

A Novel Multihop Energy Efficient Heterogeneous Clustered Scheme for Wireless Sensor Networks

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Abstract

Research on wireless sensor networks has been studied and employed in many applications such as medical monitoring, automotive safety, and many more. Typically, sensor nodes have several issues such as limited battery life, short radio transmission range and small memory speed. However, the most severe constraint of the nodes is their limited battery energy because they cease to function when their battery deplete. In this paper, we have proposed a new cluster based energy efficient routing protocol to obtain the optimal path for data transmission between cluster heads and the base station for sparse heterogeneous wireless sensor networks. To analyze the lifetime of the network, we have assumed three types of sensor nodes, primarily with different energy levels. We have evaluated and compared the performance of protocols through simulations. Simulation results show that our protocol offers a much better performance than the existing protocols in terms of stability, network lifetime and energy efficiency.

Key Words: Clustering, Heterogeneity, Lifetime, Multihop, Wireless Sensor Network

1. Introduction

Due to the recent development, Wireless Sensor Networks (WSNs) represent a new study in Micro Electro Mechanical Systems (MEMS) and have enormous potential impacts for the future in countless areas such as military, civil, health and environmental fields. A WSN comprises of thousands of tiny sensor nodes, which are deployed over a hostile, inhabitable and harsh environment, possibly for a limited period, with a common objective to provide distributed sensing, storage, and communication services. These sensor nodes can organize themselves in such a way that they act as front line observation for end users.

WSNs attracted lots of researchers because of its potential wide applications and special challenges. For past few years, researchers mainly focused on technologies based on homogeneous sensor networks in which all nodes have same system resource but recently heterogeneous sensor networks is becoming more and more popular among the researchers and users. We make the distinction between homogeneous and heterogeneous WSNs. A homogeneous sensor network is composed of tiny, resource-constrained devices, using the same platform and having the same hardware capabilities. The functionality of a homogeneous network serves mainly the purpose of gathering the sensed data and sending it to a central location. The typical research questions mainly focus on prolonging the network lifetime of the network, by designing energy-efficient protocols that distribute

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the communication overhead evenly among the sensor nodes. A heterogeneous sensor network employs a range of different devices, which are able to cooperate in order to achieve a global goal by combining the individual capabilities of the nodes. Small and cheap sensor nodes are deployed with high density and can be easily attached to people or objects moving in the environment, while the more powerful nodes are able to provide persistent data storage, intensive processing and actuation. In such a network, the objective is to distribute the workload depending on the capabilities of the nodes.

Several routing protocols have been proposed to address the issue of heterogeneity [1,2]. We are highly motivated by the fact that there are applications that would highly benefit from understating the impact of heterogeneity in terms of node energy because the cost of the sensor is ten times greater than the cost of the batteries, therefore, it is valuable to examine the lifetime of the network by simply distributing extra energy to some existing nodes without introducing new nodes.

Currently there are two basic communication patterns used in WSNs for communication – single hop and multihop. It was noticed that single hop communication approach the furthest sensor nodes tend to deplete their battery energy faster than other sensor nodes due to long range communication, and hence these nodes may die out first.

To overcome the above problems, we have proposed a novel Multihop Energy Efficient Heterogeneous Clustering (MEEHC) scheme to obtain an optimal path between Cluster Heads (CHs) and the Base Station (BS) for data transmission. MEEHC use the following schemes 1) randomized, adaptive, self organizing cluster formation, 2) low energy Medium Access Control (MAC), 3) data aggregation or compression and 4) multihop communication. All the sensor nodes organize themselves into a cluster with one node elected as a CH by using their weighted election probabilities. After receiving the information from the member nodes, each CH aggregates the data and transfers it to the BS by adopting multihop communication approach.

The rest of the paper is organized as follows. Section 2 includes a detailed survey of the related research. Section 3 exhibits the detail of the proposed protocol. Simulation results and its discussion are presented in section 4. Finally, section 5 concludes the paper.

2. Related Work

Routing in WSNs is a challenging task firstly, because of the absence of global addressing schemes; secondly, because of data from multiple paths to single source; thirdly, because of data redundancy and energy consumption and many computation constraints of the network. The conventional routing schemes are inefficient when applied to WSNs as the performance of the existing routing schemes varies from application to application. Thus, there is a strong need for development of new efficient routing schemes/protocols, which can work considerably across the wide range of applications.

