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Huffman coding: Energy efficient algorithm in wireless networks

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***Abstract*---**In the proposed Huffman LEACH model, energy consumption increases exponentially with distance and there are no maximum limits. 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. The energy consumption of the wireless sensor network is inversely proportional to the lifetime of the wireless sensor network. Here, we assume that the network lifetime is defined as the time from the deployment of the WSN till the first gateway dies. Hence, 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. The experimental result of proposed model says better with its energy faster than the nodes with lower data transmission rate when compared with the existing WSN models.

***Keywords*---**huffman coding, algorithm, wireless networks.

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 neighboring 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 must 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, to efficiently utilize the battery and other available resources, different hierarchical techniques have been proposed. The aim is to obtain energy efficiency and maximize network lifetime.

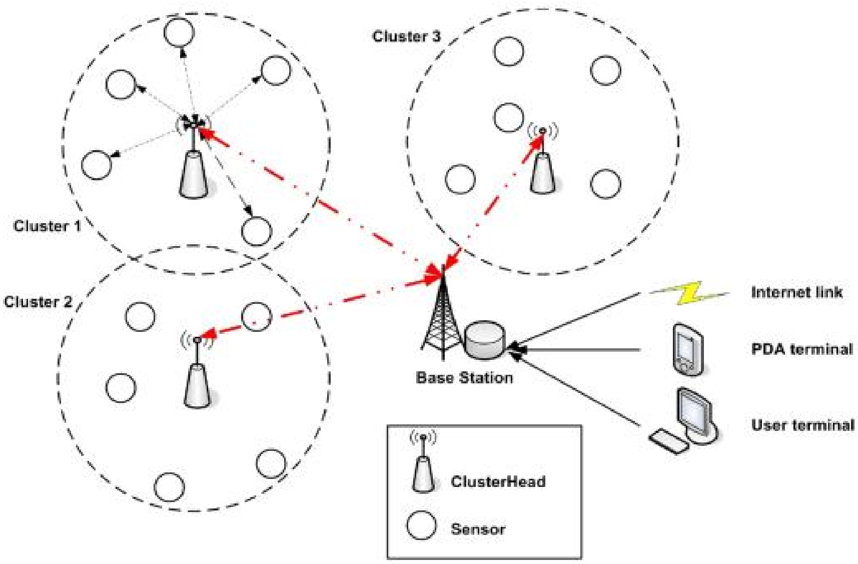

Figure 1. Basic Structure of WSN

In hierarchical approaches, nodes are clustered into groups, and by certain criteria a cluster head is selected that is responsible for routing. In hierarchical routing, two-layer approach is used, where 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 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 focus is to compress the collected data, cluster formation, cluster head selection, cluster reformation and cluster head reselection considering the energy consumption and their impact on overall network lifetime.

Huffman coding requires prior knowledge of the probabilities of the source sequence. If this knowledge is not available, Huffman coding becomes a two-pass procedure: the statistics are collected in the first pass and the source is encoded in the second pass. In the Adaptive Huffman coding procedure, neither transmitter nor receiver knows anything about the statistics of the source sequence at the start of transmission. The tree at both the transmitter and the receiver consists of a single node that corresponds to all symbols Not Yet Transmitted (NYT) and has a weight of 0. As transmission progresses, nodes corresponding to symbols transmitted will be added to the tree and the tree is reconfigured using an update procedure. Considering a simple 4-bit ADC representation for each data, then before the beginning of transmission, a fixed 4- or 5-bit code depending whether the symbol is positive or negative is agreed upon between the transmitter and receiver. The actual code consists of two parts: The prefix corresponding to the code obtained by traversing the tree and the suffix corresponding to 4- or 5-bit binary representation corresponding to positive or negative data respectively. In the process of coding, the probability for the incoming source sequence is assigned as the elements get into the tree formed. This gives rise to a problem where the elements which come in the initial stages of tree formation having lesser probability hold smaller codes. Thereby, the compression ratio obtained is lesser. The pseudo code for adaptive Huffman algorithm is shown in Fig.1.

Using Adaptive Huffman algorithm, we derived probabilities which dynamically changed with the incoming data, through Binary tree construction. Thus, the Adaptive Huffman algorithm provides effective compression by just transmitting the node position in the tree without transmitting the entire code. Unlike static Huffman algorithm the statistics of the sensor data need not be known for encoding the data. But the disadvantage in this algorithm is its complexity in constructing the binary tree which makes it unsuitable for sensor nodes.

