A Protocol to Reduce Energy Consumption in Wireless Sensor Network

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Abstract - *In wireless sensor network, a large number of sensor nodes are distributed to cover a certain area. A clustering-based protocol adapts the use of energy by balancing all nodes to become a cluster head. In this paper, we concentrate on a recent hierarchical routing protocol depending on LEACH protocol to enhance its performance and increase the lifetime of wireless sensor network. The enhanced protocol called Huffman LEACH is proposed which improves the total network lifetime. Huffman LEACH algorithm depends on both path cost and number of links between nodes to select the cluster head of each cluster. The real weight of specific node to success is measured and represented as a cluster head. The proposed algorithm overcomes the random process selection, which leads to unexpected failure for some cluster heads and it gives good performance in the network lifetime and energy consumption when compared with previous version of LEACH protocols.*

Key Words: **Wireless sensor networks, Clusters, Cluster heads, Energy, LEACH, Huffman, Huffman-LEACH**

1. INTRODUCTION

Wireless sensor network is the collection of sensor nodes that are often randomly deployed in a targeted area over changing environments. These nodes sense, process, and forward data to neighbouring nodes and base station (BS). These devices have limited capabilities such as small memory, low computation, low processing and small power unit. Sensor node uses variable or fixed power for data transmission. As the distance between the source and destination nodes increase the required power also increases. Data aggregation is accomplished by collecting and aggregating data from set of nodes. As the sensed data has to be forwarded to BS for further necessary action, routing becomes important for transferring of data from node to node or BS efficiently. The collected data is combined into a single data packet to process further. The number of transmissions is minimized by eliminating data redundancy and thus reducing the total power consumption in the network. In WSN, the battery and other available resources, different hierarchical techniques have been proposed. The aim is to obtain energy efficiency and maximize network lifetime. In these techniques, nodes are clustered into groups, and by certain criteria a cluster head is selected that is responsible for routing. In hierarchical routing, one layer is used for sensing the physical environment and the other is used for routing. The low energy nodes are used for sensing and high energy nodes are often used for collecting, aggregating, and forwarding data. Clustering is the most widely used technique and clustering schemes by design to eliminate the redundant messages in formation of clusters. The main problem of clustering is non-uniform clustering which leads to high energy dissipation of node, total energy consumption increases and network connectivity not being guaranteed. Moreover, to make the network efficient topology construction is vital in distributing nodes uniformly in the clusters. Due to frequent topological changes in the network, maintaining routes is a main issue and if not carefully handled may result in high energy consumption. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is TDMA based MAC protocol. The goal of this protocol is to improve the lifespan of wireless sensor networks by reducing the energy consumption. The main focus is to compress the collected data, cluster formation, cluster head selection, cluster reformation and cluster head reselection taking into account the energy consumption and their impact on overall network lifetime.

