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Extended RSSI based Cluster Head Selection Algorithm for Wireless Sensor Networks

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Abstract

Wireless Sensor Network is featured with inherent limitation of energy, as frequent communication between the sensor nodes (SNs) results in huge energy drain. Moreover, optimization and loadbalancing within the WSN are the significant concern to grant intellect for the extensive period of network lifetime. In this paper, we present an Extended RSSI based Cluster Head Selection (ERCHS) algorithm for Wireless Sensor Network which takes into consideration the received signal strength index (RSSI) of SNs from the base- station (BS). The ERCHS algorithm mainly focuses on maximizing the network lifetime based on RSSI values and residual energy levels of SNs. The ERCHS algorithm is simulated on Cooja Simulator and to measure its performance Low Energy Adaptive Clustering Hierarchy (LEACH) and Hybrid Energy Efficient Distributed clustering algorithm (HEED) protocols are used. Simulation analysis and results depicts that proposed algorithm can effectively enhance the network lifetime by two times and thus it is an energyefficient way to choose a CH.

Keywords: *Cluster Head Selection, Energy Efficiency, Residual Energy, WSNs*

1. Introduction

A Wireless Sensor Network (WSN) is an extremely intricate distributed system consisting large numbers of SNs and BS. The SNs are usually deployed in a random manner over a large geographical area for event detection and continuous monitoring applications [1]. The WSN gather the sensed value to intend the surroundings with further intellect. With applications in diverse fields of science and technology WSN provides a promising solution to data gathering applications. As a matter of fact, many WSNs are deployed and operating outdoors is exposed to varying environmental conditions, which may further set grounds for severe performance degradation of such networks. Therefore, it is necessary to take into consideration the factors like radio signal strength in order to reduce the impact and to adapt to varying environmental conditions. Since clustering is a topological control technique to reduce the activity of SN’s transceivers, it extensively increases overall system scalability and energy efficiency. It selects CH to manage the entire network to achieve longevity in WSN. Battery replacement or charging is complicated in WSN due to its installation in extremely remote areas. Even in case of a single SN failure due to energy drain can lead to significant impact on the performance. Therefore the recent trend in WSN is to develop energy efficient design protocols to achieve longevity [2].

The SNs in WSN are positioned in network with dynamic coordinates, under the topological control technique of base station. In each cluster, a CH is selected to manage the activities within that cluster. CH performs different task to continue with sensing operation which involves collection of nearby data values regularly, aggregation and removal of redundant values [3].

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Aggregation is followed by transmission of filtered data to next CH which finally sinks at base station. If a fixed SN performs the entire three tasks, its lifetime will be of very short span. Thus there is a need to change CH regularly and effectively. A new CH selection and transmission policy is adopted in this paper which uses residual energy and signal strength at the same time to elect new CH at the end of one round of data communication. The proposed algorithm specifies the dynamicity of the CH and determine whether to change the cluster topology is required or not with the residual energy levels.

Most of WSNs are deployed and operating outdoors is exposed to varying environment conditions like temperature and humidity, which may further set grounds for severe performance degradation of such networks. Therefore we have to consider factors like radio signal strength for the section of the CH. RSSI values changes with change in distance and nearby conditions [4]. The paper is organized in six sections. Starting with introduction and literature survey, followed by system model and proposed approach, the paper summarizes performance metrics and result analysis is carried out in the end.

2. Literature Survey

In recent years, several works have been proposed to improve network life of cluster and energy efficiency during data transmission. In this section we present the valuable prior research accomplished in clustering protocols that are mainly determined towards energy efficiency and thereby improves overall network lifetime.

The authors of paper [5] have proposed a decentralized CH election protocol ADRP in which after initial CH selection next CH is elected based upon energy remaining and average energy consumed. The authors of paper [6] addressed the issue of suitable CH selection. The proposed approach is implemented by using Fussy Logic with the standard. LEACH protocol. The inputs to Fussy inference system are the residue of energy level, location of BS and cluster's centrality. The Authors of paper [7] have presented HEED protocol with varying level heterogeneity. The author of paper [8] has proposed an EEFL-CH technique by improving the LEACH protocol with fuzzy logic to reduce the energy. The enhanced protocol includes energy-efficiency, distance between SNs and BS and residue energy of SNs for cluster formation. The author of paper [9] had presented a cluster formation technique with three equal-sized zones. The CH selection will be dynamic for providing load-balancing and uniform dissipation of energy by the deployed SNs.