Literature survey

M. Preetha, K. Sivakumar et al., [1] developed an Energy Efficient Sleep Scheduling (EE-SS) protocol is proposed for WSN. Initially, the network is divided into small clusters. The 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. The performance of the proposed method is compared with the standard LEACH protocol and CL model in terms of various factors. M. Nagarajan et al., [2] described Nearest Neighbor Algorithm transmits the data when a particular node is not available while transmission. When transmission has taken place the cluster head need to send the data once again to the destination to address this issue and keeps the data to the nearest nodes of destination node. Amrinder Kaur et al., [3] worked on LEACH which is Set-up phase, and it has three fundamental steps: Cluster Head advertisement, Cluster setup, Creation of Transmission Schedule. During the first step cluster head sends the advertisement packet to inform the cluster nodes that they have become a cluster head. Tossaporn Srisookai et al., [4] explained data compression techniques are broadly classifying into two categories: a Distributed Data Compression approach and a Local Data Compression approach.

Distributed approach is mainly applied on dense sensor networks (containing large number of sensor node) and these schemes exploit the spatial correlation among the sensor nodes. While Local approaches perform data compression locally on each sensor node and these schemes usually exploits the temporal correlation among the sensor nodes and do not depend on the WSN's specific topology. Rajesh Patel et al., [5] Each of the chosen cluster head creates a transmission schedule for the member nodes of their cluster. TDMA schedule is created according to the number of nodes in the cluster. Each node then transmits its data in the allocated time schedule. The second phase of LEACH is the Steady phase during which the cluster nodes send their data to the cluster head. The member 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 this data to the base station either directly or via other cluster head along with the static route defined. After the certain predefined time, which is decided beforehand, the network again goes back to the Set-up phase.

Yao Liang et al., [6] sophisticated framework to systematically explore the temporal correlation in environmental monitoring WSN has been presented. The presented framework optimizes lossless data compression in communications given the resource constraint of sensor nodes. The insights and analyses 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. Joel B. Predd [7] developed an algorithm for collaboratively training networks of kernel-linear least squares regression estimators. The 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 the relationship between the network topology and the representational capacity of the relevant reproducing kernel Hilbert space. Numerical experiments suggest that the algorithm is effective at reducing noise. The algorithm is relevant to the problem of distributed learning in wireless sensor networks by virtue of its exploitation of local communication. Francesco Marcelloni et al., [8] Power saving is a critical issue in wireless sensor networks since sensor nodes are powered by batteries which cannot be generally changed or recharged.

As radio communication is often the main cause of energy consumption, extension of sensor node lifetime is generally achieved by reducing transmissions/receptions of data, for instance through data compression. This gives rise to 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 a simple and efficient data compression algorithm particularly suited to be used on available commercial nodes of a WSN, where energy, memory and computational resources are very limited. Cauligi S. Raghavendra et al., [9] 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 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. Ian F. Akyildiz et al., [10] 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 save 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.

Problem statement

The main problem in today wireless communications is to design wireless sensor network in which the energy consumption in sleep mode; be it hardware or software and should be solved for the protocol to achieve the desired network lifetime [11].

- In wireless networks, each node is given a unique id, used for routing. This cannot be effectively used in sensor networks. This is because, these networks being data centric, routing to and from specific nodes is not required.

- This protocol explains how the routing algorithm proposed work to be suitable for continuous monitoring of numerous widespread sensors, which are at a large distance from the base station.
- The results using MATLAB are shown to see the energy consumption and the time estimation with respect to cluster diameter and the head set size [12].

The objective of the proposed model is as follows:

- To Simulate wireless sensor network system based on a new approach method by using MATLAB.
- Reduce the energy consumption.
- To design and develop a communication protocol which increases the Network lifetime.
- To efficiently disseminate query and query results into the network.
- To control and manage nodes according to the environment.

Proposed 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 [13]. 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 [14]. 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 [15]. 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 to prolong the network lifetime 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. 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.

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

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 [16]. 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 sensors decide of joining the clusters [17].

