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A Proposed Protocol to Enhance the Performance of Wireless Sensor Networks Based on the Reduction of Power Consumption

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Abstract—This paper represents the analysis and study of selecting the highest power node in the wireless sensor networks as a cluster head. The study assumes that the sensors are fixed and uniformly distributed, and the position of the sink and the dimensions of the sensor are known. The paper introduces a proposed protocol to prolong the time interval before the death of the first node (stability period), which is critical for many applications. The aim of this paper is also to improve the performance of the network by increasing the overall throughput of the network. The proposed protocol selects the cluster head depending on the power level of the node which is the most important factor of the behavior of the nodes. The simulation is made by MATLAB, and the results are compared with two other protocols, LEACH and SEP. It is found that the selection of the highest power node as a cluster head increases the stability region and throughput of the network compared to other protocols.

1. INTRODUCTION

Wireless sensor networks (WSNs) consist of hundreds or thousands of sensor nodes randomly distributed with limited resources such as energy, radio, storage, and processing. WSNs can manage these large numbers of small and low-cost sensor nodes. Sensor nodes usually have a small size with radio capabilities, limited computation, and sensing components. WSNs have one or more central base stations to collect the data from the nodes of the network, which are called the sinks. Sensor nodes are self-configured, which means that they take self-decisions to construct the network and the routing policy.

WSNs are usually used to monitor and collect data and report aggregated data to the base station. These networks support a wide range of diverse applications such as military surveillance, environmental, transportation traffic, temperature pressure, vibration monitoring, monitoring of animal tracking, search and rescue, industry, security, home applications, healthcare, disaster response, surveillance systems, biological monitoring systems, environmental control systems and equipment supervision systems. The advances in wireless communication and Micro-Electro-Mechanical Systems (MEMS) technologies contribute to the use of WSNs to almost every aspect of our life. Figure 1 shows some of the WSN applications [1].

The remarkable development of wireless applications has driven designers to create appropriate protocols to improve the use of the transmitting channel and maximize the signal to interference plus noise ratio (SINR) [2].

Physical layer and link layer synchronization are important. In some other wireless technologies, the physical dimensions and energy resources of the nodes enable the nodes to utilize positioning systems such as Global Positioning System (GPS) to synchronize using a common reference. For sensor networks, physical layer and link layer require to be made to allow synchronization between nodes [3].

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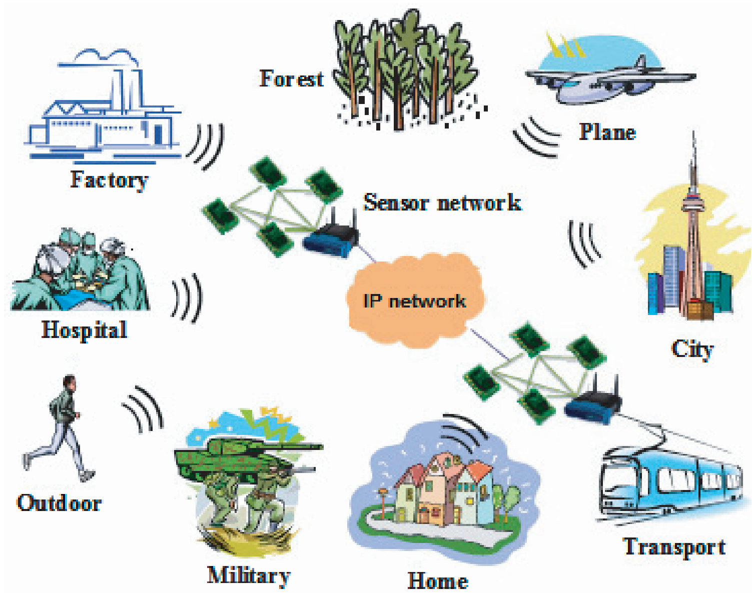

Figure 1. WSN applications [1].

The behavior of WSN is principally concerned with the Medium Access Control (MAC) in the network layer, and the perfect management of the physical layer in order to prolong the network lifetime. The adoption of a smart antenna in the communication interface is surely a perfect solution not only to decrease the RF-energy consumption, but also to maximize the efficiency of the information exchange among the network nodes [4].

WSNs are usually deployed for long period and applied in the hostile environment and places that cannot be easily accessed. Making the environmental energy harvesting is a difficult process. Nodes suffer from a shortage of energy because it usually depends on its batteries that are usually hard or even in some cases impossible to be replaced especially in large-scale networks after the deployment. So, the biggest challenge that faces WSNs is to reduce the energy consumption and to use the energy efficiently, especially in radio transmission.

This reduction in WSNs energy consumption leads to prolonging network's lifetime. The sensor must use its energy very wisely. The most energy consumption operation for the sensor is the radio transmission, so the communications should be limited [5]. Regular and long distance communications should be avoided [6]. Also, sensor nodes need to reduce the redundancies when sending data to the base station to reduce the unwanted traffic into the network and in turn reduce the overall power consumption.

It is important to select energy efficient protocols to prolong the lifetime of WSNs [7]. Routing protocols using direct transmission makes the nodes that are far away from the sink lose their energy very rapidly. When using minimum transmission energy (MTE), the nodes that are near to the sink die first which is making the large part of the network cannot be monitored. In static clustering protocol, the cluster-heads and associated clusters are chosen initially and remain unchanged during the whole lifetime of the network. When using a static clustering protocol, as soon as the cluster head dies, all nodes from that cluster are considered dead since they can't send their data to the base station.

