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An Enhancement Approach for Reducing the Energy Consumption in Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSN) consist of low power devices that are distributed in geographically isolated areas. Sensors are arranged in clusters. Each cluster defines a vital node which is known as a cluster head (CH). Each CH collects the sensed data from its sensor nodes to be transmitted to a base station (BS). Sensors have deployed with batteries that cannot be replaced. The energy consumption is an important concern for WSN. We propose an enhancement approach to reduce the energy consumption and extend the network lifetime. It has been accomplished by augmenting the energy balancing in clusters among all sensor nodes to minimize the energy dissipation during network communications. The improved method is based on a cluster head selection method. In addition, an enhanced schedule of the TDMA has been implemented. Finally, the development approach indicates the progress in terms of network lifetime, Number of cluster head, energy consumption and number of packets transferred to BS compared to LEACH and other related protocols. Mathematical analysis and MATLAB 2015a simulation results show the effectiveness of the proposed approach. The energy consumption of WSN has been reduced up to about 60% and prolong the network life cycle by 73% than LEACH.

1. Introduction

Wireless Sensor Networks (WSNs) consist of hundreds or thousands of tiny devices that are capable of communicating with each other with limited power. These wireless sensors are deployed in a real-world environment to sense various environmental effects. Sensor nodes have limited power, so the collected data from target environment is sent directly to the base station (BS). BS is a node that interested in receiving data from a set of sensor nodes. It analyzes and reduces the similarities between their data, that is used for decision-making. In addition, BS is not only able to use these data locally, but it also is able to send these data to other networks which are located in a remote area. However, this would cause a high communication overhead, which cannot be tolerated by sensor nodes. In WSN, the processes of gathering data from whole sensors and reported them to BS are known as data aggregation (Sinha, 2013; Othman, 2015).

The technology of WSNs is extended to be used in a lot of various applications. These applications may include military applications, survival monitoring, traffic control, intelligent buildings and object tracking (Zhou, 2008; Amara et al., 2013; Estrin et al., 1999; Salim, 2014; Sheng et al., 2013; Jose et al., 2013).

However, WSN suffers from extensive constraints such as limited memory, little computational ability, not rechargeable and limited battery, security and set up a global addressing for all sensor nodes. Energy-efficiency is a ticklish problem of sensor nodes that have supposed to run without care for a long time. In addition, energy consumption depends on the application requirements. Furthermore, it is sometimes deployed in a hostile environment where a person cannot be replaced or recharge batteries of sensor nodes.

So, Batteries play the main role in WSN, it's the indicator of the lifetime. In Wireless network, most of the energy is consumed in the process of data transmission. Thus, the energy efficiency routing protocols are needed. Many kinds of literature take this consideration to design WSN of more energy-efficient. Multiple Types of research are introduced for saving energy. These Researches start from physical layer of passing through routing protocols, based on how to enhance data acquisition techniques (Batra, 2016). On

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the other hand, clustering based protocols (Ye et al., 2005) have attracted a lot of researchers. It's composed of two phases: the setup phase and steady state phase. In the setup phase, WSN is split into clusters (groups of nodes). In each cluster, there is a node that acts as a cluster head (CH). In steady state phase members in the cluster (Non-Cluster Head nodes) sense and transmit their data to CH systematically. Each sensor node in the cluster has its own time to send sensed data to his CH. The sending process has performed according to TDMA (Time Division Multiple Access) schedules. This schedule has established by each CH and sends it to all members in cluster see Fig. 1.

The cluster head is responsible for reducing redundant data and apply aggregation techniques that minimizing the data size and forward it to the BS.

LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is a leading protocol that is used for micro-sensors network applications (Heinzelman, 2002). It integrates both concepts of energy-efficient cluster based routing and media access together. The idea behind LEACH is to save energy of sensors as possible to improve the lifetime of the network. In the setup phase, the nodes represent the cluster heads have chosen randomly after deploying all sensor nodes. The choice of Cluster Heads has performed at the beginning of each round. Every sensor node selects a random number between 0 and 1. If this random number is less than the threshold T(n) that node is chosen as a CH for the curren round. The T(n) is given in the next Eq. (1):

$$T(n) = \begin{cases} \frac{p}{1-p\times[r\,mod(1/p)]} & if\ n \in G \\ 0 & elsewhere \end{cases} \quad (1)$$

where:

p: is the percentage of choosing cluster heads.

R: is the current round.

G: is the set of sensor nodes that have not been cluster heads in $1/p$ rounds.

Even though LEACH protocol preserves energy in sensor nodes, and minimizes the size of the routing table. It still has some limitations (Shurman et al., 2014) such as:

- The residual energy in the nodes is not taking into account when the randomized choice of the CH is performed.
- When the size of the network increases, the CH's that are located far away from the BS consume more of their energy rapidly. The LEACH protocol is designed to work well if the deployment environment is small.
- TDMA (Time division multiple access) schedule has some restrictions: Each cluster head has its own time to send data in the designated slot in spite of there is no recent data.
- Some clusters may contain more sensor nodes than other clusters which affected on the frequency of sending data to the BS. Nodes in a smaller cluster will drain energy faster than nodes that belong to a bigger cluster.
- Sensor nodes generate a random number between 0 and 1. If a node number less than the threshold, it will become the cluster head. So, there are no restrictions produced of cluster heads. The energy efficiency of sensor node is affected by the number of using as a cluster head.
- LEACH protocol assumes that all sensor nodes have enough energy to communicate with the sink. So, more energy consumed if sensor nodes are far away from the sink.
- Also, LEACH assumed that all nodes in the network are homogeneous, which is not factual in most of the applications. Hence, it needs more improvements to handle heterogeneous nodes.
- LEACH doesn't preserve data privacy among sensor nodes and need more security.

