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OPTIMIZED LEHE: A MODIFIED DATA GATHERING MODEL FOR WIRELESS SENSOR NETWORK

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ABSTRACT

Aims: *Energy source of Sensor node in a large scale Wireless Sensor Network (WSN) is a non-replaceable and non-rechargeable small power source. Efficient use of the node's energy is the crucial issue in WSN. Lifetime of the network depends upon number of nodes alive to collect and transfer data to the remote base station. Different research proposals are tried to reduce the energy consumed by each node. Those methods are categorized as cluster based, chain based, mobile data gathering based ideas. Cluster based methods are used to subdivide the network in to groups called clusters and elect a node as cluster head whose responsibility is to collect and forward the data from members to base station.* ***Materials and methods:*** *Due to heavy usage of nodes in specific area its energy is drained and unable to participate in data forwarding. Those areas look like a hole in the network and that breaks the communication between two ends.* ***Results:*** *In proposed work, mobile data gathering method is used to prevent the network break from energy-hole issue and also tried to reduce the probability of formation of energy hole by implementing optimized sleep scheduling algorithm.* ***Conclusion:*** *The simulation result shows the improvement in average delay by 10% and packet delivery ratio by 20% due to the dynamic cluster size and multi pattern mobile data gathering.*

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KEY WORDS

Wireless Sensor Network, Network Lifetime, Mobile data Collection, Dynamic pattern.

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INTRODUCTION

Smart network applications like home automation, remote area monitoring and agriculture development are implemented based on the concept of Wireless Sensor Network (WSN). WSN collects the sensed data, process it based on application requirement and transmit the aggregated data towards base station in single or multi-hop communication method. WSN consists of large number of small sized sensor elements also called nodes, which may sense more than one physical parameter. The nodes are deployed in unattended environment, so the power source is a non-replaceable and non-rechargeable small unit which is placed inside the node [1-3]. The energy source has to be utilized effectively to extent the lifespan of node as well as the network. Many research proposals are tried to reduce the energy consumption level of each node by different methods. Those methods mostly under the following three categories, namely cluster based, chain based and mobile data gathering. In Cluster based method, the network is subdivided in to groups called clusters. The cluster size may be equal [4] or unequal [5] based on hop count for forwarding the data. The cluster elects a node as cluster head (CH) whose responsibilities are collecting the data from member node and forwarding it towards a base station or sink node. These responsibilities drain the energy of CH node and lead to a quick dead, if the node continuous as CH for long period. Hence the CH role is rotated among all members to avoid early dead issues of selective nodes [6]. Cluster formation and CH elections methods are proposed in many algorithm forms [4-8].

Chain-Cluster based Mixed routing (CCM) protocol [9] divides the network into a number of chains, which means that continuous connection towards base, and it work with two phases. First phase collects data from sensor nodes through their chain head node with the help of improved chain routing protocol. Chain head nodes are grouped in a cluster form with self-organizing capability and elect a cluster head node to transfer the collected data to base in the second phase. It combines both the concept of chain process and cluster method to provide better performance.

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Data gathering methods using WSN are applied in object tracing and monitoring applications. Some applications are time sensitive and some applications are data sensitive. Efficiency of the network is based on both these parameters. In Remote monitoring applications the node energy is the important parameter to enhance network lifetime. Most of the energy wasted in transmission of data in the form of communication cost. Mobile data gathering is the idea to overcome the energy wastage in the form of communication cost. A mobile device with more amount of resources (processing, memory, energy…) is used with dynamic path selection to collect data from different cluster head nodes which has the collected information from their member nodes [10].

Energy hole is the hidden area inside the network due to nodes in that area unable to collect or forward the data [11]. It is a critical issue for network lifetime calculation. The energy hole divides the network from base and creates unavailability of the network. Network lifetime is the time duration for three different points based on the application requirements. First Node Died (FND), Half Node Died (HND) and Last Node Died (LND) are those points for calculation of network lifetime. Time duration from initialization of network to death of first node is FND, time duration from initialization of network to death of 50 % of the nodes in the network is HND and time duration from initialization of network to death of last node in the network is LND.

The proposed method tried to overcome the energy-hole issue by considering optimized sleep scheduling and mobile data gathering methods in effective manner to provide better FND, HND and LND. Further the paper organized as literature review in section II, proposed work in section III, and performance analysis in section IV followed by conclusion in section V.

