Improved Clustering Algorithm for Wireless Sensor Network

Santar Pal Singh and S.C. Sharma

Abstract Wireless sensor network (WSN) is comprised of miniature devices with limited energy resources. In some applications, the sensor nodes are unreachable so the backup of energy resource is not possible. Therefore, energy competence is a crucial issue that is inevitably to be improved to extend the network lifetime. Usually, clustering is used to improve the energy proficiency of network routing. In this paper, we focus on the cluster-based or hierarchical routing algorithms for sensor networks. We perform the analysis of popular hierarchical routing algorithm low-energy adaptive clustering hierarchy (LEACH) and focus on how to choose the next hop nodes during data transmission phase. In this article, we propose an improved clustering algorithm for WSN. Simulation analysis confirms that proposed clustering algorithm outperforms the LEACH algorithm.

Keywords WSN · Clustering algorithms · Energy · Network lifetime · LEACH

1 Introduction

Latest advancement in embedded systems and communication technologies allows the microautonomous system comprised of small tiny devices known as sensors. These sensors can detect, compute, and communicate via suitable sensor technology that gives birth to wireless sensor network [1, 2]. Deployment ease and low-cost sensors make wireless sensor network suitable for many applications like health care, transportation, smart building, disaster management, and environmental

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monitoring. Since the sensor nodes have limited energy supply, optimization of energy must be considered as the important aim in sensor network design [3]. Clustering is a process used to handle the energy usage effectively [4]. In this scheme, each and every group of sensors has a head node recognized as cluster head (CH) that performs data fusion and data forwarding toward the base station (BS) or sink node [5]. Numerous cluster-based routing algorithms have been reported in text to extend the lifetime of network [6–8]. The LEACH is most popular routing protocol due to its simplicity and efficiency [9]. LEACH divides the complete network into a various clusters, and execution time of system is partitioned into several rounds. In every round, the member node contends to be CH in accordance with some specified criterion. However, this protocol does not guarantee that the preferred amount of CHs is selected in the network. Some enhancement on LEACH is reported in the literature [10–12].

In this article, we proposed an improved clustering algorithm to increase network lifetime. The main initiative in proposed algorithm is CH election with consideration of residual energy. The proposed method is described in Sect. 3. Simulation results analysis is presented in Sect. 4. At last, Sect. 5 concludes the work.

2 Related Work

Here, in this part or work, we concentrate on the similar work reported in the literature. Routing is a process of selecting best path in the network. Routing protocols are liable for discovering and managing efficient routes in the networks [6, 7].

2.1 Classification of Routing Protocols in WSN

WSN routing protocols can be classified on the basis of some measures like the way of constituting the routing paths, structure of network, protocol operation, originator of communications, how a protocol selects a next hop on route of forwarded message [5–7]. The categorization of routing protocols is given in Fig. 1.

On the basis of structure of network, routing protocols are categorized as flat, hierarchal (cluster-based), and location-based protocols. In flat-structured routing, each sensor node plays similar role, while in cluster-based routing, sensor nodes have dissimilar roles. Due to network scalability and transmission effectiveness, cluster-based routing is the best choice [13, 14]. LEACH is the most influential protocol of this category [9]. So, we focus on LEACH protocol and its drawbacks.

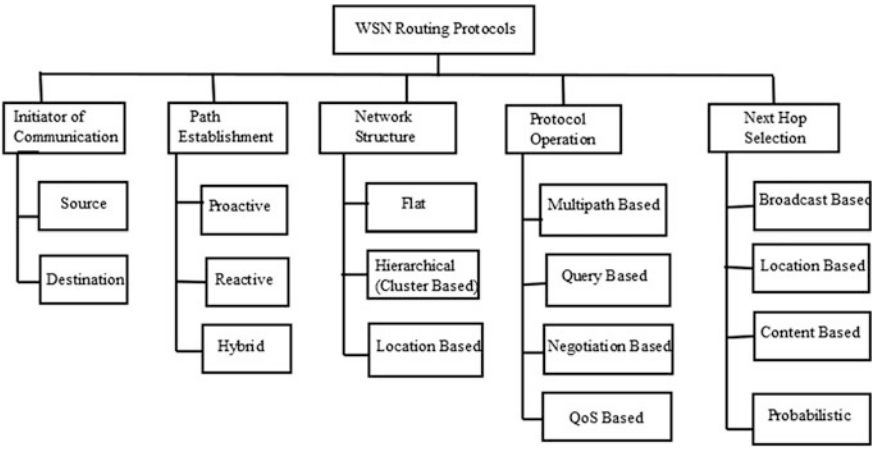

Fig. 1 Classification of WSN routing protocols

2.2 LEACH Protocol

LEACH is hierarchy-based routing protocol developed by Heinemann et al. [9]. The execution of LEACH consists of several rounds. Every round is made of setup phase and steady-state phase.