The rest of the paper is organized as follows. Section 2 shows a brief description of the related work performed on the LEACH protocol. Section 3 presents network model and assumptions. In addition, the proposed approach is discussed in Section 4. Simulation results and analysis are discussed in Section 5. Finally, the conclusion and future work are introduced in Section 6.

2. Related work

In general, LEACH is used as a guideline to cluster-based routing protocols. It introduces a randomize technique to designate cluster heads that will die as their energies are consumed. The designated technique is based on some nodes that practically have a low residual energy to be used as cluster heads. Multiple researchers are introduced to achieve the energy balanced inside the wireless sensor networks. In (Long et al., 2011); authors introduced an assistant cluster head approach. They establish a dynamic method to accomplish the ability to create an assistant cluster head or not. The assistant cluster head is based on the metrics of the geographical location of nodes to be a cluster head, the number of members in each cluster, and the remaining energy of each node. This technique extends the lifetime of a wireless sensor network by reducing the energy consumption of member nodes in a cluster. But, the implemented technique requires complex operations that causes more delays.

In (Arumugam, 2015) the authors proposed an energy routing protocol depends on the effective ensemble data and optimal cluster head selection. This protocol prolongs the lifetime of the network. But, it still suffers from the delay caused by multifaceted operations. It always chooses the sensor node that has higher residual energy without consideration to any other factors such as the location of the sensor node that may be located far away from BS.

In (Junping et al., 2008), the authors proposed an algorithm based on the random timer to construct the cluster without the need to any global information. This algorithm suffers from big gap energy consumption between cluster heads and their sensor nodes. Other researchers are presented to the number of cluster heads and the node's residual energy issues.

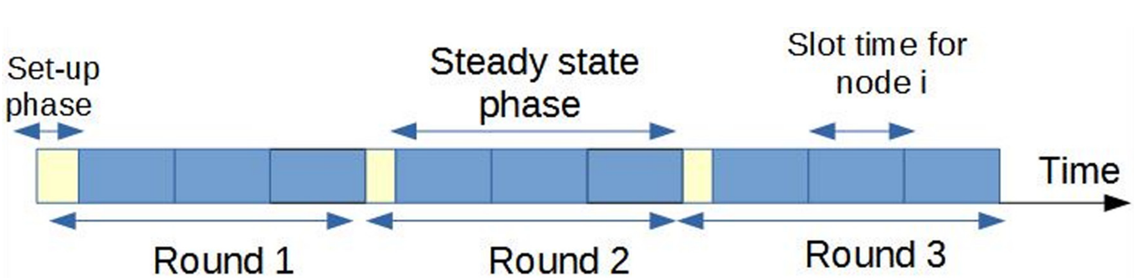

Fig. 1. Time Division Multiple Access schedule for LEACH operation.

Authors in(Tong and Tang, 2010), proposed a protocol called LEACH-B. The first selection of CH is performed according to original LEACH. But, starting from the second selection they alter the number of CHs based on the node's residual energy. Thus, per round, the number of CHs is fixed and near optimal. Their simulation shows the balance of the network energy consumption to extend the network lifetime than LEACH protocol. In (Batra, 2016), authors improved the time of the First Node Death (FND) and Last Node Death (LND) than LEACH by proposing a LEACH-MAC cluster head selection algorithm.

Authors in (Hong, 2008) presented a method of a threshold based cluster head replacement for clustering operation. The threshold of residual energy is used for minimizing the number of cluster heads selection. Authors in (Mahmood et al., 2013) proposed an algorithm called MODLEACH, They increase the lifetime of the network by minimizing the number of transmissions along with efficient cluster head. The replacement mechanism maintains the power level of inter and intra-cluster communication.

Authors in (Beiranvand et al., 2013), introduced a method for minimizing energy consumption per each node by selecting a sensor node to become a cluster head based on the highest residual energy, number of neighbors close to the base station. However, all algorithms in Handy et al. (2002), Tong and Tang (2010), Hong (2008), Beiranvand et al. (2013), Mahmood et al. (2013) and Batra (2016) don't consider the existence of tiny clusters. In addition, the cluster heads suffer from sudden death and focus only on energy consumption by threshold and nodes' residual energy.

In Murali (2016), the authors proposed a cooperative communication method. Their experimental results show that the total energy consumed by the network is minimized when cooperation exist than without cooperation. But, the traffic overhead is increased at the beginning of each round if the numbers of sensor nodes in cluster areas are relatively high.