Another clustering protocol, low energy adaptive clustering hierarchy (LEACH), is considered a dynamic clustering protocol. In this protocol, nodes are divided into clusters. Each cluster has one cluster head (CH) that collects the data from its cluster's nodes and sends them to the base station after aggregation and removing the redundant data which reduces the energy consumption and increases the network lifetime. But as a result, CH consumes more energy than normal node as CH aggregated data and sending data far away to the remote base station. LEACH overcomes this issue by changing the selection of CH randomly every certain equal interval called "round". This distributes the energy

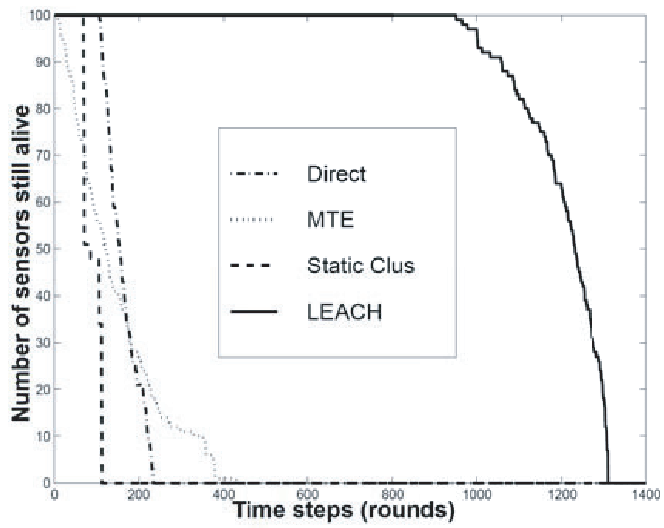

Figure 2. System lifetime using direct transmission, MTE routing, static clustering, and LEACH protocols [8].

overload among the nodes and reduces the energy consumption by distributing the load to all the nodes at different points at the same time.

Distributing the energy among the nodes in the WSNs is effective in reducing the energy consumption [8]. Figure 2 shows the system lifetime using direct transmission, MTE routing, static clustering, and LEACH protocols.

Other protocols have been presented to reduce the energy consumption by finding an optimal route with low cost such as Honey Bee Optimization (HBO) [9] and energy efficient and density control clustering algorithm (EEDCA) [10].

The proposed protocol in this paper focuses on increasing the stability region and the overall throughput of the network. It can be considered as clustering protocol where highest power sensor nodes in the cluster are choosing as cluster heads.

2. CLUSTERING HIERARCHY

Clustering is an effective architecture that helps the network to reduce the total data to be transmitted. It consists of local groups of nodes called clusters. Each cluster has one node selected to be CH. A CH may be selected by the sensors in a cluster or pre-assigned by the network designer [11].

A CH may be a normal node or a special node with more resources. The election of the cluster member may be fixed or variable. Each cluster head collects and aggregates the data sent from its cluster member's sensor nodes. This decreases the amount of data transmitted to the base station. Also, the communications inside the cluster, between the normal nodes and CH reduce the energy consumption because nodes send their data to the nearest CH rather than sending it to the remote base station. CH may allow its member nodes to enter the sleep mode for a longer time [12]. The CH also removes the redundancy in data before sending it to the base station. The clustering mechanism in WSN can reduce energy consumption in the network which in turn increases the lifetime of the network. Routing mechanism is more simple and easy in cluster-based WSN [13].

Cluster-based design helps to save the energy of the sensor nodes by making some nodes as CHs that communicate with the remote base station. Grouping sensor nodes into clusters will increase the scalability of the network. Clustering reduces the size of the routing table stored at the individual node since each node stores the route to a node inside its cluster. Clustering avoids the redundant messages among sensor nodes in the network by limiting the data exchange between the node and its CH which in turn saves the communication bandwidth.

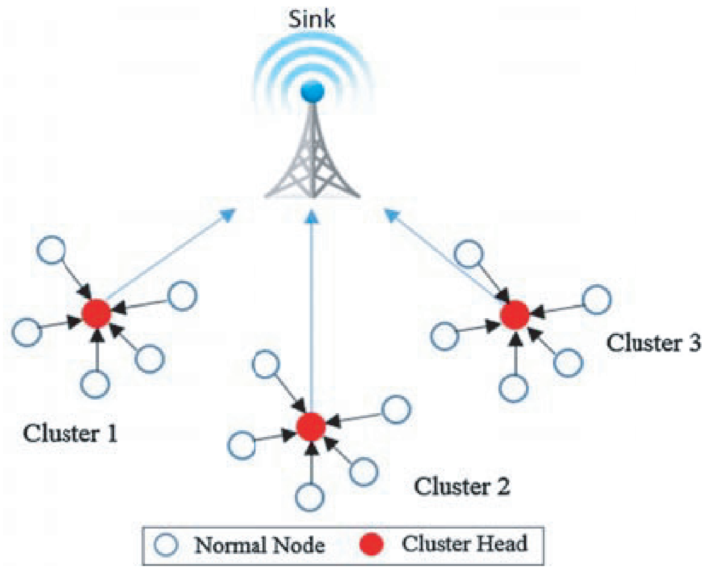

Figure 3. Clustering architecture diagram [13].

The distance between the cluster head and the base station is usually larger than the distance between the sensor node and its cluster head. The energy consumed in communication is directly proportional to the squared distance between the source and the destination. So, the cluster head consumes its energy faster than its cluster members. The uniform energy consumption of the sensor nodes will make it possible for all of them to survive over the entire lifetime of the network [14]. So, protocols using clustering are useful in minimizing the energy consumption. Figure 3 shows an example of clustering architecture diagram.

3. HOMOGENEOUS VS. HETEROGENEOUS NETWORKS

WSNs can be homogeneous or heterogeneous. Homogeneous WSNs nodes start out with the same energy level and resources. The CHs in this network are selected based on certain algorithms. Meanwhile, in heterogeneous WSNs, nodes are deployed with different initial energy levels and resources. Some nodes have more resources than the rest of the WSN nodes that are usually selected as CHs. Heterogeneity may be the result of re-energizing of the WSN nodes or replacing the dead nodes with the new nodes to extend the network lifetime.

