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# Energy Optimized Sleep Scheduling Protocol for Data Aggregation in WSN

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***ABSTRACT:*** *Wireless Sensor Network (WSN) consists of various nodes or devices those are operated on batteries. These nodes or devices have inadequate amount of initial energy which are consumed during the data transmission process. In sleep scheduling algorithms most of the sensor nodes are turn to sleep state to preserve energy and improve the network life time. This paper focuses an Energy Efficient Sleep Scheduling (EE-SS) protocol for WSN. In the initial phases, the network is divided into small clusters and these clusters are managed by the Cluster Heads (CHs). The CHs are elected based on the highest residual energy criteria. The sleep scheduling approach helps to allocate the slots to forward data from the source to base station. The nodes which are having the highest residual energy are selected as the forwarding nodes. This paper compares the performance of the proposed method with the standard LEACH protocol and CL model in terms of various factors. The result of this paper proves that the proposed method has higher network lifetime than the existing approaches.*
***Keywords—*** *Base Station, Cluster Heads (CHs), Low Energy Adaptive Clustering Hierarchy (LEACH), Residual Energy. Sleep Scheduling, Wireless Sensor Networks (WSNs)*

## I. INTRODUCTION

Wireless Sensor Network (WSN) is composed of a huge number of sensor nodes disseminated over a certain region. Each node notices its surrounding area and collects the application specific information. It transmits the gathered data to the gateway (master node). The gateway processes the data and perform necessary actions if necessary. A sensor node may require to function for long periods of time relying on a small battery. Hence, it is essential to optimize the energy efficiency of all sensor processes. It includes sensing, communication and computation. This requests for planning the communication protocols which are energy-efficient in the sense of demanding the low transmission power and low-complexity processing. Lesser the computational complexity of communication protocols is essential due to its reduced energy consumption and hardwarecost.

It is identified that the energy requisite to communicate a definite amount of information is exponential to the inverse of the transmission time. The corresponding delay-energy tradeoff principle is applied to the strategy of energy-efficient packet-scheduling protocol. It accomplishes filtering or smoothing on the packet arrival-time intervals, resulting in an output packet traffic which is less bursty than the input traffic and it leads to the significant energy savings. A discretized form of the "lazy scheduling protocol" is applied to a network, where the channel gains among the different users are expected to be identical. Some of the primary implications of reliability in the effect of cost and energy influences in WSN scheme are asfollows:

- Sensing reliability: All the sensor nodes in WSN applications cooperate together to observe physical phenomena of interest through the sensor field. As the individual nodes can sense the suitable physical occurrences inside their sensing range only, significant events may be distorted by all sensor nodes due to the possible insufficient sensing coverage. Henceforth, providing comprehensive sensing coverage needs node deployment schemes and careful network planning. The redundant sensors may entered to the sensor network which need an additional reliability for sensing the area. Though, tradeoffs should be weighed based on network management complexity and per nodecosts.
- Hardware reliability: It is associated to the tendency of the onboard hardware components in submitting to the failure at the time of normal WSN operations. While the particulars on WSN hardware design to maximize the reliability.
- Communication reliability: The complete traffic profile is very easy as the packets only drift from the sensor nodes to the data destination and vice versa, with very lesser inter-node exchanges. Although this simplicity in traffic flows, the sensor network is still estimated to provide the data and control messages with high fidelity in a timely manner. Apart from the effect of packet loss across the unstable links, the intrinsic multihop nature of network communications present extra uncertainty in assuring the packet transport reliability. It remains a considerable challenge to maintain the network connectivity in combination with low-duty cycle sleep-scheduling schemes anticipated for maximum energypreservation.

WSN MAC protocols should work under a number of major challenges due to the shared nature of the wireless channel. For example, the hidden nodes may cause wireless collisions, and large wireless usage in one location may generate substantial contention for channel access by other neighbor sensors. It degrading the performance for these sensor nodes as well. Numerous sources of wireless interruptions are also possible, which includes the external interference from wireless transmissions by other types of devices like Wi-Fi nodes.

