and number of alive node after every round for various densities of nodes, along with network life prolonged in various densities.

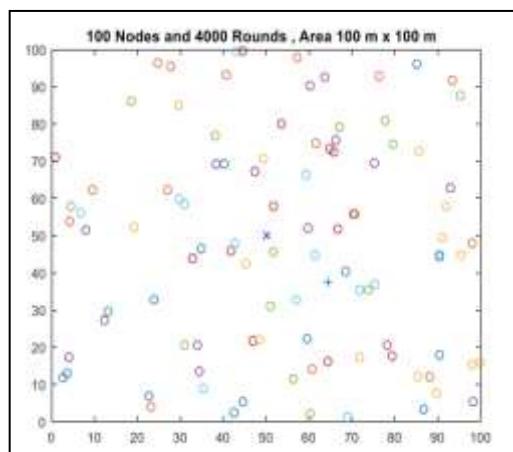


Figure 3 Distribution of node in area of 100m*100m

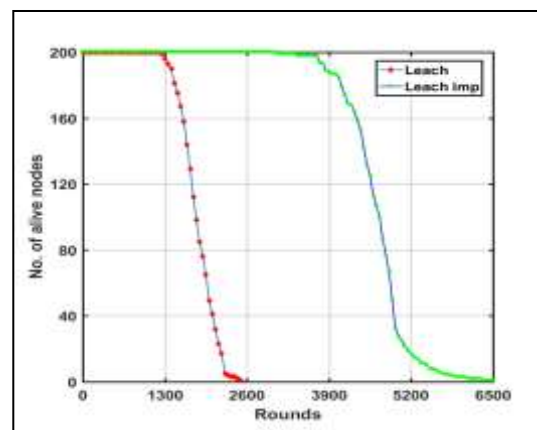


Figure 5 Alive nodes with node density 200

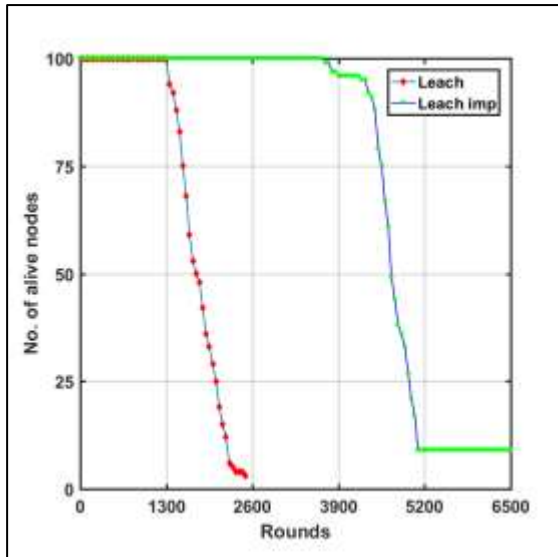


Figure 4 Alive nodes with node density 100

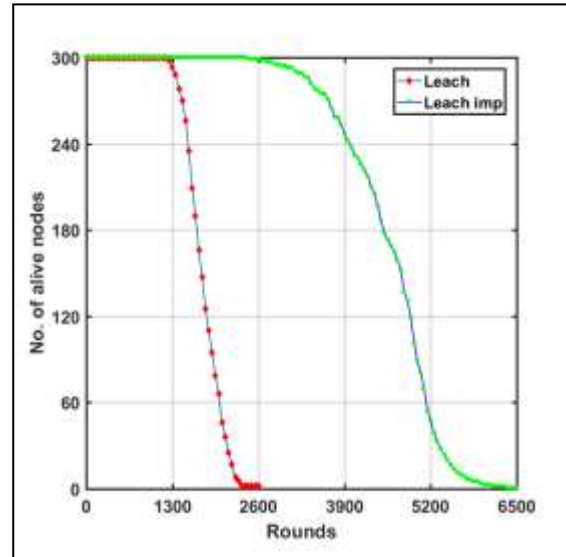


Figure 6 Alive nodes with node density 300

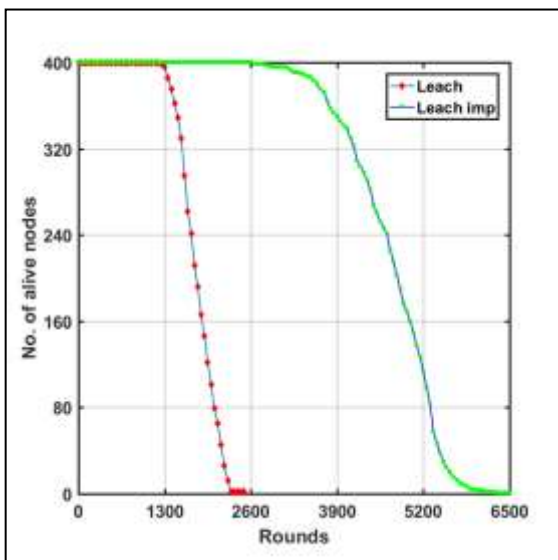


Figure 7 Alive nodes with node density 400

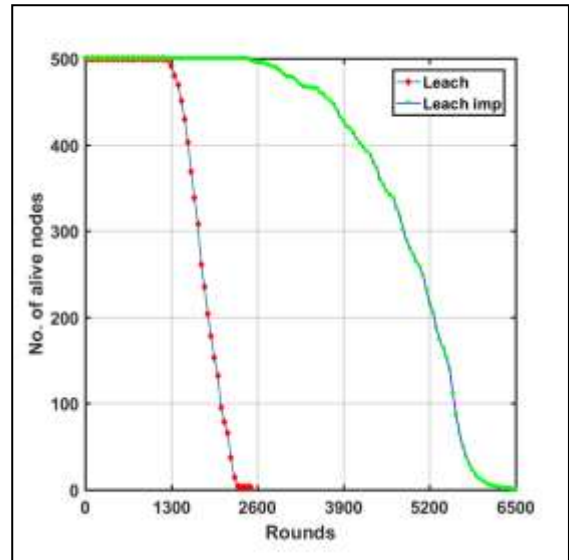


Figure 9 Comparative study of Network Lifespan for 100-, 200-, 300-, 400-, 500-nodes

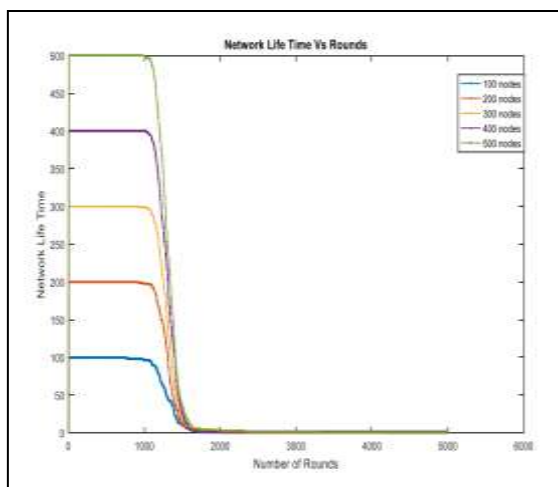


Figure 8 Alive nodes with node density 500....

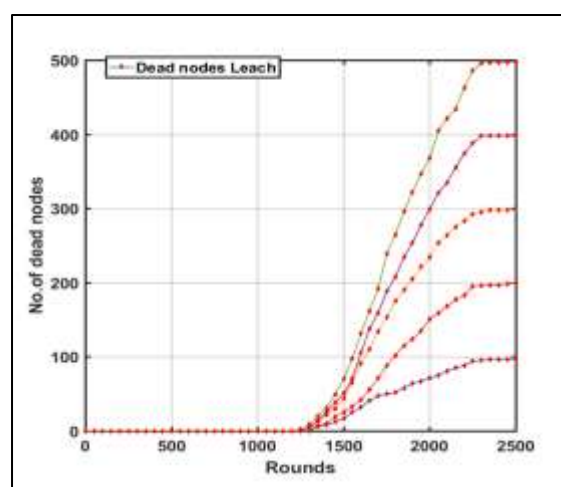


Figure 10 Dead nodes after each round for 100-, 200-, 300-, 400-, 500- node

5. CONCLUSION AND FUTURE SCOPE

This paper has presented a new approach in a three layer wireless sensor network routing protocol where the new factor scalability is added. The aim of designing this model is to sustain network performance with increase in size of network. The data has sent to cluster heads, head sets and sink using MAC protocol. TDMA slots are used for information transmission during set up and steady state phase during every round. Moreover, this shows better performance for total L levels in network in addition to load balancing among cluster heads and head sets.

The simulation results demonstrated that the strategic forwarding of data extends network life time of network with less energy consumption at node level. In future work this can be tested for mobile nodes and base station.

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