Case Reports

Load Balancing Technique Based on Broadcasting and Residual Energy Using Adaptive Clustering Hierarchy Protocol (LBEACH)

[1]Abdullah Soliman Alshraa and [2]Venus Wazeer Samawi

[1]*Department of Computer Science, Al Albayt University, Mafraq, Jordan*
[2]*Department of Computer Information Systems, Amman Arab University, Amman, Jordan*

Corresponding Author:
Venus Wazeer Samawi
Department of Computer
Information Systems, Amman
Arab University, Amman,
Jordan
Email: venus@aau.edu.jo

Abstract: One of the important factors of Wireless Sensor Networks (WSNs) is sensors lifetime. Elongating sensors lifetime increases the benefits from the network capabilities as much as possible. To elongate WSNs lifetime, power consumption should be reduced. To do so, load balance technique is applied to distribute the energy consumption among cluster's nodes in the WSN. In each cluster, the node that acts as Cluster Head (CH) is the one that significantly suffers from power consumption problem. To elongate the WSNs lifetime, different sensor node is elected to act as CH for a period of time (round). Choosing the proper CH per round greatly affects the energy efficiency in the network. In this study, a new protocol for clustered heterogeneous WSNs (called LBEACH) is suggested to reduce power consumption and prolong the network lifetime. Distributed clustering methodology, with a novel algorithm to elect cluster heads in each round, is applied and tested. The elected CH is the node that has the minimal estimated broadcast cost and the highest residual energy. The estimated broadcast cost of each node is the estimated cost needed for sending a message to all other nodes within the same cluster and to the base-station. LBEACH performance is measured using network lifetime, power consumption and throughput. By comparing LBEACH performance with other protocols, Low Energy Adaptive Clustering Hierarchy (LEACH) and Stable Election Protocol (SEP) protocols, it was found that LBEACH shows a significant improvement in the network lifetime, power consumption and throughputs toward Base-Station (BS).

Keywords: Wireless Sensor Networks, Cluster Head Election, Load Balance, Broadcast-Cost Estimation, Power Consumption

Introduction

The importance of Wireless Sensor Networks (WSNs) increased dramatically due to their significant utilizations in various domains. WSNs applications contribute in many fields including medical field, social filed, security field, service field and military field. WSN composed of many (hundreds to thousands) special nodes, called sensor nodes. These sensor nodes are scattered in a sensor-field and connected directly or indirectly to a sink node (base-station) (Ramesh and Somasundaram, 2011; Meelu and Katiyar, 2014). Each sensor node consists of sensing unit, processing unit, memory unit, transceiver unit and a power unit. It may also contains a location finding system,

a power generator and mobilize (Fabrício *et al*., 2005; Akyildiz *et al*., 2002; Bhowmik *et al*., 2014). In most WSNs, nodes are less mobile and have less hardware capabilities than mobile Ad hoc networks (Younis and Fahmy, 2004). The sensor nodes exist in a limited area (within the coverage range of a BS). Each sensor node has an energy source, usually a battery with limited energy. The main task of the sensor nodes is to sense the environment and send the data to the BS. This process is power consuming. Therefore, the life of the sensor nodes will exhaust in a short time (Bhowmik *et al*., 2014; Ramesh and Somasundaram, 2011). Splitting the network nodes into clusters is one of the solutions that reduces power consumption and elongates the network lifetime.

For each cluster, there is a Cluster Head (CH) (Maragdakis *et al.*, 2004). In WSNs, the network is established at the first phase, where each node has a location, job and attributes. These parameters will help in the process of electing the CH (specify the most proper node to act as CH). After electing the CHs, messages are broadcasted to all other nodes to inform them about their CH. The CH election could be performed by the BS, or by the nodes within each cluster. At the second phase, nodes will collect sensory information and send the information to their CH. The CH will, then, collect data from all nodes within its cluster and passes the data to the BS. Based on this information, two problems should be solved. How to elect the most proper CH that elongates the lifetime of the cluster? How to achieve fault tolerance of individual node failure? To solve such problems, network protocols must be designed in a way that decreases the energy consumption of the nodes (Heinzelman *et al.*, 2002; 2000).

One of the most popular protocols is Low Energy Adaptive Clustering Hierarchy (LEACH). It is a standard protocol, which calculates certain mathematical equation for every node and gives each node a random number between zero and one. If the random number is less than the result of the equation, then this node will be the CH in the next round (Heinzelman *et al.*, 2000). LEACH protocol elects the new CH without taking in consideration the residual power in the elected CH, or its location within the cluster (near or far from the cluster center) (Kim *et al.*, 2008). Neglecting the residual power of the elected node may cause early death of that node, since the CH tasks consume a lot of energy. On the other hand, choosing a node far from cluster center increases the power consumption when broadcasting to far nodes (Kim *et al.*, 2008). Both cases could cause premature death of the elected CH, which affects the network lifetime (Ramesh and Somasundaram, 2011). Therefore, any suggested protocol must satisfy power efficiency condition. Accordingly, Stable Election Protocol (SEP) is developed, which is a revised version of LEACH. In SEP, the weighted election probabilities of each node to become CH are specified according to the residual energy in each node. SEP improved network stability and prolong network lifetime (Maragdakis *et al.*, 2004).

It is important to realize that the performance of the CH affects the performance of WSNs. Therefore, it is essential to emphasis on the parameters that improves the CH performance. These parameters are: Power consumption (the power needed when broadcasting to nodes within the same cluster and to BS), number of nodes within the cluster and the physical distance from a BS. In this study, we will tackle the problem of CH election in heterogeneous WSN. A developed protocol,

called Load-balancing based on Broadcasting and Energy using Adaptive Clustering Hierarchy Protocol (LBEACH) is proposed. LBEACH protocol could be used with both homogeneous and heterogeneous WSNs. In this study, heterogeneous network means a network that contains nodes with different energy, or nodes with different features. LBEACH is an adaptive clustering hierarchy protocol that applies load balancing technique based on broadcasting cost and the residual energy in the nodes. The broadcasting cost is the energy consumed when broadcasting data to/from each node to all other nodes within the cluster and to the BS. The proposed protocol contributes to improve power consumption, prolong the network lifetime and improves network throughput. To evaluate the performance of LBEACH protocol, five different performance measures are used (number of packets, power consumption, network lifetime, stability period and number of CHs). LBEACH performance is compared with two popular protocols, LEACH and SEP protocols.

The rest of this paper is organized in five sections. In section two, related works are discussed. LBEACH protocol is explained in section three. In section four, the performance measures are illustrated. Assessment of simulation results is resented in section five. Finally, we concluded in section six.

Related Works

The process of clustering gives wireless networks better abilities to perform and to organize its work, especially when the network has high density. Clustering methods could be centralized, distributed, or hybrid clustering. In centralized clustering, there is a fixed CH and the other nodes in the cluster are member nodes. On the other hand, in distributed clustering, the node that acts as CH is changed constantly according to certain parameters (Razak *et al.*, 2014). Hybrid clustering is the resulting combination of both centralized and distributed clustering methodologies. The centralized architecture is not reliable (when the central node fails, the entire network will collapse). On the other hand, distributed architecture improves network reliability and minimizes redundant information, but resources allocations have to be self-organized (Meelu and Katiyar, 2014). Due to the advantages of distributed architecture over centralized, much research of distributed clustering methods will be illustrated.

Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most important protocols for WSNs (Meelu and Katiyar, 2014). In LEACH, after certain rounds, nodes with high and low residual energy have equal probability of being CH. This may cause early death of CH in case it has low residual energy.