Classical approaches like Direct Transmission (DT) and Minimum Transmission Energy (MTE) do not guarantee balanced distribution of the energy load among nodes of the sensor network. In DT, the sensor nodes transmit data directly to the BS, as a result nodes that are far away from the BS would die first. On the other hand, in MTE, data is routed over minimum-cost routes, where cost reflects the transmission power expended. In MTE protocol, nodes that are near to the Base Station (BS) act as relays with higher probability than nodes that are far from the BS. Thus, nodes near the BS tend to die first. In both the protocols, a part of the field will not be monitored during the network lifetime. The solution of the above problems was overcome in Low Energy Adaptive Clustering Hierarchy (LEACH), which guarantees that the energy load is well distributed by dynamically created clusters and the CHs are dynamically elected according to a priori optimal probability. In LEACH, during the setup phase, when clusters are being created, each node decides whether to become a CH for the current round. This decision is based on a predetermined fraction of nodes and the threshold $T(s)$, which is given by (1):

$$T(s) = \begin{cases} \frac{p_{opt}}{1 - p_{opt} \times (r \bmod \frac{1}{p_{opt}})} & \text{if } s \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where p_{opt} is the predetermined percentage of CHs, r is the count of current round. The G is the set of sensor nodes that have not been CHs in the last $1/p_{opt}$ rounds. Using this threshold, each node will be a CH at some

round within $1/p_{opt}$ rounds. After $1/p_{opt}$ rounds, all nodes are once again eligible to become CHs. In this way, the energy concentration on CHs is distributed. LEACH does not consider the residual energy of each node so the nodes that have relatively smaller energy remaining can be the CHs. This makes the network lifetime shortened.

In [1], the authors have compared the homogeneous and heterogeneous sensor networks for single-hop clusters. They have proposed a method to estimate the optimal distribution among different types of sensor nodes, but again this result is hard to use if the heterogeneity is due to the operation of the network. They have also studied the case of multihop routing within each cluster. But the main drawback of the proposed protocol is that only powerful nodes can become CHs. In [2], the authors proposed a novel energy-efficient centralized clustering algorithm for WSNs which generates a set of possible clustering alternatives and helps in finding the optimal clustering. The performance evaluation of the proposed scheme was done by using two metrics Max-min and Max-sum. After the analysis they found that Max-sum improves the system lifetime over Low Energy Adaptive Clustering Hierarchy-C (LEACH-C).

In general, most existing research works consider a heterogeneous network model where two different types of nodes are deployed, the more powerful nodes have more energy as compared to normal nodes; nodes will be grouped into clusters and powerful sensor nodes will always be the CHs for the clusters [3,4].

Many research works have been proposed to deal with nodes' limitation problems; they are related to routing within the sensor networks. In [5,6], the authors have investigated the existing clustering algorithms. It is essential to improve energy efficiency for WSNs, as the energy supply for sensor nodes is usually extremely limited. Clustering is the most energy efficient organization for wide application in the past few years and numerous clustering algorithms have been proposed for energy saving [7–9]. In clustered WSNs, two typical methods to aggregate data after it has been collected from all member nodes before the inter-cluster communication occurs [10], another is to aggregate data over each passing hop [11]. In [12], authors have presented the Multihop Routing Algorithm for Inter CH Communication (MRACHC). This algorithm is based on multihop routing, which worked on the principle of divide and

conquer, and performed well in terms of load balance and energy efficient as compared to LEACH.

In [13], the authors have studied the impact of heterogeneity of sensor nodes, in terms of their energy and have proposed a heterogeneous – aware protocol to prolong the time interval before the death of the first node, which is crucial for many applications where the feedback from the sensor network must be reliable.

In [14], the authors have proposed Energy-Efficient Hierarchical Clustering Algorithm (EEHCA) for WSNs which improves the performance of LEACH and HEED (Hybrid Energy-Efficient Distributed clustering) [15], in terms of network lifetime. EECHA adopts a new method for CH election, which can avoid the frequent election of CH. In order to improve the performance of the sensor network, the authors have introduced a new concept of backup CHs. Therefore, when nodes finished the communication within their own clusters and the CHs have finished the data aggregation, the head clusters will transmit aggregated data to the BS.

In [16], the authors have studied LEACH protocol and proposed two new protocols (i.e., Energy – LEACH and Multi-hop LEACH). Energy – LEACH improves the CH election method and Multi-hop LEACH (MLEACH) improves the communication mode from single hop to multi-hop between CH and BS. Both the protocols have better performance than LEACH protocol.

