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Article

AEECA for Reliable Communication to Enhance the Network Life Time for WSN

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Abstract: Nowadays, wireless sensor networks play a vital role in our day to day life. Wireless communication is preferred for many sensing applications due its convenience, flexibility and effectiveness. The sensors to sense the environmental factor are versatile and send sensed data to central station wirelessly. The cluster based protocols are provided an optimal solution for enhancing the lifetime of the sensor networks. In this paper, modified K-means ++ algorithm is used to form the cluster and cluster head in an efficient way and the Advanced Energy-Efficient Cluster head selection Algorithm (AEECA) is used to calculate the weighted factor of the transmission path and effective data collection using gateway node. The experimental results show the proposed algorithm outperforms the existing routing algorithms.

Keywords: Wireless sensor network; reliable communication; energy management; energy clustering; sensors; base station; gateway node

1 Introduction

In the recent past, the Wireless Sensor Network (WSN) has become the most discussed topic in the research community because of its flexibility and easy maintenance. WSN is geographic circulated self-sufficient sensors which are used to sense the environmental factors such as, pressure, temperature, sound, and etc. [1]. WSN consists of two major components: a base station and sensor nodes. The sensor nodes monitor the different types of environmental condition and transmit the data to the base station where the process over data is carried. The benefits of the WSN are utilized in various areas such as environment, health, military, home appliances and other commercial application [2]. The WSN is comprised of several thousand of sensor nodes and all the nodes can communicate through radio signals [3]. As shown in the Fig. 1 Sensor Node (SN) contain a processor, Analog to Digital Convert (ADC), power supply, memory and Radio Frequency (RF) transceiver to connect the sensor.

The base station (BS) architecture of WSN is shown in Fig. 2. The BSs are at least one segment of the WSNs with substantially communication resources and more computational energy [4]. They perform as a gateway node between the end client and SNs. They regularly forward information from the WSN. SNs are composed with computing, sensing and communication facilities, which sense the needed environment and transmit the gathered the data to BS [5,6].

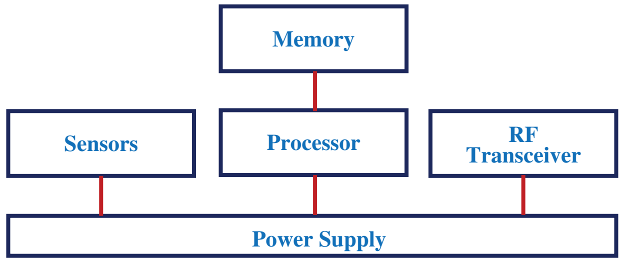


Figure 1: Components of SN

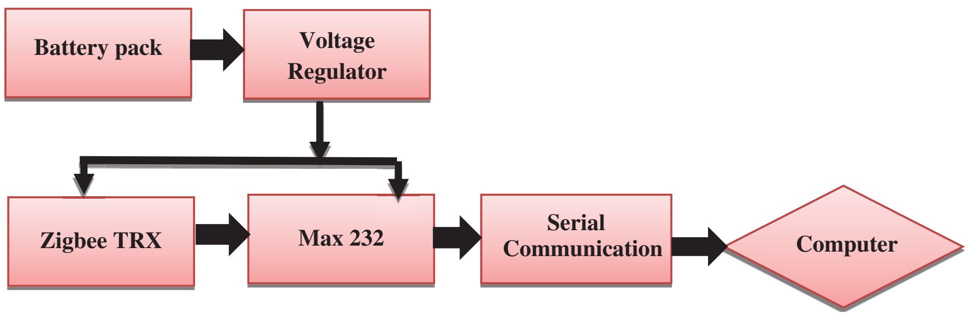


Figure 2: Architecture of BS

Using SNs and a BS of WSN for utilized reliable communication. The protocols must be able to collect the data and optimize energy consumption [7,8]. The reliable end stations running reliable protocols will cooperate to check the transmission of data to guarantee exactness and integrity of the information [9]. A reliable framework will set up an association and check that: all information transmitted is controlled carefully, is received in the right request and is intact [10,11]. Reliable protocols work best over the physical medium that loses information and is inclined to errors [12]. The error rectification, requesting and confirmatory instruments require overhead in the information parcels and increment the allowed amount of transmission capacity required to transmit information [13,14]. The drawback of using WSN in reliable communication, there may be a network delay, traffic, battery issue and distraction with another wireless device [15–17].