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

Table 1
List of notations

Symbols	Descriptions
Ep	Energy consumption for probing periods
$E[n_p]$	Expected number of probing periods before data transmission
$T_b \wedge T_s$	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

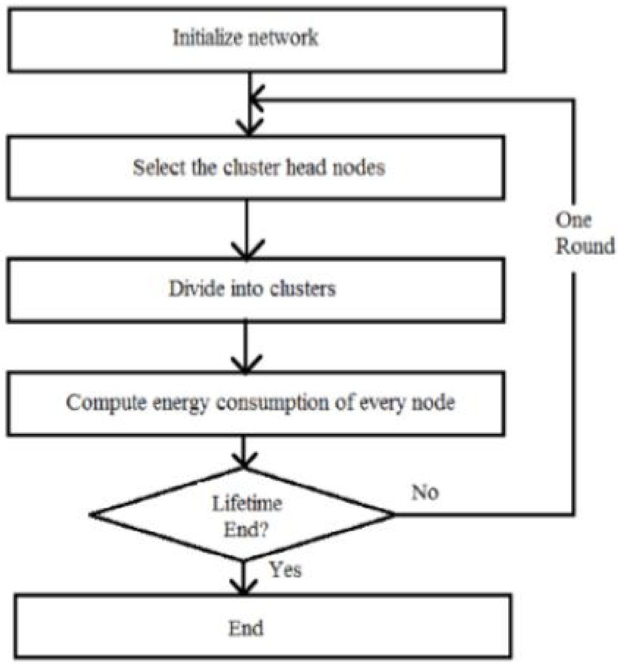

Figure 2. Block diagram of cluster head formation

Proposed 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 receiving 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: Transferring 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

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

Huffman algorithm

In the Huffman algorithm proposed, each sensor node measure mi, the collected data is converted by an ADC to binary representation ri using R bits, where R is the resolution of the ADC. For each new measure mi, the compression algorithm calculates the difference di=ri−ri−1, which is input to an entropy encoder. The encoder performs compression lossless by encoding differences di more compactly based on statistical characteristics. Each di is represented as a bit sequence bsi composed of two parts si and ai, where si represents the number of bits required to represent di and ai is the representation of di. Code si 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 [18]. The ai part of the bit sequence bsi is a variable length integer code generated as follows:

- If di>0, ai corresponds to the ni lower-order bits of the direct representation of di
- If di<0, ai corresponds to the ni lower-order bits of the two's complement representation of (di-1)
- If di = 0, si is coded as 00 and ai is not represented

The procedure used to generate ai makes sure that all the possible values have different codes. Once bsi is generated, it is added to the bit stream which forms the compressed version of the sequence of measure mi. <<si,ai>> denotes the concatenation of si and ai [19]. 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 [20]. 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.

Results and Analysis

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 is optimized. All the cluster-heads can be located near the edges of the network or adjacent nodes can become cluster heads.

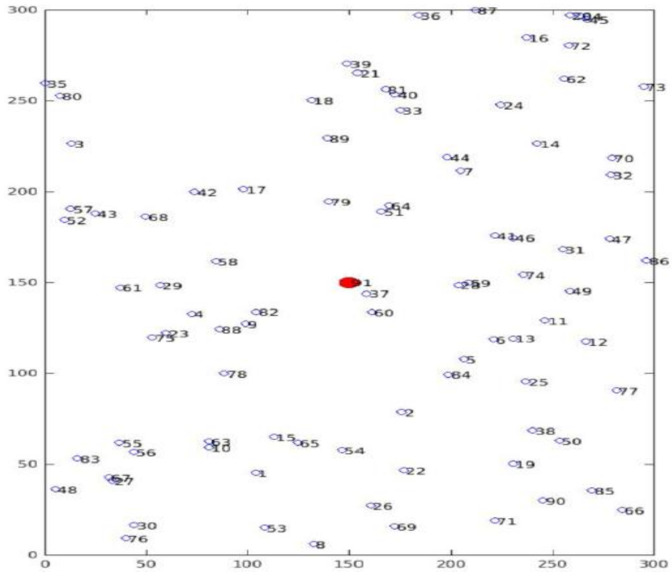

Figure 3. Network Setup

Thus, there could be several 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 Fig 3, 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.