The authors have presented a novel CH election problem in [17], specifically designed for applications where the maintenance of full network coverage is the main requirement. This approach is based on a set of coverage-aware cost metrics that favor nodes deployed in densely populated network areas as better candidates for CH nodes, active sensor nodes and routers. Compared with traditional energy-based selection methods, the coverage-aware selection of CH nodes increases the network lifetime depending on the application scenario.

In [18], the authors have proposed and evaluated an Unequal Cluster based Routing (UCR) protocol for mitigating the hot spot problem in WSNs. It is designed for long lived, source-driven sensor network applications, such as periodical environmental information reporting.

Most of the existing clustering protocols viz., MLEACH, EEHCA, HEED, and MRACHC all assume the homogeneous sensor networks. These protocols perform poorly in heterogeneous environments. The low energy

nodes will die quickly than the high energy nodes, because these clustering protocols are unable to treat each node discriminatorily in term of the energy discrepancy.

3. MEEHC: Architecture

In this section, we describe the detailed architecture of MEEHC and also discuss how efficiently it resolves different technical aspects such as energy efficiency, network lifetime and stability for different applications.

3.1 Network and Energy Model Assumption

We make some assumptions about the sensor nodes and underlying network model, which are as: i) n sensor nodes are uniformly dispersed within a square field, ii) all sensor nodes and the BS are stationary after deployment, iii) communication is based on multihop approach, iv) a WSN consists of heterogeneous nodes in terms of node energy, v) all sensors are of equal significance, vi) CHs perform data aggregation and vii) the BS is not energy limited in comparison to energy of other nodes in the network.

In this paper, we have used the simplified first order radio model presented in [5] for the radio hardware energy dissipation. In this model, the radio dissipates Q joules of energy (energy consumed in the electronics circuit) to run the transmitter or receiver circuitry. The τ and μ is the amount of energy (in joules) per bit dissipated in the transmitter amplifier. Using the given radio model, the energy consumed (E_{TL}) to transmit an L -bit message for a long distance, $d > d_0$, which is given by (2) and the energy consumed (E_{TS}) for a short distance, $d \leq d_0$, which is given by (3):

$$E_{TL} = L \times (Q + \mu \times d^4) \quad (2)$$

$$E_{TS} = L \times (Q + \tau \times d^2) \quad (3)$$

Moreover, the energy consumed (E_{RX}) to receive the L -bit message is given by (4).

$$E_{RX} = L \times Q \quad (4)$$

A sensor node also consumes E_{DA} amount of energy for data aggregation. It is assumed that the sensed information is highly correlated, thus the CH can always ag-

gregate the data received from its member nodes into a single packet.

3.2 Optimal Clustering

We assume an area ($A = M \times M$) square meters over which n nodes are uniformly distributed and the BS is located inside the field for simplicity. Therefore, the total energy dissipated in the network per round is given by (5).

$$E_t = L \times (2 \times n \times Q + n \times E_{DA} + \tau \times (k \times d_{BS}^2 + n \times d_{CH}^2)) \quad (5)$$

By differentiating, E_t with respect to k and equating to zero, the optimal number of clusters can be computed by (6).

$$k_{opt} = \sqrt{\frac{n}{2\pi}} \sqrt{\frac{\tau}{\mu}} \frac{M}{d_{BS}^2} \quad (6)$$

If the distance of a significant percentage of nodes to the BS is greater than d_0 then, the following is the same analysis as discussed in [9], we can obtain by (7).

$$d_{BS}^2 = \int_A (x^2 + y^2) \times \frac{1}{A} = 0.765 \times \frac{M}{2} \quad (7)$$

By using Equations (6) and (7), we derive the optimal probability of a node to become a CH, p_{opt} , which can be computed by (8).

$$p_{opt} = \frac{1}{0.765} \times \sqrt{\frac{2}{n\pi}} \times \sqrt{\frac{\tau}{\mu}} \quad (8)$$

The optimal probability for a node to become a CH is very important aspect. If the clusters are not constructed in an optimal way, the total energy consumed per round is increased exponentially either when the number of clusters is greater or less than the optimal value.

3.3 Cluster Head Election Mechanism

The optimal probability of a node to become a CH is a function of spatial density when nodes are uniformly distributed over the network. This clustering is optimal in the sense that energy consumption is well distributed over all sensors and the total energy consumption is minimal. Such optimal clustering highly depends on the

energy model that we use.

