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Leach Protocol with Energy Efficient Packet Transfer in Wireless Sensor Networks

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ABSTRACT

A wireless sensor network (WSN) consists of a huge number of sensor nodes that are inadequate in energy, storage and processing power. One of the major tasks of the sensor nodes is the collection of data and forwarding the gathered data to the Base Station (BS). Hence, the network lifetime becomes the major criteria for effective design of the data gathering schemes in WSN. In this paper, an Energy Efficient LEACH (EE-LEACH) Protocol for data gathering is introduced. It offers an energy efficient routing in WSN based on the effective data ensemble and optimal clustering. In this system, a cluster head is elected for each cluster to minimize the energy dissipation of the sensor nodes and to optimize the resource utilization. The energy efficient routing can be obtained by nodes which have the maximum residual energy. Hence, the highest residual energy nodes are selected to forward the data to BS. It helps to provide better packet delivery ratio with lesser energy utilization. The experimental results shows that the proposed EE-LEACH yields better performance than the existing Energy-Balanced Routing Protocol(EBRP) and Low Energy Adaptive Clustering Hierarchy(LEACH) Protocol in terms of better packet delivery ratio, lesser end-to-end delay and energy consumption. It is obviously proves that the proposed EE-LEACH can improve the network lifetime.

Keywords : Clustering ; Cluster head; Energy-efficient routing; Low energy adaptive clustering hierarchy (LEACH); Wireless sensor networks.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of a large number of small-sensor nodes used to monitor areas, collect and report data to the BS. Due to the accomplishment in low-power digital circuit and wireless transmission, most of the applications of WSN are implemented and used in military applications, object tracking, habitat monitoring. A typical WSN is composed of a huge number of sensor nodes, which are randomly disseminated over the network. The signals are picked by all types of sensors and the data acquiring unit, processing and transmitting them into a node called sink node. The sink node requests for the sensor information by forwarding a query throughout the network. When the node discovers the data matching the query, the response message is routed back to the sink node. The energy conservation of the network can be minimized by allowing the porting of the nodes called cluster heads. The data gathered from the nodes are aggregated and compressed by the cluster heads. After that, the aggregated data is forwarded to the BS, but it has some problems. The major problem is energy consumption and it is concentrated on the cluster heads. In order to resolve this issue, the cluster routing is used to distribute the energy consumption with the cluster heads. Data gathering is an efficient method for conserving energy in sensor networks. The major purpose of data gathering is to remove the redundant data and save transmission energy. A data-gathering algorithm includes some aggregation methods to minimize the data traffic. It reduces the number of message exchange among the nodes and BS. The performance of data gathering in WSN can be characterized based on the rate at which the sensing information can be gathered and transmitted to the BS (or sink node).In particular, the speculative measure to capture the demerits of collection processing in WSN is the capacity for many-to-one data collection. Data-gathering capacity reflects how efficient the sink can gather sensing data from all sensors under the presence of interference. Performing the data-gathering function over CH still causes significant energy wastage. In case of homogenous sensor networks, CH will soon die and re-clustering needs to be initiated. It causes higher energy consumption.EE-LEACH Protocol is introduced. The proposed method focuses on defining an energy-efficient routing based on Low Energy Adaptive Clustering Hierarchy (LEACH) clustering and optimal Cluster Head (CH) selection. The EE-LEACH model is incorporated for the node deployment. The data are forwarded from the different sources to the BS based on the energy-efficient routing strategy.

II. METHODS AND MATERIAL

2. Related Work

Many research activities have been carried out on the area of energy-efficient data gathering in WSN, since the basic task of the WSN is to effectively collect the data with lesser resource consumption. Most of the data-gathering algorithms are aimed to minimize the energy consumption problem. LEACH is a hierarchical protocol, in which the node details are handled by CHs. The CHs gather the data and compress them and forward to the base station (sink). The structure of the proposed LEACH Protocol is shown in Figure 1.

