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Research Article

A Centralized Energy Efficient Distance Based Routing Protocol for Wireless Sensor Networks

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Wireless sensor network (WSN) typically consists of a large number of low cost wireless sensor nodes which collect and send various messages to a base station (BS). WSN nodes are small battery powered devices having limited energy resources. Replacement of such energy resources is not easy for thousands of nodes as they are inaccessible to users after their deployment. This generates a requirement of energy efficient routing protocol for increasing network lifetime while minimizing energy consumption. Low Energy Adaptive Clustering Hierarchy (LEACH) is a widely used classic clustering algorithm in WSNs. In this paper, we propose a Centralized Energy Efficient Distance (CEED) based routing protocol to evenly distribute energy dissipation among all sensor nodes. We calculate optimum number of cluster heads based on LEACH's energy dissipation model. We propose a distributed cluster head selection algorithm based on dissipated energy of a node and its distance to BS. Moreover, we extend our protocol by multihop routing scheme to reduce energy dissipated by nodes located far away from base station. The performance of CEED is compared with other protocols such as LEACH and LEACH with Distance Based Thresholds (LEACH-DT). Simulation results show that CEED is more energy efficient as compared to other protocols. Also it improves the network lifetime and stability period over the other protocols.

1. Introduction

An infrastructure required for various industrial and governmental organizations to observe events occurring in a physical world is provided by sensor network. In recent years wireless sensor networks have been widely investigated. Wireless sensor network typically consists of large number of low cost unattended multifunctioning sensing nodes that are typically deployed in large quantities and in a high density manner with limited energy resource [1]. These sensing nodes are linked by wireless medium using radio, infrared, or optical frequency band [2]. Wireless sensor networks have various applications like flood and fire detection in remote areas, traffic surveillance, air traffic control, and so forth. Sensors jointly gather ambient condition information such as temperature, pressure, and humidity from their surrounding environment and forward it towards static data sink. In many scenarios, as nodes are deployed in remote and dangerous area, replacement of their batteries becomes impossible. So they must work without replacing their batteries for many years [3]. Thus power management has become one of the fundamental issues of wireless sensor networks. As direct transmission to base station causes uneven distribution of energy load among sensors, various types of routing protocols have been proposed for WSNs which work on issues of network lifetime, energy efficiency, stability, reliability, scalability, and so forth [4]. LEACH [5] is a well known clustering protocol in which nodes organize themselves into clusters with one node acting as a cluster head. In LEACH, each round is divided into three phases: cluster head selection phase, cluster formation phase, and steady state phase. In cluster head selection phase, few nodes are selected as cluster heads by stochastic algorithm. In cluster formation phase, each noncluster head node finds its associated cluster head based on received signal strength of advertisement message sent by all cluster heads. In steady state phase, each noncluster head node transmits its data to corresponding cluster head. As nodes located close to each other have correlated data, cluster head aggregates data from all other nodes within that cluster in order to reduce the data to be transmitted to base station. Each cluster head forwards aggregate data to base station. In LEACH high energy cluster head positions are randomly rotated as compared to static clustering protocols where cluster heads are fixed throughout the network lifetime. Simulation results showed that LEACH improves network lifetime and reduces energy dissipation considerably compared with static clustering protocols. In extended LEACH (Ex-LEACH) [6], threshold is multiplied with a factor indicating remaining level of energy of a node. In order to further reduce energy dissipation, another routing protocol known as Power Efficient Gathering in Sensor Information System (PEGASIS) is proposed in [7]. In PEGASIS, communication takes place between close neighbors and each node takes turns transmitting to the base station. PEGASIS considerably reduces the amount of data to be transmitted to base station and performs better in terms of network lifetime compared with LEACH. In LEACH and Ex-LEACH nodes at large distance from base station will consume high energy compared with nodes nearer to base station. Therefore, in order to achieve balanced energy consumption, distance of a node to its base station should also be taken into consideration while determining threshold for selection of cluster heads. Recently some cluster head selection thresholds considering distance of a node to base station have been proposed. In [8], energy load is evenly distributed through network by adjusting the cluster head selection threshold with a fixed radius of clustering and a multihop communication mechanism among the cluster heads. In [9], multihop routing is achieved through heads of far zone which is a group of sensor nodes at a location where their energies are less than threshold. A new protocol called LEACH-DT is proposed in [10]. In LEACH-DT, node's distance to the base station is considered to determine the probability of a node to become a cluster head. Simulation results showed that LEACH-DT improves network lifespan over original LEACH. A General Self Organized Tree Based Energy Balance (GSTEB) routing protocol for wireless sensor network is proposed in [11]. In GSTEB, base station assigns a root node and broadcasts its coordinates and ID to all sensor nodes. Each node selects a parent in its neighbor such that root node is nearer to parent rather than itself thus building a routing tree. In [12], Genetic Algorithm based LEACH (LEACH-GA) is proposed. In LEACH-GA, optimum probability of a node to become a cluster head is determined using genetic algorithm. Even though cluster head selection threshold is enhanced in LEACH-GA, it remains random without considering residual energy of a node. In [13], Amend LEACH (A-LEACH) protocol is proposed which improves stability period by distributed cluster head selection. In this paper, a Centralized Energy Efficient Distance (CEED) based routing protocol has been proposed to improve network lifetime of WSN by balancing the energy consumption among nodes. CEED calculates optimum number of cluster heads and their locations by considering energy dissipated in cluster head selection, cluster formation, and steady state phases. CEED assigns different probabilities for nodes to select themselves as cluster heads based on their dissipated energy and distance from base station. Once cluster heads are selected, CEED defines an objective function for each noncluster head node to find its associated cluster head. Cluster heads located far away from base station consume high energy to transmit their data to base station resulting in their death. So we extended our protocol by multihop routing scheme in which cluster heads transmit towards high level cluster heads near to sink. The rest of the paper is organized as follows. Section 2 explains radio energy dissipation model used. Section 3 gives brief description about proposed CEED protocol. Section 4 outlines simulation results and finally Section 5 concludes the paper.