Low energy adaptive clustering hierarchy (LEACH), hybrid energy-efficient distributed clustering (HEED), and power efficient gathering in sensor information systems (PEGASIS) are examples of protocols for homogeneous WSNs. Stable election protocol (SEP), distributed energy efficient clustering (DEEC), enhanced DEEC (EDEEC) and developed DEEC (DDEEC) are examples of protocols for heterogeneous WSNs [6].

4. OPTIMUM NUMBER OF CLUSTER HEADS

The optimum number of cluster heads is the ideal number of the cluster heads in the network that keeps the energy consumption at the minimum level. If the number of cluster heads in the WSNs system is lower than the optimum number, this forces some nodes in the network to send their data very far to the nearest CH, which increases the energy consumption of the network. Also, if there are more cluster heads in the WSNs system than the optimum number, more CHs are forced to transmit their data for long distances to the base station and which leads to less aggregated data in the clusters. Optimal clustering is highly depending on the energy model. Figure 4 shows the radio energy dissipation model used in the proposed protocol.

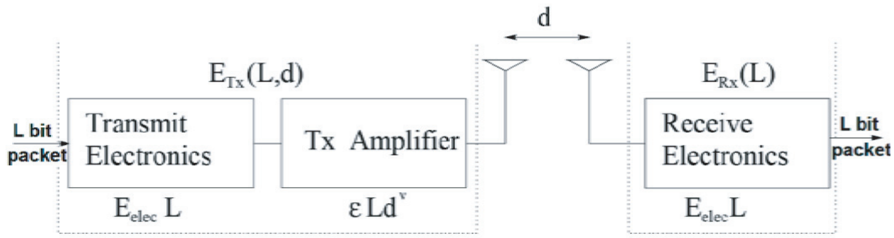

Figure 4. Radio energy dissipation model [7].

Energy consumption for message L bits and over a distance d using the radio energy dissipation model illustrated in Figure 4 is given by:

$$E_{Tx}(ld) = \begin{cases} L \cdot E_{elec} + L \cdot \epsilon_{fs} \cdot d^2 & \text{if} \quad d < d_0 \\ L \cdot E_{elec} + L \cdot \epsilon_{mp} \cdot d^4 & \text{if} \quad d \geq d_0 \end{cases} \tag{1}$$

where E_{elec} is the energy dissipated per bit for transmitter or receiver; ϵ_{fs} and ϵ_{mp} are constant depend on the amplifier model; d is the distance between the sender and the receiver.

To obtain the value of d_o, the two expressions in Equation (1) are equating and substituted with $d = d_o$ which leads to $d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$.

The numbers of nodes (n) are uniformly distributed over the area of the WSNs system. For simplicity, assume the sink is located in the center of the field, and the maximum distance of any node to the sink is less than or equal to d_o. So, the energy dissipated in the cluster head node during one round is given by:

$$E_{CH} = L \cdot E_{elec}\left(\frac{n}{k} - 1\right) + L \cdot E_{DA}\frac{n}{k} + L \cdot E_{elec} + L \cdot \epsilon_{fs} d_{toBS}^2 \tag{2}$$

where k is the number of clusters, E_{DA} the data aggregation energy cost of a bit per signal, and d_{toBS} the distance between the cluster head and the sink. The energy dissipated in a non-cluster head node given by:

$$E_{nonCH} = L \cdot E_{elec} + L \cdot \epsilon_{fs} d_{toCH}^2 \tag{3}$$

where d_{toCH} is the distance between a node and its cluster head. Assuming that the nodes are uniformly distributed $E[d_{toCH}^2]$ can be given by:

$$E\left[d_{toCH}^2\right] = \iint (x^2 + y^2)\rho(xy)dxdy = \frac{M^2}{2 \cdot \pi \cdot k} \tag{4}$$

where $\rho(xy)$ is the node distribution. The energy dissipated in a cluster per round is given by:

$$E_{cluster} \approx E_{CH} + \frac{n}{k} E_{nonCH} \tag{5}$$

The total energy dissipated in the network is given by:

$$E_{tot} = L \cdot \left(2nE_{elec} + nE_{DA} + \epsilon_{fs}(k \cdot d_{toBS}^2 + n\frac{M^2}{2 \cdot \pi \cdot k}\right) \tag{6}$$

By differentiating E_{tot} with respect to k and equating to zero, the optimal number of clusters k_{opt} can be given by:

$$k_{opt} = \sqrt{\frac{n}{2\pi}}\frac{M}{d_{toBS}} \tag{7}$$

Assuming that the nodes are uniformly distributed over the area, and the sink is located in the center of the field, $E[d_{toBS}]$ can be given by:

$$E\left[d_{toBS}\right] = \int_A \sqrt{x^2 + y^2}\frac{1}{A}dA = 0.765\frac{M^2}{2} \tag{8}$$

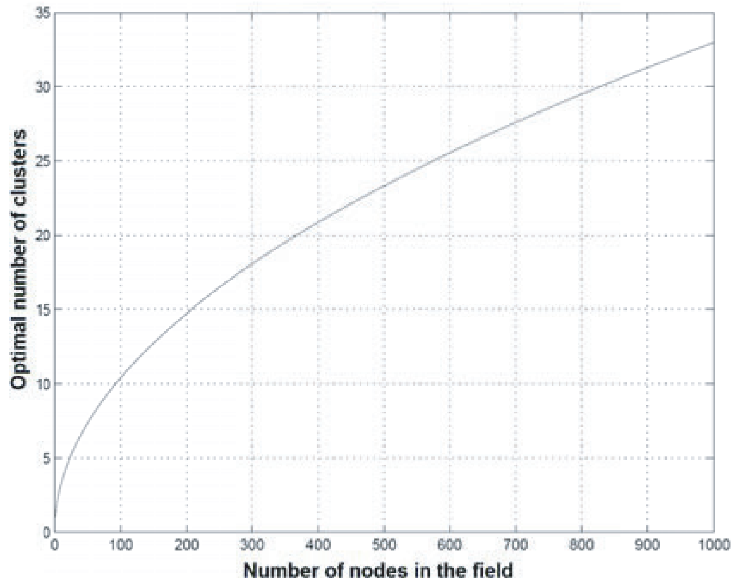

Figure 5. An optimal number of constructed clusters (k_{opt}) per round [7].