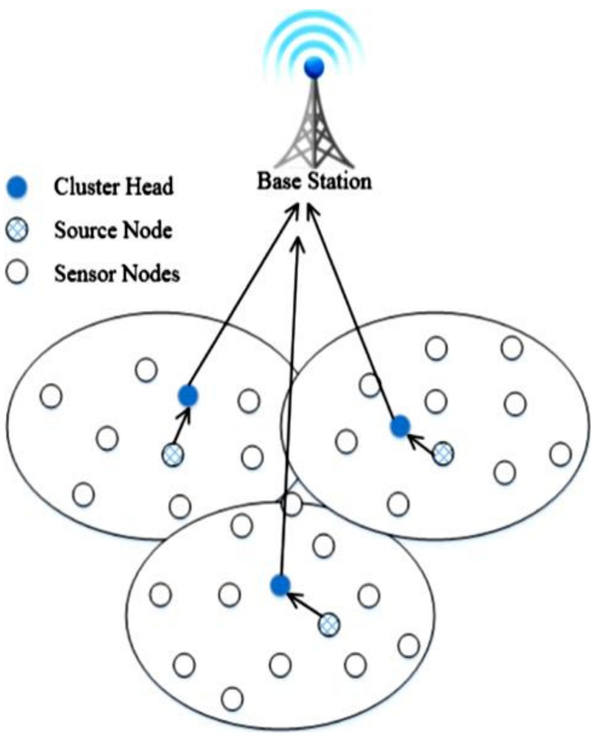

Figure 1. Structure of LEACH Protocol

The drawbacks of this protocol are as follows:

- A sensor node is selected as the CH-using distributed probabilistic approach, whereas the non-cluster nodes calculate which cluster to join based on the signal strength. This approach assures lower message overhead, but cannot assure that CHs are uniformly distributed over the network. The entire network is divided into clusters and load imbalance among the CHs may lead to minimum network lifetime.
- It is assumed that all nodes are isomorphic and all nodes have similar amount of energy capacity in each election round. Such a supposition is impractical in most application circumstances. Hence, LEACH should be enhanced to report for node heterogeneity.
- LEACH involves source nodes to send data to CHs directly. However, if the CH is extremely far away from the source nodes, they might expend excessive energy in data transmission. Further, LEACH requires CHs to transfer their aggregated data to the sink node over a single-hop link. Nevertheless, single-hop transmission may be quite costly when the sink appears far away from the CHs.
- LEACH also holds an assumption that all sensor nodes have sufficient power to reach the sink node if necessary, which might be resistant for energy-constrained sensor nodes.

3. Literature Survey

Bista, R.; Yong-ki Kim; and Jae-Woo Chang [4] A WSN is self-possessed of a large amount of sensor nodes, which are resource constraints, like limited power. This drives research on how to design routing protocols to get together data efficiently so that the life of the network can be expanded. A usual concept to collect data by a sink node is to transmit data from sensor nodes to the sink node by multi-hop. It raised two problems first is the hotspot difficulty, in which the sensor nodes closer to the sink run out of energy nearer than other nodes. As the result, the network lost its service ability, despite of a large amount of residual energy of the other nodes. The next one is that the system generates needless traffic during data transmission for choosing a proper data-sending path. To resolves the problems, authors, propose a new energy balanced and efficient data aggregation scheme for WSNs, called Designated Path (DP) scheme.

Yanwei Wu; Xiang-yang Li; Mo Li; and Wei Lou[8] A sensor in WSN periodically produces data as it monitors its area. The fundamental operation in such a network is the systematic gathering (with or without in-network aggregation) and transmitting of sensed data to a base station for further processing. A key major challenge in WSNs is to schedule nodes activities to reduce energy consumption. This research work focused on designing energy-efficient protocols for low-data-rate WSNs, where sensors consume various energy in various radio states (receiving, transmitting, sleeping, listening, and keep idle) and consume energy for state transition. With the use of TDMA as the MAC layer protocol and schedule the sensor nodes with consecutive time slots at various radio states while reducing the number of state transitions.

Arabi, Z[9] Data dissemination is an significant task performed by WSNs. The algorithms of this system depend on a number of factors such as application areas, practice condition, power, and aggregation factors. With respect to these parameters, various algorithms are recommended. An algorithm for hybrid energy efficient routing in WSN, which used two algorithms, i.e. EF-Tree (Earliest-First Tree) and SID (Source-Initiated Dissemination) to disseminate data, and employs a fuzzy method to choose group head, and to toggle between two methods, SID and EF-Tree.

Katiyar, V.; Chand, N.; Gautam, G.C.; and Kumar [6] The LEACH protocol is a hierarchical clustering protocol that provides an elegant solution for such protocols. One deficit that affects the presentation of the procedure is endurance of very large and very small clusters in the network at the similar time. This leads to reduce in life span of WSNs. This research work focused to analyze a new energy proficient clustering protocol (FZ-LEACH) that eliminates the above problem by forming Far-Zone. It is a group of sensor nodes, which are placed at locations where their energies are less than a threshold. The results and study show that planned FZ-LEACH algorithm outperforms LEACH in terms of energy consumption and network existence.