The authors of paper [10] had proposed CAFL algorithm where clustering is carried out with the help of fuzzy logics. In this algorithm, they have chosen parameters like residue energy of SNs, proximity to BS and CH and residue energy of tentative CH is taken into concern for competence. In paper [11], the author has proposed an energy aware protocols in which two BS are located on both the sides of the target field. To maximize the network lifetime, this protocol take into consideration two level of energy heterogeneity. The authors of paper [12] have presented a new protocol Energy Efficient Optimal Chain Protocol (EEOC) for prolonging network lifetime. The results of simulation are compared with LEACH, PEGASIS, and ACT etc.

The authors of paper [13] have proposed an energy-efficient dynamic clustering technique for CH selection. In this technique each SN approximates on the number of active SNs in real-time and calculates the optimum possibility of becoming a CH by examining its signal strength of the neighboring SNs. On analyzing and comparing the performance of this with standard AODV, MRE and MTE routing protocols significant increase in network lifetime has been witnessed. The authors of paper [14] presented a binary exponential cluster forwarding approach. This scheme ensures that when SNs of a cluster receives data then acceptance is required by the nominated SN. The author of

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paper [15] has presented energy aware intra-cluster routing techniques based on RSSI. This technique does not take inter-cluster routing into consideration. It is simulated on TOSSIM simulator has shown improvement in energy efficiency.

The authors of [16] and [17] have presented clustering technique to increase network lifetime as well as preserve network coverage in heterogeneous WSN (HWSNs) where SN can have different sensing radii and energy characteristics. The proposed procedure works in proactive way to preserve network coverage and prolong network lifetime by efficiently leveraging mobility to optimize the average coverage rate.

The authors in [18] also put emphasis on improving the sensor network lifetime based on the residual energy levels of cluster-heads (CHs). In their work, instead of changing CH's for dynamic clustering at every round, they introduced an optimal CH threshold function and an energy threshold function to postulate the dynamicity of CH on the based on the current energy intensities, thus enhancing the sensor network lifetime.

The above described clustering algorithms takes many important parameters into consideration like location of BS, proximity among the SNs, type of SNs and residual energy of the SNs. In this work we have developed an extended RSSI based CH selection (ERCHS) scheme which reduces communication overheads and also avoids unnecessary CH selection after every round. The algorithm is simulated to validate the improvement in energy efficiency and network lifetime.

3. Proposed Approach

This section presents Network and energy model and elaborates proposed approach where CH selection algorithm is based on residual energy and signal strength of the SN.

3.1 Network Model

The network is composed of 100 sensor nodes which are distributed evenly throughout the area under consideration as shown in figure 1. The sensor nodes are allowed to change their physical location where location at every time instant is stored in a discrete set containing x, y coordinate values. A three layered approach is used where sensor nodes transmit their data to Ch which in turn aggregate and filters the collected data and send the aggregated data to BS. All sensor nodes are considered to have equal energy at start of communication. The computation capabilities may differ depending upon distance and received signal strength. CH is involved in cluster formation where nearby nodes joins the respective CH based upon their distance value. Nearby CH is selected to increase performance.

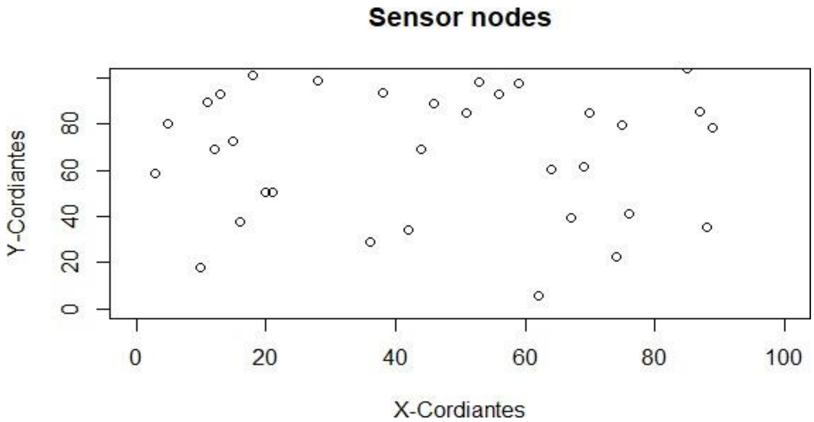

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Figure 1: Random Distribution of Sensor Nodes