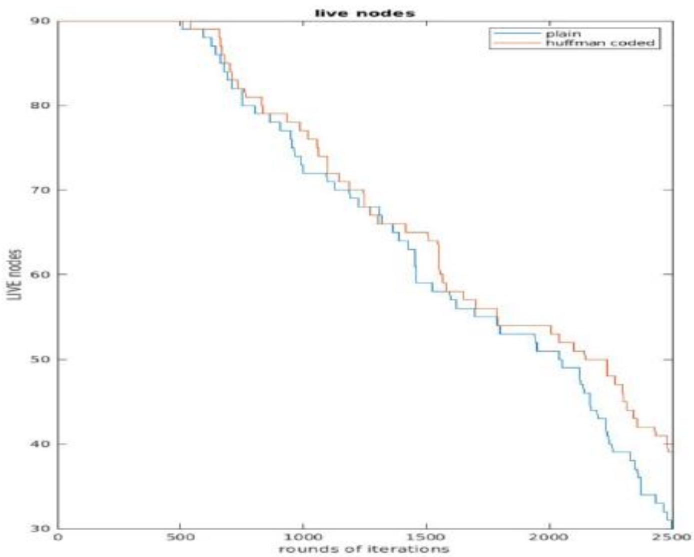

Figure 4. Live nodes with increase in number of iterations

From the comparative analysis of Fig 4, 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 existing algorithm. Thus, the new protocol is suitable to save the energy of the network, increasing the number of live nodes and energy efficiency.

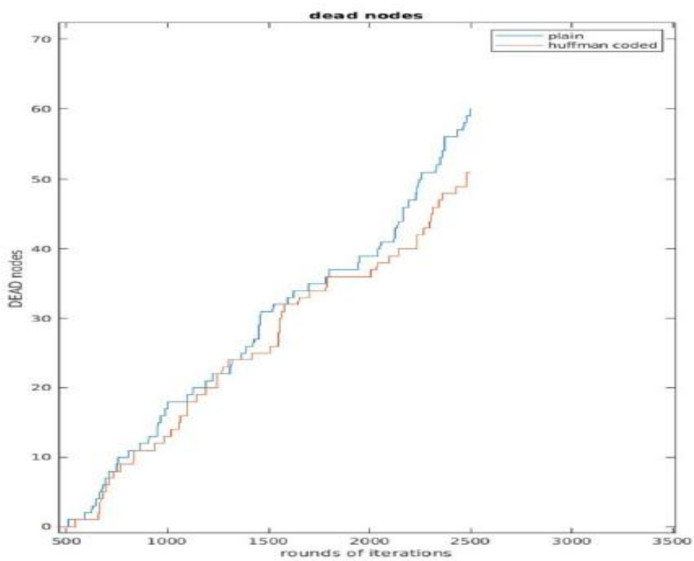

Figure 4. Live nodes with increase in number of iterations

From the comparative analysis of Figure 4, we analyze that the number of dead nodes is decreasing in Huffman LEACH protocol than LEACH protocol. Energy efficiency is analyzed by computing the number of dead nodes in the network by considering the number of rounds. The performance analysis using MATLAB shows that the number of dead nodes is decreasing in each round than in existing algorithm. Thus, the new protocol is suitable to save the energy of the network, decreasing the number of dead nodes and energy efficiency.