Finally, k_{opt} is given by:

$$k_{opt} = \sqrt{\frac{n}{2\pi}} \frac{2}{0.765} \tag{9}$$

Figure 5 shows k_{opt} with respect to number of nodes.

The optimal probability of a node to become a cluster head p_{opt} can be given by:

$$p_{opt} = \frac{k_{opt}}{n} \tag{10}$$

5. RELATED WORK

Saving energy consumption is the most important task of any routing protocol. More studies concern to reduce the energy consumption among nodes in the network. Hierarchical protocols offer a significant reduction in network's energy consumption. Clustering reduces the communication overhead, which in turn decreases the energy consumption and the signal interference. Data are transmitted to the cluster head where data are aggregated and redundant data are removed. This decreases the total data sent to the base station. Some of the clustering mechanisms applied to WSNs are discussed in the following paragraphs.

5.1. LEACH

LEACH protocol is divided into two phases. The first phase is the setup phase at which the process of CH is made. The nodes generate a random number between 0 and 1 if the random number is less than a predefined value $T(s)$, the node becomes a CH. $T(s)$ is defined as:

$$T_{(s)} = \begin{cases} \dfrac{p_{opt}}{1 - p_{opt} \cdot \left(r mod \dfrac{1}{p_{opt}} \right)} & \text{if } s \in G \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

where p_{opt} is the percentage of CHs, r the number of the current round, and G a fraction of the nodes that have $\frac{1}{p_{opt}}$ round and are capable of becoming a CH in the current round.

The second phase is the steady-state phase responsible for data transmission between the nodes and CHs, and between the CHs and base station (BS) [15].

5.2. SEP

SEP is a dynamic clustering protocol which deals with the energy heterogeneity of nodes in WSN. In this protocol, the node can be either a normal or an advanced node. The advanced node has higher energy than the normal node. The probability of selection of CH is related to the node's energy so that the chances for advanced nodes to become CH are more than the chances of the normal nodes. SEP maintains well-mannered energy consumption balance [16].

As supposed in SEP protocol [7], the weighted probabilities for normal and advanced nodes are calculated using Equations (12) and (13), respectively.

$$p_{nrm} = \frac{p_{opt}}{1 + \alpha \cdot m} \tag{12}$$

$$p_{adv} = \frac{p_{opt}}{1+\alpha \cdot m} \times (1+\alpha) \tag{13}$$

Replacing p_{opt} by the weighted probabilities in Equation (11), the threshold that can be used to select the cluster head in each round is obtained. The threshold can be defined as $T_{(s_{nrm})}$ for the normal nodes and $T_{(s_{adv})}$ for the advanced nodes as described in Equations (14) and (15), respectively.

$$T_{(s_{nrm})} = \begin{cases} \dfrac{p_{nrm}}{1 - p_{nrm} \cdot \left(r mod \dfrac{1}{p_{nrm}} \right)} & \text{if } s_{nrm} \in G' \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

$$T_{(s_{adv})} = \begin{cases} \dfrac{p_{adv}}{1 - p_{adv} \cdot \left(r mod \dfrac{1}{p_{adv}} \right)} & \text{if } s_{adv} \in G'' \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

where r is the number of the current round, G' the set of the nodes that have not become cluster heads within the last $\frac{1}{p_{nrm}}$ round, and G'' the set of nodes that have not become cluster heads within the last $\frac{1}{p_{adv}}$ round.

6. PROPOSED PROTOCOL

The proposed protocol consists of two main phases. The first phase is the setup phase. In this phase, the clusters are formed, the CH is selected, and finally, the nodes are assigned to the CH for each cluster. To create the clusters, the nodes send advertisement messages via the CHs in each round or by itself at the beginning of the network using a CSMAMAC protocol. The advertisement messages contain the node position and its energy power. These messages are analyzed in the base station to determine the clusters and the cluster heads for the network.

The WSN field is divided into a certain number of clusters equal to the optimum number of the cluster heads N_{opt}, and each cluster has the same number of nodes. The shape of the cluster is like the triangle sector, and all clusters are connected at the center of the WSN field. Figure 6 shows the clusters of the proposed protocol and its cluster heads at round 1400 as an example to illustrate how the clusters are formed. The sizes of the clusters are not equal, and they depend on the nodes distribution in the field and on the number of alive nodes on the WSN. If the nodes are adjacent together the size of the cluster will be small. The size of the cluster becomes bigger if the nodes are far away from each other.