2. LITERATURE REVIEW

In Wireless Sensor Network, most of the devices work on batteries. These nodes or devices have inadequate amount of initial energy which are consumed at different rates, based on the power level and intended receiver. In sleep scheduling algorithm most of the sensor nodes are turned to sleep state to preserve energy and increase the network lifetime. In this paper, an Energy Efficient Sleep Scheduling (EE-SS) protocol is proposed for Wireless sensor networks. Initially, the network is divided into small various clusters. The clusters nodes are managed by the Cluster Heads (CHs). The CHs are chosen based on the highest residual energy criteria. The sleep scheduling approach allocates the slots to forward data from the source to base station. The nodes with are having the highest residual energy are selected as the forwarding nodes. The performance of the proposed method is compared with the standard LEACH protocol and CH model in terms of all possible factors. The outcome proves that the proposed method results in higher network lifetime than the existing approaches [1]. Usage of energy is the most important factor. LEACH uses the higher energy nodes to process and send the data and lower energy nodes can be used for sensing. The main objective of data fusion is reducing the number of data elements to maximize the energy. Nearest Neighbour Algorithm transmits the data when a particular node is not available for transmission. When transmission takes place the cluster head needs to send the data once again to the destination to address this issue and keeps the data in the nearest nodes of destination node [2]. The LEACH operates consists in several rounds with two phases in each round. Working of LEACH begins with the formation of clusters based on the received signal strength. First phase of LEACH being Set-up phase which has three fundamental steps: Cluster Head advertisement, Cluster setup, Creation of Transmission Schedule. Second phase of LEACH is Steady phase which is comparatively longer in duration than the set-up deals with the aggregation of data at the cluster heads and transmission of aggregated data to the Base station [3]. Based on the various researches and analysis, data compression techniques are classified into two categories: a Distributed Data Compression approach and a Local Data Compression approach. Distributed approach is applied on networks containing large number of sensor nodes and these schemes exploit the spatial correlation among the sensor nodes. While Local approach perform data compression locally on each sensor node and these schemes usually exploit the temporal correlation among the sensor nodes and do not depend on the WSN's specific topology [4]. Elected cluster head creates a transmission schedule for the member nodes of their cluster. TDMA schedule is made according to the number of nodes in the cluster. Each node transmits its data only in the allocated time schedule. The sensors in each cluster communicate only with the cluster head via a single hop transmission. The cluster head then aggregates all the collected data and forwards the aggregated data to the base station either directly or via other cluster head along with the static route defined [5]. WSN has been presented in sophisticated framework to systematically explore the temporal correlation in environmental monitoring. The presented framework optimizes lossless data compression while communicating the given resource constraint of sensor nodes. The insights obtained from the framework can directly lead to innovative and better design of data gathering protocols for wireless sensor networks operated in noisy environments to dramatically reduce the energy consumptions [6]. The algorithm is developed for collaborative training networks of kernel-linear least-squares regression estimators. This algorithm is shown to solve a relaxation of the classical centralized least-squares regression problem. A statistical analysis shows that the generalization error afforded agents by the collaborative training algorithm can be bounded in terms of relationship between the network topology and representational capacity of relevant reproducing kernel Hilbert space. Numerical experiments suggest that the algorithm is effective in reducing noise. The algorithm is designed for the problem of distributed learning in wireless sensor networks by virtue of its exploitation of local communication. Several new questions for statistical learning theory are being proposed [7]. Power saving is a major critical issue in wireless sensor networks since sensor nodes are powered by batteries which cannot be generally charged or recharged. As radio communication is frequent the main cause of energy consumption, extension of sensor node lifetime is generally by reducing transmissions/receptions of data, for instance through data compression. This gives rise to a problem where the elements which come in the initial stages of tree formation having lesser probability hold smaller nodes. Exploiting the natural correlation that exists in data typically collected by WSNs and the principles of entropy compression, in this the proposed algorithm is simple and efficient data compression algorithm particularly suited to be used on available commercial nodes of a WSN [8]. Static Huffman coding suffers due to probabilities of the symbol in the compressed files. This will need more bits to encode the file. If data is unavailable, compressing the file requires two passes. FIRST PASS finds frequency of each symbol and constructs the Huffman tree. SECOND PASS is used mainly to compress the file. The code keeps changing so as to remain optimal for the current estimates. In Adaptive Huffman the decoder must be along with the encoder by continuously updating the Huffman tree so as to stay in synchronization with the encoder. The concept mainly includes about error correction and error detection. This thing is beneficial only in ternary tree [9]. The node gets selected as cluster head for the current round if the number is less than threshold. Once the node has severed the role of cluster head it cannot become cluster head again until all the nodes of the cluster have become cluster head once. This helps in decreasing the energy consumption. During the first step cluster head sends the advertisement packet to inform the cluster nodes that they have become a cluster head. In the second step, the other cluster head nodes receive the cluster head advertisement and then send join request to the cluster head informing that they are the members of the cluster under that cluster head. These non cluster head nodes saves a lot of energy by turning off their transmitter all the time and turn it ON only when they have something to transmit to cluster head [10].

3. METHODOLOGY

The proposed method uses the Huffman Energy based Low Energy Adaptive Clustering Hierarchy (Huffman LEACH) protocol in which sensor nodes are clustered into groups. Here, Cluster Heads (CHs) are selected based on the maximum residual energy among the sensor nodes. The data gathered by sensor nodes is transmitted along other nodes one by one, that will reach the sink node after a multi-hop routing and finally reach the base station, through the wireless network. The energy, the storage capacity and communication capability of nodes are limited. A compression algorithm can be evaluated in various ways. We could measure the complexity of the algorithm, the memory required to implement the algorithm, how fast the algorithm performs when implemented on a network, the amount of compression, and how closely the reconstruction resembles the original. A very logical way of measuring how well a compression algorithm compresses the gathered set of data is to look at the ratio of the number of bits required to represent the data before compression to the number of bits required to represent the data after compression which is called the compression ratio. Due to their energy constraints, wireless sensors usually have a limited transmitting range, so it makes multi hop data routing towards the cluster head more energy efficient than direct transmission. The design goal for wireless sensor networks is to use the energy efficiently. The idea of clustering is to use the data aggregation mechanism in the cluster head (CH) to reduce the amount of data transmission from source to destination thereby, reduce the energy dissipation in communication.