Fig. 3 shows the energy management framework which consists of two main components. They are energy consumption and energy provision. The framework for generalization of energy management is used to develop the proposed algorithm. The energy provision or supply can be further classified into energy supply with battery, transference and energy harvesting. The SNs are powered by batteries with minimum life duration. SN saves energy using energy harvesting to minimize power consumption while information transmission which in turns increases the lifetime of the network. In the recent past, the improvement of WSN energy transference provision is a big step forward.

Energy consumption is divided into three parts mobility-based, duty cycling, and data-driven approach. Duty cycle, where a node is occasionally set into the rest mode, is a successful strategy for reducing energy dispersal in WSNs and the sleep/wakeup mode program is done using duty-cycling. Data-Driven information transmission is highly expensive in terms of energy consumption. For the efficient energy management radio transceiver puts as a rest mode or low power mode. The mobility based methods are used in a mobile relay or sink the mobile is part of the environmental factor or one of the networks. The common ways are energy consumption, energy-conserving sampling techniques, reduction of transmitted data, and efficient analog to digital conversion techniques.

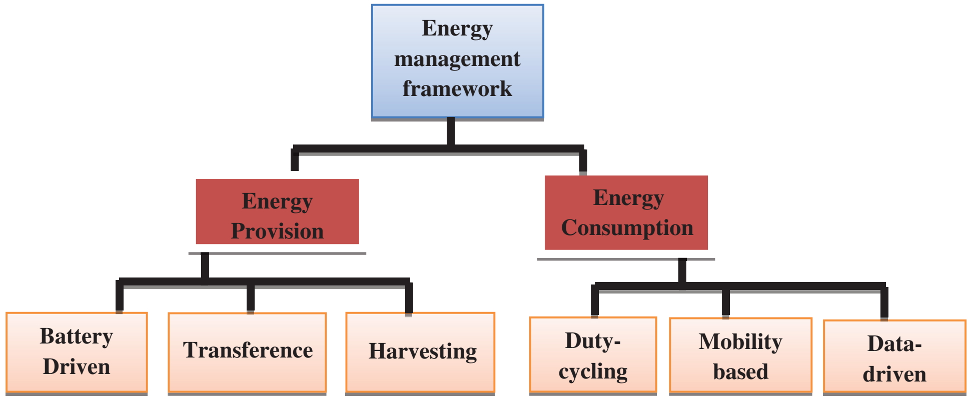


Figure 3: Energy management framework

2 Related Works

Many algorithms have been made for efficient energy management to decrease energy consumption.

Wang et al. [18] introduced the Cluster based Routing for Dynamic Networks (CRPD). This protocol is suitable for dynamic sensor networks to increase the lifetime of the networks with low power consumption and high efficiency in WSN. They suggested the network topology information which is updated at a constant period and the cluster head is selected which is having more neighbouring nodes and more residual energy for liable to data forwarding and gathering.

Yi et al. [19] suggested the method called Hamilton Energy efficient Routing Protocol (HEER) to decrease the energy consumption of sensor nodes. This protocol forms a cluster during network initialization stage and merges the member of the cluster by using Hamilton path; the overall network is developed using greedy algorithm. The node which is having high residual energy becomes a cluster head. This protocol does not consider the global location information of a node and re-cluster formation not available.

Haseeb et al. [20] introduced a Weighted Energy-Efficient Clustering with Robust Routing (WECRR) for a cluster head selection technique based on bounded mechanism to decrease the dynamism in cluster head. If there is any failed node or faulty node in primary route, this protocol selects the predetermined alternate route. Due to this, it decreases the number of retransmission and route breakages.

Ray et al. [21] developed an Energy Efficient Clustering Protocol based on K-means (EECPK-means) algorithm. Cluster has been formed by K-means clustering algorithm, but this protocol has a problem of selecting the centroid in a random manner. It may have drawback of two centroids nearer to each other. This problem is solved by midpoint algorithm which has a process of selecting the initial centroid. This algorithm has considered only the residual energy of node and distance between the nodes.

Barnawi et al. [22] initiated the enhancement of the WSN lifetime by electing the control node from a group of nodes. The different tasks have been assigning to the control node at dynamically. This node is selected based on the NP hard problem, residual energy of the node and transmission cost.

Energy consumption of SNs and enhancing the lifetime of the network are the most essential part. There are so many algorithms developed based on the cluster based algorithm that are focused on cluster formation and cluster head selection. But existing algorithms are struggled for cluster formation and Cluster Head (CH) selection.