Clusters division is also done randomly causing uneven distribution of clusters, which will Affect WSN performance (Meelu and Katiyar, 2014). Stable Election Protocol (SEP) is a heterogeneous protocol, where some nodes have more storage capacity and different mounts of power consumption when performing the same effort. It is a modified version of LEACH, which considers two different types of nodes and two levels of hierarchies. The CH election is based on the amount of residual energy in each node. This technique improves the stability periods (the time interval before the death of the first node). It also prolongs the network lifetime and improved the throughput. The main drawback of SEP is that election of CHs between the two types of nodes is not dynamic. This will cause early death of the nodes that are far from the powerful nodes (Maragdakis *et al.*, 2004). SEP protocol improvement is obtained in (Aderohunmu *et al.*, 2011a). Hybrid Energy Efficient Distributing clustering (HEED) protocol is also a developed version of LEACH. To attain power balancing, many factors are used to choose the CH. Residual energy is the main parameter, while distance from neighbor nodes and node degree are secondary parameters. The protocol provides uniform CH distribution across the network. HEED prolong the network lifetime and support scalable data aggregation, but it imposes substantial overhead in network (Younis and Fahmy, 2004). CHEF cluster head election technique based on node location and the energy information is proposed in (Kim *et al.*, 2008; Kwon *et al.*, 2008). Fuzzy logic is used in collecting and calculating to reduce overhead and prolong the network lifetime, but it generates vast overhead. The performance of simulated CHEF is compared with LEACH performance (using Matlab). The comparison results show that CHEF outperforms LEACH in about 22.7%. Vice Low Energy Adaptive Clustering Hierarchy (VLEACH) protocol is developed based on LEACH protocol (Yassein *et al.*, 2009). It is designed to reduce the consumption of power. A vice CH is specified. When the CH dies, the vice CH will be the new CH (i.e., there no need to elect new CH each time the CH dies). The researchers claim that in VLEACH, number of created messages are less than LEACH, which reduces power consumption and prolong network lifetime. A local CH election algorithm (HEED*) (Taheri *et al.*, 2011), which is a developed version of HEED protocol. In HEED*, clustering is performed locally (within the cluster), which reduces number of exchanged messages per round. The elected CH is the nodes with the highest residual energy. The researchers claim the HEED* improves power efficiency and outperforms HEED in term of network lifetime. In (Sasikumar and Anitha, 2014), Heterogeneous HEED (H-HEED) protocol is proposed. It is mainly used in heterogeneous WSNs. The simulation results show that H-HEED protocol outperforms HEED protocol where throughput, packet delivery ratio, delay and energy consumption are improved.

Rathi and Viswanathan (2014), two phase clustering protocol is suggested. It is a developed version of LEACH protocol. Self-Organizing Map (SOM) neural network and Modified Fuzzy Probabilistic Clustering Algorithm (MFPCM) are used to balance the energy consumption. Sensor node coordinates and its energy level are utilized when electing CH. This protocol prevents premature death of the nodes and permit for random death of them. Experimental results show that using SOM to elect CH improves network lifetime (with less dead nodes) compared with LEACH protocol.

A Deterministic Energy-efficient Clustering (DEC) protocol is suggested (Aderohunmu *et al.*, 2011b). DEC protocol reduces the computational overhead needed to self-organize the network compared with probabilistic base protocols. Residual energy of each node is used when electing CH. DEC improves energy consumption in homogeneous and heterogeneous networks. However, as number of rounds increases, the nodes deployed in the network will die earlier than LEACH or SEP protocol. Therefore, in DEC protocol it is difficult to attain network stability in case of long network lifetime. I-DEC protocol is proposed as an improved version of DEC protocol (Meelu and Katiyar, 2014). In I-DEC protocol, number of rounds and network stability is enhanced. IDEC uses multilevel clustering (four levels of nodes), which suites heterogeneous environment. The researchers claim that I-DEC protocol balances between stability and network lifetime and improves energy management.

LBEACH Protocol

LBEACH is a WSN protocol that utilizes sensors features to elect proper CH and prolong network lifetime. The developed protocol (LBEACH) is a modified version of SEP protocol. It performs load balancing based on estimated energy spent during broadcasting process and the residual node energy. Broadcast cost of each node is used as factor in CH election process, because nodes do not consume energy in constant manner (over time, nodes could consume different amount of energy). This difference in power consumption could be caused by characteristics of radio communication, or some events such as short-term link failures, or morphological characteristics (Maragdakis *et al.*, 2004). Therefore, for power heterogeneous networks, two protocols are applied for electing CHs. At the first round, SEP protocol is applied. Subsequently, CHs are elected based on broadcasting cost and residual energy. For each cluster, three nodes (advance or normal nodes) with minimum

broadcasting cost are nominated to be CH. Among the three nominated nodes, the node with the highest residual energy will be elected as CH. In this case, we make sure that the selected CH consumes less energy during data broadcasting and has sufficient residual energy. The architecture of the suggested protocol (LBEACH) uses adaptive clustering hierarchy protocol.

Three scenarios, that illustrate the connection with the BS, are investigated. The general architecture of L BEACH protocol is shown in Fig. 1. One of the scenarios allows direct connection between nodes and the BS, in case the BS is closer than any other CH to that node. At the end of a round, clusters will be reorganized. Each node will join the closest CH. This will reduce power consumption for nodes and CHs.

In this study, we assume that the BS has unlimited power. The WSN is a two level hierarchy. It consists of advanced and normal sensor nodes with limited energy. The advanced nodes have power more than normal nodes. Like SEP protocol, the advance node will have extra chance to be elected as CHs. The nodes and the BS are not mobile. Such assumptions are important for certain applications. Sensor nodes are uniformly distributed. Any sensor node can be elected as CH for any number of rounds since the network is power heterogeneous. LBEACH protocol consists of many rounds. Rounds will carry on until the network lifetime expires. Each round consists of two phases: Setup phase (establishing clusters) and steady phase (CHs election and clusters reorganization). In both phases, the process of CHs election is performed by the BS.

In the setup phase, the location and amount of energy for each node is specified by utilizing the setup phase used in LEACH and SEP protocols (Heinzelman *et al*., 2000; Maragdakis *et al*., 2004). At the first round, LEACH protocol is not only used to specify number of clusters, but will also to perform initial election of CHs. Each node could be a CH once every k rounds (k for normal nodes is different than k of advanced node), which is called EPOCHs (as in SEP protocol). Each node will join the nearest CH. Calculating the epoch (the period between the first and last round) means that, any node can be a CH for only one time for certain number of rounds (k rounds). The value of the epoch differs based on node type (normal or advance) as in (Maragdakis *et al*., 2004). At the end of the setup phase, the clusters are formed and node parameters are specified (energy, location and node type). At this point, the next phase, which is the steady phase, starts.

In steady state phase, the sensor nodes will send data (message and periodically sends their residual energy) to the CH. The CH gathers the data and sends it to the BS. The BS continues to store and process data that arrives from the CHs. The main steps of the steady phase are:
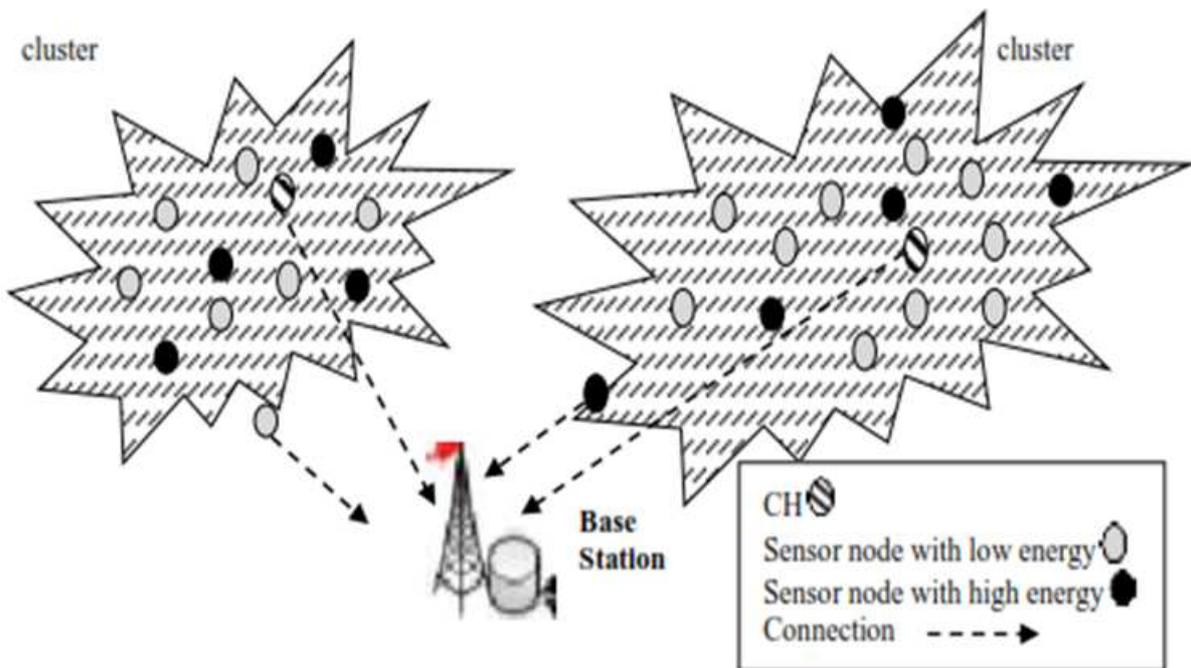
Fig. 1. WSN architecture For LBEACH protocol