Equalizing the number of sensor nodes in each partition would help to distribute the load among sensor nodes and leads to proper utilization of the available power resources.

A set of cluster heads are assigned to each different partition in each level. These nodes are selected as intermediate nodes in the clusters formed. This step is essential in order to prolong the network life time of cluster heads since these nodes usually consume power more quickly compared to other nodes in the cluster. Moreover cluster heads need not send their data for long distances, as proposed in LEACH where each cluster head transmits data directly to the base station. The node senses its target and forwards the appropriate information to its CHs. The role of the CHs is to aggregate and compress the data received from all the sensors and forwards to the base station. E-LEACH uses the random rotations of the sensors needed to be the CHs to evenly allocate energy consumption in the network. The operations of E-LEACH are classified into two phases:

1. Setup phase

2. Steady phase

During the setup phase, a scheduled fraction of nodes m, are chosen as CHs. This is based according to a threshold value T (n). The threshold value is calculated 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.

$$T(n) = \frac{m}{1 - m\left(r * mod\frac{1}{m}\right)} \qquad \forall\, n \in H$$

Every node which qualifies to become a CH selects a value from 0 and 1. If this random number is smaller than the threshold value T (n) then the node becomes the CH for the current round. The selected CH broadcasts 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 sensor makes a decision of joining the clusters.

$$Ep = \sum_{i=1}^{\infty} i\,.\,(1-m)^{i-1}\,.\,m\,.\,E\left[n_p\right].\left(T_b\,.\,e_{tx} + T_s\,.\,e_{idle}\right) + T_s\,.\,e_{rx}$$

Table - 1: List of notations

Symbols	Descriptions
Ep	Energy consumption for probing periods
$E\left[n_p\right]$	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

3.1 FLOWCHART

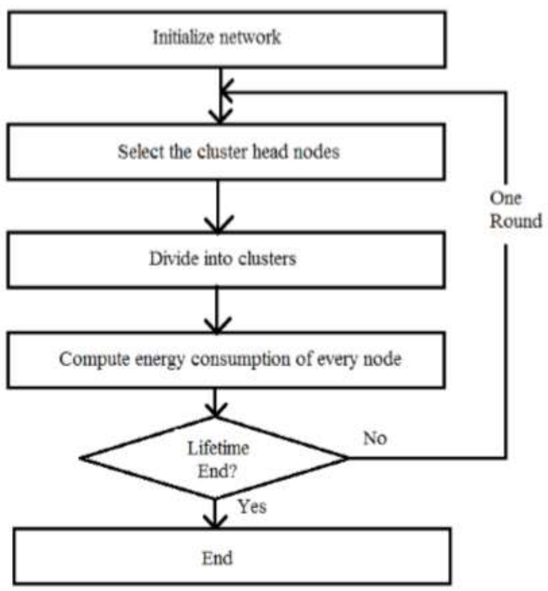

Fig - 1: Flow chart of cluster head formation

3.2 ALGORITHM

Step 1: Initializing the network (Node (N), Base station (BS), Location L(x,y), Energy(E),distance(d))

Ni=1 to 100

Ei=E1 to E100

Ni-send Ei information to BS

Ni-sends L(x,y) to BS

Step 2: Call for Huffman function

CH_sz: hfman(CH_sz)

BS_sz: hfman(BS_sz)

Step 3: Cluster head selection

for(i=0;i<=100;i++)

{

if(Ei=Emax & di=dmin)

then

Ni=Chi

}

end if

end for

Step 4: Giving and receving message internally

BS->CH to Ni

Ni->Back to BS

Step 5: Chain formation and selecting a leader

Leader - Chi(L(x,y) & Emax)

Path – CH1- CH2 -..... CHn _ BS

Step 6: Trasferring the data

Ni of respective CHi -> D(Ni) to Chi

Chi<- D(Ni)

CH1->CH2 ->..........CHn ->BS

Step 7: Change of cluster head

for(i=0;i<=100;i++)

{

if

Emax (Chi)<=Eeff

then

Ni(Emax2)=CHi

}

end if

end for

An algorithm for data establishment of modified compression in wireless sensor network the following Huffman algorithm is used.