2. Radio Energy Dissipation Model

Tremendous research has been done in the development of low energy dissipation models. In our work we have used same model as mentioned in [5] where some energy is dissipated by receiver to run radio electronics and that of transmitter to run radio electronics and power amplifier. Energy dissipated by transmitter for transmitting k bit message to a distance r is given by

$$E_T(k,r)=\begin{cases}k\left(E_{\mathrm{TX}}+E_{\mathrm{fs}}*r^2\right) & \text{if } r<r_o,\\ k\left(E_{\mathrm{TX}}+E_{\mathrm{mp}}*r^4\right) & \text{if } r\geq r_o.\end{cases}\quad (1)$$

Energy dissipated by receiver to receive k bit message is given by

$$E_R(k)=k*E_{\mathrm{RX}},\quad (2)$$

where E_{TX} and E_{RX} represent per bit energy dissipated to run radio electronics of transmitter and receiver, respectively. Whereas E_{fs} and E_{mp} represent energy consumed by transmitting node to run radio amplifier in free space and multipath propagation models, respectively. Threshold distance r_o is given by

$$r_o=\sqrt{\frac{E_{\mathrm{fs}}}{E_{\mathrm{mp}}}}.\quad (3)$$

3. Centralized Energy Efficient Distance (CEED) Based Routing Protocol

3.1. Optimum Number of Clusters. Network lifetime and energy dissipation of WSN are strongly affected by number of cluster heads. In this section, We calculate optimum number of clusters by considering energy dissipated in entire network during a single round containing cluster head selection phase, cluster formation phase, and steady state phase. There are few assumptions about the network such as the following: all uniformly distributed nodes are fixed at their locations and each node has global knowledge about the network. The nature of communication channel is symmetric in which each node has equal communication ability. Base station is static having enough energy resources. Assume that N sensor nodes are randomly distributed in a sensor field having $M \times M$ area. Expected number of cluster heads per round is K. Whole network is divided into K clusters and each cluster contains one cluster head and remaining $N/K - 1$ noncluster head nodes. Once each node elects itself as cluster head according to our proposed algorithm, it broadcasts an advertisement message having length l_{adv} corresponding to a distance of $\sqrt{2}M$. Energy dissipated by cluster head node to broadcast this message is given by

$$E_{\text{CH\_adv}} = l_{\text{adv}} \left(E_{\text{TX}} + E_{\text{mp}} * 4M^4 \right). \tag{4}$$