3.2 Proposed Approach

The extended RSSI based CH selection works by setting up cluster in very first phase where JOIN message is being advertised by CH in beginning of the round. All nearby sensor nodes are directed to JOIN by acknowledging. By exchange of few messages network is being established where links become active to send and receive data.

$$JOIN(CHi,SN[i]) = \sum_{k=0}^{n} \max(R[i]), \min(D[i])$$

where, n = number of SNs k =
i^{th} SN under consideration
R[i] = i^{th} RSSI value corresponding to SN
D[i] = distance of i^{th} SN with CH

As the initial energy of all SNs would be same, the energy factor is not considered in the setup phase to find the initial CHs. Now the BS broadcasts message to all SNs to inform about the initial CHs, the SN in near proximity will transmit join-request message to CH. The CH will acknowledge them accordingly.

1. Assign random position to SN
2. Construct vector arrays containing of following data for each SN (i=1 to 100)
    a. VX[i]= X coordinate of SN
    b. VY[i]= Y coordinate of SN
    c. E[i]= Energy of SNs and is initialized by E0
    d. S[i]= Status of each SN (Died=0 or Active=1)
    e. Type[i]=Type of SN(Normal =0 or CH=1)
    f. R[i]= RSSI value
    g. D[i]= Distance from BS/ CH
    h. SN_id[i]= Sensor Node ID 3. Assign a central fixed location to BS.
4. Fix the coordinate of SNs & BS.
5. Compute D[i] of each SN from BS.
6. Send R[i] value of each SN to BS.
7. BS will create lookup-table with node-id and its R[i] value
8. BS will choose CH depending upon max (R[i]) value from equation 5 and acknowledge each SN with 0 or 1(Normal=0 and CH=1)
    a. if SN receive 1, change Type[i]=CH
    b. if SN receive 0, change Type[i]=SN
9. Each SN will send join-request message to its nearby cluster's CH.
10. CH will acknowledge SNs by sending a tuple (SN_id, Response).
    a. If response=1, SN will belongs to that CH
    b. If response=0, SN will belongs to that CH.

3.3 Data Communication Phase

The BS sends a message to all SNs to update details about the recently selected CHs to all clusters in the WSN. A round of communication consists of several time bound sub rounds where in each

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successive round a data value is expected to be sensed and aggregated by the base station. A sensor node is allowed to transmit their sensed data value in its designated time slot only.

1. All SNs will send the sensed data to their respective CH.
2. Energy of SN will change as: $E[i] = E[i] - ETX$
3. CH upon receiving the sensed data will aggregate it.
4. Energy of CH will change as: $E[i] = E[i] - ERX$

3.4 CH Re-Election Phase

CH reelection uses RSSI values at beginning of every round of communication. By analyzing different RSSI value sets threshold is computed and the same is communicated to all CH and SN by means of broadcast messages. The minimum energy required for selecting the next CH is estimated and present CH will execute following steps:

1. if (E[CH] < 40% its initial energy)
   c. CH broadcast a CH-ELECT to BS and all SNs belongs to that cluster
   d. Else Continue to be CH.
2. Upon receiving CH-ELECT, SNs of that cluster will send their R[i] and E[i] to the CH 3. CH will elect the new CH by calculating and comparing S_CH[i] value of each SN with S[i]
4. SN with just higher S[i] value than S_CH[i] will be then selected as a new CH.
5. CH acknowledge each SN with 0 or 1(Normal=0 and CH=1)
6. CH change its Type[i]=CH and other SN will receive 0 and changes their Type[i]=SN.

Above algorithm will be executed each time CH determination is carried out. Respective messages are stored and forwarded to distribute complete network information to every sensor node. Base station upon receiving these messages will update the respective cluster head entry for next round of communication. Performance is evaluated in terms of number of rounds network will work accurately without any data loss.

4. Performance Evaluations

This section list the parameters used for simulation along with the protocols used for comparison. The proposed protocol is varied by experimenting cluster size of 5, 10, 20 and 25. To investigate the impact of varying RSSI values upon threshold selection the proposed protocol is compared with LEACH and HEED. Cooja simulator [19] is used to simulate the proposed model network of SN. RSSI values and distance is used to control and coordinate data values of transmission and to decide CH in every iteration.

Network Lifetime, RSSI Threshold and Node Death Rate is used to compare performance. Lifetime is measured by estimating operational time of the network during which it is capable of performing sensing, aggregation and transmission tasks. RSSI threshold is used to fix the CH reelection criteria value. Node death rate defines the total number of live SN over the rounds where a low value is expected to achieve high performance.