3.3 HUFFMAN ALGORITHM

In the Huffman algorithm proposed, each sensor node measure m_i, the collected data is converted by an ADC to binary representation r_i using R bits, where R is the resolution of the ADC. For each new measure m_i, the compression algorithm calculates the difference $d_i = r_i - r_{i-1}$, which is input to an entropy encoder. The encoder performs compression lossless by encoding differences d_i more compactly based on statistical characteristics. Each d_i is represented as a bit sequence bs_i composed of two parts s_i and a_i, where s_i represents the number of bits required to represent d_i and a_i is the representation of d_i. Code s_i is a variable code length generated by using Huffman coding. The basic idea of Huffman coding is symbols which occur frequently have a smaller representation than those that occur rarely.

The procedure used to generate a_i makes sure that all the possible values have different codes. Once bs_i is generated, it is added to the bit stream which forms the compressed version of the sequence of measure m_i. <<s_i , a_i>> denotes the concatenation of s_i and a_i. Since transmission of a bit needs energy comparable to the execution of thousand instructions, just saving a single bit by compressing original data which corresponds to reduce power consumption. Using Huffman algorithm, we derived probabilities which dynamically change with the incoming data. Thus the Huffman algorithm provides effective compression by just transmitting the node position without transmitting the entire code.

4. RESULTS

LEACH divides the system operation into fixed intervals called rounds. A round is defined as the period from one instance of clustering phase till the next cluster head selection. It can be observed that LEACH produces an uneven distribution over cluster heads throughout the sensor field. In worst case scenario, it may result in cluster heads becoming concentrated in one part of the network.

The reason behind this is LEACH cluster heads selection mechanism does not guarantee that the location of cluster heads are optimized. All the cluster-heads can be located near the edges of the network or adjacent nodes can become cluster heads.

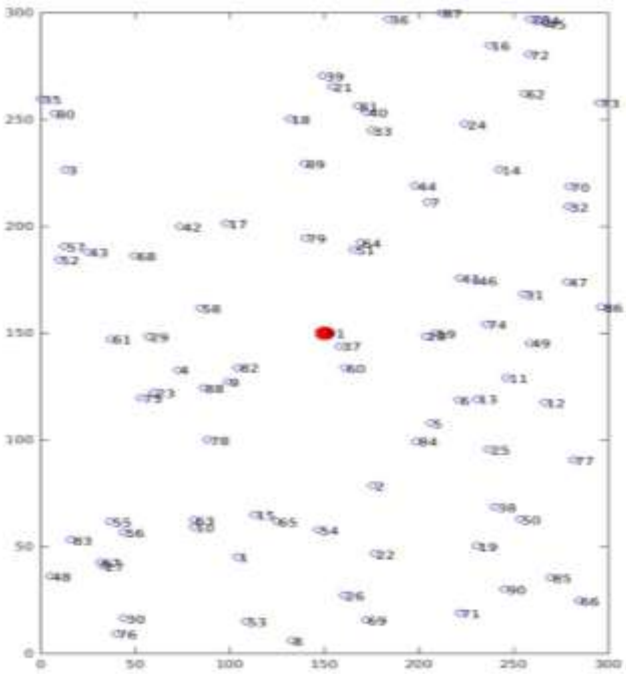

Chart - 1: Network Setup

Thus, there could be a number of nodes that are located far from the cluster heads, and as a result, these nodes will deplete their energy more rapidly as they need higher power to transmit successfully to their cluster heads. The normal position is the position in the network where the node has multiple neighbors. This kind of nodes may tend towards the cooperative behavior, to increase the amount of the important information collected in the network. Furthermore, as shown in Chart - 1, LEACH protocol does not guarantee that nodes are evenly distributed amongst the cluster head nodes. The number of member nodes in each cluster is highly variable in LEACH as seen.

From the comparative analysis of Chart - 2, we analyze that the number of live nodes is increasing in Huffman LEACH protocol than LEACH protocol. Energy efficiency is analyzed by computing the number of live nodes in the network by considering the number of rounds. The performance analysis using MATLAB shows that the number of live nodes is increasing in each round than in exiting algorithm. Thus the new protocol is suitable to save the energy of the network, increasing the number of live nodes and energy efficiency.