Chand, K. K.; Bharati, P.V.; and Ramanjaneyulu, B.S [5] A new routing protocol named Optimized Energy Efficient Routing Protocol (OEERP) that improve the lifetime of WSN. It is a cluster based protocol in which the node that acts as cluster-head is changed in each time period. This way enhances the lifetime of the WSN for two reasons primarily. The first cause is the consistent battery drain of the nodes and the second reason is that no node depends on beacon- based transmissions for long time to reach the contact point. Data sensing and performing data aggregation are also carried out in such a way to reduce the number of transmitted messages to the entrance point. This procedure can be use for any sporadic monitoring application using WSN.

Tyagi, S.; Gupta, S.K.; Tanwar, S.; and Kumar, N[7] An Enhanced Heterogeneous LEACH (EHE-LEACH) Protocol for Lifetime Enhancement of Sensor Networks. A preset distance based threshold is used for the bifurcation of direct communication and cluster based communication in the planned scheme. WSNs near to the BS be in touch straight and those which are distant from the Base use group based communication. To assess the act of the proposed system two key parameters known as: Half Nodes Alive (HNA) and Last Node Alive (LNA) are selected. By selecting the distance based threshold with the ratio of 1:9 between direct communication and cluster based communication it has been observed that EHE-LEACH has better network lifetime with respect to various parameters in comparison to the other well-known proposals such as LEACH and SEP.

4. Proposed Method - EE-LEACH: energy-efficient LEACH Protocol

EE-LEACH is mandatory for data gathering. All the sensor nodes have similar significance and equal capabilities. This motivates the need for improving the lifetime of the sensor nodes and sensor network. The objective of the proposed EE-LEACH Protocol is to reduce the energy consumption and increase the network longevity. Here, EE-LEACH is used for effective coverage of the sensing network area. Also, conditional probability theorem is used for node aggregation. The flow of the EE-LEACH Protocol is depicted in Figure 2.

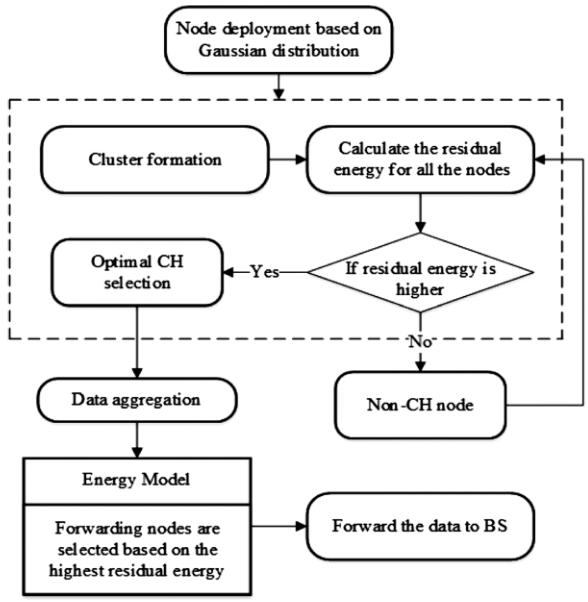

Figure 2. Flow of the EE-LEACH Protocol

4.1 Node deployment based on EE-LEACH

Random method:

In the random deployment, the nodes are randomly scattered with respect to the radial and angular directions from the BS. Sensors in the field have equal probability of being positioned independently of the other sensors. Though the sensor nodes are homogenous, they have some equal parameters like energy, bandwidth etc., but uneven distance among them creates problem. This introduces data latency and uneven energy dissipation throughout the network.

4.2 Optimal cluster formulation

Sensor nodes typically use irreplaceable power with the limited capacity, the node's capacity of computing, communicating, and storage is very limited, which requires WSN protocols need to conserve energy as the main objective of maximizing the network lifetime. An energy-efficient communication protocol LEACH, has been introduced which employs a hierarchical clustering done based on information received by the BS. The BS periodically changes both the cluster membership and the CH to conserve energy. The CH collects and aggregates information from sensors in its own cluster and passes on information to the BS. By rotating the cluster-head randomly, energy consumption is expected to be uniformly distributed. However, LEACH possibly chooses too many cluster heads at a time or randomly selects the cluster heads far away from the BS without considering nodes residual energy. As a result, some cluster heads drain their energy early thus reducing the lifespan of WSN. In each round of the cluster formation, network needs to follow the two steps to select cluster head and transfer the aggregated data. (i) Set-Up Phase, (ii) Steady-State Phase, which provides data transmission using Time Division Multiple Access (TDMA).