In MEEHC, we have assumed three types of sensor nodes viz., normal, advanced and super nodes. Let us assume E_0 is the initial energy of each normal node, m is the fraction of advanced nodes among normal nodes which are equipped with α times more energy than the normal nodes, and m_o is the fraction of super nodes among advanced nodes which are equipped with β times more energy than the normal nodes. Note a new heterogeneous setting has no affect on the spatial density of the network so the setting of p_{opt} does not change. On the other hand, due to heterogeneous nodes the net energy of the network is changed as the initial energy of each super node become $E_0 \times (1 + \beta)$ and each advanced node become $E_0 \times (1 + \alpha)$. Therefore, the total initial energy of the new heterogeneous network setting is given by (9).

$$N \times \{(1 - m) \times E_0 + m \times (1 - m_o) \times E_0 \times (1 + \alpha) + m \times m_o \times E_0 \times (1 + \beta)\} = n \times E_0 \times (1 + m \times (\alpha - m_o \times (\alpha - \beta))) \quad (9)$$

Hence, the total energy of the system is increased by a factor of $(1 + m \times (\alpha - m_o \times (\alpha - \beta)))$. The first improvement to the existing LEACH is to increase the epoch of the sensor network in proportion to the energy increment. In order to optimize the stable region of the system, the new epoch must become equal to $(1/p_{opt}) \times (1 + m \times (\alpha - m_o \times (\alpha - \beta)))$ because the system has $m \times (\alpha - m_o \times (\alpha - \beta))$ times more energy. If the same threshold is set for super, advanced and normal nodes with the difference that each normal node $\in G$ becomes a CH once every $(1 + m \times (\alpha - m_o \times (\alpha - \beta)))/p_{opt}$ rounds per epoch, each super node $\in G$ becomes a CH $(1 + \beta)$ and each advanced node $\in G$ becomes a CH $(1 + \alpha)$ times every $(1 + m \times (\alpha - m_o \times (\alpha - \beta)))/p_{opt}$ rounds per epoch, then there is no guarantee that the number of CHs per round per epoch will be $p_{opt} \times n$. So the constraint of $p_{opt} \times n$ CHs per round is violated. Our approach is to assign a weight to the optimal probability p_{opt} . This weight must be equal to the residual energy of each node divided by the average initial energy of that node. Let us define p_n, p_a and p_s is the weighted election probability for normal nodes, advanced nodes, and for super nodes. Virtually there are $(1 + m \times (\alpha - m_o \times (\alpha - \beta))) \times n$ nodes with energy equal to the initial energy of a normal node. In order to maintain the minimum energy consumption in each round

within an epoch, the average number of CHs per round per epoch must be constant and equal to $p_{opt} \times n$. In the heterogeneous scenario the average number of CHs ($CH_{average}$) per round per epoch is given by (10).

$$CH_{average} = (1 + m \times (\alpha - m_o \times (\alpha - \beta))) \times n \times p_n \quad (10)$$

The weighed probability for normal, advanced and super nodes is given by (11–13) [19].

$$p_n = \frac{P_{opt}}{1 + m \times (\alpha - m_o \times (\alpha - \beta))} \quad (11)$$

$$p_a = \frac{P_{opt}}{1 + m \times (\alpha - m_o \times (\alpha - \beta))} \times (1 + \alpha) \quad (12)$$

$$p_s = \frac{P_{opt}}{1 + m \times (\alpha - m_o \times (\alpha - \beta))} \times (1 + \beta) \quad (13)$$

In (1), we replace p_{opt} by the weighted probabilities of normal, advanced and super nodes to obtain new thresholds so that it can be used to elect the CH for each round. Substitute (11) in (1), and we can find a new threshold for normal nodes which is given by (14).

$$T(s_n) = \begin{cases} \frac{p_n}{1 - p_n \times (r \times \text{mod} \frac{1}{p_n})} & \text{if } s \in G' \\ 0 & \text{otherwise} \end{cases} \quad (14)$$

where r is the current round, G' is the set of normal nodes that have not become CHs within the last $1/p_n$ rounds of the epoch, $T(s_n)$ is the threshold applied to a population of $n \times (1 - m)$ normal nodes. This guarantees that each normal node will become a CH exactly once every $(1 + m \times (\alpha - m_o \times (\alpha - \beta)))/p_{opt}$ rounds per epoch, and that the average number of CHs that are normal nodes per round per epoch is equal to $n \times (1 - m) \times p_n$. Similarly, we can find the thresholds for advanced and super nodes. During this phase, each non-CH node has decided to join the closest CH node. This decision is based on the received signal strength of the advertisement message. After this the sensor node must inform the CH node that it will be a member of the cluster by sending the short join message. Each sensor node transmits this information back to the CH again using a

CSMA MAC protocol. During this phase, all CH nodes must keep their receivers on. The CH node receives all the messages from its member nodes. Based on the member nodes in the cluster, the CH node creates a TDMA schedule telling each node when it can transmit.