The main aim of this paper is to prolong the lifetime enhancement of WSN. For that, the Modified K-means++ algorithm has been proposed to form optimal number of clusters and also proposed an Advanced Energy Efficient Cluster head selection Algorithm which is used to calculate the weighted factor of the transmission path, residual energy, distance between SNs and BS and effective data collection for gateway nodes. The proposed algorithms outperform the existing method.

3 The Proposed Model

3.1 Network Model

The following assumptions, we have made for our simulation experiment.

- The SNs are deployed randomly in the network and static once deployed.
- The BS has no limitation for power sourced by battery, computation, memory and hardware constraints, which is stable after the deployment.
- All nodes are homogeneous in nature that is same initial energy; communication cost and computation facilities are equal and preset.
- In addition, all nodes know its location coordinates. The residual energy and location of SNs are communicated to the BS.
- CHs aggregate the data from its data members, and sent to BS.
- All nodes are run by battery powered and not replaceable after its energy is exhausted.

This proposed system consists of two important stages namely first stage is cluster formation using Modified K-means++ clustering algorithm and second stage is CH selection based on AEECA.

3.2 Modified K-Means++ Clustering Algorithm

In WSN, there are N SNs deployed in distinct environment and a BS is located at various places such that inside the network, corner of the network and outside of network. To achieve the energy efficiency for reliable communication, we formed a cluster in an efficient manner using the modified K-means++ clustering algorithm. The K-means clustering algorithm has a problem that the initial centriod is selected randomly. So there may be chance for having two centroids closely and it may reduce the cluster formation efficiency. Thus we have developed a modified-K-means++ clustering algorithm to solve the above problem and clusters are formed in an optimal way.

Algorithm 1: Modified K-means++ clustering algorithm

Step 1	Select one of the sensor node in S at random as centroid c_1
Step 2	For each SN s in S calculates the Euclidean distance between s and c_1 that have already been defined. Thus if centroids $c_1,\ldots, c_m$ have already been selected as $d_m(s) = d^2(s, c_j)$ where j = that t, $1 \le h \le m$, for which Min $(d^2(s, c_h))$
Step 3	Select one of the SN in $S-\{c_1,\ldots, c_m\}$ at random as centroid c_{m+1} where the probability of any SN s being selected is proportional ton $d_m(s)$. Thus the probability that x is selected is equal to $\frac{d_m(s)}{\sum_{z\in S} d_m(z)}$
Step 4	Repeat step 2 until k centroids have been selected.

3.3 Advanced Energy Efficient Cluster Head Selection Algorithm (AEECA) for WSN

The cluster is formed by modified K-means++ clustering algorithm and the selection of CH is not performed in an optimal way. For that purpose we have proposed AEECA for reliable communication. The WSN, we need to consider two important factors. One is the battery power available in the sensor node is limited and the other one is the cost of computing a network or individual devices for transmission. The longer communication distance node can take much energy for transmission, so the communication is another important consideration for energy conservation.

The total transmission power can be reduced by using routing protocols for WSNs. In wireless links, the transmitted signal with power S_t along with link distance H takes attenuated and the power received in constant power scenario like the following Eq. (1) is,

$$S_r \propto \frac{S_t}{H^L} \qquad L \geq 2 \tag{1}$$

As shown in the Eq. (1) where L is the constant that relies on the network characteristics and medium of propagation.

In the variable power scenario, the optimal transmission power is calculated with link distance H as in the following Eq. (2) is,

$$R_{opt} = Rh * \alpha * H^L \tag{2}$$

As shown in the Eq. (2) where R is the transmission power, Rh denotes the threshold value, α is the constant proportionality and L is the constant attenuation.

The Energy optimal transmission along with a link in a network is shown in the following Eq. (3),

$$W_{opt}(H) = \beta H^L \tag{3}$$

where β is the number of transmission per bit. Let's consider the M number of the energy nodes; M−1 is the number of transferring nodes between destination end nodes. The indexed nodes are denoted as j where $j = \{2, \ldots, M\}$

$$W_{total} = \sum_{j=1}^{M} {W_{opt}}^{j,j+1} \tag{4}$$

$$W_{total} = \sum_{j=1}^{M} \beta H^L_{j,j+1} \tag{5}$$

The minimum energy transmission case, the energy nodes are of equal length $\frac{H}{M}$ as in the following Eq. (6),

$$W_{total} = \sum_{j=1}^{M} \beta \frac{H^L}{M^L} = \frac{\beta H^L}{M^{L-1}} \tag{6}$$

For the reliable communication the energy spent on computing, let us consider M which affects the transmission error probability over the entire paths,

$$\mu = 1 - (1 - \mu_{link})^M \tag{7}$$

As shown in the Eq. (7) where μ_{link} is the transmission error probability over the entire paths.