Each node receives the advertisement sent by all cluster heads. Hence energy dissipated by a single noncluster head node to receive advertisement message is given by

$$E_{\text{nonCH\_adv}} = K * l_{\text{adv}} * E_{\text{RX}}. \tag{5}$$

Once a single noncluster head node receives these advertisements, it selects its parent cluster head according to proposed objective function mentioned in D. Then each noncluster head node transmits join-request message having length l_{join} to its cluster head. As distance to cluster head is small, dissipated energy following free space propagation model is given by

$$E_{\text{nonCH\_req}} = l_{\text{join}} \left(E_{\text{TX}} + E_{\text{fs}} * d_{\text{toCH}}^2 \right). \tag{6}$$

In the above equation, d_{toCH} is the distance of a cluster head from its member node. As we have assumed uniform distribution of nodes, we put d_{toCH}^2 the same as that mentioned in [5]:

$$d_{\text{toCH}}^2 = \frac{M^2}{2\pi K}. \tag{7}$$

Therefore the above equation becomes

$$E_{\text{nonCH\_req}} = l_{\text{join}} \left(E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right). \tag{8}$$

Energy dissipated by cluster head to receive such join-request message from its member nodes is given by

$$E_{\text{CH\_join}} = l_{\text{join}} * E_{\text{RX}} * \left(\frac{N}{K} - 1 \right). \tag{9}$$

After receiving this message, each cluster head transmits TDMA schedule having length l_{TDMA} to all its members for which energy dissipated is given by

$$E_{\text{CH\_TDMA}} = l_{\text{TDMA}} \left(E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right) \left(\frac{N}{K} - 1 \right). \tag{10}$$

Energy dissipated by each noncluster head node to receive this TDMA schedule is given by

$$E_{\text{nonCH\_TDMA}} = l_{\text{TDMA}} * E_{\text{RX}}. \tag{11}$$

After this network goes into steady state phase in which each noncluster head node transmits its data to its parent cluster head by consuming the following amount of energy:

$$E_{\text{nonCH\_data}} = l_{\text{data}} \left(E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right). \tag{12}$$

A single cluster head node receives data from all its member nodes; it adds its own data in it and aggregates all data to obtain single packet and transmit it to base station. So energy dissipated by cluster head node in steady state phase is given by

$$\begin{aligned} E_{\text{CH\_data}} = {} & l_{\text{data}} * E_{\text{RX}} * \left(\frac{N}{K} - 1 \right) + l_{\text{data}} * \frac{N}{K} * E_{\text{DA}} \\ & + l_{\text{data}} \left(E_{\text{TX}} + E_{\text{mp}} d_{\text{toBS}}^4 \right), \end{aligned} \tag{13}$$

where E_{DA} is the energy required for data aggregation and d_{toBS} is the distance of a base station from a cluster head. So total energy dissipated by a cluster head during a single round is given by

$$\begin{aligned} E_{\text{CH\_total}} = {} & E_{\text{CH\_adv}} + E_{\text{CH\_join}} + E_{\text{CH\_TDMA}} \\ & + E_{\text{CH\_data}}. \end{aligned} \tag{14}$$

Substituting values of $E_{\text{CH\_adv}}$, $E_{\text{CH\_join}}$, $E_{\text{CH\_TDMA}}$, and $E_{\text{CH\_data}}$, from (4), (9), (10), and (13) into (14),

$$\begin{aligned} E_{\text{CH\_total}} = {} & l_{\text{adv}} \left(E_{\text{TX}} + E_{\text{mp}} * 4M^4 \right) + l_{\text{join}} * E_{\text{RX}} \\ & * \left(\frac{N}{K} - 1 \right) + l_{\text{TDMA}} \left(E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right) \left(\frac{N}{K} - 1 \right) \\ & + l_{\text{data}} \left(E_{\text{RX}} \left(\frac{N}{K} - 1 \right) + \frac{N}{K} E_{\text{DA}} + E_{\text{TX}} \right. \\ & \left. + E_{\text{mp}} d_{\text{toBS}}^4 \right). \end{aligned} \tag{15}$$

Similarly total energy dissipated by a noncluster head node during a single round is given by

$$\begin{aligned} E_{\text{nonCH\_total}} = {} & E_{\text{nonCH\_adv}} + E_{\text{nonCH\_req}} \\ & + E_{\text{nonCH\_TDMA}} + E_{\text{nonCH\_data}}. \end{aligned} \tag{16}$$