2.2.1 Setup Phase

Initially when clusters are being formed, each node makes a decision either to become a CH for present round. This decision is performed by a node in choosing a random number between 0 and 1. If chosen number is less than a threshold $T(n)$, the node becomes a CH for present round.

$$T(n) = \begin{cases} \frac{p}{1-p\times[r\bmod(1/p)]} & n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where p represents the ratio of CHs in network (generally p is 5%), r is the present round number. G is the set of nodes which have not been the CH in running round.

Using the above threshold, nodes those have been CH cannot become CH for subsequent time for p rounds. Afterward, every node has a chance of $1/p$ becoming a CH and attach to that cluster. The CHs merge and compact the data and advance it to sink; thus, it extends the network lifetime.

2.2.2 Steady-State Phase

The formation of a CH in every cluster at some stage in setup phase gives an assurance intended for data communication in steady-state phase. Intra-cluster transmission is based on TDMA schedule. The inter-cluster communication is based on CDMA schedule. After certain amount of time in steady-state phase, CHs are again elected during the setup phase.

2.2.3 Drawbacks of LEACH

Although cluster-based routing protocols act in fine way, they also experience many troubles. Here, we focused on the drawbacks of LEACH protocol [9, 15]. This protocol suffers from the following weaknesses like:

(i) CH's election is random and does not consider the node's remaining energy.
(ii) Reclustering frequency is high so the some energy is wasted.
(iii) It covers small area.
(iv) Non-uniform distribution of cluster heads (CHs).

3 Proposed Algorithm

We propose a new clustering algorithm to extend the network lifetime. The proposed method is given in Fig. 2.

The proposed method consists of two phases such as:

3.1 Cluster Formation Phase

During the period of the cluster creation, to avoid the node with small remaining energy to be chosen as CH; take the consideration of the remaining energy when we define the threshold $T(n)$

$$T(n) = \begin{cases} \frac{p}{1-p\times[r \bmod (1/p)]} \times \frac{E_{\text{residual}}}{E_{\text{initial}}} & n \in G \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where p, r, G are same as in Eq. (1). E_{residual} and E_{initial} are the remaining energy and initial energy of node correspondingly.

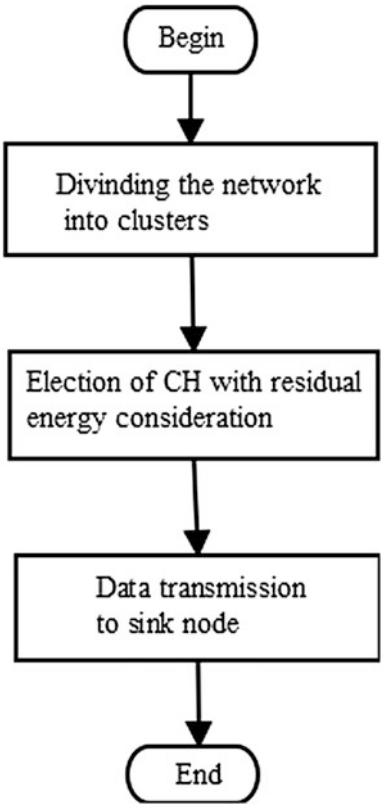

Fig. 2 Flowchart of proposed method

3.2 Data Transmission Phase

In this phase, the intra-cluster communication uses TDMA schedule similar to LEACH. In LEACH, every CH accomplishes direct communication with base station, regardless of the distance among CH and BS. Here, in proposed method, the communication between CHs and BS has two types: one-hop communication and multi-hop communication. The objective of the proposed method is to reduce the transmission loss. The proposed algorithm described here chooses optimal path and follows multi-hop communication between CH and BS.

4 Simulation Results

We simulated the proposed improved algorithm and analyzed with the original LEACH in this section. Simulation parameter setting is as per Table 1.