3.4 Multihop Route Selection Mechanism

At present, there are two types of inter-transmission approaches: single hop approach and multihop approach. MEEHC adopt multihop communication approach to achieve the inter-cluster transmission.

After CHs have been selected, each CH first aggregates the data from its member nodes, and then sends an aggregated data packet to the BS via multihop communication. In MEEHC, relay nodes do not aggregate the incoming data packets because the degree of sensed data correlation between different clusters is comparatively very low. Thus, we present an energy efficient multihop routing for the inter cluster communication.

At the beginning of the process each elected CH broadcast a control packet across the network which consists of its node ID, residual energy, and distance to the BS. The channel interference is reduced by choosing adjacent CH node as the relay node. On the other hand, choosing a relay node with more residual energy helps balance the energy consumption to prolong the network lifetime. However, only considering residual energy may lead to a waste of network energy. Let us consider c_i chooses c_j as its relay node and c_j chooses c_k as its relay node. We assume a free space propagation channel mode for simplicity, and c_k communicates with the BS directly. To transmit an L -length packet to the BS, the amount of energy consumed by c_i , c_j and c_k is given by (15)

$$E_{3-hop} = (E_{TS}(L, d(c_i, c_j)) + E_{Rx} \times L + (E_{TS}(L, d(c_j, c_k)) + E_{Rx} \times L + (E_{TS}(L, d(c_k, BS))) \quad (15)$$

$$E_{3-hop} = 5 \times L \times Q + L \times \tau(d^2((c_i, c_j) + d^2(c_j, c_k) + d^2(c_k, BS)) \quad (16)$$

Substitute (3) and (4) in (15). Thus we define (16) as the energy cost of the link. The bigger the d_{relay} which is given by (17), the more energy will be consumed by the relay process.

$$d^2_{relay} = d^2((c_i, c_j) + d^2(c_j, c_k) + d^2(c_k, BS)) \quad (17)$$

After each CH has chosen a relay node to transmit its data packet to the BS directly, a tree rooted at the BS is constructed.

3.5 Data Transmission Phase

Once the clusters are formed and the TDMA schedule is fixed, the data transmission phase can begin. The active sensor nodes periodically collect the data and transmit it during their allocated transmission time to the CH. The radio of each non-CH or member node can be turned off until the node's allocated transmission time which minimizes the energy consumption in these nodes. The CH node must keep its receiver on to receive all the data from the member nodes in the cluster. When all the data has been received, the CH nodes aggregate the data and route the same data via multihop communication approach to the BS.

3.6 Traffic Model

The network traffic model depends on the network application and the behavior of sensed events. The process of data reporting in WSNs is usually classified into three categories: (i) time driven, (ii) event driven and (iii) query driven. In the time driven case, sensor nodes transmit their data periodically to the BS. Event driven networks are used when it is desired to inform the BS about the occurrence of an event. In query-based networks, BS sends a request of data gathering when it is needed. The time driven scenario is the main focus in MEEHC protocol.

4. Simulation Results and Discussion

In this paper, we have introduced a new MEEHC protocol whose goal is to increase the lifetime, load balancing and stability of the network in the presence of heterogeneous nodes. To validate the simulation results, we have used following performance metrics.

4.1 Network Lifetime

The network lifetime is an important metric for evaluating the performance of WSNs. It depends on the lifetime of the single nodes that constitute the network. The lifetime of a sensor node basically depends on two factors: how much energy it consumes over time, and how much energy is available for its use. In the literature, we can find a great number of definitions that address the

problem of network lifetime. But in this paper, we examine the network lifetime of different protocols by evaluating the time interval from the start of the operation until the death of the 10% alive nodes, 50% alive nodes and last alive node.

4.2 Stability

This is the time interval from the start of network operation until the death of the first alive node. We call this period as stable region or period.

4.3 Simulation Environment

We have carried out comparison among MEEHC, EEHCA and HEED protocols through simulations in MATLAB. The simulation parameters are summarized in Table 1. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the normal sensor nodes in the network. The deployment of the heterogeneous nodes in the network is shown in Figure 1(a), we denote with 'o' a normal node, with '+' an advanced node, with '*' a super node, and with 'x' the BS. After some rounds, all the heterogeneous nodes die which is denoted with '.' as shown in Figure 1(b).