Substituting values of $E_{\text{nonCH\_adv}}$, $E_{\text{nonCH\_req}}$, $E_{\text{nonCH\_TDMA}}$, $E_{\text{nonCH\_data}}$, the above equation becomes

$$\begin{aligned} E_{\text{nonCH\_total}} &= l_{\text{adv}} * E_{\text{RX}} * K + l_{\text{join}} \left(E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right) \\ &\quad + l_{\text{TDMA}} * E_{\text{RX}} \\ &\quad + l_{\text{data}} \left(E_{\text{TX}} + E_{\text{fs}} * \frac{M^2}{2\pi K} \right). \end{aligned} \tag{17}$$

Total energy dissipated in a cluster is given by

$$E_{\text{cluster\_total}} = E_{\text{CH\_total}} + \left(\frac{N}{K} - 1 \right) E_{\text{nonCH\_total}}. \tag{18}$$

As there are K clusters in a network, total energy dissipated in a network is given by

$$E_{\text{network\_total}} = K * E_{\text{cluster\_total}}. \tag{19}$$

By substituting $N/K - 1 \approx N/K$, (19) becomes

$$\begin{aligned} E_{\text{network\_total}} &= l_{\text{adv}} * K \left(E_{\text{TX}} + E_{\text{mp}} * 4M^4 + N \right. \\ &\quad \left. * E_{\text{RX}} \right) + N * l_{\text{join}} \left(E_{\text{RX}} + E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right) \\ &\quad + l_{\text{TDMA}} * N \left(E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} + E_{\text{RX}} \right) \\ &\quad + l_{\text{data}} \left(N \left(E_{\text{RX}} + E_{\text{DA}} + E_{\text{TX}} + E_{\text{fs}} \frac{M^2}{2\pi K} \right) \right. \\ &\quad \left. + K \left(E_{\text{TX}} + E_{\text{mp}} d_{\text{toBS}}^4 \right) \right). \end{aligned} \tag{20}$$

Optimum number of clusters can be obtained by equating derivative of $E_{\text{network\_total}}$ with respect to K to zero which is given by (21)

$$K_{\text{opt}} = \frac{M}{\sqrt{2\pi}} \sqrt{\frac{N * E_{\text{fs}} \left(l_{\text{TDMA}} + l_{\text{join}} + l_{\text{data}} \right)}{l_{\text{adv}} \left(E_{\text{TX}} + E_{\text{mp}} * 4M^4 \right) + l_{\text{data}} \left(E_{\text{TX}} + E_{\text{mp}} d_{\text{toBS}}^4 \right) + N l_{\text{adv}} E_{\text{RX}}}}. \tag{21}$$

3.2. Probability of a Node to Become a Cluster Head. In LEACH, the probability of a node i to become a cluster head is given by

$$p(i) = \frac{K_{\text{opt}}}{N}. \tag{22}$$

In contrast with original LEACH, we determine the probability of a node to become a cluster head based on its dissipated energy in a current round. As that of original LEACH, expected number of cluster heads is given by

$$\sum_{i=1}^{N} p(i) = K. \tag{23}$$

Let distance of cluster head nodes i, j to base station be $d(i)$, $d(j)$ and let probabilities of nodes i and j to become cluster heads be $p(i)$ and $p(j)$, respectively. We consider the following balance equation of energy consumption:

$$\begin{aligned} & p(i) E_{\text{CH\_total}}(i) d(i) + (1 - p(i)) E_{\text{nonCH\_total}} \frac{M}{\sqrt{2\pi K}} \\ &= P(j) E_{\text{CH\_total}}(j) d(j) \\ &\quad + (1 - p(j)) E_{\text{nonCH\_total}} \frac{M}{\sqrt{2\pi K}}. \end{aligned} \tag{24}$$

Further simplifying the above equation,

$$p(i) = \frac{p(j) \left(E_{\text{CH\_total}}(j) d(j) - E_{\text{nonCH\_total}} \left(M/\sqrt{2\pi K} \right) \right)}{E_{\text{CH\_total}}(i) d(i) - E_{\text{nonCH\_total}} \left(M/\sqrt{2\pi K} \right)}, \tag{25}$$

where $0 \leq p(i) \leq 1$.