The protocol determines the shape of the cluster by counting the nodes starting from the end of the last cluster, and when the number of nodes reaches the optimum number of nodes in the cluster N_{opt}, the cluster ends, and another cluster will start and so on until all clusters are formed. After sectors are formed, the highest power node in each cluster is selected as a cluster head in each round. As a result,

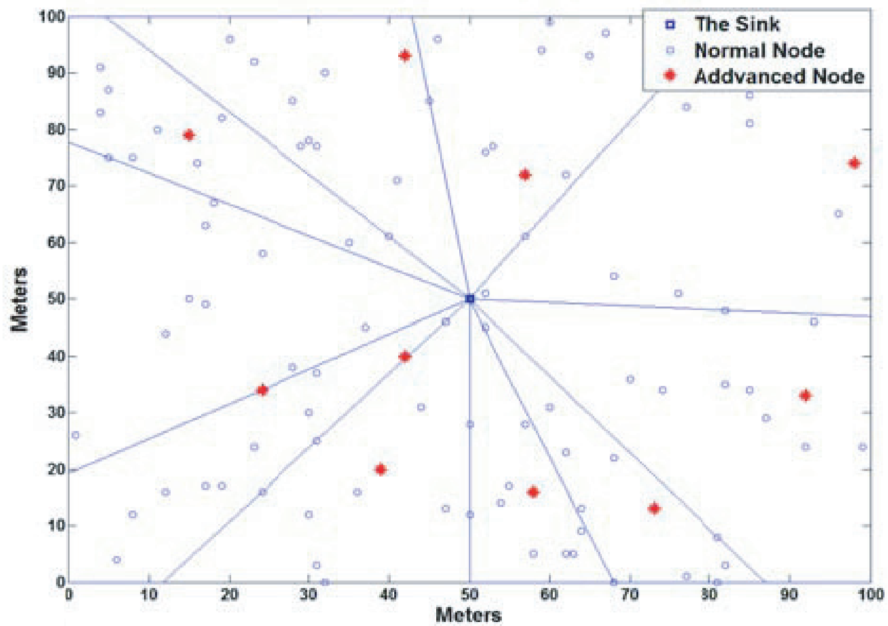

Figure 6. The proposed protocol clusters with CHs after 1400 rounds.

in each round, the cluster may have a new cluster head, and the cluster size may also change according to the number of alive nodes.

At the end of the setup phase, the base station sends broadcast messages containing the cluster heads. To reduce the energy consumption, the nodes select the nearest cluster head to send its data to it. Otherwise, nodes can send to the base station directly if the distance between the node and the base station is smaller than the distance between the node and its nearest cluster head.

The second phase is the steady state phase in which each cluster member will transmit the data to the cluster head. The trans-receivers of the cluster head should be in the active mode throughout the operational time so that it can receive data from all the cluster members. Before sending the data to the base station, data aggregation is done by the cluster heads. Also, data redundancy is removed by cluster heads. Figure 7 shows the flow chart of the proposed protocol.

The main difference between the proposed protocol and LEACH and SEP is the selection of the CHs. The process of selecting the CHs is mainly random for LEACH and SEP, which depend on predefined probability, and doesn't take the current node energy into consideration. While in the proposed protocol, the highest power energy nodes are always selected as CHs for the cluster. Selecting the highest power node in the cluster as a CH makes no chance to select CH with low power that may be die thought the transmission of the data to the base station.

7. NUMERICAL EXAMPLE

The field is assumed to be 100×100 m with 100 nodes as shown in Figure 8. The nodes are distributed uniformly in this field, and they are not mobile. The 20% of the nodes ($m = 0.2$) are having 100% more energy than normal nodes ($\alpha = 1$). According to Equation (9), the number of the optimum cluster head is equal to 10 so, there are 10 cluster heads at the beginning of the simulation, and this number will decrease as the number of alive nodes decreases. The sink is not energy limited and locates in the center of the field. The configuration parameters of the system are illustrated in Table 1.

To show the accuracy of the proposed protocol, the results of other nine different layouts with the same number of nodes and the same characteristics except the location of the nodes in the field are discussed in the section of the results.

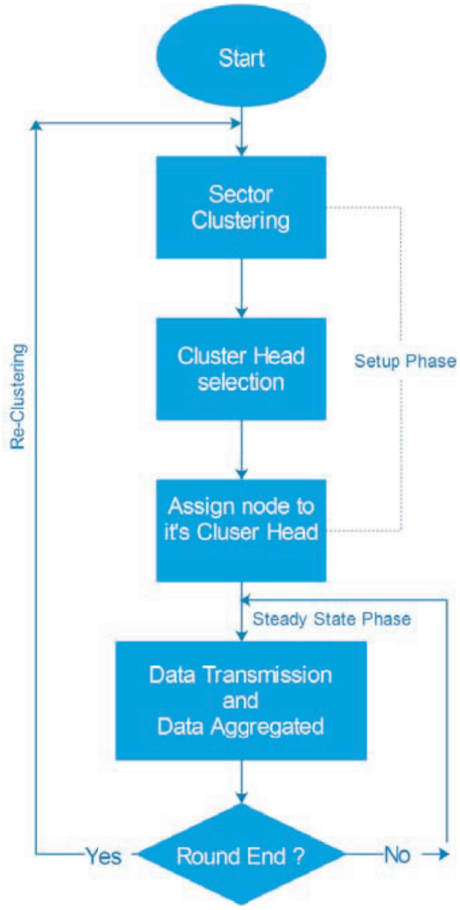

Figure 7. The flow chart of the proposed protocol.

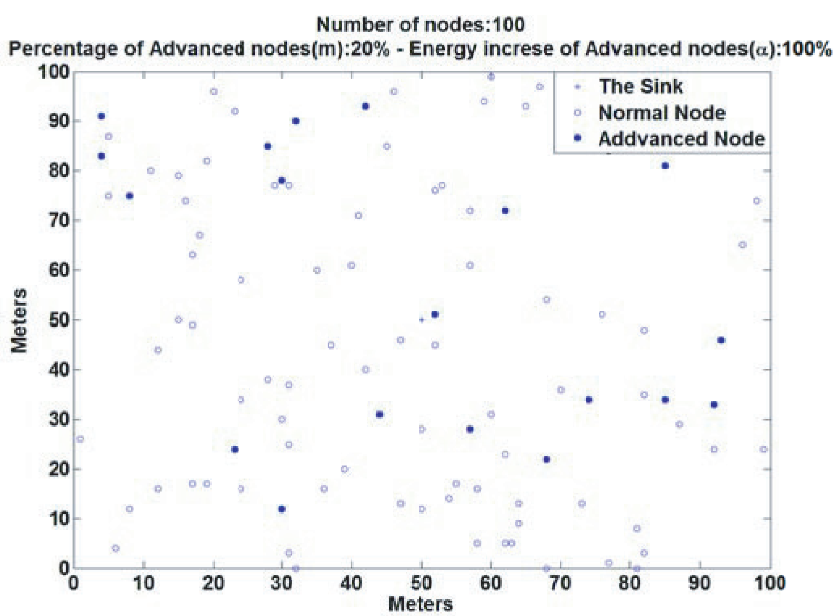

Figure 8. WSN Layout for the illustrated example with 100 nodes.