- Specify the dead nodes by reading the available power in the battery of the node. If the battery is empty, this means that the node is dead
- Make sure that the epoch-period is expired to give the node a new chance to be the CH
- Elect CH: For each cluster node, estimate the broadcasting power consumption for all other nodes within the cluster (will be explained in the next section). Nominate three nodes, with the least broadcast power consumption. Among these three nodes, elect the one that has the highest residual energy to be the new CH. One of the suggested scenarios will consider the power consumption needed to send data to BS in addition to broadcasting power consumption
- Cluster reorganization: When new CHs are elected, all the nodes will search for the nearest CH to join its cluster

One of the suggested scenarios will allow a node to be directly connected to BS, if it is closer than any other CHs to the node. The reorganization process is needed because some nodes may join other cluster, or died. This means, that clusters may change in every round (just a possibility)

Performance Measures

To evaluate LBEACH behavior, five sensor network metrics are used in this study. Some of these metrics have various definitions (Dietrich and Dressler, 2009). Therefore, we need to define the metrics that are used in this study:

- *The Network Lifetime:* In this study, network lifetime is the time interval from the start of network operation until termination (viz. the death of all its nodes). So, the Lifetime is the total number of rounds from start to the end of network operation (Dietrich and Dressler, 2009; Maragdakis *et al.*, 2004)
- *Stability Period:* Is the time interval until the death of the first node (Rashed *et al.*, 2011). In other words, number of rounds until the first node is dead.
- *Average Network Energy Consumption (ANEC)*: In this study, Equation 2 is used to find the amount of energy consumption per round. We assume that the total consumed energy in network lifetime equals the initial total energy in the network (used in (Maragdakis *et al.*, 2004)). The total of the network power is divided by the number of rounds (r) to find the average of energy consumption per round (as in Equation 1):

$$ANCE = (N \times M) \times ((a+1) \times 1) + (N - (N \times M) \times 1) / r \quad (1)$$

N: Total number of nodes
M: Percent of the advance node
a: Quantity of the multi power
r: Total number of rounds
I: The initial power, in this work=50

- *Number of CHs:* Number of CHs represents the total number of selected CHs during the network lifetime (Maragdakis *et al.*, 2004). Number of CHs is used to express load balanced and work distribution between nodes in the same network (Maragdakis *et al.*, 2004)
- *Throughput:* In (Maragdakis *et al.*, 2004), throughput is defined as "The measure of the total rate of data sent over the network, the rate of data sent from CHs to the sink, as well as, the rate of data sent from the nodes to their CHs". In other word, throughput is obtainable from, number of messages that carry data reported from the nodes to the CH over all rounds in network lifetime and number of messages from CH to BS over all rounds in network lifetime

Heterogeneous Model of WSNs

LBEACH protocol is suggested to manage the performance of WSNs that consists of static sensor nodes with heterogeneous initial power. To study the behavior of LBEACH compared with LEACH and SEP, different simulation environments and node energy specifications are considered. Normal nodes have initial power=50 joules, while advanced nodes power is multiple of normal nodes initial value. In this study, advance nodes may have initial power=100 or 200 joules. These values are arbitrary and it doesn't affect the behavior of the protocols. Also, these values are used by (Maragdakis *et al.*, 2004) is SEP protocol. All sensor nodes are assumed to have the same radio range, (i.e., to transmit at the same power level).

LBEACH depends on nodes power to organize the WSN task. LBEACH uses hierarchal algorithms, which is started by LEACH protocol. Based on the radio energy dissipation mode in (Maragdakis *et al.*, 2004), acceptable Signal-to-Noise Ratio (SNR) is achieved when a massage of size L-bits is transmitted over the physical distance (d). The power expended by the radio is calculated using Equation 2:

$$E_{Tx}(l,d) = \begin{cases} L.E_{elec} + l.\varepsilon_{fs}.d^2 & if \ d \le d_9 \\ L.E_{elec} + l.\varepsilon_{mp}.d^4 & if \ d > d_9 \end{cases} \quad (2)$$

When d=d_0, $d_0 = \sqrt{\dfrac{\varepsilon_{fs}}{\varepsilon_{mp}}}$

where, d is the distance between sender and receiver and E_{elec} is the power dissipated per bit. E_{Tx} is the power

consumption when sending a message-size of l-bit over d. E_{Rx} is the node power consumption when receiving l-bit message (E_{Rx}=l.E_{elec}). The factors ε_{mp} and ε_{fs} are stability factors that help in calculating the amount of energy consumption (Maragdakis *et al*., 2004). The values of ε_{mp} and ε_{fs} depend on the used transmitter amplifier model. The power of node (initial value) decreases when the node sends a data to another node or to BS. The amount of consumed energy depends on the message length (in this study, it is equal to 4000 bits) and the physical distance. The physical distance depends on calculating and finding parameters to reduce power consumption, such as, nominated CH location, BS location and the comparison between the physical distance and the parameter d0 to find the power consumption.

Four cases are constructed to compare the performance of LBEACH protocol with LEACH and SEP protocols. These four cases are considered to cover different areas, with varied number and types of sensor nodes. The considered cases are:

- *Case One*: Assume the area of sensor filed is (100m′100m), where network sensor nodes are uniformly distributed. Normal nodes have initial power that equals 50 joules. Advance nodes have initial power=100 joules. Number of advance nodes represents 10% of the total nodes
- *Case Two*: The suggested area is (100m′100m). Normal node has initial power=50 joules. Advance node has initial power=200 joules. Number of advance nodes represent 20% of total nodes
- *Case Three*: The suggested area is (1000m′1000m). Normal node has initial power=50 joules. Initial power of advance node=100 joules. Number of advance node represents 10% of total nodes

- *Case Four*: The suggested area is (1000m ′1000m). Initial power of normal node=50 joules. Advance node has initial power=200 joules. Advance nodes represent 20% of total nodes

In this study, three different scenarios are suggested. In each scenario, different procedure is used to elect CH.

- *First Scenario (LBEACH₁)*: Calculates the estimated total consumed power (P_i) for every alive node i. In this scenario, P_i is calculated using Equation 3., where MCi is the estimated message broadcasting cost from node i to all nodes within the cluster (CM$_i$) and BSM$_i$ is the cost of sending a message from node i to the BS. Both costs (CM$_i$ and BSM$_i$) are calculated using Equation 2:

$$p_i = MC_i + BSM_i \tag{3}$$

Three nodes with minimum (P_i, i=1 to total number of alive nodes within the cluster) will be nominated to be CH. Among the three nodes, select the node with the highest residual energy to be the new CH in the current round:

- *Second Scenario (LBEACH₂)*: It is similar to the first scenario, except that P_i = CM$_i$. The cost of sending a message from node i to the BS is not considered in this scenario. The CH election technique is the same as in the first scenario
- *Third Scenario (LBEACH₃)*: In this scenario, CH is similar to *LBEACH₂,* except that *LBEACH₃* allows nodes to directly send data to the BS in case the BS is the nearest point to that node from any CH. In this case P_i = BSM$_i$. The CH election technique is the same as in the first scenario
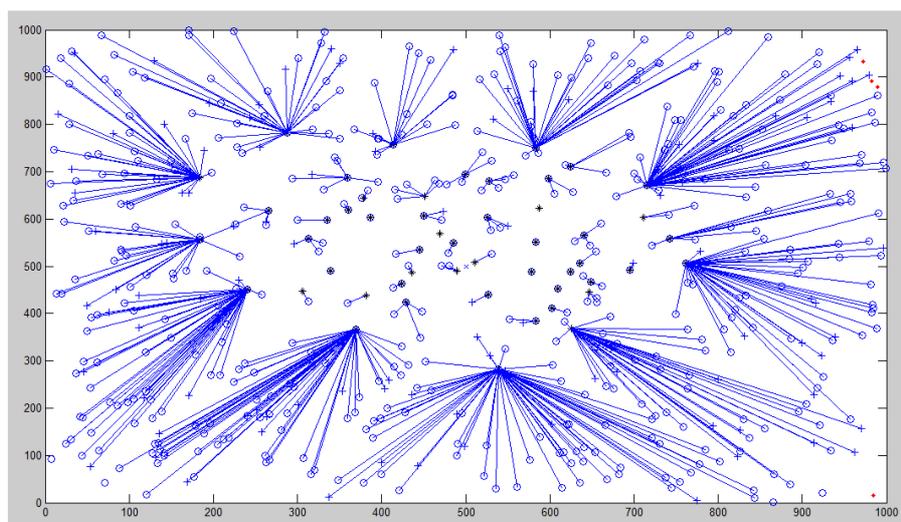
(a)
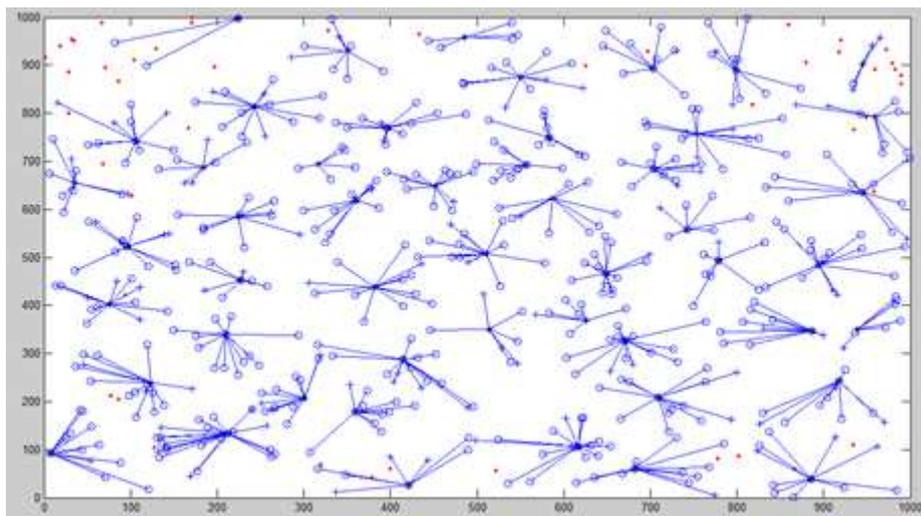
(b)
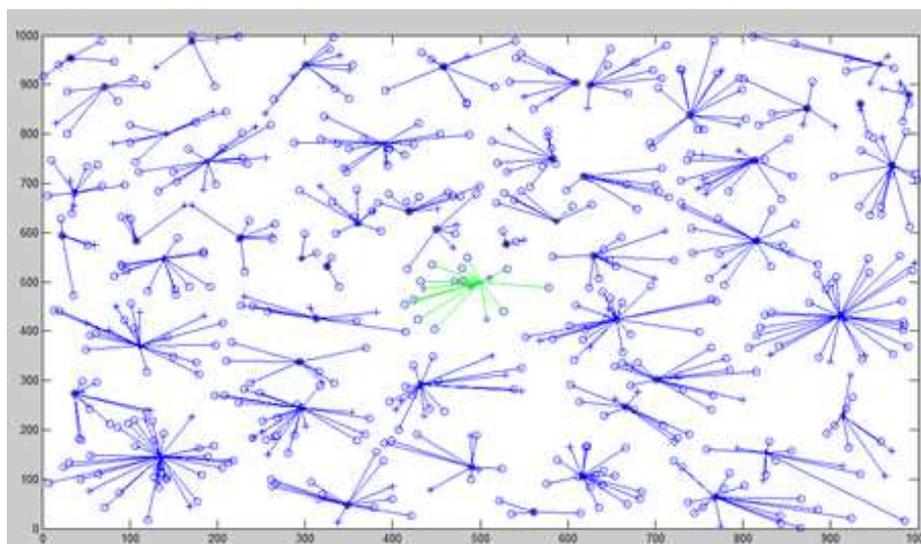
(c)

Fig. 2. The behavior of LBEACH scenarios (a) $LBEACH_1$ (b) $LBEACH_2$ (c) $LBEACH_3$

Figure 2 helps in understanding the behavior of the three LBEACH scenarios. *LBEACH_1* elects the new CH depending on the broadcast cost to all nodes within the cluster and to the BS. In this scenario, the CH location is almost in half of the physical distance between the BS and the other nodes within the network. The locations of CHs are not in clusters centers, which consumes a lot of CH power. Also, it is clearly seen from Fig. (2a), that nodes are not normally distributed between clusters. Some CHs (especially those that are near the BS) are connected to few nodes, while far CHs are connected to many nodes. This will increase power consumption of these CHs, which will highly affect network stability. *LBEACH_2* behavior is illustrated in Fig. (2b). *LBEACH_2* elects the new CH only depending on the broadcast cost to all nodes within the cluster. It doesn't allow nodes to

be directly connected with the BS (connection between any node and the BS must be through a CH). In this scenario, the nodes (almost) uniformly distributed among clusters. Generally, this situation increases the network power consumption. This is because some nodes will send packets to CHs, then from CH to BS, while actually they are closer to the BS. We think it is better to send messages directly to the BS if the BS is closer than any other CH, as in *LBEAH_3*. In this scenario, the BS, also, acts as CH for close nodes.

Assessment of Simulation Results

The simulation results of the three scenarios indicate that $LBEACH_3$ outperforms the other two scenarios. The improvement in all cases of $LBEACH_3$ is due to the

feature of LBEACH₃, which allows direct connection between some nodes and the BS. This will improve the network performance for two reasons: (1) Reduces number of nodes far from CH (for some clusters), which will reduce power consumption spent by the CH (saves some CH energy). (2) Reduces power consumed by nodes that are close to the BS and far from all CHs, which elongate their lifetime. This is because; long distance between the node and the CH consumes more energy. This will save nodes and CHs energy and elongate their lifetime.

In this section, the simulation results of LBEACH₃ is compared with SEP and LEACH results since LBEACH₃ outperforms the other two scenarios. The comparison is based on five performance measures (illustrated in the previous section).