The remaining part of the paper is organized as follows: Section II involves the works related to the existing algorithms for energy efficient cluster head election and scheduling algorithms. Section III involves the description of the proposed energy efficient MAC scheduling protocol for WSN. Section IV involves the performance analysis of the proposed work. Section V presents the conclusion.

## II. RELATED WORKS

Someoftheenergyefficientclusterheadselectionmethodsandschedulingmethodsarediscussed.Mahajanetal

[1] proposed an energy balanced QoS based cluster head selection method in WSN. A cluster weighted selection approach named Cluster Chain Weight Metrics (CCWM) was presented which takes the service parameters for improving the performance. Here, CHs were selected based on the weight metric and cluster formation takes place. This method conserves both the energy and load among the sensor nodes. A local clustering mechanism was considered with the cluster to minimize the communication cost and computation. Singh and Lobiyal[2] presented an energy aware CH selection using Particle Swarm Optimization (PSO) and analysis of packet transmissions in WSN. PSO provides an energy aware clusters with optimal selection of CH. It minimizes the cost of locating the best position of CHs. It was performed inside the clusters instead of performed in base station. The objective function was formulated based on the minimum distance from the CH and member nodes and residual energy approach.

Wang et al [3] introduced a clustering algorithm based on the energy information and CHs expectation. A sliding window set up was used to adjust the electing probability and stable number of CHs based on the initial energy and the average energy information. The number of CHs was fixed in the whole network lifetime in LEACH was changed to be a variable based on the number of the active nodes. Amgoth and jana[4] presented an energy aware routing algorithm. This algorithm was formulated based on the clever strategy of CH selection. It was selected based on the residual energy of CHs and the intra cluster distance to form the clusters. A directed virtual backbone was constructed with the CHs to route the data to the sink node. Saleem et al [5] proposed an improved density controlled divide and rule scheme for energy efficient routing in WSN. This divide and rule strategy splits the entire network into small portions with the stable CHs. CH was selected based on the maximum residual energy. Latif et al [6] discussed about the divide and rule approach. This approach selects the definite amount of CHs for each round instead of the probabilistic CHselection.

Hao et al [7] presented an energy efficient clustering algorithm for data gathering in WSN. The spatial correlation of nodes was exploited to build the cluster of nodes sensing similar values. Yanwei et al [8] proposed an energy efficient wake up scheduling for data collection and aggregation. Here, TDMA was used as the MAC layer protocol and sensor nodes was scheduled with the consecutive time slots at diverse radio states while minimizing the number of state transitions. Kannan and Sree[9] formulated an energy efficient distributed CH scheduling approach for two tired WSN. Here, the network was divided into primary and secondary tiers depends on the received signal strength indication among the nodes to the base station. This method applied for two tier architecture and provides suggestions to choose the CHs and gateway nodes for primary and secondary tiers. It satisfies an ideal dissemination of the CH among the sensors and eliminates the frequent CH selection. Shrivastava and Pokle[10] introduced an energy efficient scheduling strategy for data collection in WSN. Two major aspects were considered. One of the formation of data gathering tree and the other is the energy efficient scheduling. Scheduling approach uses the TDMA and programs the activities of the sensor nodes into different groups with successive time slots. Hence the energy consumption and the state transition werereduced.

Lee and Ju Jang [11] designed an Ant Colony Optimization (ACO) based scheduling algorithm for energy efficient coverage. This algorithm was a simplified version of the existing ACO algorithm, which was optimized to solve the energy coverage problem. Also, the probability sensor detection approach was used to a heterogeneous sensor set to solve the coverage problem. Zhang et al [12] proposed a routing and connectivity availability metric of low duty cycle random sleep scheduled multi hop WSN. A continuous time markov chains connectivity availability model was proposed to validate the end to end packet delivery ratio of multi hop networks with respect to the impact of random sleep latency and frequent disconnection. The key metric was used for route path selection to attain stable and high performance. Bagaa et al [13] formulated an intertwined path formation and MAC scheduling for fast delivery of aggregated data in WSN. For each node, a parent node can be chosen from the scheduled nodes. Hence, the time delay was reduced and the cycles were prevented. Parent selection criteria was applied to maximize the time slots.