The geometrical spread of variable A and the following Eq. (8) is expressed as,

$$prob\ (A = L) = \mu^{L-1} \times (1 - \mu), \ \ \forall\, L \tag{8}$$

The total energy needed in the reliable communication of a single node is expressed as the following Eq. (9) is,

$$W_{total\ rel}^{EEC} = \beta \frac{H^L}{M^{L-1}} * \frac{1}{1-\mu}$$
$$= \frac{\beta H^L}{M^{L-1} * (1-\mu_{link})^M} \tag{9}$$

the above Eq. (9) indicates the impact of raising M of the total energy needed, the denominator M^{L-1} term increases with M. The error term $(1-\mu_{link})^{\ M}$ reduces with M.

Using energy-efficient clustering algorithm for the total energy cost evaluation case is,

$$W_{total\ rel}^{EEC} = \sum_{j=1}^{M} \beta \frac{H_{j,j+1}^L}{(1-\mu_{j,j+1})} \tag{10}$$

As shown in the Eq. (10) M indicates the nodes in a WSN with energy nodes in a distance $\frac{H}{M}$ with data packet error rate μ_{link} and this is minimized as in the Eq. (11) is,

$$W_{total\ rel}^{EEC} = \beta \frac{H^L}{M^{L-1} * (1-\mu_{link})} \tag{11}$$

Each node in a sensor network should be a part of a cluster. The energy consumption depends on the clustering nodes in multi-hoping which communicate directly resulting in high energy consumption. The clustering protocols consist of relaying data via gateway nodes and relaying data via cluster heads as shown in Fig. 4. The relay data with cluster heads utilize the nodes on cluster boundaries. If CH is near to BS then it will transmit the data to BS. Otherwise it will transmit the data through the gateway node. When designing the efficient energy clustering algorithm we need to consider the lifetime of the network and transmit range to ensure the connectivity.

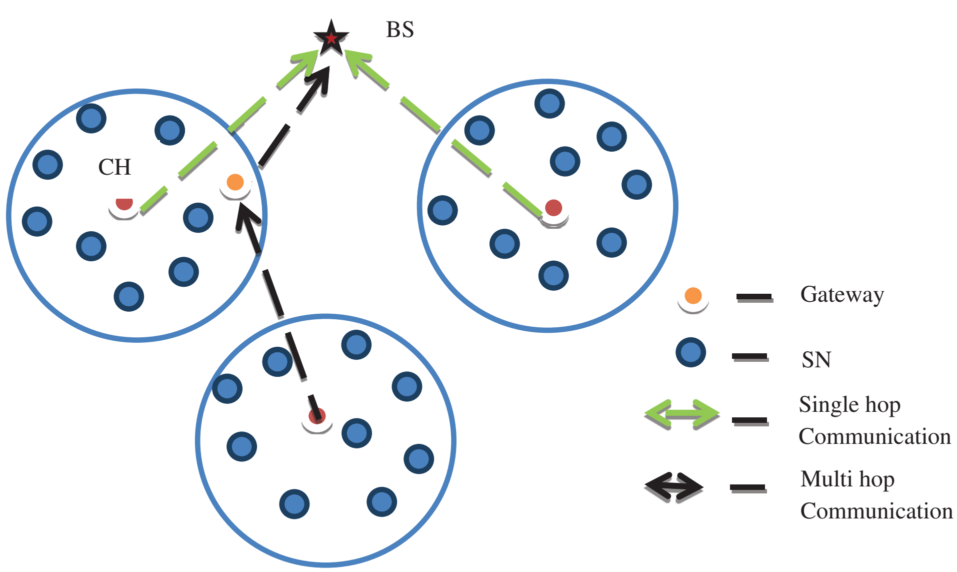


Figure 4: Communication between CH, Gateway node to BS

Using AEECA, Let us consider the path S for data transmission to node H that contains of M−1 mean nodes indexed as $\{2, \ldots, M\}$. The total energy cost W can be evaluated as in the following Eq. (12) is,