Figure 2 shows the nodes death rate is substantial in HEED and EEHCA as compared to MEEHC. Figure 3 indicates the network lifetime for HEED, EEHCA and MEEHC respectively. These graphs show that the 10% alive nodes, 50% alive nodes and last alive node die earlier in case of HEED and EEHCA as compared to MEEHC, because in MEEHC, every sensor node independently elects itself as a CH based on its weighted election probability and also treat each heterogeneous

node discriminatorily in terms of energy discrepancy. Therefore, MEEHC survives longer than HEED and EEHCA protocols.

Figure 4 shows the network stability when the first node dies. We observe that the stable region of MEEHC is extended in comparison with HEED and EEHCA protocols by a factor of 6%. HEED and EEHCA protocols in the presence of node heterogeneity yields a larger unstable region because all the advanced and super nodes are

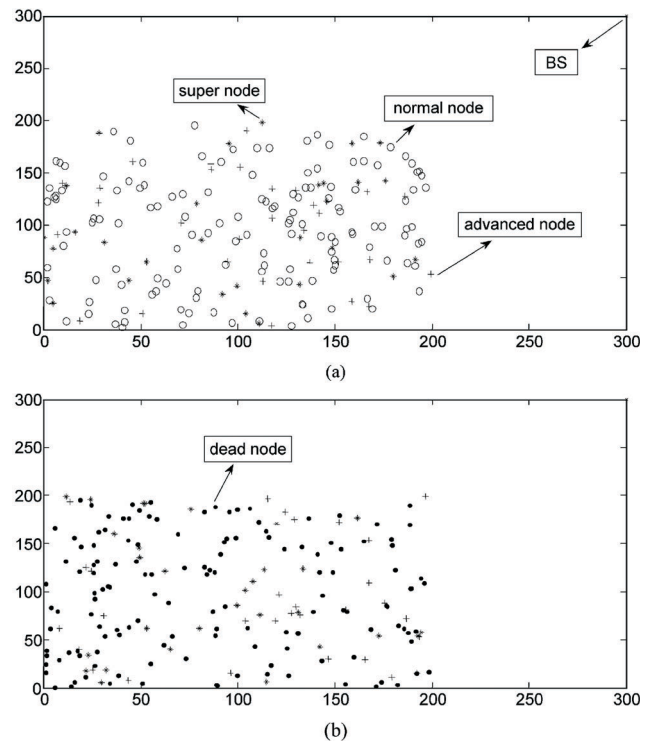


Figure 1. A heterogeneous WSN, (a) a snapshot of the network when all the nodes are alive in an area $200 \times 200 \text{ m}^2$ and (b) snapshot of the network when some nodes are dead in an area $200 \times 200 \text{ m}^2$.

Table 1. Simulation parameters for MEEHC

Description	Symbol	Value
Number of nodes	n	200
Proportion of advanced nodes	m	0.3
Proportion of super nodes among advanced nodes	m_o	0.5
Energy factor for super nodes	β	1
Energy factor for advanced nodes	α	2
Initial energy level of normal nodes	E_0	0.5 J
Location of the BS	BS	(300,300)
Data packet size	L	4000 bits
Network area	$M \times M$	$200 \times 200 \text{ m}^2$
Transmit amplifier if $d_{BS} \leq d_0$	τ	10 pJ/bit/m ²
Transmit amplifier if $d_{BS} > d_0$	μ	$0.0013 \text{ pJ/bit/m}^4$