Network Power Consumption

The amount of power consumption per round for the three protocols (LEACH, SEP and LBEACH) is compared. Figures (3-6) show that LBEACH outperforms the other two protocols (i.e., LBEACH consumes less power based on Equation 1. This is because LBEACH has the best capability of load balancing and work distribution among the network nodes. LBEACH elects new CH depending on nodes location, residual power and broadcast cost. In this case, power consumption is decreased since CH, almost always, reside in the center of the cluster (Fig. 2c). In other words, power consumption is reduced when broadcasting messages to the other nodes within the cluster and to the BS.
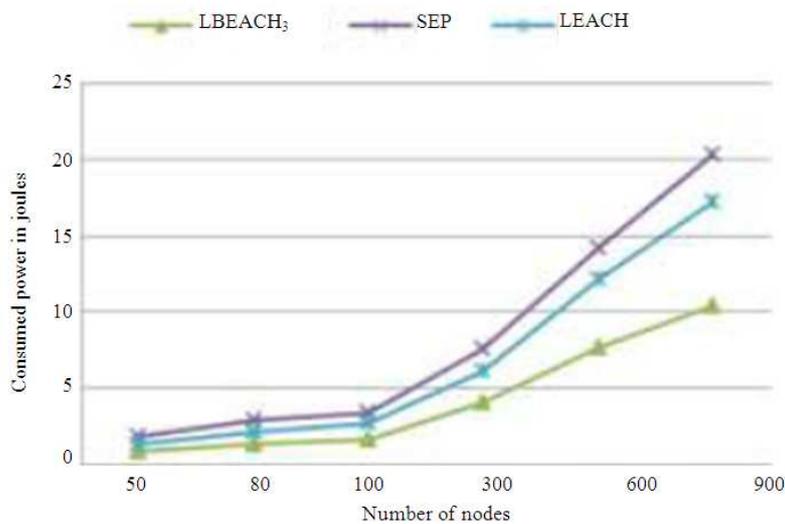
Fig. 3. Power consumption for case-one
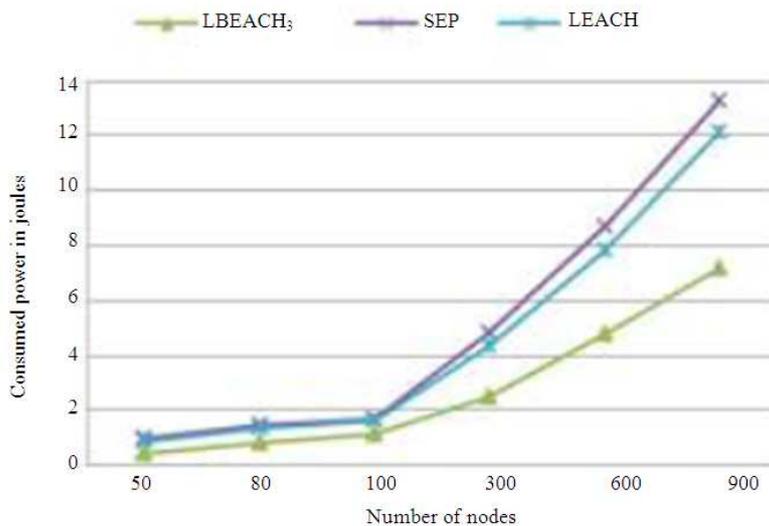
Fig. 4. Power consumption for case-two
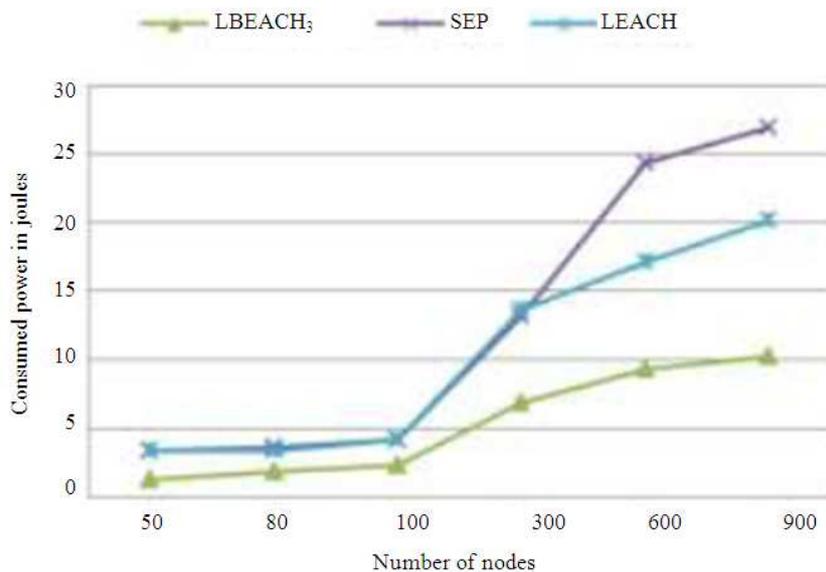
Fig. 5. Power consumption for case-3
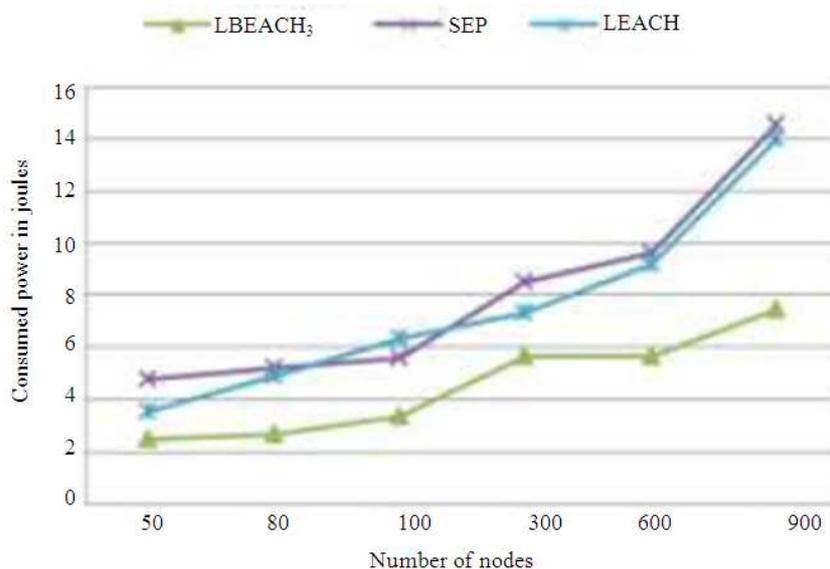
Fig. 6. Power consumption for case-four

Network Lifetime

Decreasing of power consumption leads to prolong network lifetime and benefit from its sources in a proper way. From Figs. (7-10), it is clearly seen that LBEACH outperforms LEACH and SEP protocols. This is due to the load balance strategy used in this protocol. The used load balancing strategy considers power consumption per round, in addition to the residual energy in each node. This strategy guarantees the elongation of network lifetime. LEACH did not consider any load balancing strategy, while SEP protocol only considers residual energy in each node.