Authors in Ali et al. (2008) introduced a protocol named ALEACH with a new cluster head selection method. In spite of, the algorithm achieves balance energy distribution among all nodes; it doesn't consider the position factor of sensor nodes that influences on choosing the proper CH nodes. Authors in Peng and Li (2010) minimized energy consumption and prolongs the network lifetime through proposed a Variable Round LEACH (VR-LEACH). However, this algorithm depends on the residual energy in the CH at the start of the round which causes data collision over the network. Therefore, in this paper, we present a novel technique to enhance energy consumption and extend the network lifetime by augmenting the energy balancing in the cluster among all sensor nodes. The proposed approach is based on two enhancement methods. In the first, cluster head selection method is modified to ensure a stable generation of cluster heads among all sensor nodes in WSN. In the second, TDMA schedule is modified to avoid consuming more energy in smaller clusters than bigger clusters.

3. Network model and assumptions

Node deployment in Wireless sensor networks (WSNs) is considered as a fundamental issue that affects on many circumstances of network operations such as routing, security, and energy. The lifetime of the WSN depends on the node deployment method. Sensor nodes that locate near to sink (one hop away from it) will consume energy faster than other nodes because they have to receive and retransmit packets from and to other nodes. The whole network affected by the energy hole problem. Thus to overcome this problem, the location of sensor nodes and the base station is defined by using 2D Elliptical Gaussian distribution function. Gaussian distribution is achieving energy balancing and enhancing network lifetime because standard deviation factor has a significant influence on both energy and network lifetime. Consider a WSN of N sensor nodes and a base station are distributed randomly in $M \times Mm^2$ region. Gaussian distribution is given as:

$$f(a,b) = \frac{1}{2\pi\sigma_a\sigma_b} exp - \left(\frac{(a-a_0)^2}{2\sigma_a^2} + \frac{(b-b_0)^2}{2\sigma_b^2}\right) \quad (2)$$

where:

(a_0, b_0): Denotes the position point of each node.
σ_a and σ_b: are the standard deviations for a and b dimensions, respectively.

The sensor nodes are deployed to occupy their positions. Each sensor node has an unparalleled ID and recognizes its location and its deposited energy. Taking into account a_0 and b_0 will be equal to zero.Each sensor node senses the monitoring area continuously. It can communicate directly to the BS if the signal is strong enough to cover the distance between them. Each sensor node has the same amount of initial energy as the other sensor nodes. Since the node battery is not rechargeable, the node died just as the energy of its battery is consumed.

3.1. Energy radio model

In this paper, a light model for radio hardware is used (Heinzelman, 2002). Two models have been used for energy consumption examination, free space model $\varepsilon_f d^2$ and multipath fading model $\varepsilon_m d^4$. Both models are relying on the distance between the receiver and transmitter. The radio energy model is shown in Fig. 2.Hence, to transmit a k- packet at a distance d, the radio uses up is given as:

$$\begin{aligned} E_{TX(k,d)} &= E_{TX-elec}(k) + E_{TX-amp}(k,d) \\ &= \begin{cases} k * E_{elec} + k * \varepsilon_f * d^2, & d < d_0 \\ k * E_{elec} + k * \varepsilon_m * d^4, & d < d_0 \end{cases} \end{aligned} \quad (3)$$

$$E_{RX}(k) = E_{RX-elec}(k) = k * E_{elec} \quad (4)$$

where,

$E_{TX:}$ required energy utilization for packet transmission.
E_{elec}: is electronic energy that counts on the filtering, modulation the digital coding and spreading of the signal.
$E_{RX:}$ required energy utilization for packet receiving.
d_0: is equal to the square root of the dividing E_{DA} free space model by multipath fading model.

3.2. Optimal number of clusters heads

Consider that there are N sensor nodes and if there are clusters divided the network, there are N/C average numbers of nodes per cluster. Energy consumption in the cluster head node in a single frame is given in Eq. (5):

$$E_{CH} = kE_{elec}N/C + KE_{DA}N/C + K\varepsilon_m d_{toBS}^4 \quad (5)$$

where,

E_{DA}: is the energy consumed in aggregation.
d_{toBS}: is the average distance from the base station to the cluster head nodes.

The energy consumption in non-cluster head nodes for transmitting the packet to the cluster head is given in Eq. (6):

$$E_{non-CH} = kE_{elec} + k\varepsilon_f d_{toCH}^2 \quad (6)$$

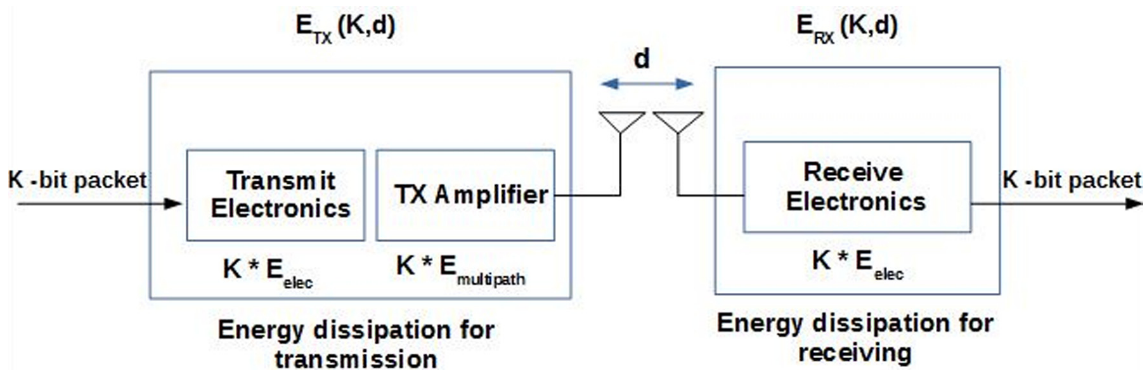

Fig. 2. Radio Model.

where,

$$d^2_{toCH} = \frac{M^2}{2\pi C} \quad (7)$$

is the average distance from the non-cluster head nodes to their cluster head nodes. The network radius is R and the area of each cluster is M^2/C.