Alkhdour et al [14] discussed an optimal energy efficient and minimum delay scheduling for periodic WSN applications. This method examines an optimal cross layer routing and scheduling challenges for WSN with periodic data gathering. This problem was constructed as an integer linear program model such that routing and scheduling was designed to improve the network lifetime and to reduce the delay. In [15], the author proposed an optimal cross layer scheduling for periodic WSN applications. The aim of this approach to build an energy efficient joint routing tree and TDMA scheduling which considers the energy efficient distributed schedule based protocol. Karahan et al [16] investigated an effects of transmit based and receive based slot allocation strategies on energy efficiency in WSN MACs. The energy efficiency can be improved by including an appropriate MAC. It reduces the packet collisions and eliminate overhearing. Chen et al [17] presented a chain type WSN node scheduling strategy. A node dormant scheduling mode was analyzed from geographic coverage and three neighboring nodes scheduling policy was proposed. A hybrid coverage scheduling algorithm and dead areas were introduced.

Yaxiong et al [18] proposed a virtual backbone scheduling to maximize the lifetime of WSN. The rotation on multiple backbones balances the energy consumption among the nodes. Tang et al [19] proposed an energy efficient predictive wakeup MAC protocol for WSN. It minimizes the energy consumption by enabling the nodes to predict the receiver wakeup times to permit accurate predictions. It uses an on demand prediction error correction mechanism to address the timing challenges such as operating system delays and clock drift. This method introduces a prediction based retransmission approach to attain the high energy efficiency when the collision occurs. In [20], the authors proposed a dynamic multichannel energy efficient MAC protocol for WSN. It enhances the channel utilization and data transmission efficiency while resisting the wireless jamming and interference. Incel et al [21] discussed about a multi- channel MAC protocol for WSN. The objective of this method is to maximize the throughput by coordinating the transmission through multiple channels. Time was sequenced into time slots and each node was assigned to control over the time slot to transfer the message on particularchannel.

## III. ENERGY EFFICIENT SLEEP SCHEDULING PROTOCOL

In this section, an energy efficient sleep scheduling protocol is introduced. Nowadays, the time slot allocation algorithms for improving the node energy consumption in time based sleep scheduling protocol is crucial. As the energy consumption among the sensor nodes estimates the lifetime of the network. Hence, it is essential to identify the best slot allocation to apply for data transmission. The proposed method uses the sleep scheduling algorithm to transfer the packets within the time slots of the sensor nodes.

### *A.* E-LEACH based ClusterFormation

The proposed method uses the Energy based Low Energy Adaptive Clustering Hierarchy (E-LEACH) protocol to cluster the sensor nodes into groups. The proposed E-LEACH protocol arranges the sensors into small clusters. Here, Cluster Heads (CHs) are selected based on the highest residual energy among the sensor nodes. The nodes are senses its target and forwards the appropriate information to its CHs. The role of the CHs are to aggregates and compresses the data received from all the sensors and forwards to the base station. E-LEACH uses the random rotation of the sensors need to be the CHs to evenly allocate energy consumption in the network. The operations of E-LEACH can be divided into two phase:

1. Setup phase
2. Steadyphase

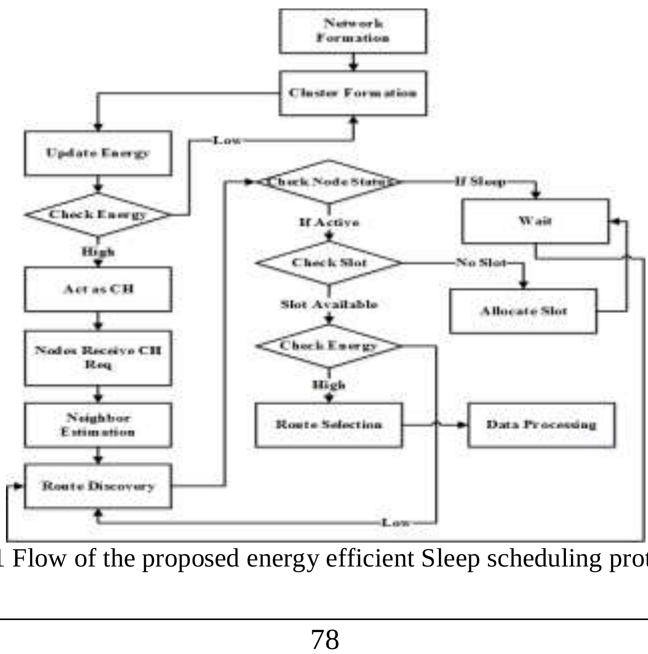


Fig.1 Flow of the proposed energy efficient Sleep scheduling protocol

During the setup phase, a scheduled fraction of nodes, m, choose themselves as CHs. This is made according to a threshold value T(n). The threshold value based on the desired percentage to become a CH m, the present round r, and the set of nodes that have not become the CH in the last 1/m rounds, which is denoted by H.

T(n)=m/(1-m(r*mod1/m))∀n∈H (1)

Every node want to be CH selects a value from 0 and 1. If this random number is smaller than the threshold value T (n) then the node become the CH for the present round. The selected CH are broadcast an announcement message to the other nodes in the network to call the nodes to join their clusters. Based upon the strength of an announcement signal, the sensors decide to join the clusters. After getting the announcement message, based on the number of nodes under their cluster and the type of information requisite by the system, the CHs establishes the sleep schedule and allocates each node a time slot in which it forward the sensed data. If the size of cluster is large, then the CH select another CH for thecluster.

During the steady phase, the sensor nodes starts sensing data and sends it to their CH according to the sleep schedule. The CH node, after receiving data from all the member nodes, aggregates it and then sends it to the base-station. After a time slot, which is determined a priori, the network again goes back into the setup phase and new CHs are selected. Each cluster communicates using different timeslots in order to minimize interference from sensors belonging to other clusters.

*B.* Sleep Scheduling Protocol

Each sensor node wakes up for the periodoflength $\tau_{wake}$ and switch into the sleep state of length $\tau_{sleep}$. Let us consider thatthewakeupeventusesthePoissonprocesswithrater.AccordingtothedefinitionofPoissonprocess, $\tau_{sleep}$ isan exponentially random function with mean 1/r. The Poisson scheduling is used due its memory less property that makes the computations tractable. There are two important factors raised in scheduling overhead.

1. Ep – It is the energy consumption to probe periods before transferringdata.
2. Ewake – It is the energy consumption taken for wakeperiods.

Suppose there are N sensor nodes in the sensor network, then the average hop count to the destination is H. Hence, the number of sensor nodes transferring data per time unit is $\delta$. The objective function is,

$$Minimize\ \delta.H.E_p + (N - \delta.H).E_{wake} \quad (2)$$

(3)
$$E_p = E[n_p].(T_b.e_{tx} + T_s.e_{idle}) + T_s.e_{rx}$$

Assume that the sender broadcasts a beacon at time t. As the length of the wakeperiod is $\tau_{wake}$, the receivers wake up fromt - $\tau_{wake}$ and t can get the probing beacon. The wake up actions follow the Poisson process with rater.

$$E[n_p] = \sum_{i=1}^{\infty} i.(1-m)^{i-1}.m \quad (4)$$

The energy conservation for wake periods can be expressed in the following equation which incorporates the energy cost for beacon reception, wake periods and ack transmission.

$$E_{wake} = E[n_p].\tau_{wake}.\frac{\tau_{wake}.e_{idle}}{\frac{1}{\lambda}+\tau_{wake}} + \gamma.(T_b.e_{rx} + T_a.e_{tx} + T_s.e_{idle})$$

(5)

| **Symbols** | **Descriptions** |
|---|---|
| $E_p$ | Energy consumption for probing periods |
| $E_{wake}$ | Energy consumption for wake periods |
| $E[n_p]$ | Expected number of probing periods before data transmission |
| $T_b$ and $T_s$ | Time units to transmit a beacon to wait for acknowledgement |
| $e_{tx}$ | Energy consumption for transmission |
| $e_{rx}$ | Energy consumption for reception |
| $e_{idle}$ | Energy consumption for idle state per time unit |

**Table 1** List of Notations used in Sleep Scheduling

*C.* Time Slot Selection

The sleep scheduling algorithm allows the sensor nodes to select a timeslot, such that it does not restrict the communication among the sensor nodes in the network. Each sensor node gets periodically updates in a time interval called timeslot. During the allowed timeslot, the sensor transmits its data. Timeslots are usually structured into frames. If there is no conflict in the channel, the sensor node uses the same timeslot in the next frames. Each frame is composed of a fixed number of timeslots. Due to the multi-hop fashion in WSN, the reuse of timeslots is possible.