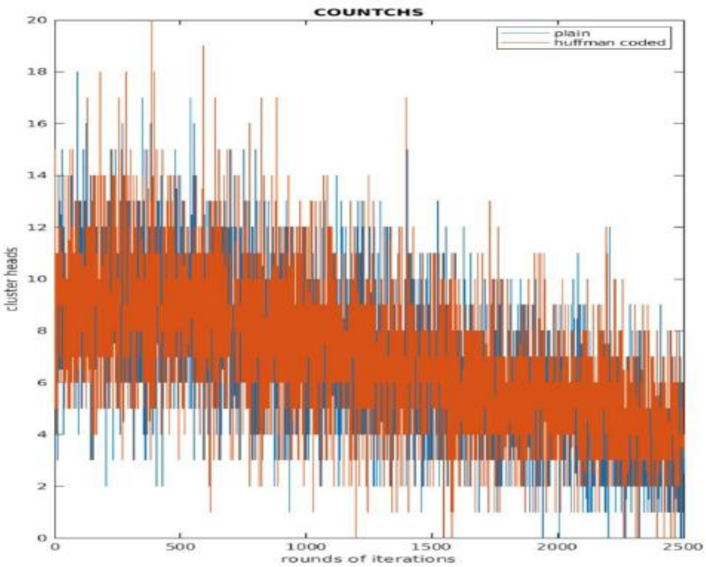

Figure 5. COUNT of Cluster Head

Several cluster heads are impacting on the energy efficiency of WSNs. As the number of cluster heads increases the more amount of energy is consumed due to large numbers of aggregation processes performed by these cluster head nodes. On the other hand, as the number of cluster head nodes are minimized, the energies are also consumed largely due to the bulky amount of data aggregated by each cluster head node and longer time. Each cluster head needs to communicate with BS to provide the aggregated data. Thus, these CHs will be dead at the earliest. So, in successive rounds the stability of the CH numbers around an optimum number is required to get balanced energy consumption. Fig. 5 shows the number of the cluster heads in every round compared with LEACH and Huffman Leach. The number of packets received by the Cluster Head is more in proposed Huffman Leach algorithm than existing LEACH protocol shown in the Fig 6. The number of packets is estimated based on the energy consumption, more is the stability in energy consumption, then more is the number of packets received by Cluster Head. This enhancement is obtained due to Cluster head selection method, which ensures a balanced generation of cluster heads among all clusters. This balance causes stability in CH selection which leads to regularity in energy dissipation.

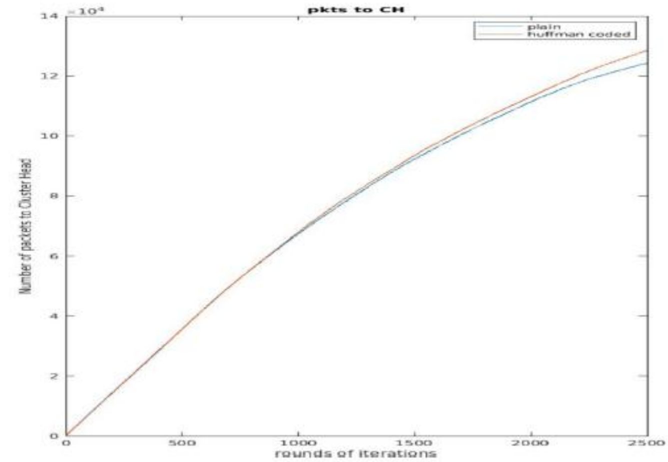

Figure 6. Number of packets to Cluster Head

In the proposed Huffman Leach algorithm, the number of packets received at the base station is more than the numbers of packets received by LEACH protocol, as shown in Fig 7. The number of packets is determined based on the amount of energy consumption, more is the stability in energy consumption, more is the number of packets received at the base station. This obtained due to Cluster head selection method, which ensures a balanced generation of cluster heads among all clusters. This balance causes stability in selection of CH which leads to regularity in energy dissipation. Another reason for this improvement is modified TDMA which ensures that all sensor nodes have approximately the same amount of energy which is due to sending the same amount of data. More the regularity of energy consumption means the more in the number of packets received at the BS. The number of packets received at base station per round is more in Huffman Leach as compared to existing LEACH protocol, as shown in the Fig 8.