Table 1. Configuration parameters of the system in the illustrating examples.

Parameter	Values
Size of the network	$100 \times 100\,\text{m}$
N (Number of deployed nodes)	100
E (Initial energy of normal nodes)	0.5 J
Transmitter/Receiver Electronics	$E_{elec} = 50\,\text{nJ/bit}$
Data Aggregation	$E_{DA} = 5\,\text{nJ/bit/signal}$
Transmit Amplifier energy of free space if $d_{maxtoBS} \leq d_0$	$\varepsilon_{fs} = 10\,\text{pJ/bit/m}^2$
Transmit Amplifier energy of multi-path if $d_{maxtoBS} \geq d_0$	$\varepsilon_{mp} = 0.0013\,\text{pJ/bit/m}^4$
Packet Length	4000 bits

8. RESULTS FOR THE PROPOSED PROTOCOL

In this section, the results obtain from MATLAB for the proposed protocol and for other two protocols LEACH and SEP are discussed.

8.1. Simulation Results

8.1.1. Stable Region

Stable region is the interval starts from the beginning of the deploying of the network until the death of the first node in the network, and it measures in rounds. The larger the stable region is, the better the stability of the network is. The result in Figure 9 shows the comparison among LEACH, SEP and the proposed protocol. The figure indicates the total number of the alive nodes at each round. The first node to die in the proposed protocol is happend at round 1301 and for LEACH and SEP is happened at 929 and 1133, respectively. So, the proposed protocol has stable region bigger than LEACH and SEP by 20% and 13%, respectively.

The unstable region is defined as the interval from the death of the first node until the death of all nodes, and it measures in rounds. The smaller the unstable region is, the better the reliability of the

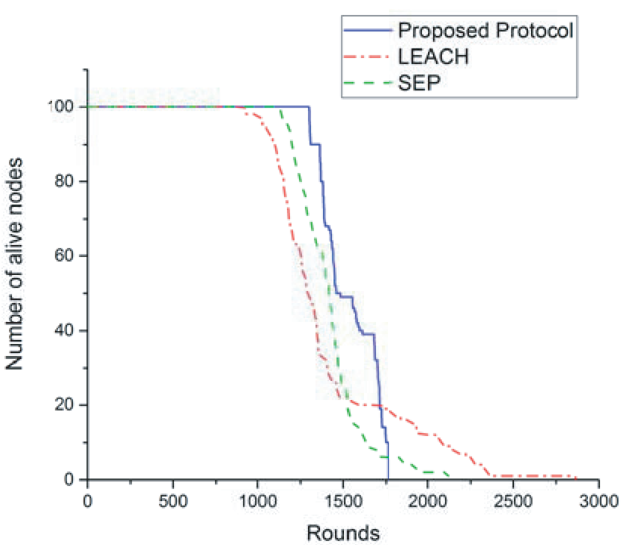

Figure 9. System lifetime using the proposed protocol, LEACH, and SEP.

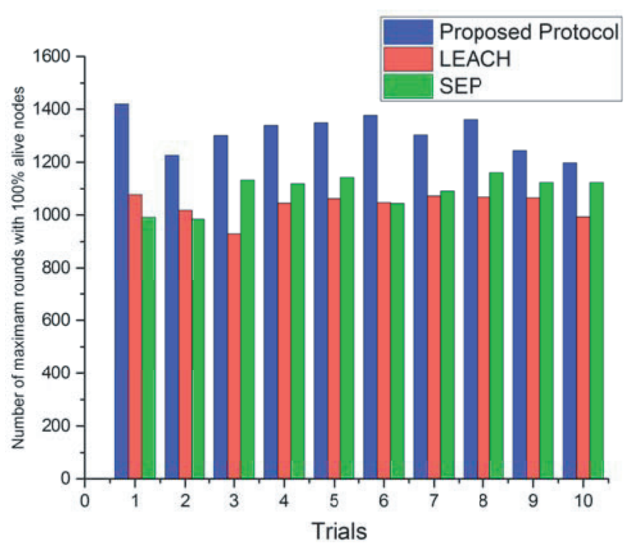

Figure 10. Numbers of maximum rounds when 100% of nodes are alive for deferent trials.

network is. The percentage of the unstable region in the proposed protocol is 26%, and it is 67% and 59% for LEACH and SEP, respectively.

Table 2 shows the metrics used in the comparison of the three protocols. These metrics are First Node Dies (FND), Half of the Nodes Alive (HNA) and Last Node Dies (LND) based on the results shown in Figure 9.

Table 2. Values of FND, HNA and LND metrics for each protocol.

Protocol	FN	HN	LN
Proposed Protocol	1301	*1485*	*1767*
LEACH	929	*1304*	*2865*
SEP	1133	*1418*	*2119*

By making other trials with different layouts but the same characteristics, the results shown in Figure 10 indicate that the proposed protocol is better than LEACH and SEP for all ten trials for the stable region. Even when the percentages of alive nodes are 90% or 50%, the proposed protocol is still giving better results as indicated in Figures 11 and 12.