Number of CH

Increasing the number of CHs over network lifetime will improve the work distribution and load balancing. This will occur, especially, if the physical distance and the residual energy are considered when electing the CH. Increasing number of CHs over network lifetime results in reducing power consumption in true style. As illustrated previously, LBEACH protocol elongates network lifetime. Therefore, number of CHs is increased over network lifetime. Figures (11 to 14) show how LBEACH increases number of CHs, after certain rounds (in this case, after 100 rounds) compared with SEP and LEACH results. LBEACH presents successful consumption of energy.
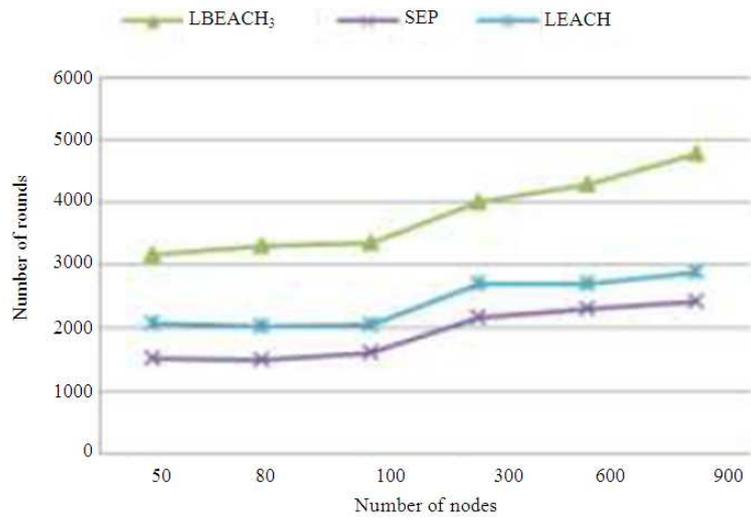
Fig. 7. Lifetime for case-1
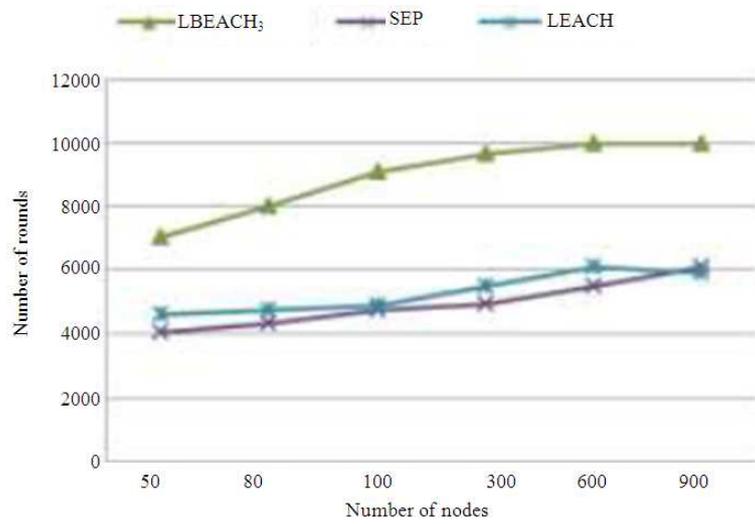
Fig. 8. Lifetime for case-2
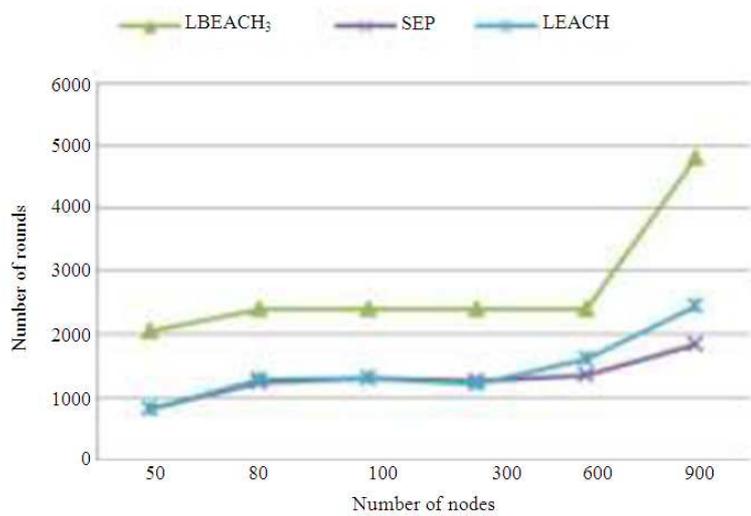
Fig. 9. Lifetime for case-3
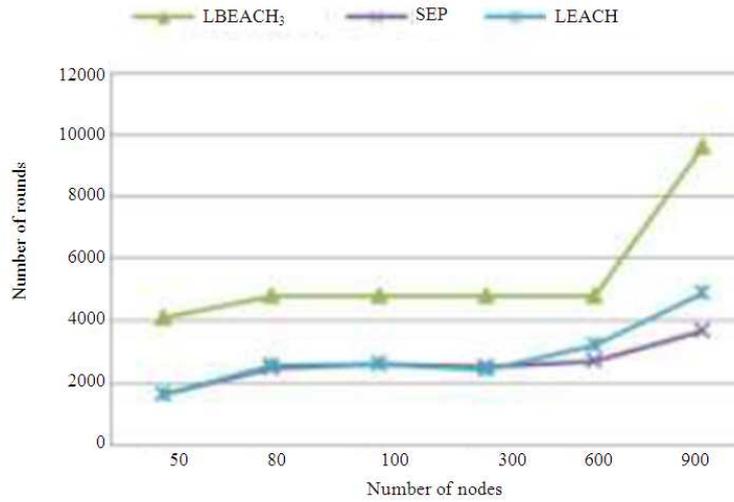
Fig. 10. Lifetime for case-4
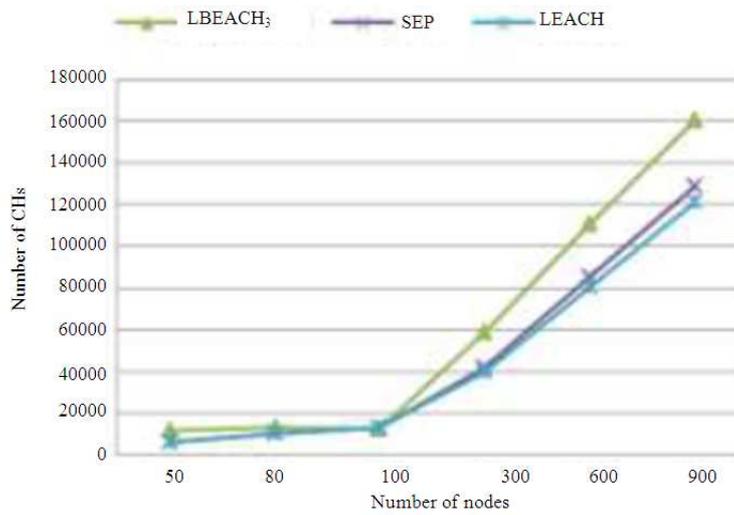
Fig. 11. Number of CHs for case–one
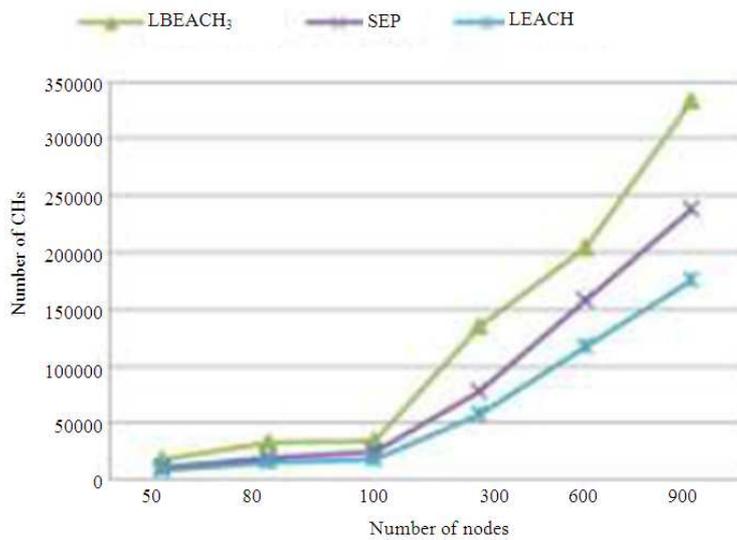
Fig. 12. Number of CHs for case-two
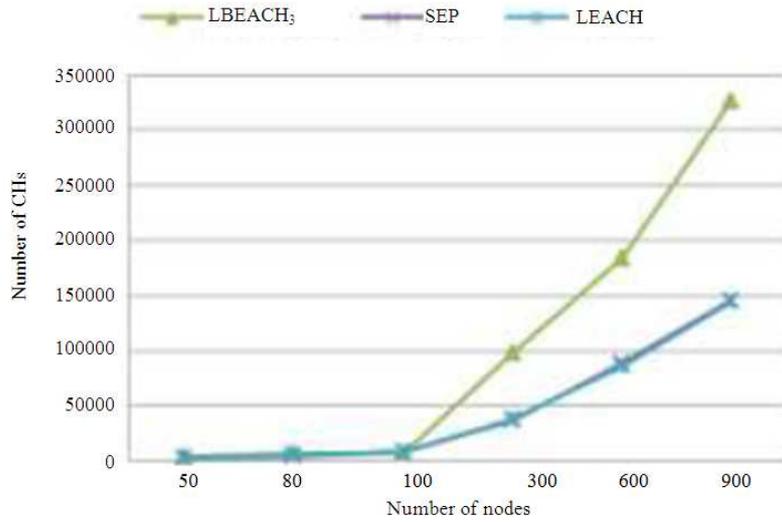
Fig. 13. Number of CHs for case-three
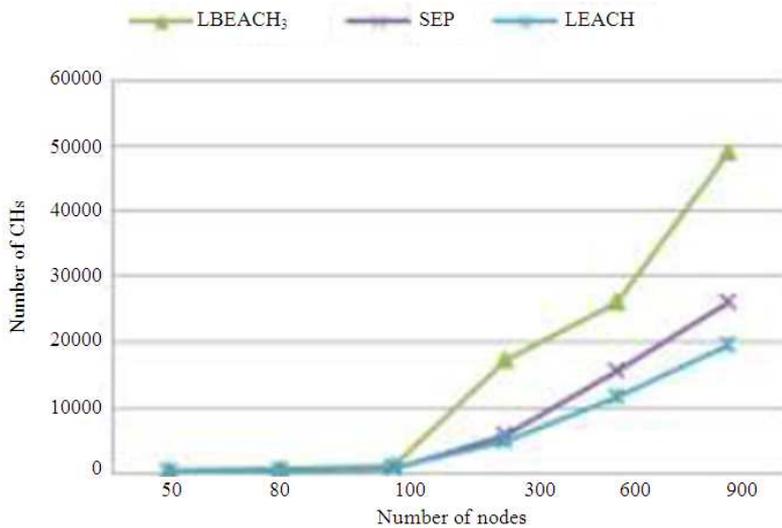
Fig. 14. Number of CHs for case-four

Stability Period

As mentioned before, the election of CHs in the 1st round is based on SEP and LEACH protocols (i.e., normal or advance nodes are chosen randomly to act as CHs). Some of these CHs could exist at borders of the WSN and could be normal nodes (have 50 joules as initial power). These nodes will die at early stages (at the 1st or the 2nd round) when case-three and case four are considered. This will happen with the three protocols (LEACH, SEP and LBEACH). The main reason behind this early death is the long physical distance between that CH and the BS, which will consumes its power quickly. This means CH energy is not enough to make more than one or two connections with the BS. The three protocols show the same behavior in case-three and case-