$$W_S = \sum_{j=1}^{M} \frac{W_{j,j+1}}{(1-\mu_{j,j+1})} \tag{12}$$

To choose a minimum cost path M + 1 from L, the following Eq. (13) is expressed as

$$D_{j,i} = \frac{W_{j,i}}{(1-\mu_{j,i})} \tag{13}$$

The multiplicative error term is involving a data transmitting packet, the probability of error over the link can be expressed as in the following Eq. (14) is,

$$W_S = \frac{\sum_{j=1}^{M} W_{j,j+1}}{\prod_{j=1}^{M}(1-\mu_{j,j+1})} \tag{14}$$

In specific, the data path contains L identical links,

$$W_S = \frac{lW}{(1-\mu)^L} \tag{15}$$

The approximation of total transmission cost functions for link is expressed as in the following Eq. (16) is,

$$D_{j,i}{}^{approx} = \frac{W_{j,i}}{(1-\mu_{j,i})^U} \tag{16}$$

The energy efficiency for the data transmission cost is evaluated using the clustering algorithm where the cost function is expressed as the following Eq. (17),

$$W_S = \sum_{j=1}^{M} \frac{W_{j,j+1}}{(1-\mu_{j,j+1})^U} \tag{17}$$

Algorithm 2: Advanced Energy Efficient Cluster head selection algorithm (AEECA)

Input: Distributed N node

Output: CH Node

Initialize S

for each j node

compute $W_S = \sum_{j=1}^{N} \frac{W_{j,j+1}}{(1-\mu_{j,j+1})}$

calculate the residual energy E_j of $node_j$

calculate the distance $dist_j$ between $node_j$ to BS

If weight==maximum and residual energy== high and distance ==minimum

node j become cluster head

else if residual energy == maximum and distance == minimum

node j become Gateway node

else

j=j+1

end for

An AEECA is a Machine Learning method which includes the gathering of information point. Clustering is a strategy for unsupervised learning and is a typical procedure for statistical information analysis utilized in numerous fields. So clustering can be done by using modified K-means++ clustering algorithm. In an each cluster, CH have been selected using this algorithm. N numbers of SN are distributed randomly. CH are selected from N nodes that node is having maximum of weight, high residual energy and minimum distance between node to BS as shown in above algorithm.

4 Experimental Results and Discussions

The simulation experiment has been performed on the machine with 2.5 GHz processing power, main memory of 4GB, Windows 7 OS and MATLAB software. For our simulation analysis, the network parameters are assumed as per the Tab. 1. Where ε_{fsm} is the energy required for free space model, ε_{mpm} is the energy required for free space model, E_{Tx} and E_{Rx} is the energy needed for transmitting and receiving a single bit respectively and E_{DA} is the energy needed for data aggregation.

Table 1: Simulation parameters

Parameter	Value
Node initial energy	0.5 J
E_{ele} (E_{Tx} and E_{Rx})	50 nJ/bit
ε_{fsm}	10 pJ/b/m^2
ε_{mpm}	0.0013 pj/b/m^4
E_{DA}	5 nJ/b
Threshold distance	87.7 m
Data packet size	500 B
Control packet size	25 B

The simulation experiment has been performed and the proposed system is compared with existing algorithms namely CRPD, HEER, WECRR and EECPK-means algorithm using parameters such as number of alive nodes, node lifetime, appropriate network area, number of packets received by BS and average residual energy.

The simulation is carried in six different cases to analyse the proposed system with respect to network terrain size, number of SNs and location of BS as shown in Tab. 2. For case 1, 100 nodes are deployed in 100 m X 100 m random environment along with the location of BS is (50 m, 50 m). The BS is located inside and exactly at the centre of the network area. In case 2, number of nodes and network terrain size are exactly same as case 1 but only the difference is the location of BS at (100, 100 m). BS is located in the corner of the network. As similar case 1, for case 3 sizes of network and number of nodes are same. The location of BS is outside of the network area such as (50, 150 m).

For case 4, the size of the network is 150 m × 150 m and the location of BS is at (75, 225)m but the number of nodes for this case is 150. The location of BS and network area is same as case 4 but total numbers of SN are 200 for case 5. In case 6, 300 nodes are deployed in same network area and BS location is as same as case 5.