$M/\sqrt{C}$: determines the radius of the clusters.

Thus the total energy dissipated by a cluster in a single frame is given as:

$$E_{cluster} = E_{CH} + E_{non-CH} N/C \quad (8)$$

The total energy dissipated for the frame is given as:

$$E_{total} = CE_{cluster} \quad (9)$$

By differentiating E_{total} with respect to C to zero, the optimum number of cluster heads can be obtained:

$$k_{optimal} = \frac{\sqrt{N * \varepsilon_f}}{\sqrt{2\pi}} \frac{1}{\varepsilon_m} \frac{M}{d^2_{toBS}} \quad (10)$$

For the simulation, we considered all sensor nodes are distributed over x and y coordinates between (x = 0, y = 0) and (x = 100, y = 100) and base station is located between (50,175), free space model $\varepsilon_f d^2$ = 10 pJ/bit/m^2, multi-path fading model $\varepsilon_m d^4$ = 0.0013 pJ/bit/m^4, with these factors, the expected number of cluster heads lies between 1 and 6. Over the verification of analytic results using simulations, the optimal number of CHs is found to be between 3–8, Thus, in this paper, value C = 5 has been taken.

4. Proposed approach

The drawbacks of LEACH protocol could be briefed into three basic problems. The first problem deals with the inaccurate choice of the cluster head. The second problem instigated by the inequitable distribution of sensor nodes within each cluster. The energy consumption of the sensor nodes in smaller clusters is more than those of a larger cluster. Because nodes in smaller clusters send the most amount of data than others.

The third problem has formalized during the steady state phase. All sensor nodes within each cluster are continuously sending. Sending has performed even if there is no updating of sensed data. These three problems represent the reason for dropping inefficient consumption of energy. This dropping causes reduction of the network lifetime.

The proposed approach presents two methods to resolve the mentioned problems of the LEACH protocol. The proposed methods aim to decrease an amount of the consumed power of spread sensor nodes. The selection method of the cluster heads has enhanced based on how to alter threshold $T(n)$ to choose the proper CH nodes. In addition, each sensor node sends its updated sensed data only in its sending slot. It's not practical to allow every sensor node to send data without updating. Furthermore, inequality of sensor nodes that cause the unbalance in the energy consummation among clusters has solved through the modified TDMA schedule that enhances the transmission mechanism.

4.1. Cluster head selection modification

The cluster heads are samples of the sensor node that have been elected among all sensor nodes in WSN. Once the sensor nodes are deployed to cover a specific geographical area, the process of cluster head choice for first round operation is initiated. The election process of sensor node as a cluster head is a dominant process. So, the proposed Modified LEACH algorithm takes into account set of valuable factors that are misplaced by the LEACH protocol. These factors include the residual energy of each sensor node, the several times' sensor node being selected as a CH, The distance between CH nodes and the base station, the number of neighbor nodes and the average energy of sensor nodes in the current round. The number of neighbors of each sensor node has examined in the CH nodes election phase.

According to Handy et al. (2002), sensor nodes are considered as neighbors of a sensor node if these nodes are in the radius of a neighborhood of that node. Sensor node that has more neighbors than other has higher chance to be elected as a CH node. The radius of the neighborhood is given in Eq. (11):

$$R_{neighborhood} = \sqrt{\frac{M^2}{\pi * C}} \quad (11)$$

The average distance between sensor nodes and their cluster heads is calculated in Eq. (12). The average distance between cluster head nodes and the base station is calculated in Eq. (13):

$$d_{StoCH} = \frac{M}{\sqrt{2 * \pi C}} \quad (12)$$

$$d_{toBS} = \frac{0.755 * M}{2} \quad (13)$$

Another factor that can increase the network lifetime is the remaining energy level in each sensor node. $T(n)$ is multiplied by a factor representing the current energy level of a sensor node given in Eq. (14). Our simulations show that this modification of the cluster head threshold can increase the lifetime of a LEACH by 15% for first node death(FND).

$$T(n)_1 = \begin{cases} T(n) \times \frac{E_{re}}{E_{in}} & if\ n \in G \\ 0 & elsewhere \end{cases} \quad (14)$$

E_{re}: is the residual sensor node energy in the current round.
E_{in}: is the initial sensor node energy.

This modification has crucial disadvantages. The network is stuck after a number of rounds because the cluster head threshold is too low, even if there are still sensor nodes have enough energy to transmit data to BS. The solution of this problem is solved by extended $T(n)_1$ by a factor E_{avg} that increases the cluster head threshold for any node to ensure that data is transmitted to BS as long as sensor nodes are alive. Sensor nodes that have higher remaining energy than other sensor nodes have high chance to be chosen as a CH node. Improved Threshold $T(n)_2$ is given in Eq. (15)

$$T(n)_2 = \begin{cases} T(n)_1 \times \left(1 - \frac{1}{E_{avg}}\right) & \text{if } n \in G \\ 0 & \text{elsewhere} \end{cases} \quad (15)$$

E_{avg}: is the average energy of all sensor nodes in the current round.