RELATED WORKS

Clustering method introduced in LEACH (Low-Energy Adaptive Clustering Hierarchy) [4] protocol is the motivation for most of the energy based routing protocol researches. The overall network is subdivided in to equal portions, named it as clusters. Based on nodes density of that area, number of member nodes may vary from cluster to cluster. Cluster members share their availability through messages and use a clustering algorithm to select cluster head (CH) node as their leader. CH node collects the information from member nodes through TDMA slots and forwards the aggregated information to base station. CH role drains the energy of that node and leads to early dead. To overcome this issue, LEACH-C [6] uses the concept of rotating the CH role among all the members based on the threshold values which is shown in equation (1). Network nodes density measured by ρ, current round CH election is intimated by r and n is the node which is winning in the set G for calculation.

$$T(n) = \begin{cases} \frac{r}{1-r\left(\rho \bmod \left(\frac{1}{r}\right)\right)} & , n \in G \\ 0 & , \text{Others} \end{cases} \quad (1)$$

Different cluster formation and CH election methods are proposed in [5-8] to improve the performance of the network by considering the sleep scheduling algorithm and node's residual energy. A hybrid model with chain and clustering concepts introduced in [9] utilizes the positive points in both the methods.

A modified Mobile Data Gathering protocol proposed in [10] with load balanced clustering technique and dual data collection methods in a mobile device. The path used in this method is fixed and this method leads quick energy drain of nodes along the fixed path.

Energy-hole inside the network is the challenging issue for lifetime analysis of WSN. It creates unavailability of the network by early death of the nodes [11-14]. The load balancing method is used to handle the energy-hole problem in a large-scale WSNs, and proposed a distributed solution to balance the consumed energy of nodes by tuning their transmission level. A mathematical model given in Lifetime and Energy Hole Evolution (LEHE) [15] analyze the entire network lifetime from network initialization to complete disable of network, and calculates the boundary of energy-hole inside the network. Based on boundary values the transmission power increased to overlap the data from the energy-hole. But this method not tried to prevent the formation of energy hole.

A Hybrid Energy Consumption model proposed in [16] give a way for multi pattern mobile data collection to avoid early death of nodes nearby fixed path used in other methods.

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MATERIALS AND METHODS

Optimized LEHE

Network lifetime enhancement based on prevention of energy-hole formation consists of different stages. Network initialized with large cluster formation and the cluster uses modified clustering algorithm to elect the CH nodes and Data collection using TDMA slots. High node density leads to energy wastage in the form ideal listening, this issue is addressed by implementing optimized scheduling algorithm in the field. A Multi-pattern dynamic path selection method of mobile data collection idea reduces the energy wastage in routing and also prevents the formation of energy-hole inside the network.

Cluster Formation

After initialization of network, the clusters are configured with sensor nodes self-configurable property. In Each round of the cluster it elects a CH with modified method **[Figure 1]**. The role of CH is to collect the data from member node and aggregate the information received. Aggregated information is kept for relay to mobile data collection.

Modified Threshold value calculation is given by equation (2), were $E_{re(n)}$ is the residual energy of the node calculated in current round and E_{max} is the initial energy of node and it should be equal to all nodes.

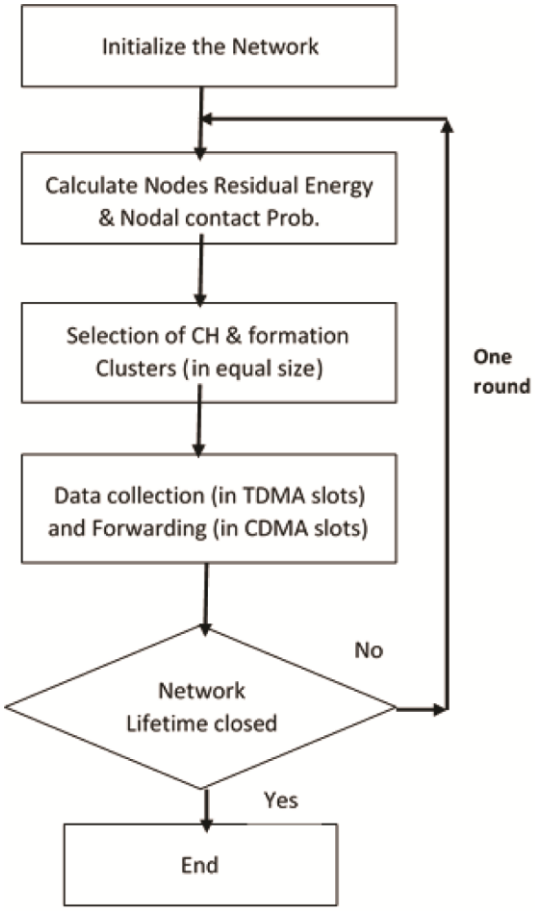

Fig: 1. Modified Cluster Head Election

$$T(x) = \begin{cases} \frac{r E_{re(x)}}{(1-r(p \bmod (\frac{1}{p})))E_{max}}, & x \in G \\ 0, & \text{Others} \end{cases} \quad (2)$$