Table 2: Number of case with respect to network size, number of node and BS location

Case	Network terrain size	Number of SN	BS location (in meter)
1	100 m × 100 m	100	(50, 50)
2	100 m × 100 m	100	(100, 100)
3	100 m × 100 m	100	(50, 150)
4	150 m × 150 m	150	(75, 225)
5	200 m × 200 m	200	(100, 300)
6	200 m × 200 m	300	(100, 300)

4.1 Number Of Alive Nodes

We have compared for the number of alive nodes. The proposed system has been compared with existing algorithms such as CRPD, HEER, WECRR and EECPK-means which gives better results. The Proposed system has less number of dead nodes for every rounds of transmission in the network. The number of alive nodes is illustrated in Figs. 5a–5d.

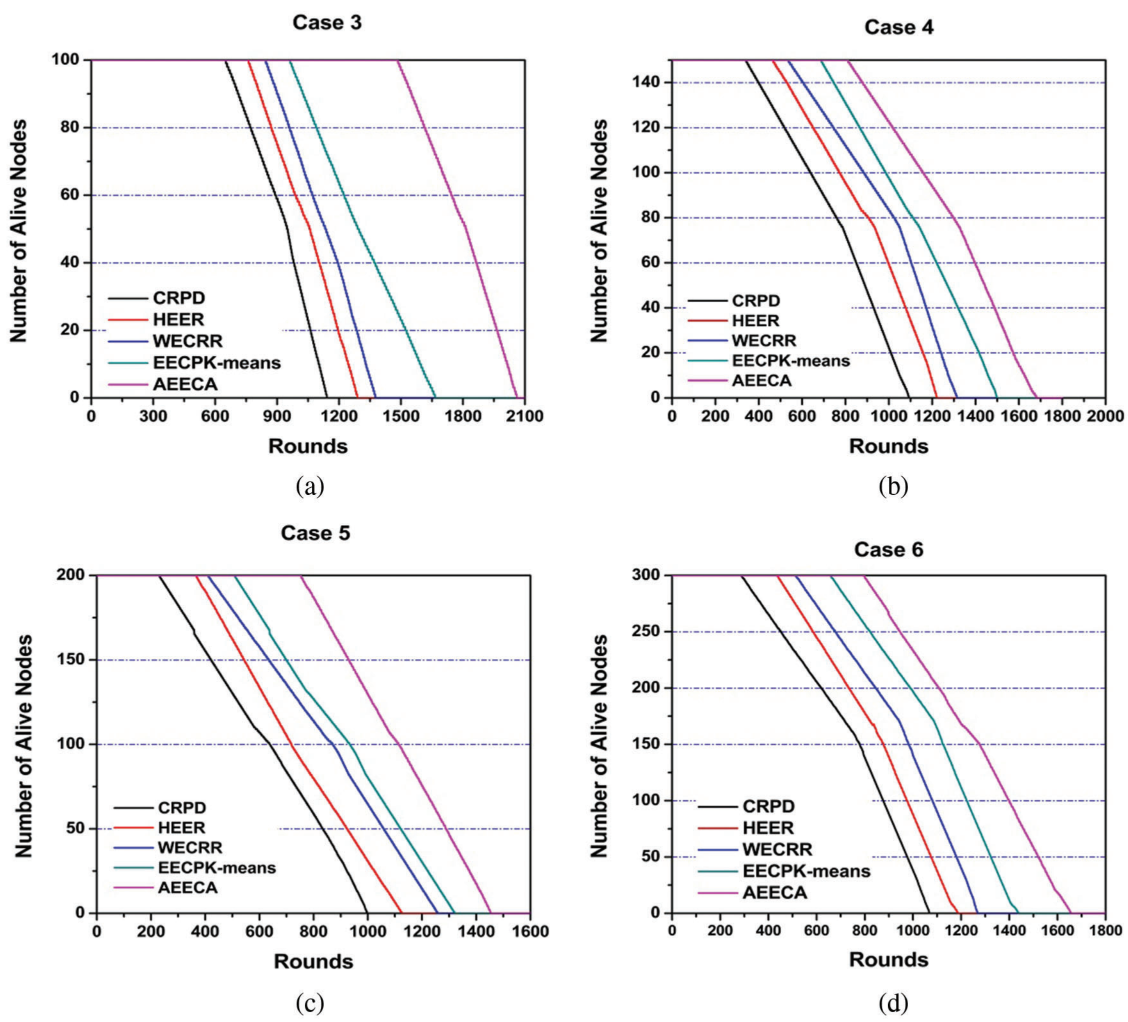


Figure 5: The number of alive nodes *vs*. Rounds for all algorithm (a) 100 nodes with BS located outside of network (50, 150) m (b) 150 nodes with BS located at (75, 225) m (c) 200 nodes with BS located at (100, 300) m and (d) 300 nodes with BS located at (100, 300) m

4.2 Wsn Lifetime

The network lifetime is characterized as the functioning time of the WSN during which it can execute the task. Network lifetime is also stated at the time until the first node dies. The minimization the SN load in a WSN can enhance the network lifetime.

