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Enhancement of Network Lifetime by Improving the Leach Protocol for Large Scale WSN

K. Somasundaram[1*], S. Saritha[2] and K. Ramesh[3]

[1]Department of CSE, Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Chennai - 600062, Tamil Nadu, India; soms72@yahoo.com
[2]Department of ECE, Nandha College of Technology, Erode - 638052, Tamil Nadu, India; sarithas.ece@gmail.com
[3]Department of IT, Nandha Engineering College, Erode - 638052, Tamil Nadu, India; rameshk.me@gmail.com

Abstract

Background: Wireless Sensor Network (WSN) is a network of self-configurable nodes. Nodes are operated using irreplaceable and small energy source. Node's operation includes sensing and transferring of data towards base station. **Methods:** Network Lifetime depends on lifespan of nodes in that network. LEACH is the basic protocol for cluster based routing algorithm. Many proposals with modification of LEACH are proposed and have some suggestion for future work. Optimized Far-Zone LEACH and EAR are few of that and tried to modify the LEACH to augment the network lifetime. **Findings:** The proposed work covers the efficient usage of energy, nodes mobility, hidden zone issues and routing in WSN design. Nodal contact probability and Weighted moving average concepts are used to reduce the impact on mobility issue. Residual energy of the sensing node, distance towards base and adaptive sleep scheduling algorithm are used to reduce the node early dead issue and also improve the lifespan of the network. Multi-hop communication and uneven clustering concepts are used to provide energy efficient transmission and routing. **Improvements/Applications:** The proposed work is developed to cover all these issues with the consideration of above mentioned parameters. Simulation results show the 10-15% improvement in lifetime of network and average delay.

Keywords: Lifetime, Network Lifetime, Residual Energy, Routing Protocol, Wireless Sensor Network

1. Introduction

Wireless Sensor Network (WSN) is an infrastructure-less (Ad-Hoc) network. Its functionalities include sensing the environment, computing the sensed data and communicate with other nodes for data sharing in a specified area or application field. The properties of the sensor node includes small in size, applicable to low-cost, self-configurable and some sensitive sensors are required to enable the realization of environment and low cost sensor network[1].

WSN applications generally divided into two types. A mesh based multi-hop large scale network with dynamic routing is called Category 1 WSN and point-point or Multi-point to point, star topological single hop network with static routing is called Category 2 WSN. Military-theater systems typically belong to Category 1 WSN and Residential control systems typically belong to Category 2 WSN. The motivational research in WSN, originally for military applications like battlefield surveillance and stockpile surveillance[2].

In a hierarchical network a top layer node always check its next layer nodes for the new update and create idle listening[3]. Habitat monitoring proposed a scheduled communication[4]. It uses routing tree, each node is assigned for work duration and transmits to the next layer node. After completion of scheduled work it returns to sleep. This process progress up to all nodes has completed their scheduled transmission. A cluster-based Wireless Sensor Network idea is used to detect forest fire in real-time mode[5]. Many other applications of Wireless Sensor Technologies in Agriculture and Food Industry are

* *Author for correspondence*

reviewed as per current trends in[6]. Following are the some important challenging[7] issues in cluster based WSNs: Limited Energy, Network Lifetime, Cluster formation and CH selection, Synchronization, Data Aggregation and Node Mobility.

Comparison of CH selection methods in each round and transmission modes used in cluster and its distribution are discussed in[8] and suggests the creation of clusters shows a need of a combined strategy for better results.

Existing work has shown that mobility of sink improved network the performance[9,10]. Sink mobility may be associated with some people or animals in random movement for collection of data in a sensed area. Sink mobility based on path constrain is updated for the improvement of sensor networks with single hop and this may case high communication cast for direct communication to base from a member node or a CH node. In a large-scale Wireless Sensor Networks multi-hop communication method with mobile sinks is proposed for an efficient data gathering methods which improves energy consumption simultaneously.