Selection of timeslot is designed as follows:

- All the sensor nodes maintain a bit vector termed as occupied slots vector with the size equal to the number of timeslots. It is used for information storage regarding the slots occupied by the neighbors and the vector is communicated during the timeslot to share the information for possiblereceivers.
- Initially, it is occupied with '0', It refers that all the slots arefree
- When a data packet is received during the timeslot, then the node appends '1' in the vector at the particular position of thetimeslot.

The total number of timeslots per frame are defined based on the network topology. Suppose, the number of timeslots is greater than it is required, then the bandwidth and energy among the sensors gets wasted during the empty slots. If there are not enough slots, then the node remains in initialization state. It periodically monitors the frames for an unfilled slots.

*D.* Route Selection and DataProcessing

By using the sleep scheduling, the time slots are allocated. The topology information of the network is sensed with the exchange of the beacon messages. The energy among the sensor nodes are updated and the highest residual energy sensors are selected to forward the packets from the sources to the CHs. The CHs collects and forward the packets to the base station.

## IV. PERFORMANCEANALYSIS

This section describes about the simulation results of the proposed EE-SS protocol with the existing LEACH and CL-LEACH protocols. The simulations are performed under various performance metrics and the results are compared with the existing protocols.

*A.* CHProcessing

If the network has more number of CHs, then the control overhead is also substantially increased. The proposed method uses less number of CHs than the existing protocols. Hence, the energy consumption is also reduced. Fig.2 shows the CH processing for the proposed method and the existing LEACH and CL-LEACH protocols.

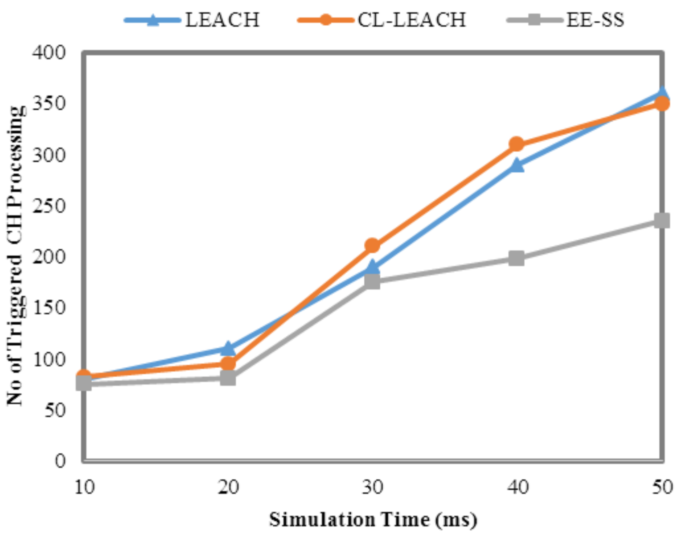


**Fig.2** No of triggered CH processing for proposed EE-SS with the existing LEACH and CL-LEACH protocols

*B.* Message CostAnalysis

As the proposed method uses the less number of control messages, the cost for data transmission is also reduced. Fig.3 shows the message cost analysis for the proposed EE-SS and the existing protocols. The results shows the proposed method yields lesser message cost than the existing protocols.