4.2.1 Cluster formation steps

- **Step 1: neighbor information retrieval**

The neighbor node information are sensed by broadcasting the beacon messages throughout the network.

- **Step 2: perform selection algorithm**

The selection algorithm is performed to retrieve the list of all neighbor nodes about its hop distance. All nodes in the network are arranged in decreasing order of residual energy. Initially all nodes in the network are unclustered.

- **Step 3: candidate for cluster**

When its two- hop neighbor node is not enclosed, analyze all the members of stage 2 one-by-one and crown any one two-hop neighbor for being as a candidate for the cluster.

- **Step 4: calculate the residual energy of neighbor nodes**

Finally, the selection algorithm is executed based on the residual energy of the neighbor nodes.

4.3 CH Selection

There are two steps of phases to perform cluster formation operation are setup phase and steady state phase.

4.3.1 Setup Phase

In the setup phase, every node decides to become a cluster head or not. In LEACH protocol, each node elects itself as a cluster head on the basis of the desired percentage of the cluster heads for the network and number of times a node has been a cluster head. Each node chooses a random number from zero to one and then calculates the threshold T(n). The node then compares the random number with T(n). If the random number is less than or equal to T(n), the node becomes a cluster head for the current round. The threshold for cluster head selection is calculated by using Equation.

$$T(n)=\begin{cases}\dfrac{P_d}{1-P_d*\left((r)\bmod\dfrac{1}{P_d}\right)} & \text{if } n\in A\\ 0 & \text{Otherwise}\end{cases}$$

Where P_d is the desired percentage of cluster heads, A is the group of nodes which are not selected as cluster heads in previous 1/p rounds and r is the current round. After several rounds, the energy of nodes in the network will become uneven, and nodes with high energy and low energy will have the same probability of becoming the cluster heads, so there will be an inappropriate cluster head selection. Unlike LEACH, our proposed protocol follows a different approach for cluster head selection. From each rectangular cluster, the node with the highest remaining energy will be selected as the cluster head. The current cluster head will decide the next cluster head for the next round in its cluster. All the nodes send their remaining energy information along with data packets to the cluster head. From this information, the current cluster head selects the node with the highest remaining energy as the cluster head for the next round.

4.3.2 Steady State Phase

After cluster heads selection and TDMA slots allocation, the steady state phase starts. The steady state phase of EE-LEACH is almost similar to LEACH. Based on TDMA protocol, the communication starts between the cluster head and their respective CHs in their allocated time slots. The cluster node can only communicate with its respective CH in a predefined time slot. All cluster nodes remain in sleep mode during unallocated time slots. This leads to better energy efficiency of the protocol.

4.3.3 Benefits for optimal CH selection

The selection of CH nodes in the sensor networks can provide the following three benefits:
Prolonging network lifetime - In the form of heterogeneous networks,

- The average energy utilization for transmitting the data from the sensor node to the BS will be much lesser than the energy utilized for homogenous networks.
- Improving reliability of data forwarding - It is generally known that the links tend to be low reliability. Each hop significantly minimizes the packet delivery rate. In heterogeneous nodes, there will be lesser hops between the nodes and the BS. Hence, the heterogeneous sensor networks can achieve a much better packet delivery ratio than the homogenous networks.
- Decreasing latency for data transmission - Computational heterogeneity can minimize the latency in immediate nodes. The heterogeneity among the links can minimize the waiting time in the forwarding queue. Choosing lesser hops among the nodes to BS will reduce the forwarding latency.

4.4 Data Aggregation based on data ensemble

Data aggregation is the process of collecting and aggregating the useful data. Data aggregation is considered as one of the fundamental processing procedures for saving the energy. In WSN data aggregation is an effective way to save the limited resources. The main goal of data aggregation algorithms is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. Data aggregation is a widely used technique in WSN. A cluster of nodes is replaced with a single node without changing the underlying joint deployment of the network. During node aggregation, the data ensemble process also takes place. It is essential to identify the macro node for data aggregation.
The procedure includes two steps:

- Path definition and
- Pair of combinable nodes.

The conditional probability is applied for the node aggregation process. The conditional probability of the macro node should be equal to the product of all the component nodes. Consider the following network in Figure 4.