four (i.e., the stability period is the same for the three protocols). Therefore, the comparison will consider case-one and case-two only. Figures (15 and 16) show that, LEACH and SEP protocols outperform LBEACH. This is due to the fact that both protocols (LEACH and SEP) will elect CHs randomly which will reduce the probability of electing the same node as CH by random form. While in LBEACH protocol, this might happen since the protocol follows special measurements in electing CHs. In LBEACH, at first, three nodes are selected depending on its broadcast cost, which may lead to ignore some nodes that have higher power. In the second step, from the nominated nodes, elect the node with highest residual power in its storage as CH. This might cause electing the same node more than once causing early death of some nodes.
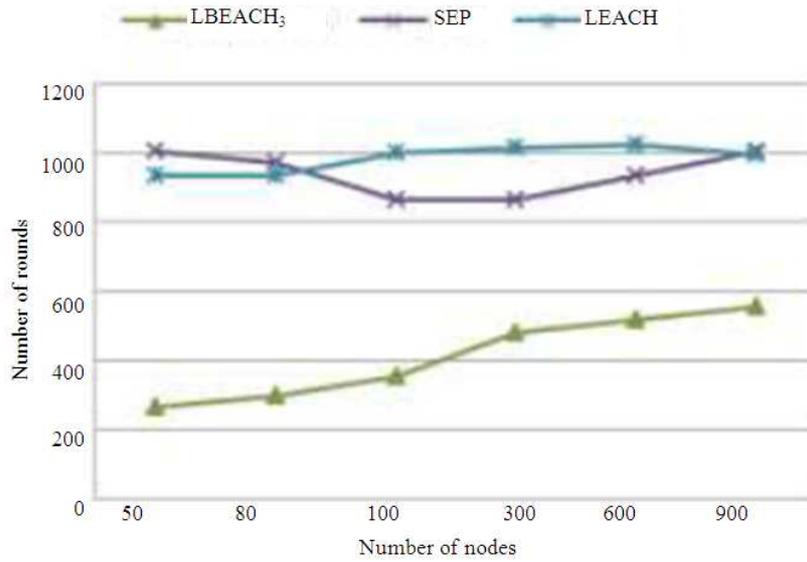
Fig. 15. Stability period for case one
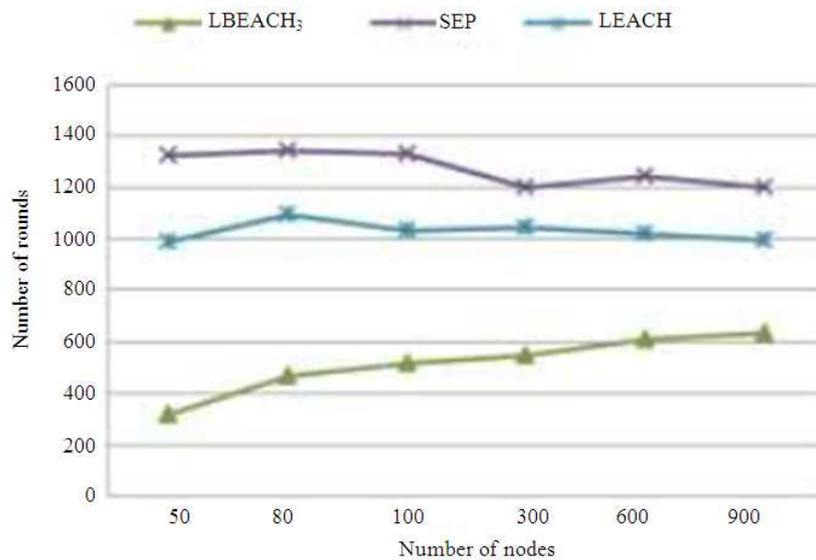
Fig. 16. Stability period for case two

Throughput

Packets to CHs: Elongating network lifetime will increase number of rounds. As mentioned in previously, LBEACH protocol may cause early death of some nodes. Therefore, after certain number of rounds, some clusters will contain very few nodes (sometimes none). This will decrease number of nodes that can send packets to CHs at network lifetime. As number of nodes per cluster is reduced in LBEACH protocol, the amount of data transmitted to CHs will also be reduced (the throughput to CHs is decreased in LBEACH protocol). Figures (17 and 18) show that the amount of throughput from the nodes to CHs for the three protocols (LBEACH, SEP and LEACH) are comparable. However, from Figs. (19 and 20), it is clearly seen that when number of nodes increases, SEP and LEACH protocols outperforms LBEACH protocols.