Distance is another factor that affects on the cluster head threshold. The more is the distance between the sensor node and the base station the more is the energy consumed for sending data to base station. Thus, it's not cost effective for selecting a sensor node to be a cluster head if it's far away from the base station. Eq. (16) is calculated:

$$T(n)_3 = \begin{cases} T(n)_2 \times \frac{dtoBS_{av}}{dtoBS_n} & \text{if } n \in G \\ 0 & \text{elsewhere} \end{cases} \quad (16)$$

$dtoBS_a v$: is the average distance of sensor nodes in the network to the base station.
$dtoBS_n$: is the distance between sensor node to the base station.

Last factors that can affect on the choice of cluster head is the number of times that node selected as a cluster head. Also, the distance between sending node to receiving node. In the following, Eq. (17) is a novel modified threshold formula. This formula has resulted due to multiple experiments using MATLAB 2015a. All the following factors are experienced to get the accuracy threshold to select the proper CH nodes.

$$T(n)_{new} = \begin{cases} T(n)_3 \times (1 - \log_{10} d) \times \frac{1}{CH_s} \times Nb_n & \text{if } n \in G \\ 0 & \text{elsewhere} \end{cases} \quad (17)$$

where:
CH_s: is the time that node selected as a cluster head.
Nb_n: is the number of neighbors of n nodes.

Based on the threshold value deduced from the formula, the following operations are performed.

- Every sensor node will generate a random number between 0 and 1
- Compare the generated number with the threshold value obtained from the formula.
- If the selected random number is less than the threshold value, the sensor node will become a CH node for this round.

This formula ensures that sensor nodes which have a higher energy level will have higher chance to become a cluster head in the current round. Also, it guarantees that as long as sensor nodes are alive the data is transferred to the base station. Furthermore, as the distance between the sensor node and the base station is increased, the opportunity of being a cluster head in the current round is minimized.

4.2. Modified TDMA Schedule

The proposed method aims to overcome the weakness in the LEACH protocol by reducing the gap of energy among all sensors in each cluster. So, when the operation of cluster head selection is performed, each cluster head broadcasts an advertisement message to declare itself as a CH node. Based on the strength of an advertising message, each sensor node receives this message will respond to a request to join to that cluster head. So, every cluster head knows the number of sensor nodes that will join to it. Of course, there are a different number of sensor nodes join to each cluster. Steady state phase is broken into frames, where each sensor node belongs to a cluster sends its data at most once per frame during its slot time. Cluster head will be awake to receive all data from the nodes in the cluster. The time line operation of the steady state is longer than setup phase. After a certain time, the network again enters another round starts with the setup and ends with steady state phase. In each round,a new cluster heads are selected to form a new cluster. Thus, the network lifetime can be calculated based on the number of rounds. The duration of steady state phase for each cluster will be the same in LEACH protocol. The clusters that have a small number of nodes will drain more energy than other clusters of larger nodes in steady state phase because the frequency of sending their data is more than others. So, the modified TDMA schedule is presented in the proposed approach in four steps to solve this problem. The proposed protocol is drawn in Fig. 3

Step 1. Each cluster head computes the number of sensor nodes assigned to its cluster based on the number of receiving requests.
Step 2. Each cluster head will broadcast a message includes the number of its own nodes attached to the entire cluster heads in the WSN. At this end, each cluster head knows the capacity of the largest cluster.
Step 3. The capacity of the largest cluster is selected to be the implemented duration of the TDMA schedule in all clusters for steady state phase.
Step 4. Each sensor node within each cluster has a chance to transmit data according to modified TDMA in steady state phase. So, All nodes will send the same amount of data to their cluster heads. Thus, All nodes will drain the same amount of energy. Clusters that contain a small number of nodes after sending their amount of data for the current steady state phase, they go into the sleep mode during the remaining time of steady state phase. It's also avoiding that nodes go into an idle listening mode that affects on the node's energy level. The modified TDMA example shown in Fig. 4 for steady state phase.

The difference between the proposed approach and LEACH protocol can be clarified in the following example. Consider 20 nodes from 4 clusters for one round. Each node has a unique ID ordered from 1 to 20.TDMA schedule used for 4 clusters in LEACH protocol is shown in Fig. 5.

Assume each sensor node takes x ms to send sensed data to the cluster head. In cluster (A), each node starting from node 8 up to node 16 will take x ms to send its sensed data. This means each sensor node will send data only 1 time during steady state phase of this round to its CH.

In contrast, in the cluster(D) that contains only two sensor nodes. Namely, node 15 and node 17. Each of them will have a time of 4× to send sensed data during the steady state phase of this round. This means, each sensor node has a chance to send four times during the steady state phase for this round to their CH. So, the energy of sensor nodes 15 and 17 is consumed more than nodes in the cluster (A).