3.3. Cluster Head Selection Phase. In LEACH, cluster head selection is stochastic. Due to such random cluster head selection, nodes energy becomes unbalanced resulting in increased energy consumption of the system. In LEACH, nodes with any energy have equal threshold for determining cluster heads. If nodes with less energy become cluster heads, they die quickly which reduces network lifetime [14]. In order to balance the energy consumption among all nodes, we introduce a new cluster head selection threshold based on proposed cluster head selection probability, residual energy, and distance of a node to base station. The improved threshold in this paper is given by (26)

$$T(i) = \begin{cases} \dfrac{p(i)}{1 - p(i)(r \bmod (1/p(i)))} * \dfrac{E_{\text{current}}(i)}{E_{\text{initial}}} * \dfrac{d_{\text{toBS}}(i)}{d_{\text{toBS\_max}}} & \text{if } i \in G \\ 0 & \text{otherwise}. \end{cases} \tag{26}$$

In the above equation, $p(i)$ is the probability of a node i to become a cluster head in current round r. $E_{\text{current}}(i)$ and E_{initial} are residual and initial energies of node i, respectively. $d(i)$ is the distance of a node i to base station and $d_{\text{toBS\_max}}$ is the distance of farthest node from base station. G is the set of nodes which never became cluster head in last $1/p(i)$ rounds. Each node selects a random number between 0 and 1 and compares it with the above cluster head selection threshold. If selected number is less than the threshold, then that node acts as a cluster head in current round. A node which elects itself as a cluster head broadcasts an advertisement (ADV) message containing its ID, header indicating control message, and spreading code to avoid intercluster interference using CSMA MAC protocol.

3.4. Cluster Formation Phase. After the selection of cluster heads, the key problem is to assign to each node a specific cluster head. Around cluster head, energy consumption should be balanced. Sometimes, assigning a cluster head nearer to a node compared with other cluster heads may result in unbalanced energy consumption. A node i should select its cluster head by following constrained objective function:

$$\begin{aligned} j = \operatorname{argmin} \quad & \frac{d(i,j)}{e^{d_{\max}(i)} * E_{\text{current}}(i)} + \frac{d_{\text{toBS}}(j)}{e^{d_{\text{avg}}} * E_{\text{current}}(j)} \\ \text{Constraints:} \quad & 1 \leq j \leq K, \\ & d(i,j) \leq d_{\max}(i) \\ & 0 < E_{\text{current}}(i), \\ & E_{\text{current}}(j) \leq E_{\text{initial}} \\ & d_{\text{toBS}}(j) \leq d_{\text{toBS\_max}}. \end{aligned} \tag{27}$$

In the above equation $d(i,j)$ is the distance of node i from cluster head j, $d_{\max}(i)$ is the maximum distance between node i and all cluster heads, and d_{avg} is the average distance between base station and all cluster heads. Each noncluster head node chooses its corresponding cluster head according to above objective function and transmits a join-request (JOIN) message to it containing its own ID, cluster head's ID, and relevant spreading code using CSMA MAC protocol. After receiving join-request message, each cluster head creates a TDMA schedule to assign time slots to noncluster heads and transmits this schedule to all its members. The TDMA schedule is used to reduce intracluster interference and energy consumption by allowing nodes to turn off their radio components every time except their allocated time slots. Once each noncluster head node receives TDMA schedule, cluster formation phase is finished and steady state phase begins.

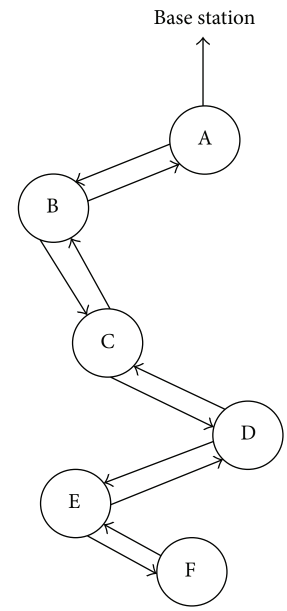

Figure 1: Multihop routing scheme.

3.5. Steady State Phase. In steady state phase, each noncluster head node starts sensing the data and transmits the data to its cluster head according to the TDMA schedule. In order to reduce intercluster interference, each cluster communicates using unique spreading code. After receiving data from members, each cluster head forms a single packet by aggregating the data. Such packets are transmitted to base station by cluster heads. Cluster heads located far away from base station consume high energy to transmit their data over long distance. In order to distribute energy load evenly among all cluster heads in such scenarios, we extend our proposed protocol by multihop routing scheme in which each cluster head will receive data from one neighbor and transmits to another neighbor thereby forming a chain among themselves. Cluster head node nearest to base station is starting point of the chain and transmits an ADV message containing its id and level in the chain to its neighbor cluster head. Neighbor cluster head in turn transmits similar ADV message to its another neighbor and so on. Cluster head farthest from base station is end point of the chain. After chain establishment, data flow occurs in opposite direction.