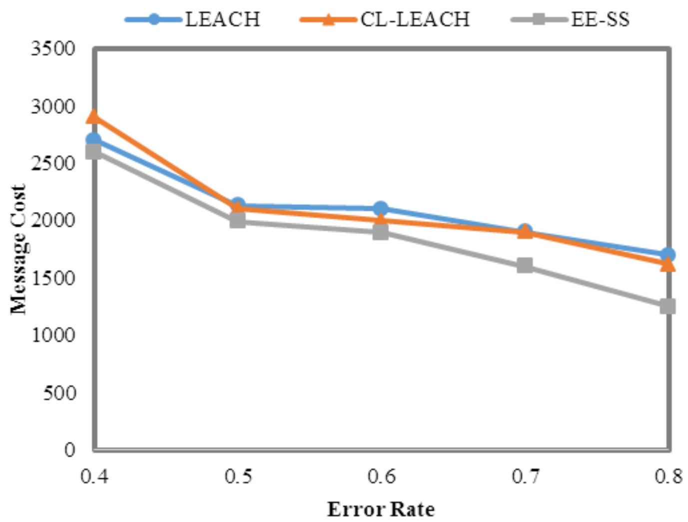


**Fig.3** Message cost for proposed EE-SS with the existing LEACH and CL-LEACH protocols

*C.* EnergyConsumption

The total energy consumption includes the energy consumption in transmission, reception, idle and sleep states of operation. In the simulation energy consumption at idle mode is ignored and it is noticed that transmission consumes greater energy than reception for transferring data packets while estimating the total energy consumption in our simulation. During sleep time, there is no energy consumption. Fig.4 shows the energy consumption for the proposed and the existing protocols for the simulation time up to 50ms. Fig.5 shows the residual energy after the data gathering in the network. The proposed method remains higher energy after the data transmission. The existing LEACH and CL-LEACH utilizes higher energy to collect the data from sources to base station.

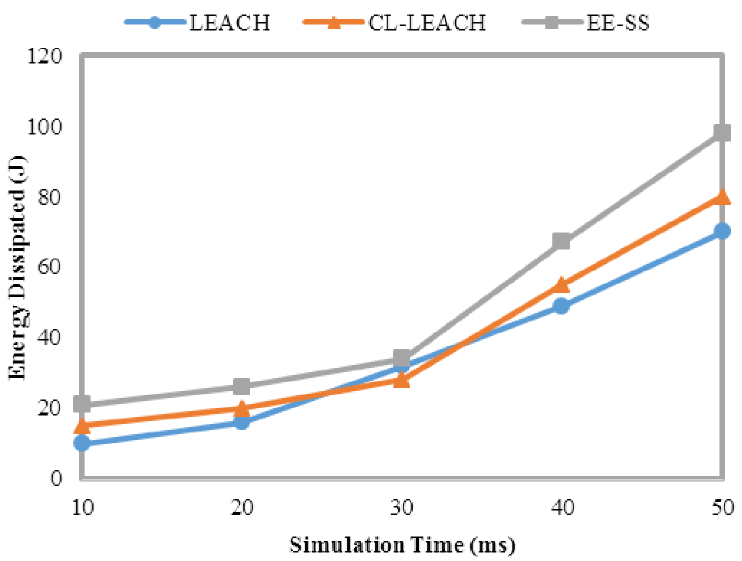


**Fig.4** Energy Dissipation for proposed EE-SS with the existing LEACH and CL-LEACH protocols

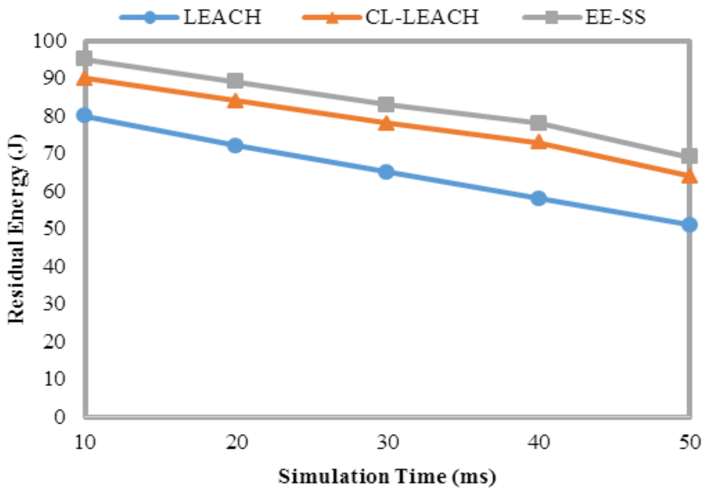


**Fig.5** Residual Energy for proposed EE-SS with the existing LEACH and CL-LEACH protocols

*D.* Average Error for DataProcessing

A source that does not receive a reply from its destination can guess that packets are being dropped. An intermediate node that forwards a packet to the next node on the path but does not receive a reply within a timeout period guesses that its neighbor is dropping packets. The rate of error occurred during data gathering is depicted in fig.6. The proposed method results lesser error rate at the time of data transmission from sources to base station. Lesser drop rate helps to improve the packet delivery ratio.