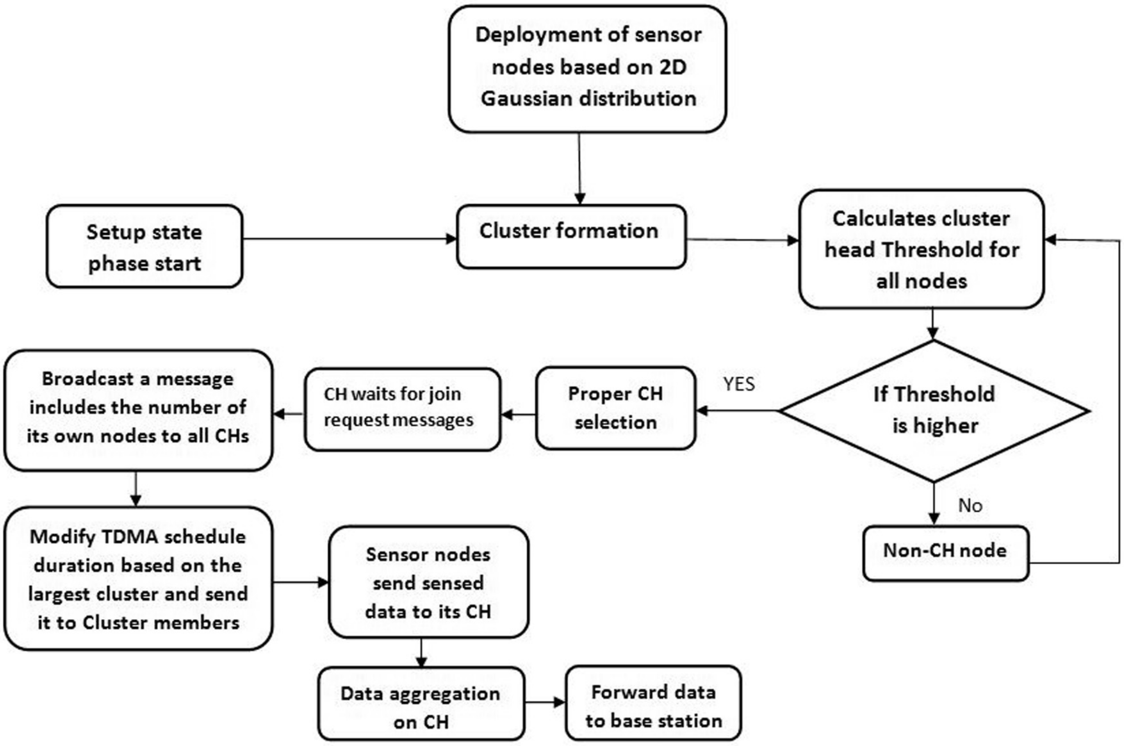

Fig. 3. Flow of the proposed Modified LEACH.

A	8	10	1	6	12	18	7	16	Biggest cluster
B	2	8	3	19	Sleeping time				
C	9	13	14	Sleeping time					
D	15	17	Sleeping time						Smallest cluster

Fig. 4. Modified TDMA for steady state phase.

A	8	10	1	6	12	18	7	16	Biggest cluster
B	2	8	3	19	2	8	3	19	
C	9	13	14	9	13	14	9	13	
D	15	17	15	17	15	17	15	17	Smallest cluster

Fig. 5. TDMA in LEACH for steady state phase.

However, according to the proposed approach, each cluster head sends the modified TDMA schedules to their members. So, each sensor node knows its assigned time slot to send data to its CH. In addition, each sensor node knows when it must switch off its radio and go to the sleep mode. As shown in Fig. 4 which displays the modified schedule. In cluster (A), node 1 sends data1 time and in the cluster(D) node 17 also sends data 1 time during the steady state phase. No sensor node will send more data than other nodes in the whole network. This enhancement achieves the balance to overcome the inequality of sensor node in the cluster. Furthermore, it protects each sensor node energy from inefficient consumption.

5. Simulation results and analysis

The proposed approach is simulated using MATLAB 2015a. 2D Elliptical Gaussian distribution is implemented. The WSN is represented by 100 sensor nodes that are deployed in $100 \times 100\,\text{m}^2$ square regions. The base station is located at (50,175). The initial

Table 1
Simulation parameters.

Parameters	Value
No. of. Rounds	100
p	0.1 or 100%
E_{elec}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{DA}	5 nJ/bit/message
E_{amp}	0.0013 pJ/bit/4
Control Packet Size	25 bytes
Data Packet Size	500 bytes

energy is 5 J for each sensor node. The simulation of the proposed approach is running at an average of 20 times. The measured simulation results are compared with the measured results of LEACH protocol, LEACH-MAC, IBLEACH, VRLEACH, and A-LEACH. The comparison between the measured results of the proposed simulation and the other protocols are performed based on four performance metrics that include, number of cluster heads, network lifetime, number of packets received for assuming energy at the base station and total energy dissipation. The proposed simulation parameters are shown in Table 1.

5.1. Results

5.1.1. Number of cluster heads

A number of cluster heads are extremely impacting on the energy efficiency of WSNs. As the number of cluster heads increased, the energies are severely consumed due to the large numbers of the 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 severely consumed due to the bulky amount of data aggregated by each cluster head node and longer period time, each cluster head needs to communicate with BS to submit the bulk aggregated data. Thus, these CHS will dead earlier.