After the Calculation of threshold value for node 'x', it send for CH election. Elected CH node send TDMA slot to all member node and the member nodes send data to their respective slot to CH. CH aggregate the data to remove redundant information from received data. It also reduces the transmission cost of unwanted data. After the Collection of data from CH, it checks for the

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availability of network and also residual energy of the node. If residual energy of the node is above the maximum reachability power level then it goes for next round of cluster otherwise it considered as a dead node. The lifetime calculation using three different methods is shown in [**Figure -2**]. R1,R2,R3…are the cluster rounds and each of the round has clustering and data collection phases. The Network continuously monitor the death of each node by its energy level calculation after each round and it records the time duration for each death from network initialization.

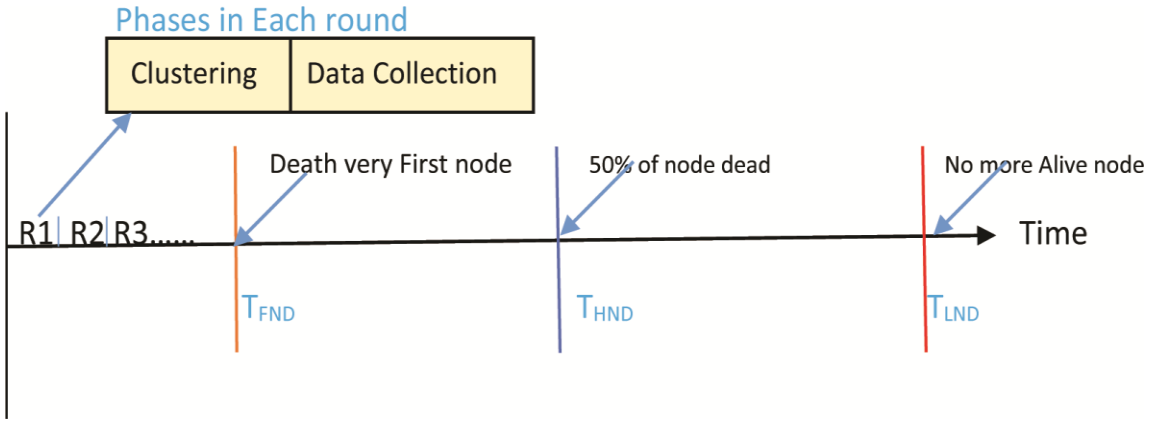

Fig: 2. Network Lifetime Calculation

Network Model

Network model for the proposed work is shown in **[Figure -3]**. Each node acted as transmitter and receiver. Number of bits used for transmission is 'n' and the distance between two end points is 'd'. Energy loss due to transmission of n bit data is denoted by E_{Txr} and same for receiver is E_{Rxr}. The distance threshold d0, denotes the minimum distance of air interface with free space channels. If the distance d>d0, then multipath fading model channels are used for transmission. These information's are highlighted in the equations (4) & (5), were ε_{fs} is the energy for amplification in free space channel and ε_{mp} is the energy for amplification in multipath channel.

$$E_{Txr} = \begin{cases} nE_{Elec} + n\varepsilon_{fs}d^2 & ,d \le d_0 \\ nE_{Elec} + n\varepsilon_{mp}d^4 & ,d > d_0 \end{cases} \quad (4)$$

$$E_{Rxr} = nE_{Elec} \quad (5)$$

Mobile data Collection

Routing overheads in cluster based algorithms are overcome by a mobile device called RelayCar [10]. It is a mobile device with maximum sensing, processing and transmitting capabilities with rechargeable energy source. The device does not covered by lifetime issue, because of rechargeable power source. The device passes through the application field in air, collect data from CH node in each round and process it for removal of redundant information and forward it directly to the base with large transmitting range. The path, which the mobile device passes through the field is not a fixed one. Different pattern of paths are stored in the device and based on the requirement or environmental condition, the paths are selected dynamically. The following algorithm describes more in deep about the process of the proposed algorithm.