Table 1 Simulation parameters

Parameters	Values
Number of nodes	100
Area	200 m × 200 m
Initial energy	2 J
Base station position	[100, 175]
Electronics energy (E_{elec})	50 nJ/bit
Energy for data aggregation (E_{da})	5 nJ/bit/signal
Packet size	25 bytes
Number of CH	5
Simulation time	600 s

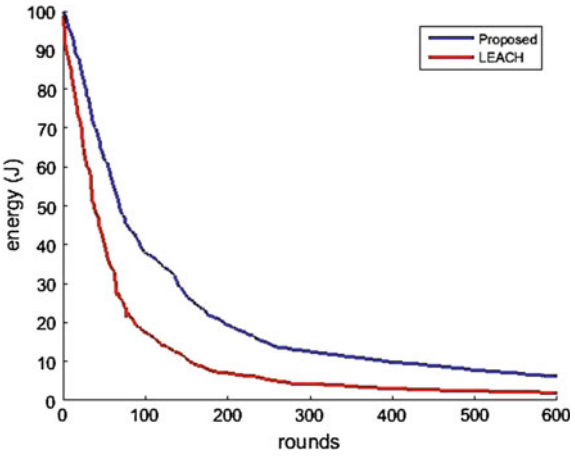

Fig. 3 Remaining energy with 100 nodes

The performance analysis of our improved algorithm with original LEACH is shown in Figs. 3, 4, and 5.

Figure 3 shows the comparative presentation of remaining energy of LEACH with improved clustering algorithm. From the above presentation, we make out that improved algorithm has more residual energy in comparison with LEACH. Figure 4 shows the performance of first node dead (FND) means after how much round the first node dies. From the results, we know that our improved algorithm takes more rounds for FND. Figure 5 shows the performance of half node dead (HND) means after how much round the half nodes die. From the results, we know that our improved algorithm takes more rounds for HND. So, from the simulation result analysis, it is understandable that improved clustering algorithm extends the lifetime of network in comparison with LEACH protocol.

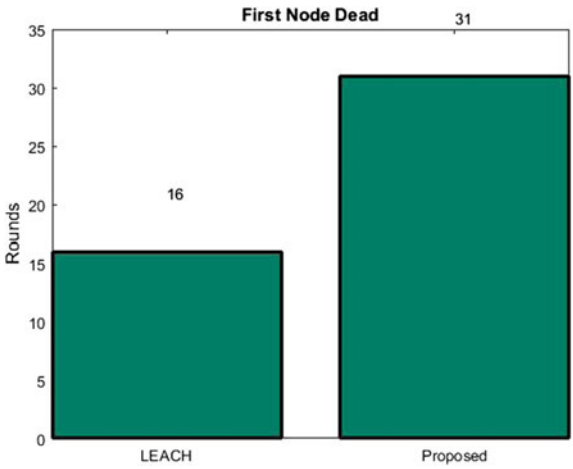

Fig. 4 Time of first node dead

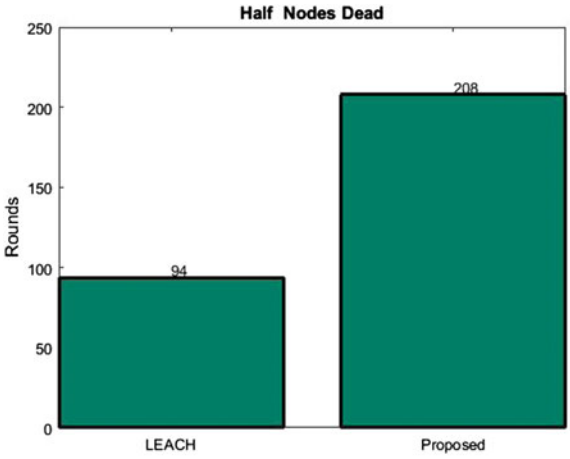

Fig. 5 Time of half nodes dead

5 Conclusion

The improved clustering algorithm for wireless sensor network is described in this paper. This proposed improved algorithm uses residual energy for CH election process and follows multi-hop approach among cluster and base station. It is clear from simulated result analysis that proposed algorithm outperforms the LEACH protocol. Future works include the implementation of load balancing approaches among cluster head nodes to further improve energy efficiency.

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