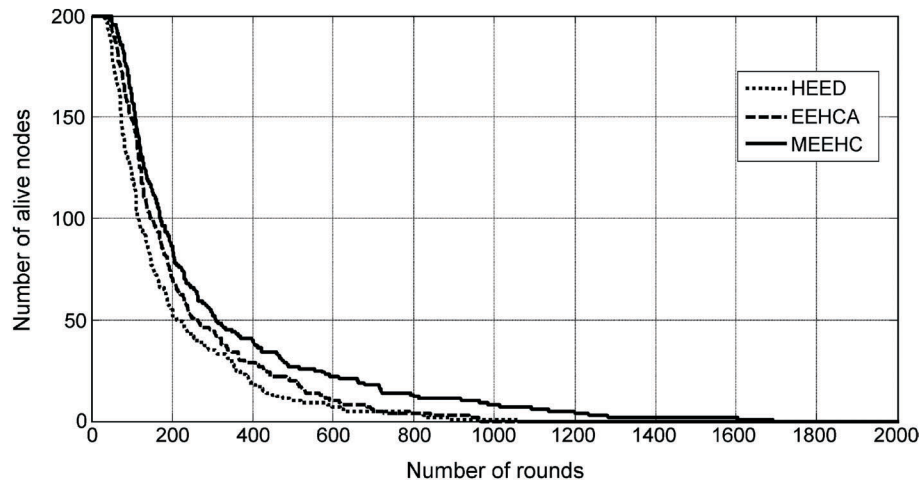


Figure 2. Number of alive nodes over rounds.

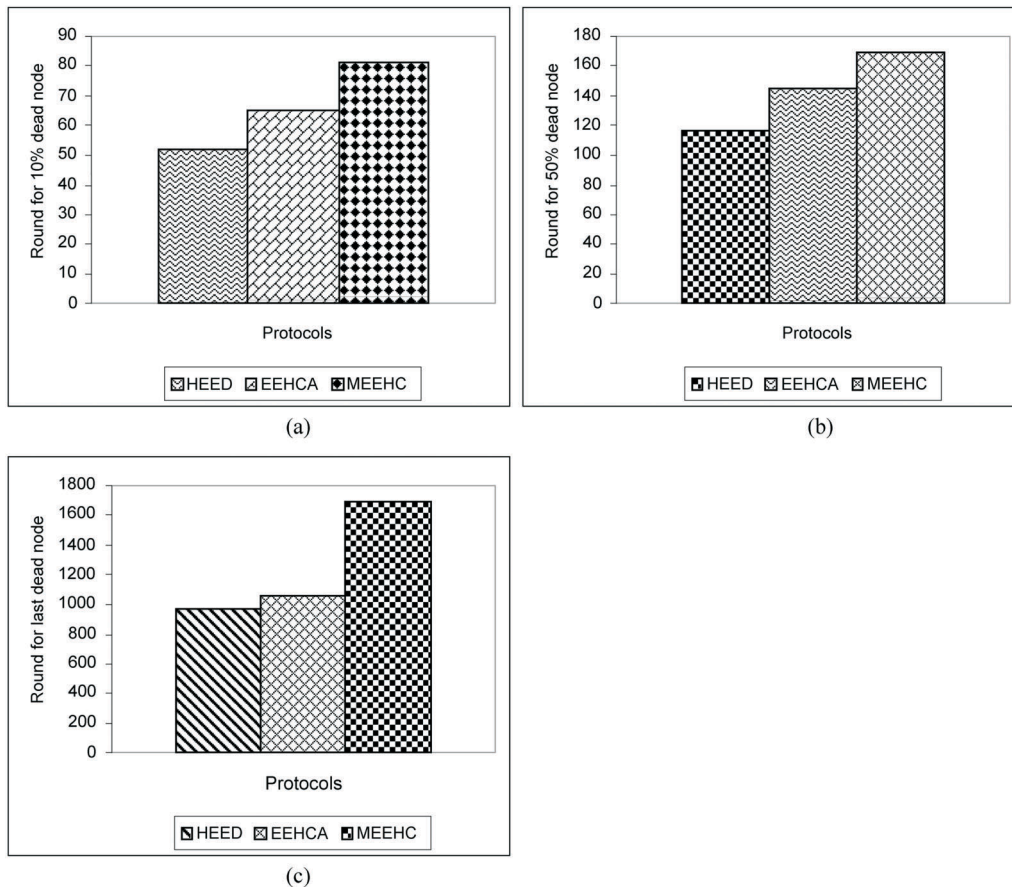


Figure 3. Network lifetime: (a) round for 10% dead nodes, (b) round for 50% dead nodes and (c) round for last dead node.

left equipped with almost the same energy. Therefore, the CH election process is unstable and as a result, most of the time, no CH is elected and these advanced and super nodes are idle. But in homogeneous networks HEED and EEHCA protocol assures the shorter unstable

region because after the death of the first alive node, all the remaining sensor nodes are expected to die on average within a small number of rounds as a consequence of the uniform remaining energy due to the well-distributed energy consumption.