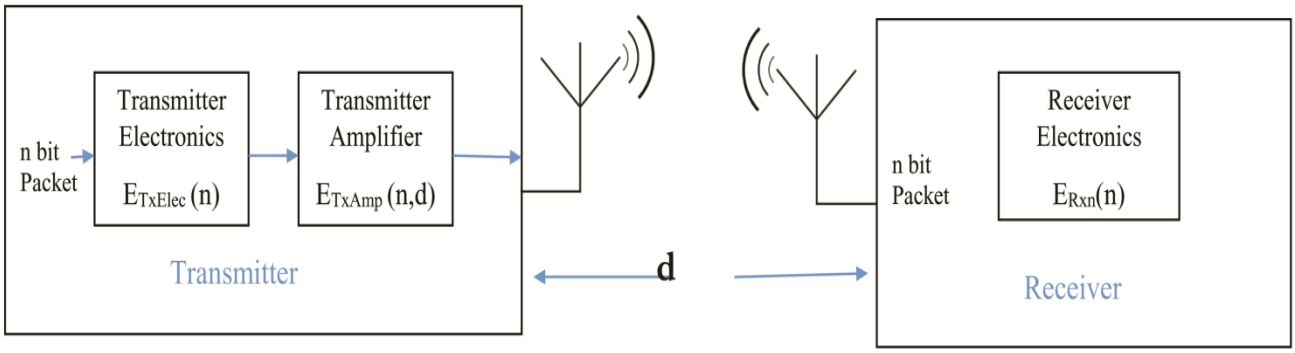

Fig: 3. Network Model

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Algorithm for Optimized LEHE

Step 1: Identify the group nodes for sleep schedule
Step 2: Set 10% duty cycle
Step 3: Cluster Head election with updated Residual energy values
Step 4: Data Collection through TDMA Slots
Step 5: RelayCar applied with Dynamic Mobile pattern
Step 6: Check for death nodes and record the time duration
Step 7: Repeat the steps 3 to 6, if network available
Step 8: End the process, if network unavailable after current round

Table 1. Simulation parameters

Parameter	Value
Number of nodes	100
Network Grid	500×500m2
Channel BW	1 Mbps
Size of data packet	500 bytes
Initial energy of nodes	1J
Duty Cycle	10%
ε_{fs}	10pJ/bit/m2
ε_{mp}	0.0013pJ/bit/m4
E_{Elec}	50nJ/bit
E_{Idle}	0.88 mJ/s

RESULTS

Performance Analysis

Performance of the Optimized LEHE protocol is analyzed with the help of simulation tools. The parameters used for analysis is listed in table 1. 50 nodes are considered for analysis with 1J as initial energy for all nodes. 10 % duty cycle is considered for sleep scheduling. Single round time duration for clustering is set as 10s. Optimized LEHE protocol is compared with LEHE protocol and First Node Died Time (FNDT) for better analysis. Analysis parameters Average Delay, Packet Delivery Ratio (PDR), Control Overhead and Average remaining energy are discussed one by one as bellow.

Average Delay

End to end average delay is the time duration in which the collected information reaches the base. Compared with other data gathering methods mobile data gathering reduces the time delay. With increased number of nodes the delay reduces 10% compared with LEHE protocol due to implementation of mobile data collection method [**Figure -4]**.

Packet Delivery Ratio (PDR)

PDR is the ratio between number packets received at the base to the total number of packets send. After the variations PDR value improved with 20% difference [**Figure -5].** The difference is due to considering the proper scheduling algorithm and implementation of mobile data collection method.

Control Overhead

The ratio between control packets send to the total packets send in the network for specific duration. Control overhead value has to be minimum for a better protocol. The performance is improved by 5-10% when compared with LEHE protocol [**Figure -6]**. The variation is due to more number of control messages are required when number of nodes are increased.

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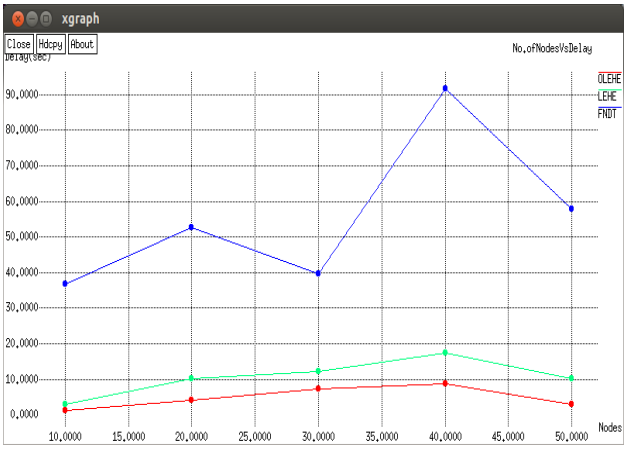