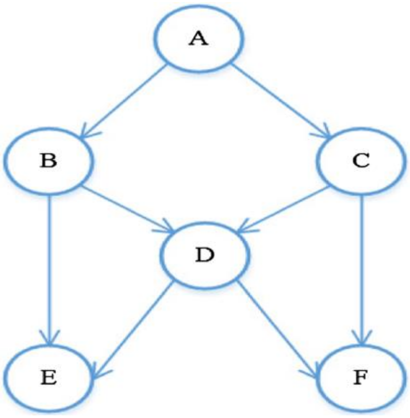

Figure 3. Network to compute the conditional probability.

If the nodes B, C, and D are combined into a macro node M, then the condition probability is given by:

$P_c(M|A)=P(B,C,D|A)=P(B|A)P(C|A)P(D|B,C)$

The conditional probability of a macro node's successor is equivalent to the conditional probability of the successor given all the component sensor nodes in the macro node, except the nodes that are not linked directly to the successor node. Here, E is the successor and the above statement is given as:

$P_c(E|M)=P(E|B,C,D)$

By aggregating the sensor nodes using the above equations, the data also gathered for transmission.

4.5 Energy-Efficient Data Routing

Energy Efficient Routing is a hierarchical cluster based protocol which achieves a good performance in terms of lifetime by minimizing energy consumption for in-network communication and balancing energy load among all nodes. After gathering the data from different clusters, the CHs need to forward the data to the BS. Hence, the forwarding nodes are selected based on the highest residual energy among the nodes. Residual energy is defined as the remaining power of a sensor node whenever topology changes, which can be an indicator of the stability of a link and the survival time of a node. The nodes which are having the highest energy are selected to forward the data to the BS. It helps to improve the packet delivery ratio from the packet loss.

III. RESULTS AND DISCUSSION

In this study, table 1 to 4 and figure 4 to 7 shows the result table and graph for average end to end delay, packet loss rate, number of nodes alive and remaining energy in joules respectively.

Table 1. Average End to End Delay

Number of nodes	Number of Sinks =3	Number of Sinks =5	Number of Sinks =7
75	0.001269	0.001334	0.001306
150	0.001376	0.001614	0.00138
225	0.013186	0.014906	0.01389
300	0.022284	0.018148	0.022215
375	0.046353	0.041454	0.047885
450	0.04891	0.044692	0.051963

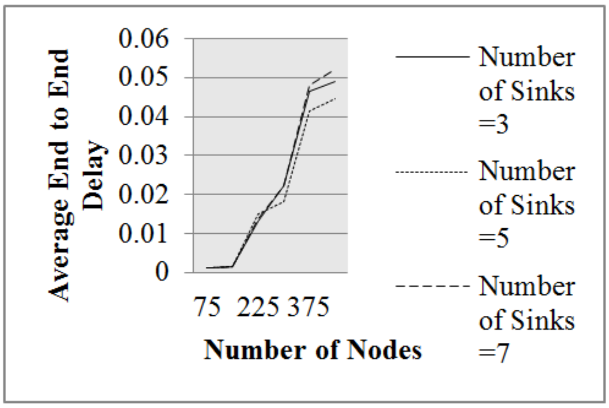

Figure 4. Average End to End Delay

From table 1 and figure 4 it is observed that the average end to end delay is measured with different number of sinks such 3, 5 and 7. Result show that the delay reduced for number of sinks=3 by 4.99% and 2.87% than number of sinks=5 and 7 respectively at node 75. Also at node 450, the delay reduced for number of sinks=5 by 9.01% and 15.05% than number of sinks=3 and 7 respectively.

Table 2. Average Packet Loss Rate %

Number of nodes	Number of Sinks =3	Number of Sinks =5	Number of Sinks =7
75	9.58	8.52	7.98
150	14.59	12.89	11.86
225	15.01	14.49	12.16