Packets to BS: Number of packets sent to the BS (throughput to BE) will increase with increasing number of CHs during network lifetime. LBEACH shows improvement in number of CHs, which cause improvement in the amount of throughput to BS. Figures (21 to 24) illustrate that LEACH protocol outperforms LEACH and SEP protocols.
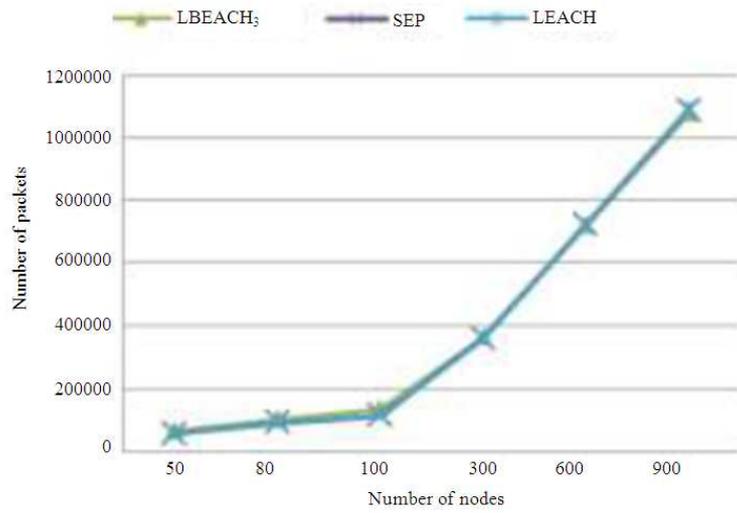
Fig. 17. Packets to CHs for case one
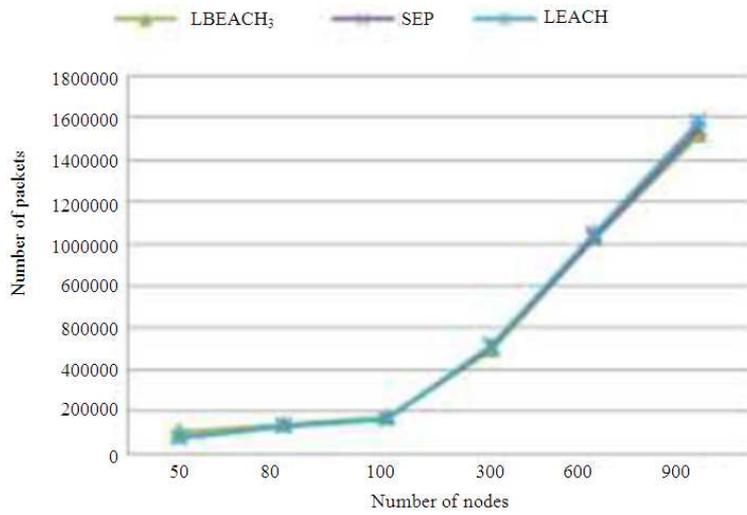
Fig. 18. Packets to CHs for case two
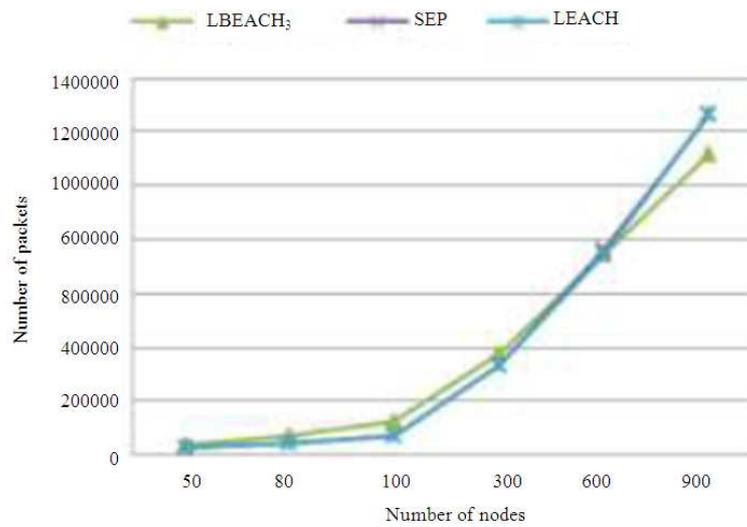
Fig. 19. Packets to CHs for case three
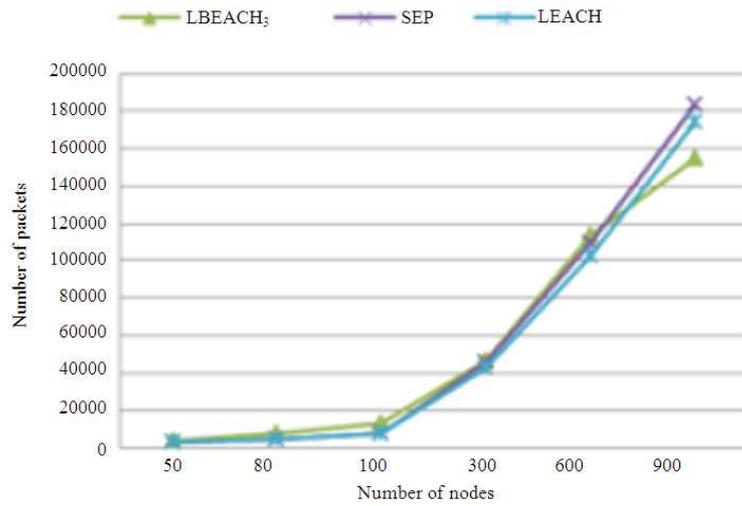
Fig. 20. Packets to CHs for case four
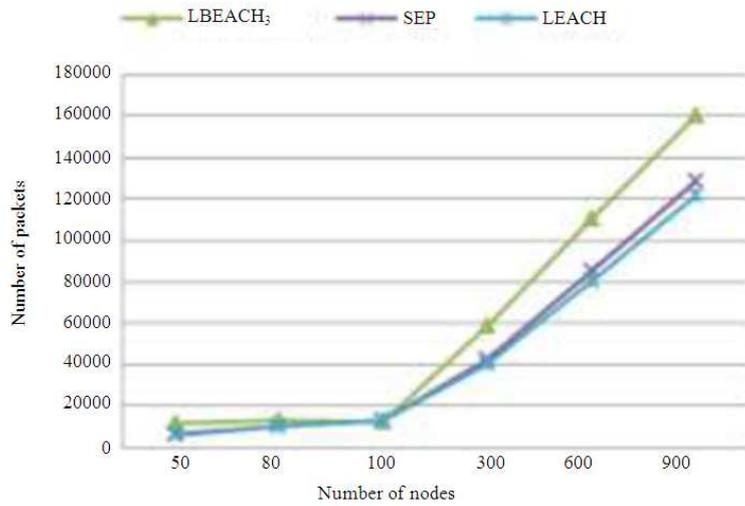
Fig. 21. Packets to base station for case one
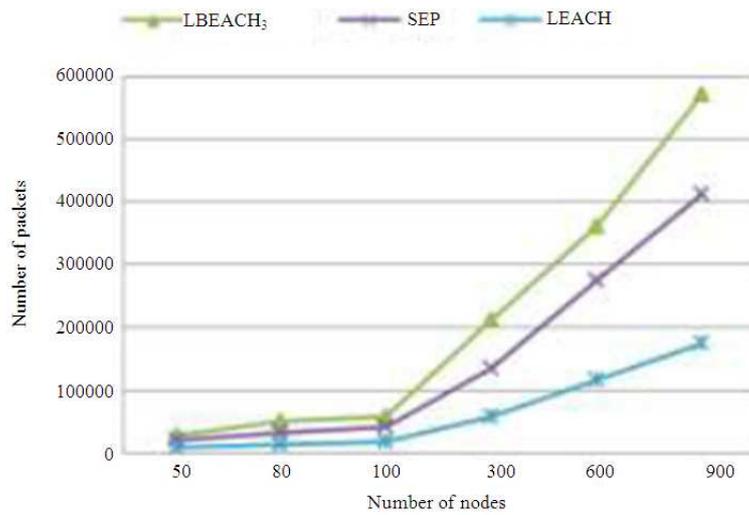
Fig. 22. Packets to Base station for case two
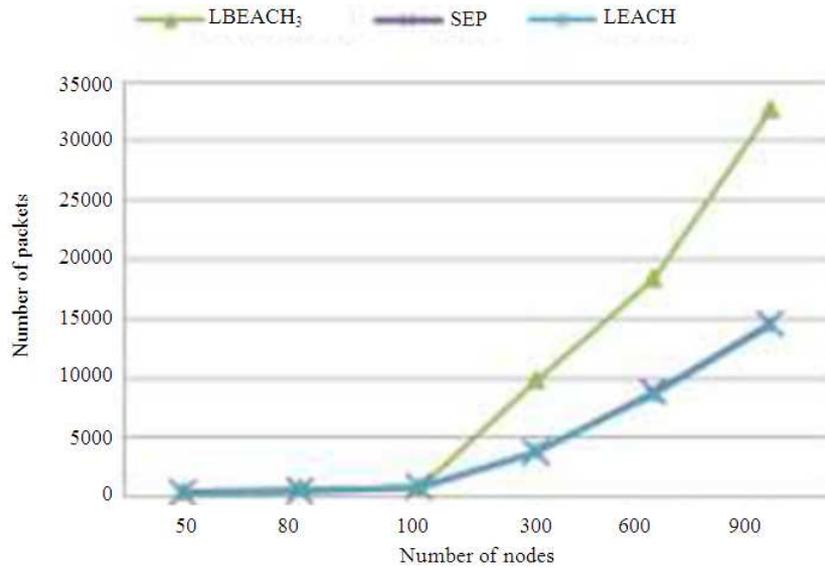
Fig. 23. Packets to base station for case-3
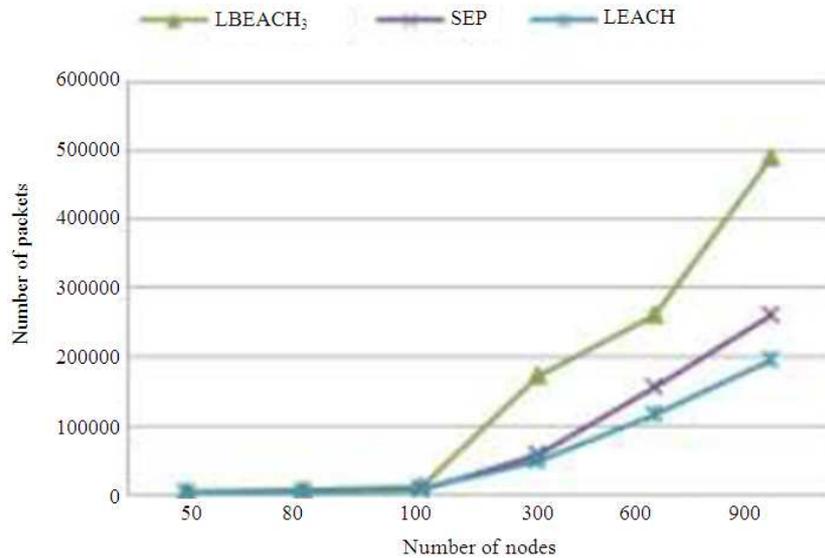
Fig. 24. Packets to Base station for case four

Conclusion

Elongating the lifetime of WSN is the main objective that most research is concerned with. Therefore, to achieve this objective, researchers must decrease power consumption and invest nodes power in a way that maximizes their benefits. In this research, we develop a protocol to improve the performance of WSN. LBEACH protocol uses centralize algorithm that requests complete information about all nodes in the network and fairly distribute CH duty among the nodes. The needed information is node location, node power, node cluster, node broadcast cost (the connection cost to all node within its cluster only), node EPOCH time, the distances of node from neighbors CHs and the distance of node from the BS.

In this study, WSN environment (which is presented by Matlab) managed by three scenarios for LBEACH protocol. From simulation experiments, it was found that the 3rd scenario outperforms the other two suggested scenarios. By comparing the performance of LBEACH with SEP and LEACH protocols, it was found that, LBEACH outperforms SEP and LEACH from power consumption, network lifetime and throughputs toward BS, point of views. While, SEP and LEACH outperforms LBEACH from throughputs toward CH and stability period, point of views.

The simulation results show that LBEACH protocol reduce the nodes power consumption about 46-62% compared with SEP protocol and 30-61% compared with LEACH protocol. Numbers of CHs are increased about 24-124% compared with SEP protocol and 31-149% compared with LEACH protocol, which indicates that LBEACH protocol improves load balancing. Network throughput toward BS is improved between 24-124% compared with SEP and between 31-225% compared with LEACH protocols. Finally, network lifetime is elongated between 63-161% compared with SEP protocol and between 41-155% compared with LEACH protocol. This means that the main goal of this research is achieved.

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Author's Contributions

Abdullah Soliman Al Sahraa: Undertake the research work, responsible of the implementation and execution phases. He has significant contribution in designing and performing the experiments, analyzing data, interpretation and writing of the manuscript.

Venus Wazeer Samawi: Suggested the major contribution of the research, approved the experimental design, supervised the experiments, verify data analysis and writing the manuscript.

Ethics

The corresponding author confirms that the other author has read and approved the manuscript and there is no ethical issue involved. This paper is original and contains unpublished material.

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