The proposed system is analysed for network lifetime with existing algorithm such as CRPD, HEER, WECRR and EECPK-means. The Proposed algorithm outperforms the above existing algorithms. The network node lifetime in the round analysis is illustrated in Fig. 6. Tab. 3 shows the performance comparison of existing algorithms with proposed algorithm in terms of percentage.

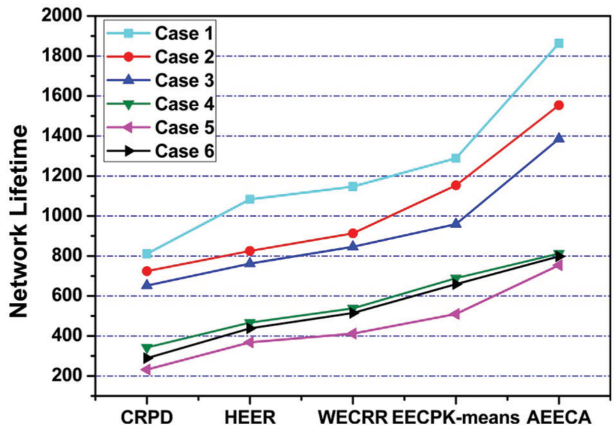


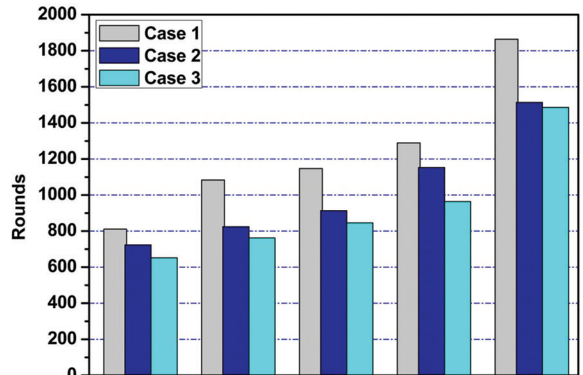
Figure 6: Network Lifetime with respect to different case

Table 3: The performance comparison of existing algorithms with proposed algorithm

Scenarios/Algorithms	Percentage					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
CRPD	56	53	53	68	69	64
HEERA	42	47	45	42	51	45
WECRR	38	41	39	34	45	35
EECPK-Means	31	26	31	15	32	17

5. Appropriate Sensor Network Area

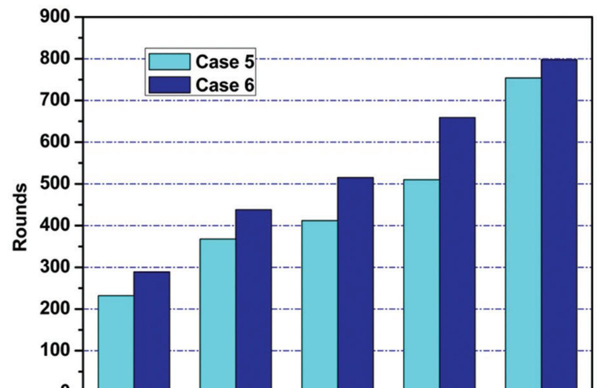
The different number of SNs are deployed in sensor area such as (100 m × 100 m), (150 m × 150 m) and (200 m × 200 m) with 100 nodes, 150 nodes and 200 nodes respectively. Case 1, 2 and 3 indicate the location of BS such as inside the sensor network area i.e., centre of the network, corner of the sensor network area that is (100, 100) m and outside of the sensor network area such that (50, 150) m respectively as shown in Fig. 7 For this cases, the BS which is located inside of the sensor network has better lifetime when compared with other two cases such that corner and outside. But in all situations, we cannot expect the location of BS is to be inside the network area. The BS may locate outside the sensor network. In such a case the energy of the nodes may be depleted quickly due to the increases in the distance and it may lead decrease in sensor lifetime. But our proposed algorithm can manage the above case efficiently by increasing the energy of the node and thus by network lifetime is also increased.