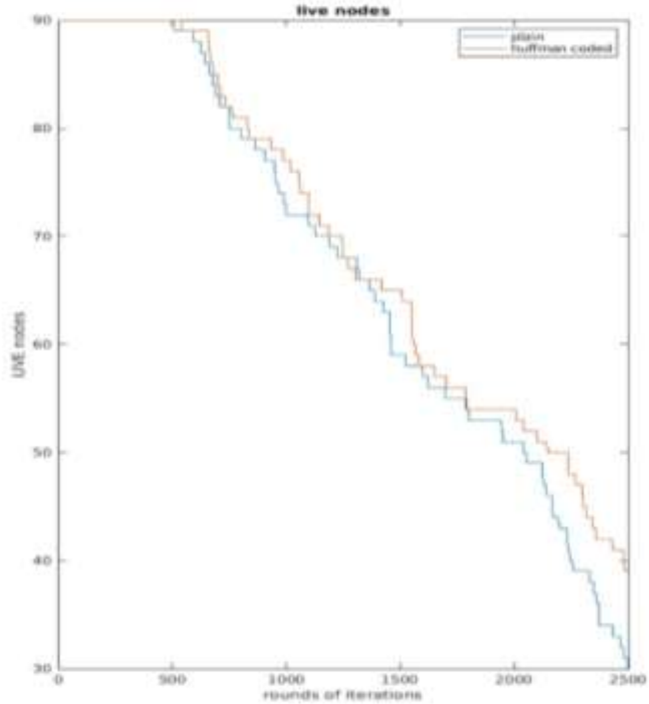

Chart - 2: Live nodes with increase in number of iterations

Chart - 3, shows the probability threshold, T (n) for the nodes to become cluster head in each round based on cluster head selection algorithm. The simulated results is based on P=0.05. The probability of each node to become a cluster head is 0.05 when the round is 0. As the number of round increases, the probability increases and becomes 1 at last round.

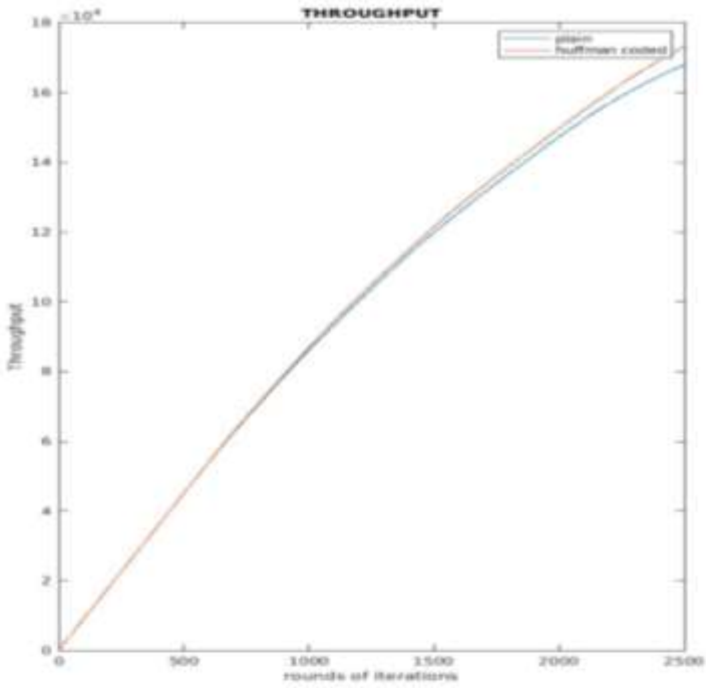

Chart - 3: Throughput

Simulation result shows significant improvement of throughput for all rounds in a network. It also saves a great amount of energy during data transmission phase for multiple periods.

Overall significant performance improvement is seen based on several factors such as enhancement in the network life time, energy efficiency and utilizing maximum energy of each individual network node; with the increase in rounds, the network throughput also increases.

The goal of the transceiver modeling and simulation is to allow accurate screening of different parameters that influence energy consumption in WSNs nodes. An accurate energy model enables precise performance measurements and more energy efficient protocols to be designed and examined. The power computation is performed to determine the power consumed from the energy source, LEACH protocol models the energy loss based on the distance. The algorithm depicts that, as the distance increases, energy consumption also increases exponentially and there are no maximum limits as shown in Chart - 4.