So, in successive rounds, the stability of the CH numbers around an optimum number is required to get balanced energy consumption. Fig. 6 shows the number of the cluster heads in every round compared with LEACH, ALEACH, and IBLEACH. The experiments show that the optimal number of cluster head is around 5 as an

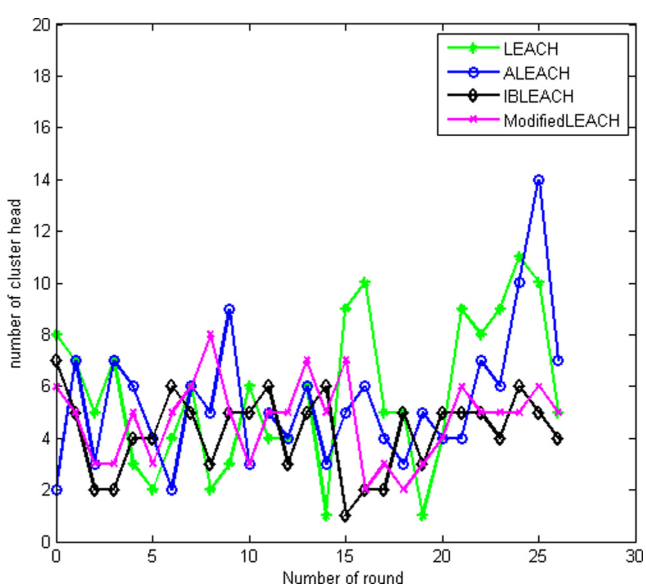

Fig. 6. Number of cluster heads versus number of rounds.

Table 2
Cluster head counts in three rounds.

Protocols	Rounds		
	R 5	R 12	R 26
LEACH	2	4	5
IBLEACH	4	3	4
ALEACH	4	4	7
Modified LEACH	3	5	5

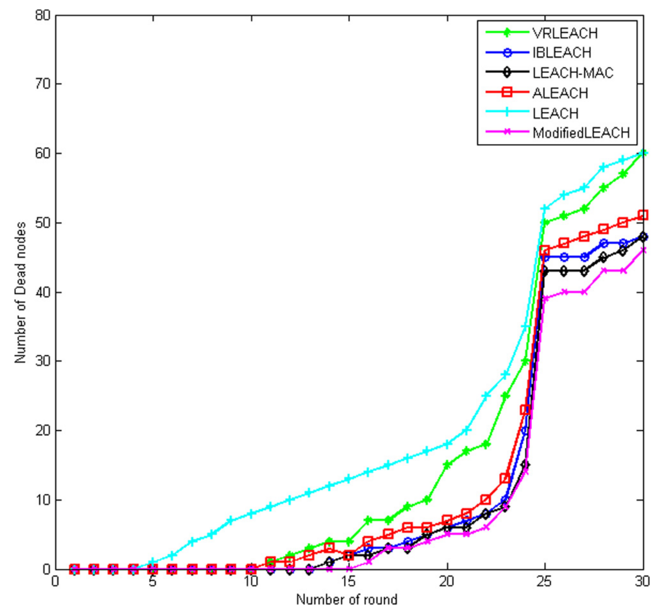

Fig. 7. Network Life time based on Number of dead nodes.

optimum number to accomplish better performance than other numbers. This improvement is based on the Modified cluster head selection algorithm which also increases the number of rounds. Table 2 shows a comparison between protocols in three rounds. IBLEACH in some rounds achieves stability of an optimal number of cluster heads equal 5 due to distribute energy consumption overall sensor nodes by dividing the cluster heads work over its cluster members.

5.1.2. Network lifetime

Network lifetime is defined as the maximum amount of time between First Node Death (FND) and Last Node Death (LND). Longer stability period for the network is an important requirement as loss of one sensor node's data affects the final results. Fig. 7 shows the lifetime for VRLEACH, IBLEACH, LEACH-MAC, ALEACH and LEACH and the proposed Modified LEACH. It is observed that in proposed LEACH, it enhances FND to be in round 16 as compared to LEACH in round 5 against VRLEACH in round 11, IBLEACH and LEACH-MAC both in round 14. In round 16, LEACH lost 13 sensor nodes compared with IBLEACH 3 nodes, VRLEACH 7 nodes, LEACH-MAC 2 nodes and ALEACH 4 nodes. Thus, there is a significant improvement in the stability period, which is required for some applications. This is a normal result due to modified cluster head threshold and balance energy among sensor nodes in steady state phase. Table 3 shows the comparison between all protocols in different rounds 14, 24 and 30.

5.1.3. Number of packets at the base station

In the proposed approach, the number of packets received at the base station is more than the numbers of packets received by each

Table 3
Number of dead nodes in three rounds.