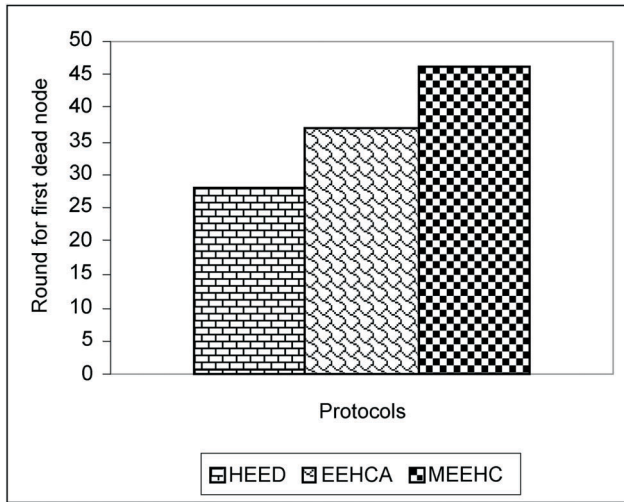


Figure 4. Network stability: round when first node dies.

Figure 5 represents the overall throughput in terms of the number of data messages received at the BS from CHs, which is greater in MEEHC against HEED and EEHCA protocols. The extension of the network service duration is made by the reduction of the number of the messages transmitted inter cluster due to avoiding the transmission of redundant information. Consequent to this reduction, the transmission and reception nodes energy is economized, and, therefore, the network lifetime is extended.

The simulation results show that the MEEHC pro-

vides best characteristics compared to the HEED and EEHCA in terms of lifetime, throughput and stability. It allows a good energy balance over the sensor nodes. The first dead node appears later, and the death rate of nodes is lower, that permits surveying the environment fairly. Thus MEEHC grants a maximal network lifetime, stability and throughput as compared to HEED and EEHCA protocols.

5 Conclusion

In this paper, we have presented a comprehensive study of the design of path weight structure between cluster heads and the BS for heterogeneous WSNs. A new cluster head election scheme and a multihop communication path between cluster heads and the BS with lowest weight structure can maintain the balance of energy consumption in the network. The simulation results show the effectiveness of MEEHC in terms of prolonging the stable period and network lifetime when compared to the existing protocols. For future work, MEEHC can be extended to deal with an energy efficient dissipation algorithm through data gathering in a mobile sensor network.

Acknowledgement

This work is supported in part by the AICTE New

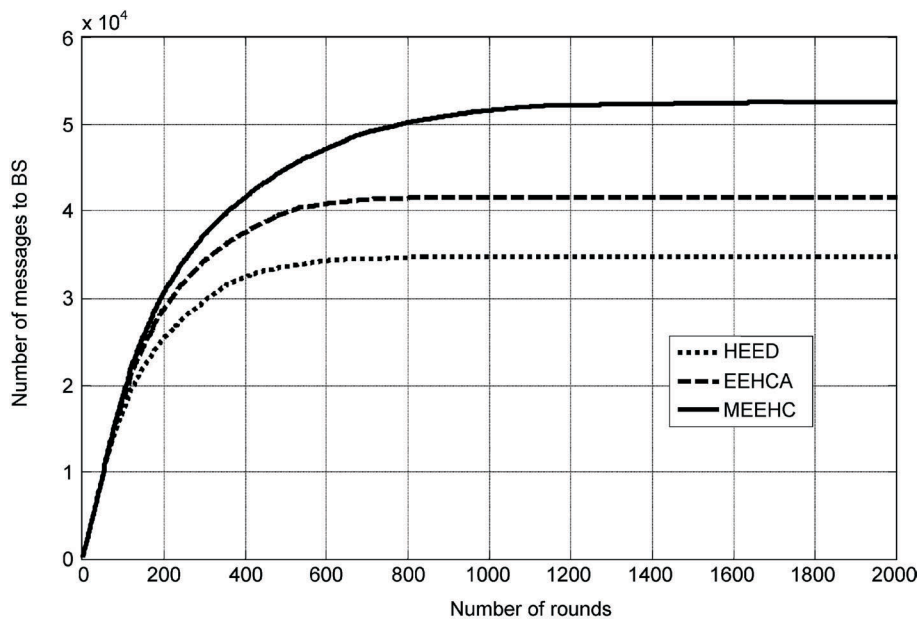


Figure 5. Comparison of number of data messages at the BS over rounds.

Delhi, India under Research Promotion Scheme (RPS) and MODROBS under Grant 8023/BOR/RID/RPS-97/2007-08, and 8023/RID/BOR/MOD-39/2006-07 (sponsor and financial support), respectively.

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Manuscript Received: Jul. 9, 2010

Accepted: Jan. 24, 2011