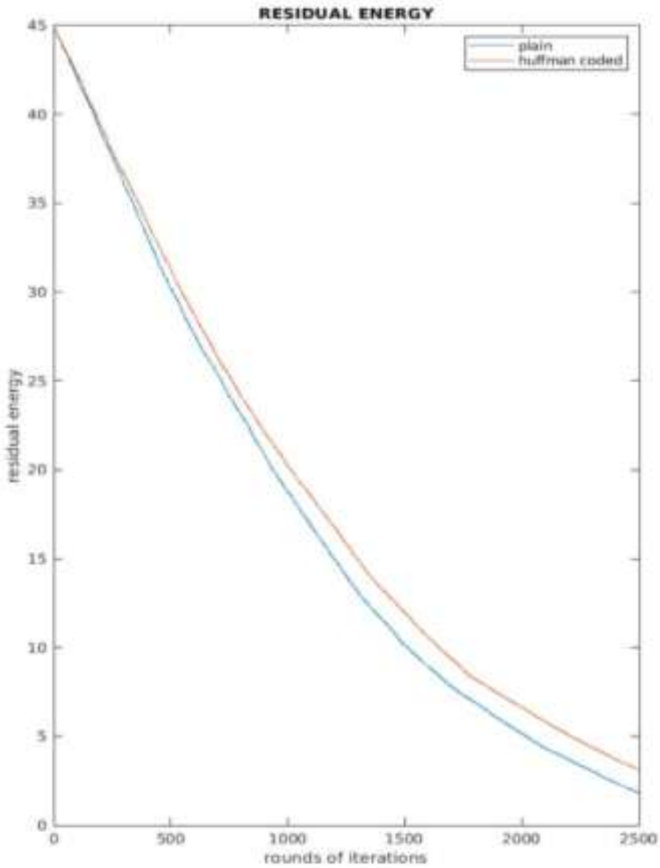

Chart - 4: Residual Energy

In a large scale sensor network with nodes that have limited energy sources, we expect CHs to consume more energy to communicate with other nodes. If required, they aggregate their own data together and send them to the BS or the next-step CH. Thus, a CH node consumes more energy than a non-CH node and is likely to run out of energy quicker than its member nodes. Therefore, the clustering process includes the periodical assignment of the CH role among nodes with the highest residual energy. So, a criterion for a node with highest residual energy to obtain more score than other nodes is to be qualified as the next cluster head. When the data is compressed using Huffman LEACH algorithm and then fed as input to the transceiver we can see that there is less energy consumed as compared to LEACH algorithm.

The below Table - 2 is comparison of amount of residual energy in LEACH and amount of residual energy in Huffman - LEACH per round.

Table 2: Comparison of Residual Energy

No. Of Rounds	Residual Energy in Leach	Residual Energy in Huffman - LEACH
0	3.3380	3.7253
1	1.9940	2.3303
2	0.6980	1.4444
3	0.1600	0.9764
4	0.0700	0.7408
5	0	0.5664
6	0	0.3919
7	0	0.0690
8	0	0
9	0	0
10	0	0

5. CONCLUSION

In the Huffman LEACH model, energy consumption increases exponentially with distance and there are no maximum limits. In reality, the transmit power level of a sensor node can only be adjusted to discrete values that may result in one transmit power level for various distances. The resulting energy consumption for two links of different distances can be equivalent. The number of clusters generated in LEACH does not converge to a fixed value which shortens the lifespan of the network. In some cases, LEACH cluster head selection algorithm produces uneven distribution of clusters within the network area. All cluster heads can be located near the edges of the network or adjacent nodes can be elected as cluster heads. The energy consumption of the wireless sensor network is inversely proportional to the lifetime of the wireless sensor network. Reasonably deploying the wireless sensor nodes can improve the coverage effect of the wireless sensor network and reduce the movement of the wireless sensor nodes. We assume that the network life time is defined as the time from the deployment of the WSN till the first gateway dies. Therefore, network lifetime can be maximized by using the parameter discussed in this paper.

If we can minimize the energy consumption of the CH nodes then energy consumption of the sensor nodes can be minimized if we can minimize their relative distance from their corresponding CH's. Therefore, the nodes that have to transmit data to cluster heads at shorter time intervals decrease their energy faster than the nodes with lower data transmission rate.

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