Multihop routing scheme is shown in Figure 1. In which cluster head closest to base station is A. A transmits an ADV message to its neighbor cluster head B which in turn transmits similar message to C and so on. Data is then transmitted in opposite direction. Each intermediate cluster head in the chain receives data from its lower cluster head, fuses its own data in it, and transmits aggregate data to upper cluster head. Cluster head A transmits data directly to base station. Data aggregation takes place everywhere along the chain except at end cluster head node F.

4. Simulation Results

Our protocol is simulated and its performance is compared with other clustering protocols such as LEACH and

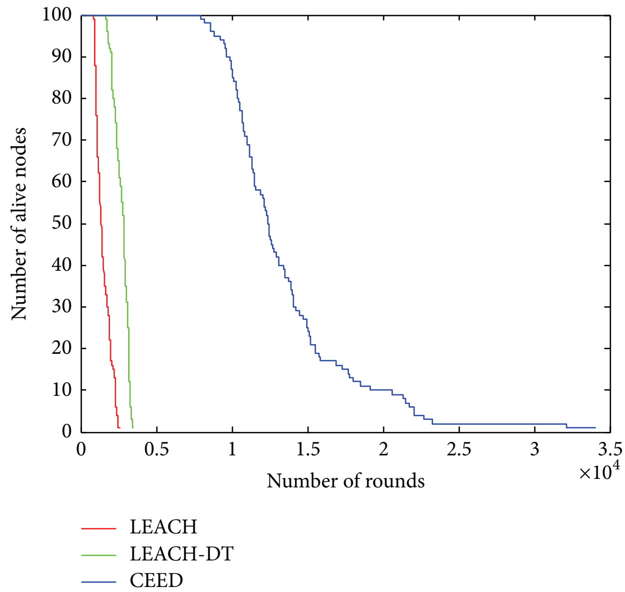

Figure 2: Network lifetime (BS = (50, 350)).

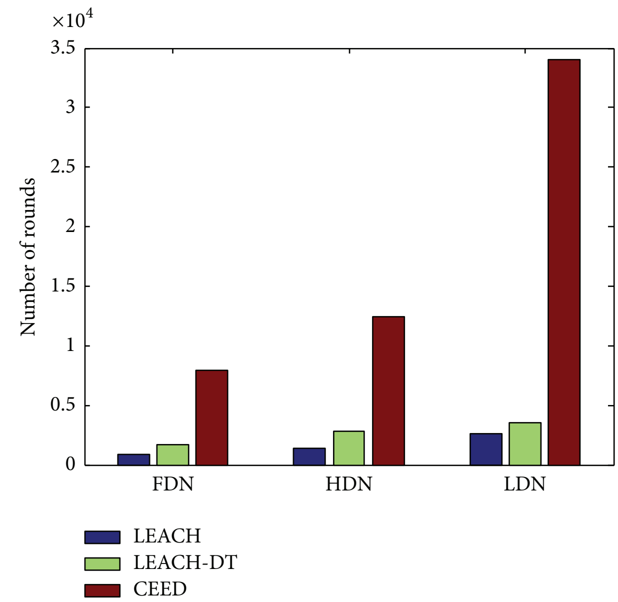

Figure 3: Results of FDN, HDN, and LDN (BS = (50, 350)).

LEACH-DA using Matlab 8.3. Performance of proposed protocol is measured in terms of network lifetime, energy efficiency, and stability. In our experimental work, we simulated 100 m × 100 m network topology consisting of randomly distributed 100 nodes. There are two cases for the location of base station: Case 1: BS = (50 m, 350 m) and Case 2: BS = (100 m, 300 m). The length of each data message is 500 bits and that of controlling packet header is 64 bits. Each node is assigned with an initial energy of 0.5 J. Communication energy parameters are taken the same as that of [5]: $E_{TX} = E_{RX} = 50$ nJ/bit, $\epsilon_{fs} = 10$ pJ/bit/m^2, $\epsilon_{mp} = 0.0013$ pJ/bit/m^4, and data aggregation energy $E_{DA} = 5$ nJ/bit/signal.

Case 1 (BS = (50, 350)). The network lifetime is defined as the time interval between the start of communication and death of last alive sensor node [11]. The comparison of network lifetime of proposed CEED protocol with LEACH and LEACH-DT is shown in Figure 2.