Protocols	Rounds		
	R 14	R 24	R 30
LEACH	11	35	60
VRLEACH	4	30	60
IBLEACH	1	20	48
LEACH-MAC	1	15	48
ALEACH	3	23	51
Modified LEACH	0	14	46

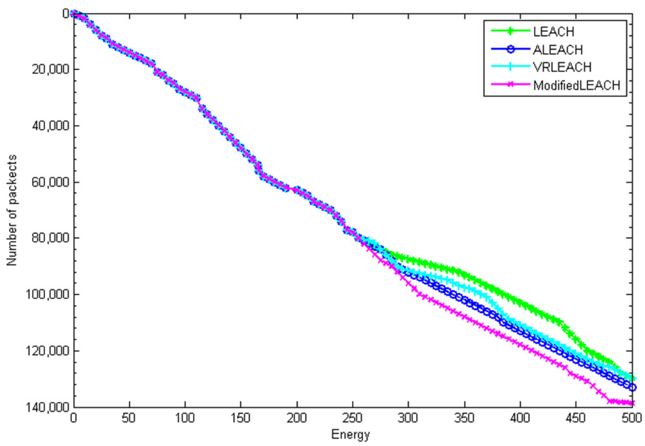

Fig. 8. Number of packets versus Energy (J).

of the other comparative approaches as shown in Fig. 8. The number of packets is estimated by energy consumption, more is the stability in energy consumption, more is the number of packets received at the base station. 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 regular in energy dissipation. Another reason for this improvement is modified TDMA which ensures that all sensor nodes approximately the same amount of energy due to sending the same amount of data. The more regularity of energy consumption means the more in the number of packets received at the BS.

Table 4
Different node number simulation results.

Node numbers	Algorithm type	Average Energy Consumption (J) in both CHs and Non-CH	Alive node numbers
N = 100	LEACH	0.0158	5
	Modified LEACH	0.0011	15
N = 200	LEACH	0.0135	18
	Modified LEACH	0.0012	30
N = 300	LEACH	0.0187	33
	Modified LEACH	0.0014	52

5.1.4. Energy consumption

Energy consumption means the total energy consumed by the network to perform transmission, reception and data aggregation. The comparisons performed among the different approaches based on the energy consumption in both cluster head sensor nodes and cluster member sensor nodes. For both of them, the simulation is running on the number of nodes equal 100, 200 and 300.

As shown in Fig. 9, the proposed Modified LEACH approach achieves the minimum energy consumption compared with all other approaches. In addition, the enhancements of energy consumption are satisfied for both cluster head sensors and cluster members sensors. This improvement is achieved due to the switch off and sleep mode assigned to each sensor node after transmission and proper CH selection that mentioned before. Finally, the Switch off and sleep mode protect the sensor node from the inefficient transmission and cluster head from an idle listening stage. Table 4, shows energy consumption and a live node number for both LEACH and modified LEACH for different sensor node numbers.

6. Conclusion and future work

In this paper, an efficient approach to enhance the routing procedures in the LEACH protocol for WSN has proposed. Two novel methods have proposed. The first method aims to select the proper cluster head node for each cluster at each round. It's done by modifying the cluster head election threshold. The second method has targeted to avoid the process of some sensor nodes, which send more data packets than other nodes in the entire network. We solve this problem by rescheduling the TDMA schedule for each

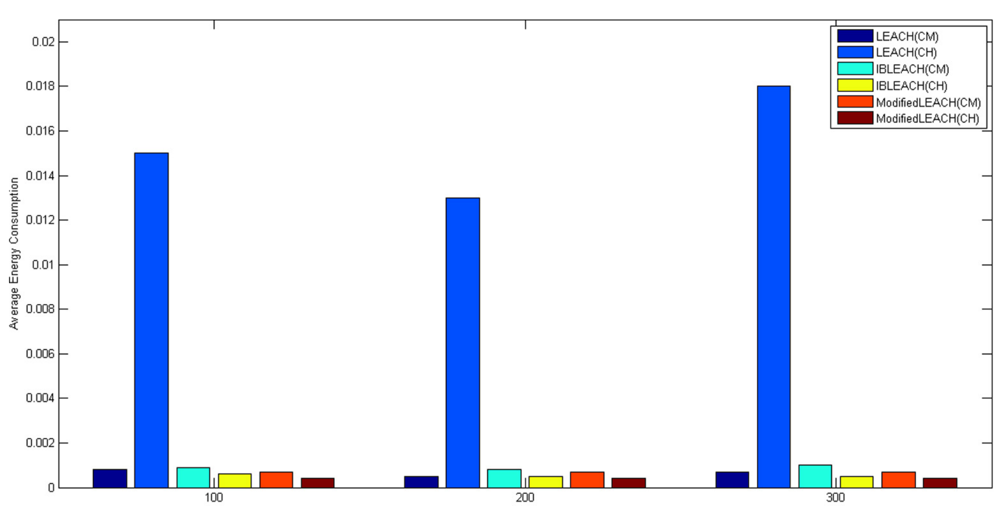

Fig. 9. Energy consumption versus number of nodes.

sensor node by its cluster head to balance all nodes to send an almost same amount of data. Following the procedures of the two proposed methods will enhance the energy consumption of the wireless sensor nodes. So, the lifetime of the wireless network has extended compared with LEACH protocol. The implementation results of the proposed approach have verified using MATLAB 2015a simulation. Through the implementation, the proposed approach has compared with LEACH and other improvements preceding protocols in terms of network lifetime, number of cluster head, energy consumption and number of packets transferred to BS which yields better outcomes than others. In a future work, we will attempt to apply the proposed approach to the heterogeneous networks. This paper only targets the energy consumption problem and how to reduce it. We don't provide the data privacy and security to the WSN here, but we will extend this work to security concepts. We will do also a deeper research to apply this approach to the real world environment.

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