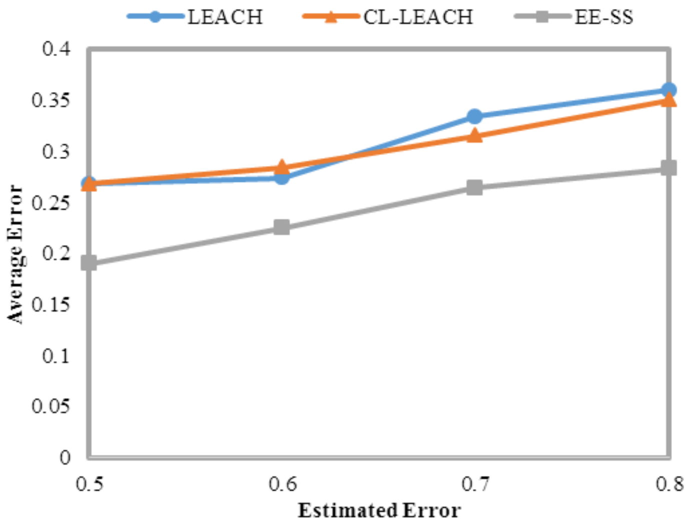


**Fig.6** Average Error for proposed EE-SS with the existing LEACH and CL-LEACH protocols

*E.* NetworkLifetime

It is the amount of time that a sensor network is fully operative. When a network should be considered nonfunctional is, though, application-specific. For instance, when the first sensor expires, a percentage of sensors expire, the network partitions or the loss of coverage happens. Fig.7 shows the average network lifetime for the proposed method and the existing protocols. There 50 iterations are used to estimate the network lifetime. As the proposed method incorporates the sleep scheduling strategy, the method results higher network lifetime than the existingprotocols.

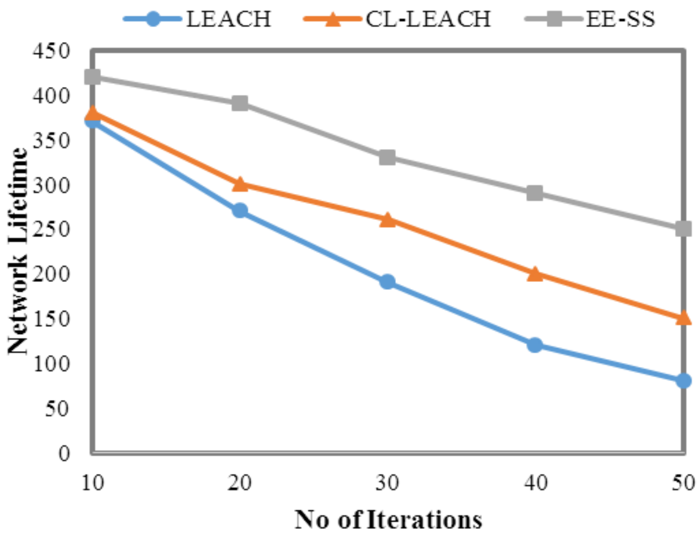


**Fig.7** Network lifetime for proposed EE-SS with the existing LEACH and CL-LEACH protocols

## V. CONCLUSION

This paper proposes an energy efficient sleep scheduling protocol for data aggregation in WSN. The proposed utilizes the properties of energy efficient LEACH protocol to cluster the sensor nodes. To improve the network lifetime, the proposed method selects the CHs based on the highest residual energy among the nodes. Sleep scheduling is introduced to allocate the slots for data transmission. The forwarding nodes from the source to CHs are selected based on the residual energy, which significantly improves the network performance. To show the efficiency of the proposed protocol, we compare the results with the standard LEACH and CL-LEACH protocols. The results shows that the proposed method results improved network lifetime than the existingprotocols.

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