2. Earlier Works

Low-Energy Adaptive Clustering Hierarchy[1] introduced the concept of clustering and cluster based network. Fixed CH method failed due to quick drain of CH node, leads to implement the rotation based clustering and CH schemes. Cluster formation method, first finds threshold values for all eligible nodes based on the equation given. Here x indicates the node in which the calculation going on and r is the current round.

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

LEACH is not considering the energy level of the node, but elected as CH. The energy drains quickly, if low energy level node is elected as CH, as a result, network is broken.

Optimized Far Zone LEACH eliminates the problem of node mobility in FZ-LEACH. By using Exponential Moving Average (EMA), the mobility of the Far Zone Cluster Head is monitored and its next movement is predicted by using previous values. If the movement is beyond the limit of Far Zone then automatically a new CH elected without losing the data.

In Improved Far-Zone LEACH proposed in Modified Sleep Scheduling algorithm used to reduce active node in one round. Gateway note which is common for two clusters used to move data from one cluster to others and update Cluster table (for all nodes) and Gateway table (for Gateway notes). Uneven clustering method is used to improve the performance of the system. Nodes with bellow average energy which are far away from base are grouped and zone head coordinates the members.

In new updated Sleep Scheduling algorithm[11] used to keep only half of the total nodes to be active node in one round and update Cluster table (for all nodes) and Gateway table (for Gateway notes). Cluster size calculation updated in uneven clustering method. Nodes with bellow average energy which are far away from base are grouped and zone head coordinates the members. Calculate for eligible node's threshold value T(n) which includes node's Residual energy, Number of neighbors and distance from base. CH eligible nodes send advertisement to other nodes within the coverage. Get response from member nodes. A node which receives large number of response from members elected as CH. CH elected information with TDMA slot is sent to all member nodes. Member nodes send the sensed data in their TDMA slot to CH. CH aggregates (using in-network aggregation method) collected data before send to next Hop.

In energy efficient part[12], this study considered different methods for Cluster Head (CH) election. In routing part optimized load balanced idea is used to find quality path between node and base and unequal cluster sizes. Weighted Rendezvous Planning (WRP)[13] uses near-optimal traveling tour method to minimize the sensor nodes energy consumption. A Survey of Energy Conservation and Efficient Data Collection give detailed discussion about different data collection methods[14]. In CLUE-HOPE[15] the network divided into different level of virtual grids. A node nearby sink may need to transfer more number of packets rather than other nodes and called as hotspot. Hotspot node drains its energy quickly due heavy transmission and super cluster formation method tried to overcome[16].

3. Proposed System

Proposed model try to improve the energy consumption and reduced overhead in routing the sensed data. Figure 1 show the system flow model for EFZ-LEACH protocol. In Cluster formation phase, Nodal cost is calculated and compared with MRP value. If nodal cost is above MRP then that node is either neglected for CH nomination or considered for CH role. Adaptive optimal Sleep Scheduling algorithm used to keep only half of the total nodes to be active node in one round update Cluster table (for all nodes) and Gateway table (for Gateway notes). Cluster size calculation updated in uneven clustering method and nodes with below average energy which are far away from base are grouped and zone head coordinates the members. Far-zone created based on nodes average signal strength which are far away from base.

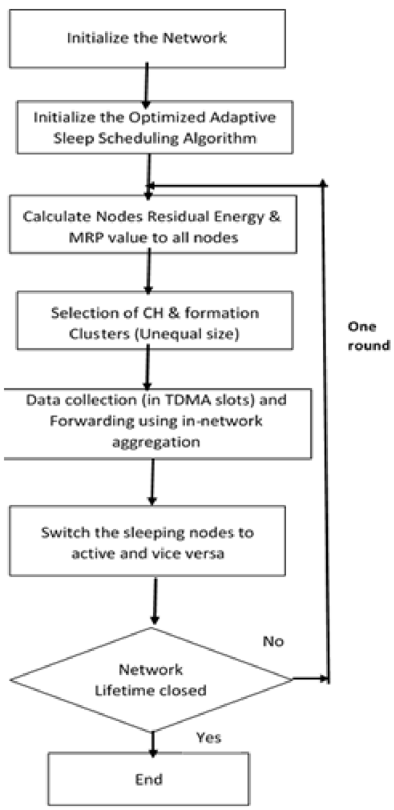

Figure 1. System flow model for proposed work.