Figure 2 clearly indicates that CEED extends network lifetime by 31428 and 30596 rounds compared with LEACH and LEACH-DT protocols, respectively. First Dead Node (FDN) also known as stability period indicates number of rounds after which death of first sensor node occurs. Half Dead Node (HDN) is the number of rounds after which half number of sensor nodes are dead. Similarly Last Dead Node (LDN) is the number of rounds required for the death of all sensor nodes [15]. Figure 3 shows FDN, HDN, and LDN metrics of LEACH, LEACH-DT, and CEED protocols, respectively. From Figure 3, it is noticed that CEED improves FDN metric by 7077 and 6292 rounds and HDN metric by 11044 and 9572 rounds compared with LEACH and LEACH-DT protocols, respectively.

The dissipated energy of the entire network for all three protocols is shown in Figure 4. It is observed that CEED reduces average dissipated energy per round by 92.10% and 89.58% compared with LEACH and LEACH-DT.

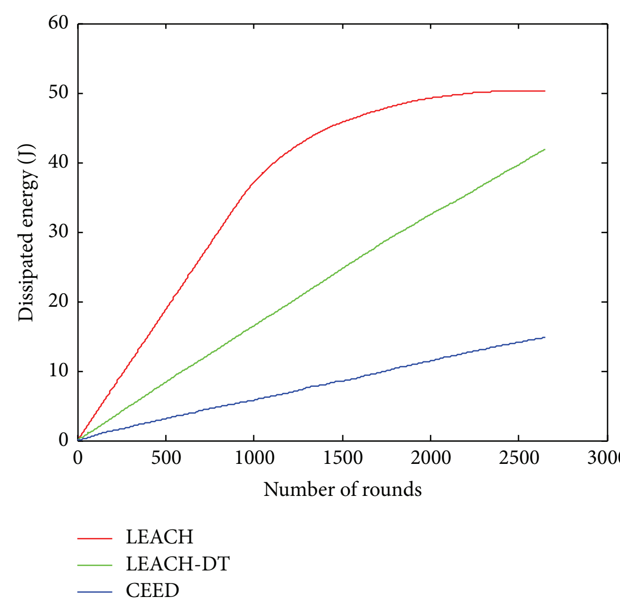

Figure 4: Dissipated energy (BS = (50, 350)).

Case 2 (BS = (100, 300)). The effect of CEED on network lifetime compared to LEACH and LEACH-DT for this case is shown in Figure 5. From Figure 5, it is noticed that CEED extends network lifetime by 32542 and 32316 rounds compared to LEACH and LEACH-DT, respectively.

Figure 6 shows FDN, HDN, and LDN measures for LEACH, LEACH-DT, and CEED from which it is clear that CEED improves FDN and HDN measure by 5417 and 10022

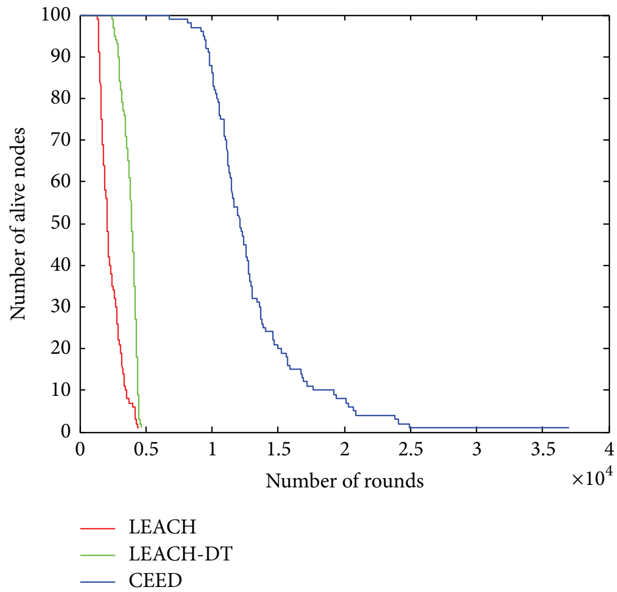

Figure 5: Network lifetime (BS = (100, 300)).