300	20.62	19.55	17.97
375	28.53	27.04	24.34
450	39.22	37.96	27.98

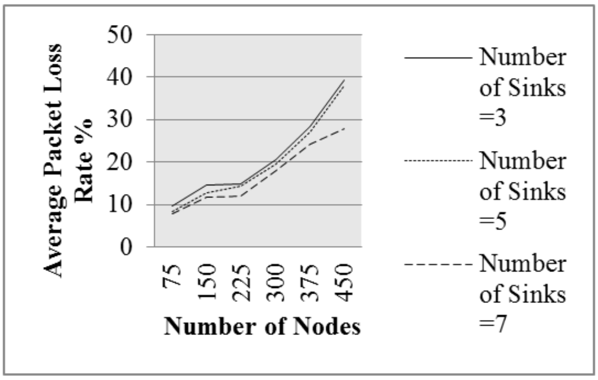

Figure 5. Average Packet Loss Rate %

From table 2 and figure 5 it is observed that the average packet loss rate is measured with different number of sinks such 3, 5 and 7. Result show that the packet loss rate reduced for number of sinks=7 by 18.22% and 6.54% than number of sinks=3 and 5 respectively at node 75. Similarly at node 450, the delay reduced for number of sinks=7 by 33.45% and 30.27% than number of sinks=3 and 5 respectively.

Table 3. Percentage of Nodes Alive

Number of rounds	Number of Sinks =3	Number of Sinks =5	Number of Sinks =7
0	100	100	100
100	100	100	100
200	91	93	99
300	70	86	95
400	74	78	82
500	23	55	66
600	3	19	22
700	0	0	4
800	0	0	0

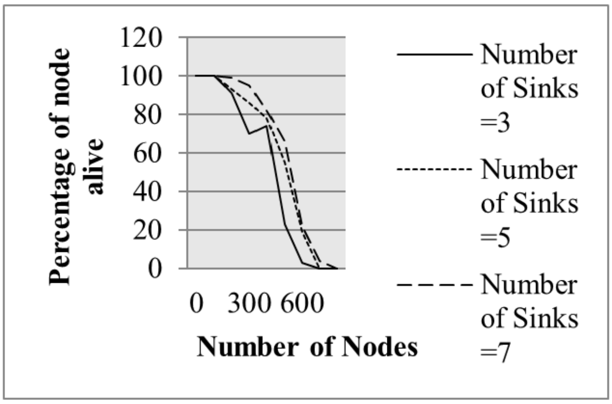

Figure 6. Percentage of Nodes Alive

From table 3 and figure 6 it is observed that the percentage of nodes alive is better for number of sinks=7 in the range of 0 to 200% than number of sinks=3 and 5.

Table 4. Remaining Energy in Joules

Number of rounds	Number of Sinks =3	Number of Sinks =5	Number of Sinks =7
0	0.5	0.5	0.5
100	0.46	0.51	0.48
200	0.26	0.36	0.39
300	0.2	0.32	0.36
400	0.21	0.3	0.34
500	0.12	0.19	0.29
600	0	0.11	0.25
700	0	0	0.11
800	0	0	0

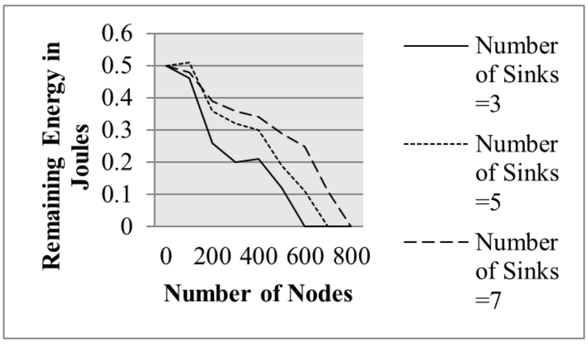

Figure 7. Remaining Energy in Joules

From table 4 and figure 7 it is observed that the remaining energy in joules is better for number of sinks=7 in the range of 0 to 200% than number of sinks=3 and 5.

IV. CONCLUSION

The EE-LEACH Protocol is presented to improve the lifetime of the sensor network. The coverage probability is derived with respect to the EE-LEACH. A selection algorithm based on the residual energy of the neighbor nodes is executed to obtain the list of neighbor nodes. Data ensemble also takes place while aggregating the nodes. Data ensemble can save considerable energy while the source nodes forming one cluster are deployed in a relatively small area when the sink node is far away from the source nodes. An election weight is determined by taking account of the concentration degree of SNs and their residual energy for optimal CH election. The EE-LEACH Protocol results in a better packet delivery ratio, lesser energy consumption and lesser E2E delay than the EBRP and LEACH Protocols. The experimental results shows that the proposed EE-LEACH yields better outcomes than the existing EBRP and LEACH Protocols. This paper only focuses on reducing the energy consumption. But it lacks to provide the confidentiality and integrity of data. We extend this work with the security concepts, which analyses the traffic flow among the sensor nodes. Hence, in the future, the proposed EE-LEACH Protocol is integrated with the security mechanisms to protect the network from security attacks.

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