Fig: 4. Average Delay

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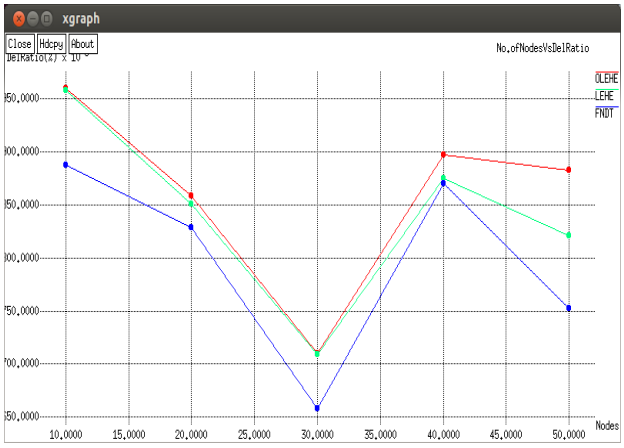

Fig: 5. Packet delivery ratio

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Nodes Remaining Energy Level

The sum of all alive nodes remaining energy is considered for analysis. Up to 40 nodes combination the remaining energy level is comparatively high in LEHE protocol and after that 50 nodes combination, need of more number of control messages and more number of active node conversions the remaining energy level is reduced considerably [**Figure -7**].

CONCLUSION

The proposed work focused on the network lifetime enhancement by preventing the formation of energy-hole inside the network. Sleep scheduling and dynamic multipath mobile data gathering methods are used to reduce the energy consumption in each node. Nodes residual energy level consideration for CH election provides better improvement. First node died (FND), Half node died (HND) and Last node died (LND) are considered for analysis of the proposed work. Network lifetime is improved when compared with the other existing methods because of considering average residual energy level and Dynamic path selection for mobile data gathering. Packet delivery ratio and average delay are improved much better than the compared methods.

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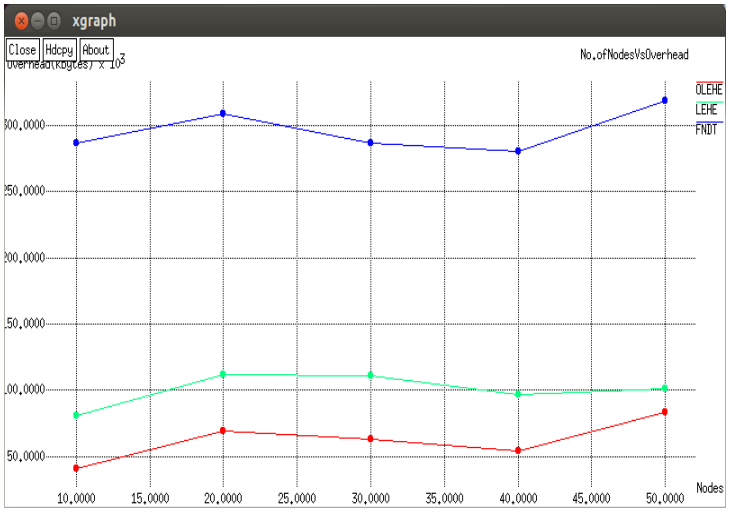

Fig: 6. Control overhead

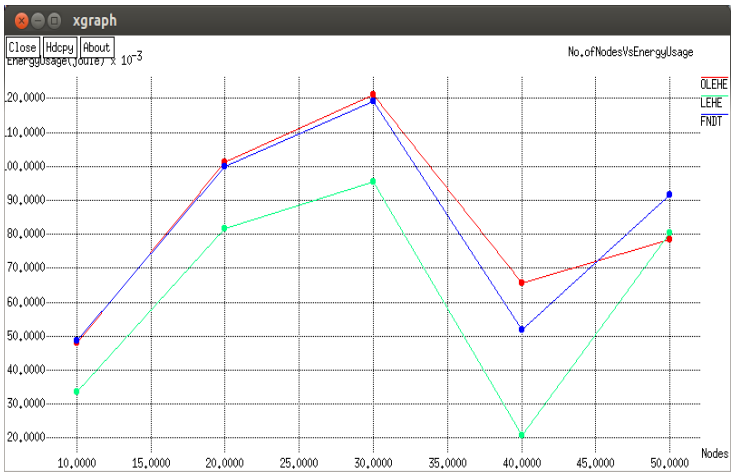

Fig: 7. Nodes Remaining Energy Level

CONFLICT OF INTEREST

The authors declare no conflict of interests.

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FINANCIAL DISCLOSURE

None.

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