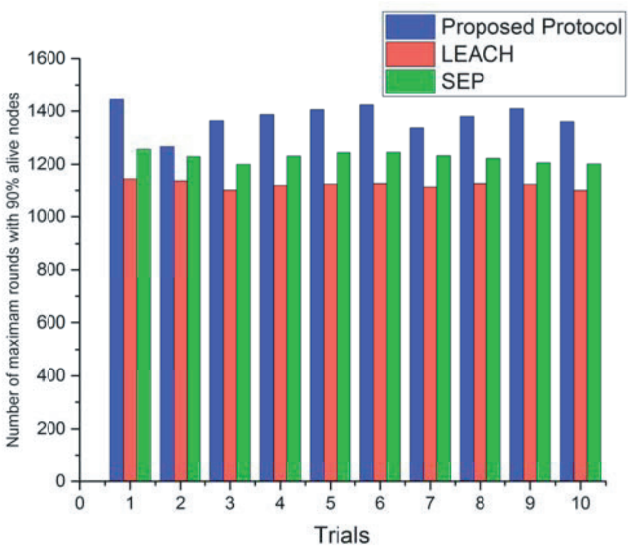

Figure 11. Numbers of maximum rounds when 90% of nodes are alive for deferent trials.

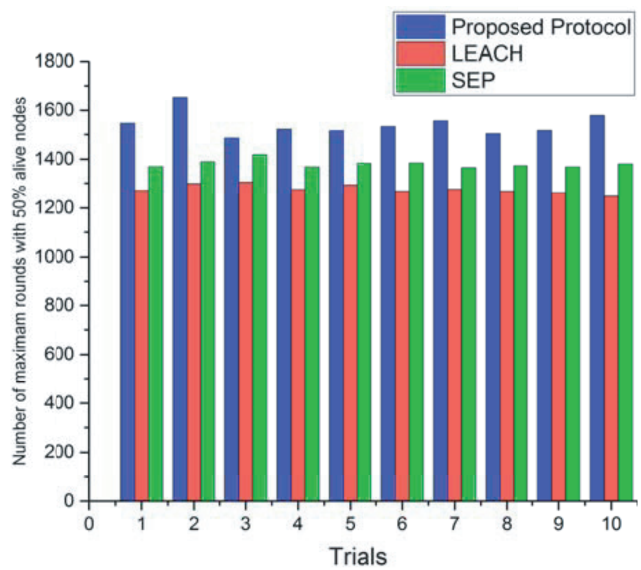

Figure 12. Numbers of maximum rounds when 50% of nodes are alive for deferent trials.

This section studies the effect of adding extra energy to the network in the stability region by adding advanced nodes to the network. This can be done by varying either m, the percentage of advanced nodes, or α, the amount of extra initial energy for advanced nodes.

Figure 13 shows the length of the stability region versus $\alpha \times m$. The stability region for the proposed protocol is increased faster than LEACH and SEP as the value of $\alpha \times m$ increased. As shown in Figure 13, when $\alpha \times m$ equals zero, which means no extra energy, the length of the stability region for the proposed protocol is more than the length of the stability region for LEACH and SEP by 30% and 30.1%, respectively.

When $\alpha \times m$ equals 0.9, the length of the stability region for the proposed protocol is more than the length of the stability region for LEACH and SEP by 35.8% and 15.42%, respectively. This indicates that the proposed protocol is more efficient in the use of extra energy than LEACH and SEP.

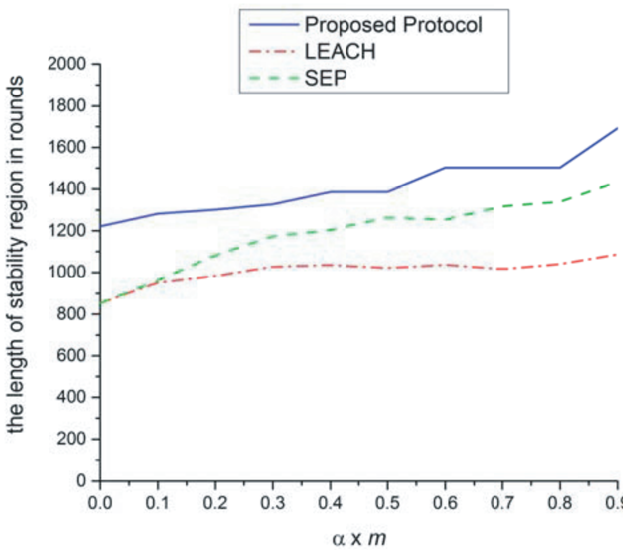

Figure 13. The effect of adding extra energy to the network.

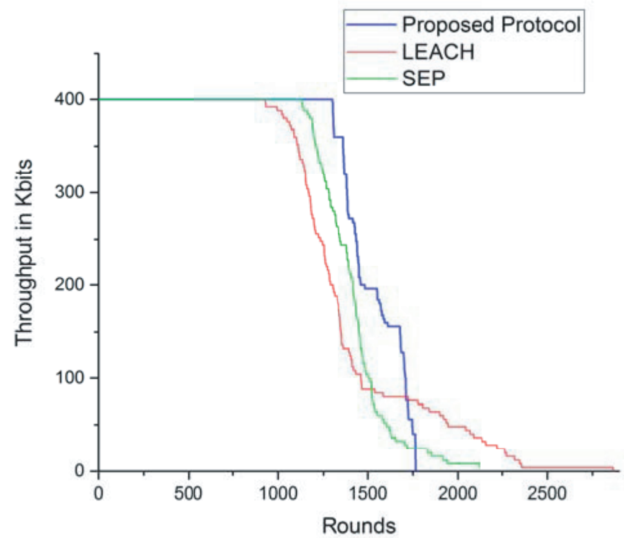

Figure 14. The throughput of the Network.