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Table 1: Simulation Parameters

Parameter	Value	Parameter	Value
WSN network area	100m * 100m	**Eelec (for Tx and Rx)**	50 * 10^{-9} J/bit
No of SN/ Distribution	100/Random	**Eamp**	100 * 10^{-12} J
BS Coordinates	50,50	**Control Packet size**	25 bytes
SN initial energy	2 J	**Data packet size**	100 bytes

Several experiments have been performed to determine the RSSI threshold value for selecting the next CH given in figure 2. A relation was established between residual energy and network lifetime.

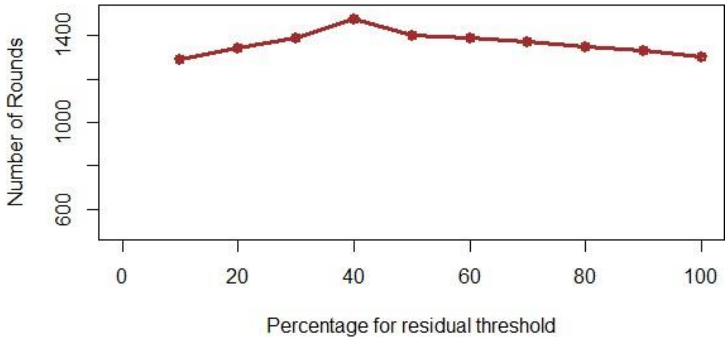

Figure 2: Selection for threshold value for CH

It can be seen from the figure 3 that if 10% of residual energy is taken as threshold, the lifetime of WSN will be about 1140 rounds. On varying the residual energy percentage till 40%, the WSN lifetime reaches to 1476 rounds and if we vary residual energy level further the number of rounds decreases gradually. Therefore we have taken threshold for selecting new CH to 40% and this value was used for calculation in CH Re-election Phase.

To examine the performance of our ERCHS algorithm we have compared its performance with classical LEACH and HEED for each of the approach. The simulation parameters are listed in Table 1. The performance of our ERCHS algorithm was demonstrated on the basis of four metrics, NDR, FND, HND and LND.

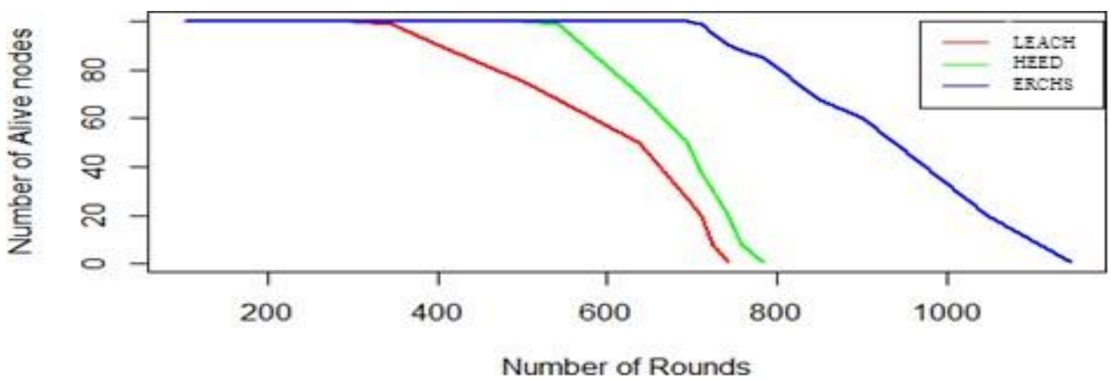

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Figure 3: Node Death Rate

Figure 3 shows the comparison between LEACH, HEED and ERCHS in term of NDR. It is evident from figure 4 that the Node death rate of our approach is always less than that of LEACH and HEED. We have taken four cluster sizes (5, 10, 20 and 25) to analyze the impact of varying load on CH and to determine overall network in all the cases. Table 2 lists the variation in cluster size with a total network size of 100 SNs.

Table 2: FND, HND and LND value for various approaches

Protocol	Cluster size	FND	HND	LND
LEACH	-	346	637	744
HEED	-	543	694	783
ERCHS	5	712	980	1147
ERCHS	10	680	1016	1368
ERCHS	20	597	1087	1578
ERCHS	25	522	1068	1476

The results of simulation that has been carried out to determine the network lifetime in terms of FND of different algorithms like LEACH, HEED and our proposed ERCHS are represented in Figure 4. It is evident that total lifetime in terms of number of rounds of above algorithms with cluster size 5, 10, 20 and 25 take for FND found to be 346, 543, 712, 680, 597 and 522 correspondingly. The ERCHS algorithm takes more rounds with all cluster sizes for FND in comparison to other approaches.