In energy efficient CH election and data collection phase, eligible node's threshold value T(n) is calculated which includes node's Residual energy, Number of neighbors and distance from base. CH eligible nodes send advertisement to other nodes within the coverage and get response from member nodes. A node which receives large number of response from members is elected as CH for that area.

The eligible CH nodes are updated their threshold values in the proposed system using given equation and it uses the node's residual energy and its maximum or initial energy.

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

CH elected information with TDMA slot is sent to all members and Member nodes send the sensed data in their TDMA slot to CH. CH node early dead issue is avoided by considering nodes remaining energy and distance from base. CH aggregates (using in-network aggregation method) collected data before forward it into next hop. In hop selection and data relay from CH phase, distance is calculated from base (d) and compared with distance limit (do). If d< do, Data reach base in single hop, otherwise multi-hop mode selected for data transmission. With this modification energy wastage in direct transmission is avoided with tolerable delay. Pseudo Code for proposed protocol is shown Figure 2.

```
Event – Round (p)
Input: No of nodes N
begin
Update Residual Energy of all nodes E_res(n)
Calculate Threshold value T(n)
Generate Sleep Schedule updates
Submit Active node list to execute
end
PROCEDURE: CH selection
Input: Cluster Size, No of nodes in CH election
begin
Generate Advertisement message
Update Responses from members
Submit TDMA slots
end
PROCEDURE: Data Collection and Aggregation
input: No of members N_m, TDMA slots T_i
begin
Update Data collection through TDMA slots
Generate Dependency list
Submit Aggregated Data for Txn.
end
PROCEDURE: Data Txn to base
input: Data stream D[x], No of hop j
begin
Generate Route through gateway nodes
If Txn Success for D[x], then
Verify Hop Count y
end if (Gi,j, i+1)
Repeat (1) for N rounds
end
```

Figure 2. Pseudo code for proposed protocol.

The performance analysis on the system proposed in this study is done through Network simulator-2.

Experimental parameters for simulation are number of nodes 100, deployment area 500 x 500 m^2 and other parameters are listed in Table 1.

Table 1. Simulation parameters

Parameter	Values
Number of nodes	100
Network Grid	500×500m^2
Channel BW	1 Mbps
Size of data packet	500 bytes
Initial energy of nodes	1J
Processing Delay	50µs
εfs	10pJ/bit/m^2
εmp	0.0013pJ/bit/m^4
Eelect	50nJ/bit
EDA	5nJ/bit/signal

4. Performance Analysis

List of parameter considered for analysis are Control Overhead, End-to-End Delay and Packet Delivery Ratio.

4.1 System Control Overhead

System Control Overhead is defined by ratio between numbers of control message request send and received.

$$\text{Overhead} = \frac{\text{Number of control route packet send} + \text{control route reply packet send}}{\text{Total control packet recived}} \tag{3}$$

Figure 3 shows the Control Overhead comparison analysis of Existing and Proposed System.

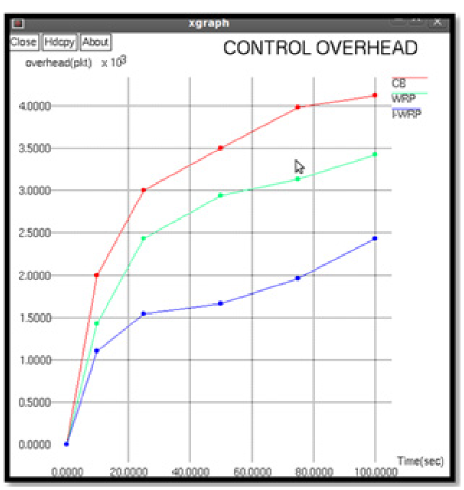

Figure 3. Comparison graph for control overhead.

4.2 End-to-End Delay

It is defined as the measure of average times taken by the packet to reach the base station from the sensing node.