8.1.2. Throughput

Throughput measures the total rate of the data sent over the network, including the data sent from the nodes to their cluster heads plus the data sent from the cluster heads to the sink. The measurement is done using a packet size of 4000 bits. The result in Figure 14 shows that the throughput of the proposed protocol is higher than LEACH and SEP, and it is more stable until the end of the system's lifetime.

When determining the cumulative throughput over the rounds for three protocols as shown in Figure 15, it is noticed that the proposed protocol is also higher than LEACH and SEP.

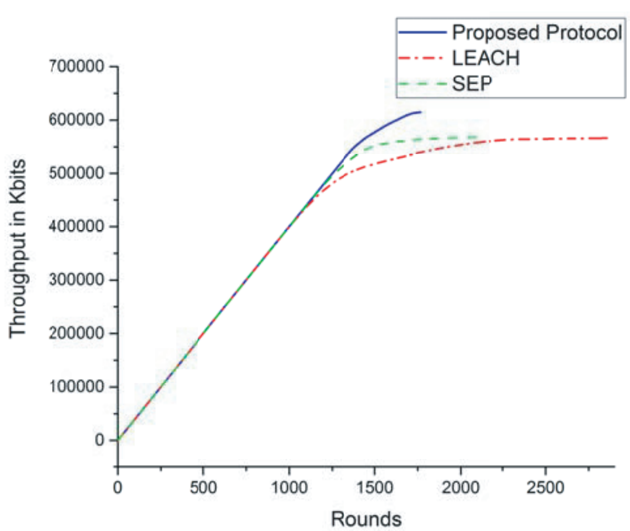

Figure 15. The cumulative throughput of the Network.

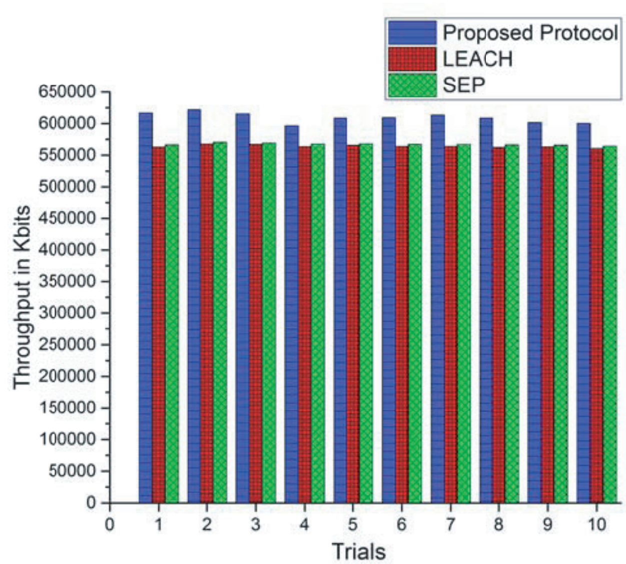

Figure 16. Maximum throughput of the Network for different trials.

By making other trials as shown in Figure 16, the maximum throughput for the proposed protocol is also higher than LEACH and SEP for all trials.

8.1.3. Reliability of the System

In this section, more experimental scenarios are performed with different node distributions to show the reliability of the system. To get better statistical results, 100 trials with different layouts for the same configuration parameters shown in Table 1 have been performed for different number of deployed nodes (N equals 100, 150, 200, 300, 600, 800 and 1000). These trials have been also performed with different energy heterogeneity of nodes for $m = 0$, 0.1 and 0.2 with 100% more energy than the normal nodes ($\alpha = 1$).

Table 3 presents the mean of the First Node Dies (FND) which is calculated for 100 trials for each protocol with different N. It is obvious that the proposed protocol has the largest mean for each distribution with different N which means that the proposed protocol maintains all nodes alive for the largest period compared with other protocols.

Table 3. Values of the mean of FND for each protocol.

Number of Nodes	Proposed Protocol	LEACH	SEP
100	1252	929	963
150	1252	923	930
200	1246	918	938
300	1253	904	899
600	1252	880	878
800	1254	865	880
1000	1251	854	866

Table 4 shows the standard deviation of FND which gives a good evaluation of stability and reliability of the system. It is clear from the results that the proposed protocol has the lowest standard division of FND which means that the proposed protocol has better stability and reliability compared with other protocols. The table also proves that the proposed protocol does not depend on the layouts distribution since these results have been obtained for 100 different layouts for each N as described before.

Table 4. Values of the standard deviation of FND for each protocol.

Number of Nodes	Proposed Protocol	LEACH	SEP
100	55	108	141
150	55	108	121
200	50	105	125
300	54	104	117
600	53	101	118
800	56	100	124
1000	51	99	124

Finally, the values of the total average energy consumption have been calculated to indicate the enhancement of the overall system performance with low power consumption. It is clear from Table 4 that the proposed protocol has the smallest total average energy consumption compared with other protocols which increase the reliability of system.

Table 5. Values of the total average energy consumption (J) for each protocol.

Number of Nodes	Proposed Protocol	LEACH	SEP
100	29.75	37.75	34.24
150	43.98	57.25	51.78
200	58.66	77.35	71.21
300	87.27	117.29	107.79
600	173.51	237.7	221.44
800	231.51	318.65	299.34
1000	288.5	400.14	374.97

9. CONCLUSIONS

In this paper, the proposed protocol considers the highest power nodes as cluster heads. The results show that the proposed protocol increases the stability region and the overall throughput of the network. Also, the proposed protocol is stable and reliable in the selection of cluster heads and does not depend on the probability and the chance to select the cluster heads.

The statistical results show that the proposed protocol has the ability to maintain all nodes alive for the largest period compared with other protocols. The results also prove that the proposed protocol has lower standard deviation and lower power consumption than other protocols which means that the system has more stability and reliability since the results have been performed for 100 trials with different layouts for each number of nodes (N) with energy heterogeneity.

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