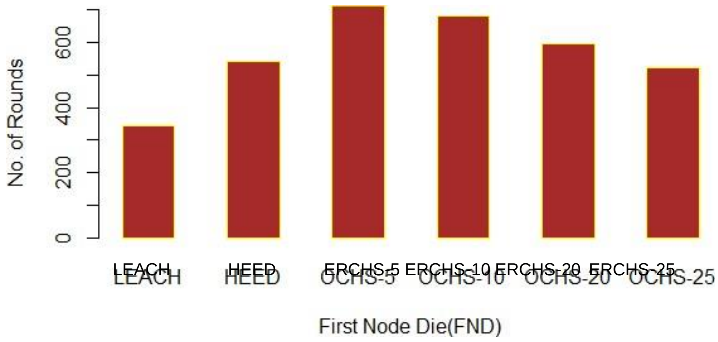

Figure 4: First Node Die

Similarly, the results of simulation carried out between the HND and performance for different approaches with varying cluster size is represented in Figure 5.

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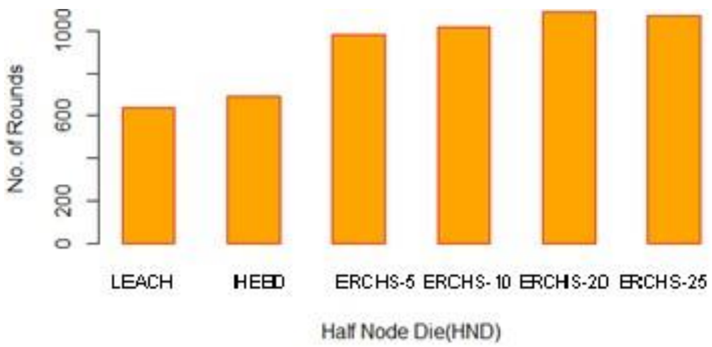

Figure 5: Half Node Die

It is evident that total lifetime with number of rounds of above mentioned algorithms with respect to HND is 637, 694, 980, 1016, 1087 and 1068 corresponding to LEACH, HEED and ERCHS-5, ERCHS-10, ERCHS-20 and ERCHS-25. The ERCHS algorithm results into more rounds with all cluster sizes for HND in comparison to other approaches.

Similarly, the results of simulation carried out between the LND and number of rounds for different approaches with varying cluster size is represented in Figure 6. . It is evident that total lifetime with number of rounds of above mentioned algorithms with respect to LND is 744, 783, 1147, 1368, 1578 and 1476 corresponding to LEACH, HEED and ERCHS-5, ERCHS-10, ERCHS20 and ERCHS-25 correspondingly. The ERCHS algorithm takes more rounds with all cluster sizes for LND in comparison to other approaches.

Figure 6: Last Node Die

On the basis of above analysis and results, it has been apparently confirmed that ERCHS ensures higher energy efficiency and prolonged network lifetime.

5. Conclusion

To improve energy utilization and enhance network lifetime of a WSN, we have proposed and simulated an extended RSSI based CH selection ERCHS approach. The ERCHS reduces communications overheads and avoids unnecessary selection of CHs. The algorithm has considerably achieved 35% to 45% efficiency in terms of energy preservation when compared to LEACH and the number of rounds has increased from around 750 to 1550. Similarly when compared with HEED, ERCHS algorithm achieves 25% to 35 % efficiency in terms of energy preservation and the number of rounds has increased from around 800 to 1550. The proficiency of ERCHS was evaluated on the basis of NDR and Network lifetime (FND, HND and LND). The ERCHS algorithm results in almost

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similar energy consumptions with each round of communication thus energy available for next rounds is saved which results in higher performance in terms of network lifetime and consistency.

Our proposed algorithm reduces communications overheads and avoids unnecessary selection of CHs in each round and outperforms other standard protocol during comparison. The ERCHS has uniform energy utilization and thus it has more residual energy available for a large number of rounds. The proposed work may be extended by implementing the same protocol for large applications to improve scalability and to provide reliability.

6. Conflict Of Interest

There is no Conflict of Interest.

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