Figure 4 shows the comparative analysis of End-to-End Delay of Existing and Proposed System.

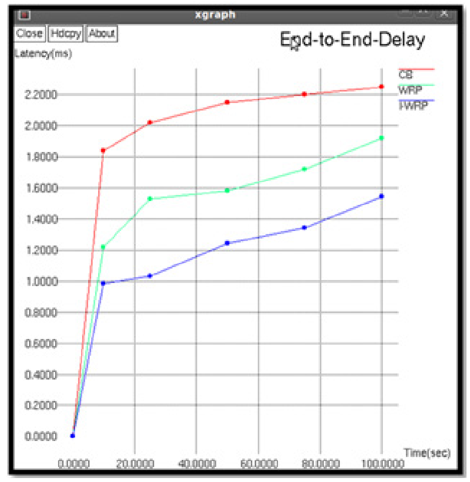

Figure 4. Comparison graph for end-to-end delay.

4.3 Packet Delivery Ratio

It is defined as the ratio between the numbers of data packets received by Base station and number of data packets sent by all member nodes over a specified duration.

$$\text{Delivery Ratio} = \frac{\text{Number of Packets Received at base station}}{\text{Number of Packets Sent by all member nodes}} \tag{4}$$

Figure 5 shows the study of Packet Delivery Ratio comparison and Figure 6 shows the comparative Analysis of Packet Received for Existing system and Proposed System are studied and explained in graphical representations.

By the inclusion of node's Residual energy, node's distance towards base and Adaptive Sleep scheduling algorithm are used to reduce the node early dead issue and also improve the lifespan of the network. Multihop communication and uneven clustering concepts are used to provide energy efficient transmission and enhance the network's lifespan.

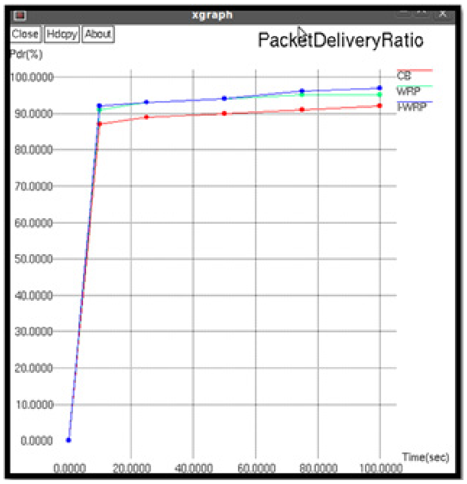

Figure 5. Comparison graph for packet delivery ratio.

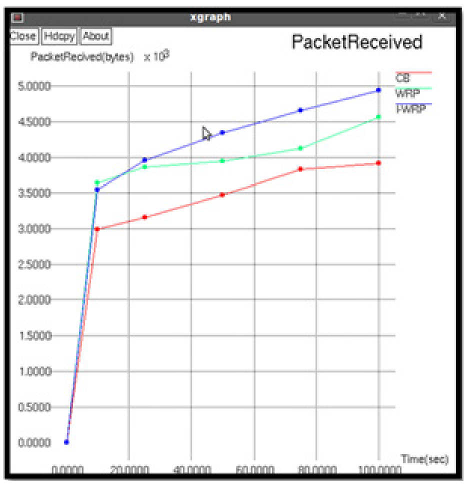

Figure 6. Comparison graph for packet received.

5. Conclusion

An energy based routing protocol to enhance the network's lifespan is proposed with uneven clustering and multi hop mode of communication. A network with large number of nodes is difficult to maintain the lifetime enhancement. By the inclusion of node's Residual energy, node's distance towards base and Adaptive Sleep scheduling algorithm, the proposed work reduces the nodes early dead and increases the lifetime of the nodes. Increasing lifetime of each node leads the improvement in network lifetime. The result improved by 10% of energy consumption and 15% in residual energy, 15% in throughput and PDR in the proposed system. Energy consumption and residual energy enhancement show the improvement in each nodes lifespan and leads to the improvement in network.

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