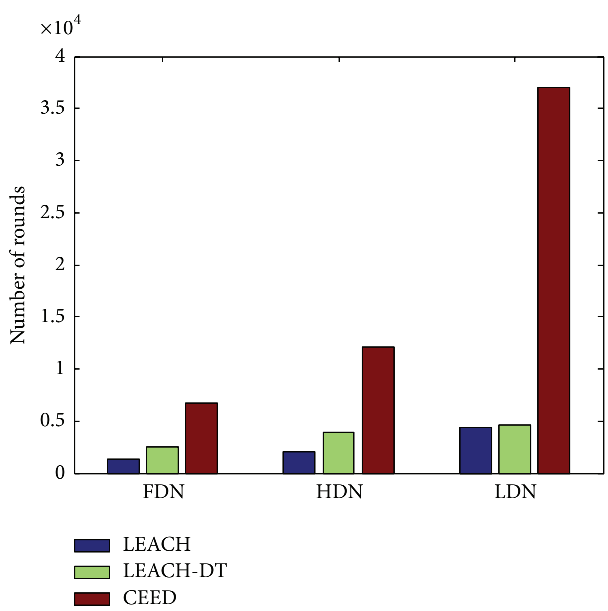

Figure 6: Results of FDN, HDN, and LDN (BS = (100, 300)).

rounds, respectively, compared with LEACH and by 4274 and 8151 rounds, respectively, compared with LEACH-DT.

Figure 7 shows CEED dissipated energy compared with LEACH and LEACH-DT. It is observed that CEED dissipates energy more slowly compared with LEACH and LEACH-DT. CEED reduces average dissipated energy per round by 87.61% and 87.03% compared with LEACH and LEACH-DT protocols, respectively.

The number of rounds required for the death of 5%, 25%, and 75% of total number of nodes for all three protocols in both cases is listed in Table 1. Table 1 indicates that for BS location of (50, 350), CEED extends 5% of node death by 7930 rounds, 25% of node death by 9619 rounds, and 75% of node

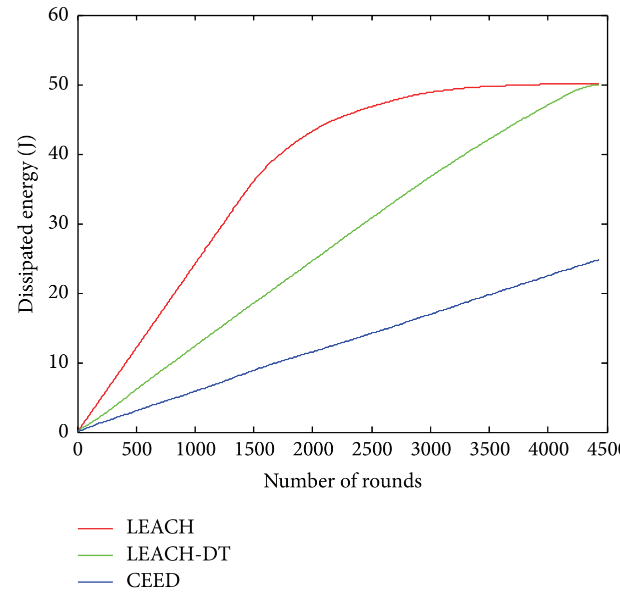

Figure 7: Dissipated energy (BS = (100, 300)).

Table 1: 5%, 25%, and 75% of node death.

Sink location	Protocol	Number of rounds 5%	25%	75%
50, 350	LEACH	913	1053	1900
	LEACH-DT	1844	2315	3144
	CEED	8843	10672	14946
100, 300	LEACH	1457	1651	2870
	LEACH-DT	2649	3429	4270
	CEED	9372	10677	13879

death by 13046 rounds compared with LEACH and by 6999, 8357, and 11802 rounds, respectively, compared with LEACH-DT. For BS location of (100, 300), CEED extends same parameters by 7915, 9026, and 11009 rounds, respectively, compared with LEACH and by 6723, 7248, and 9609 rounds, respectively, compared with LEACH-DT.

5. Conclusion

In this paper, we have presented a new clustering protocol called a Centralized Energy Efficient Distance (CEED) based routing protocol for randomly distributed wireless sensor networks to improve the lifetime and stability period of WSNs. This protocol finds optimum number of cluster heads based on minimizing the dissipated energy in all phases of communication. We have introduced a new distributed cluster head selection algorithm based on nodes' dissipated energy and its distance to BS. We have extended our protocol by multihop routing scheme in which only cluster head closest to BS transmits its data directly to BS to reduce energy dissipated by cluster heads located far away from BS. Simulation results showed that the proposed protocol is more energy efficient as compared to other protocols, namely, LEACH and LEACH-DT. Moreover, it extends network lifetime and stability period over the other two protocols.

Competing Interests

The authors declare that they have no competing interests.

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