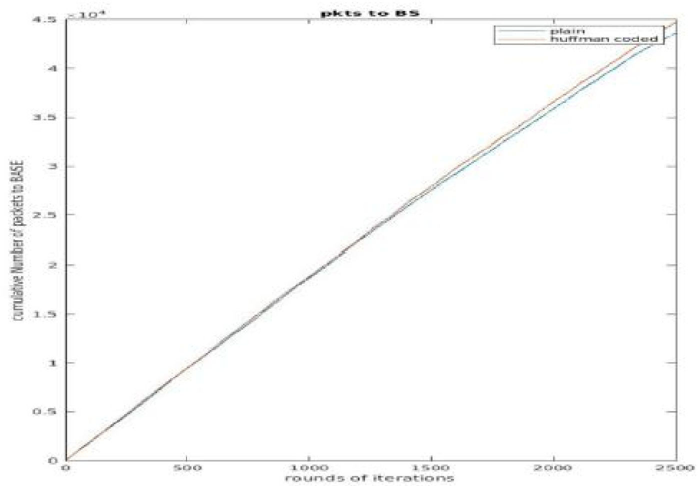

Figure 7. Packets to Base Station

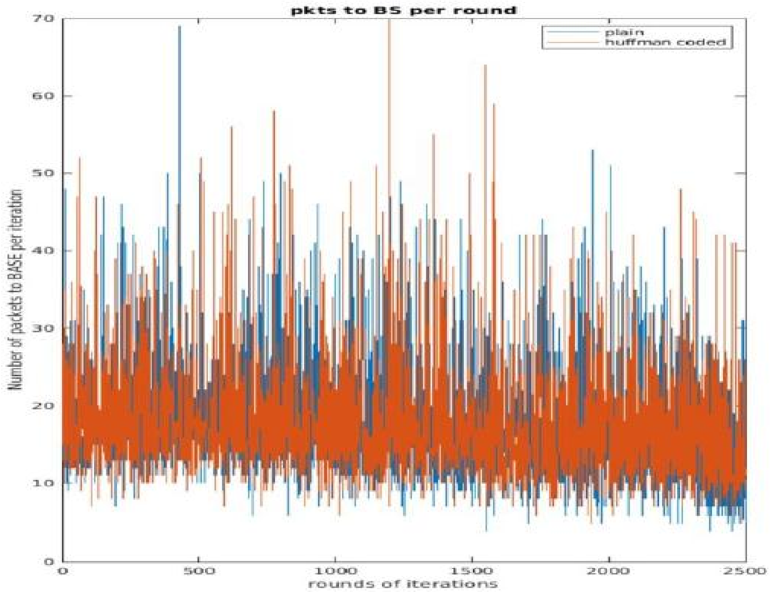

Figure 8. Packets to Base Station per round

Fig 9., 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 are 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.

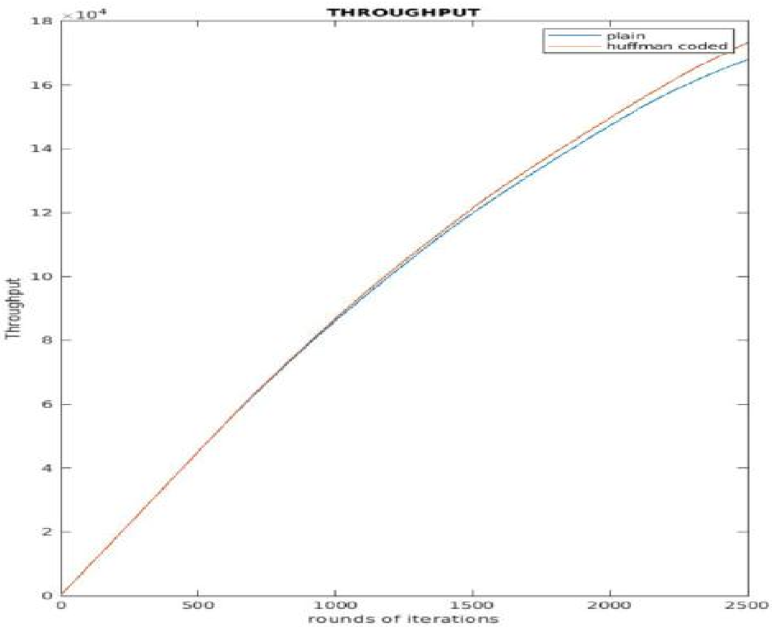

Figure 9. Throughput

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 lifetime, energy efficiency and utilizing maximum energy of each individual network node; with the increase in rounds, the network throughput also increases.

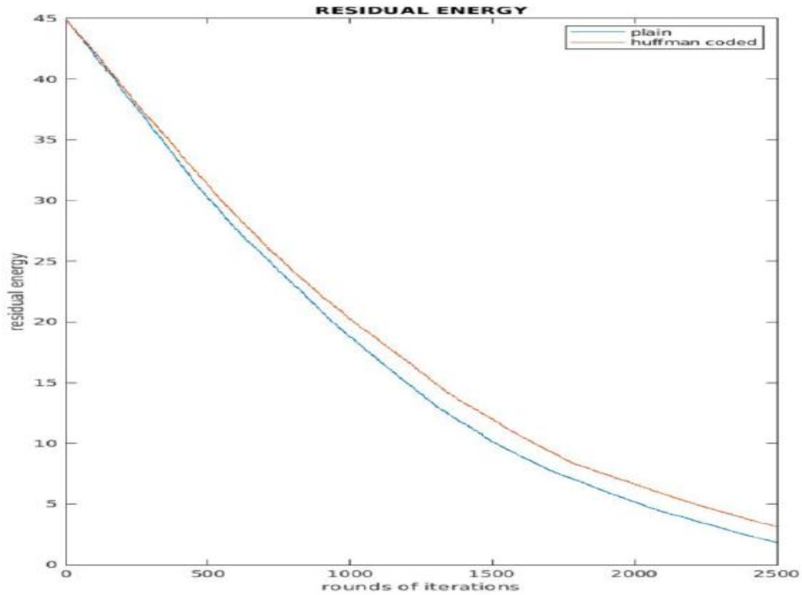

Figure 10. Residual Energy

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 Figure 10.

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

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.

Conclusion

In the Huffman LEACH model, energy consumption increases exponentially with distance and there are no maximum limits. 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 lifetime 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 must 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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