	CRPD	HEER	WECRR	EECPK- means	AECA
#1 (Centre)	811	1083	1147	1289	1864
#2 (Corner)	724	825	913	1153	1514
#3(Outside)	652	762	846	964	1486

Figure 7: comparison the different algorithms with respect to BS location

From case 5 and 6, the network area and location of the BS are same but the numbers of SNs being deployed may vary. As shown in Fig. 8 the number of SNs are essential factor for deciding the network lifetime enhancement. The proposed system has provided better performance when compared with other existing protocols.

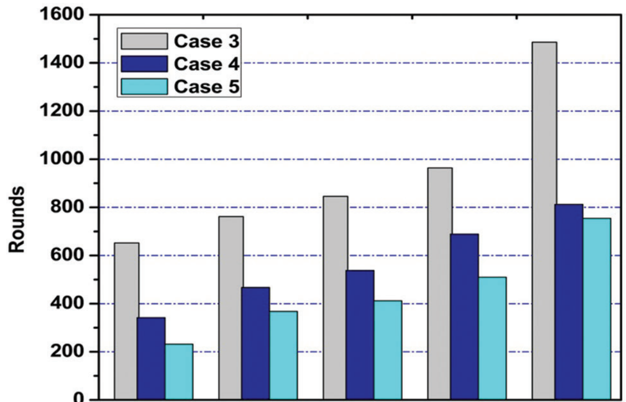


	CRPD	HEER	WECRR	EECPK - means	AEECA
#5 (200 nodes)	232	368	412	510	754
#6 (300 nodes)	289	438	515	659	798

Figure. 8: Comparison of different protocols for FND with respect to number of nodes

Fig. 9 shows that the sensor network area is distinct with the location of the BS is outside the sensor network. The performance of proposed system is better than other existing protocols such as CRPD, HEER, WECRR and EECPK – means.

From all these analysis, it is clear that the lifetime enhancement of sensor network is based on the appropriate sensor network area, the number of SNs and location of BS.



--	CRPD	HEER	WECRR	EECPK - means	AECCA
#3 (100X100)	652	762	846	964	1486
#4 (150X150)	342	467	538	689	812
#5 (200X200)	232	368	412	510	754

Figure. 9: Comparison of different protocols for FND with respect to network terrain size

6 Number of Packets Received by Bs

Here the total number of packet received by BS is compared with existing algorithms. Throughput refers to rate of packets transmitted to destination successfully. For this case, the proposed algorithm AEECA for WSN performs better than the existing algorithms such that CRPD, HEER, WECRR and EECPK-SHOWN IN Fig. 10

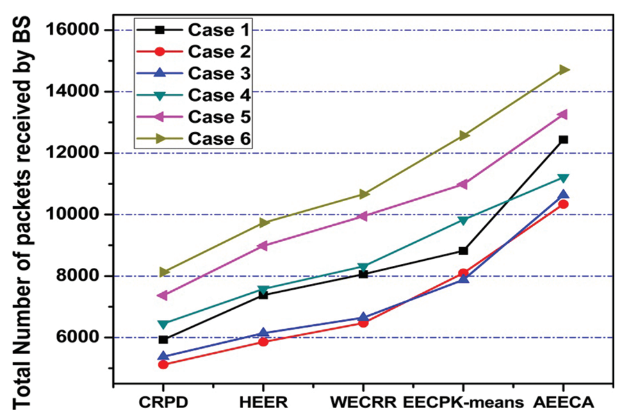


Figure. 10: Number of packets received by BS for all cases

7 Average Residual Energy

The residual energy is the amount of energy a node is having after receiving, transmitting and routing a packet. Average residual energy is an essential factor while considering energy consumption in a WSN and it should be high. The proposed system achieves high average residual energy when compared with existing algorithms such as CRPD, HEER, WECRR and EECPK-means as shown in Fig. 11.

Modified K-means++ clustering algorithm is used to form optimal way of clustering. The AEECA algorithm is proposed for selecting the cluster head for utilizing the node energy in a optimal way. Further from this analysis, the energy depletion of the nodes have depends on the distance between the nodes, BS location, density of nodes in network field and the number of transmission.

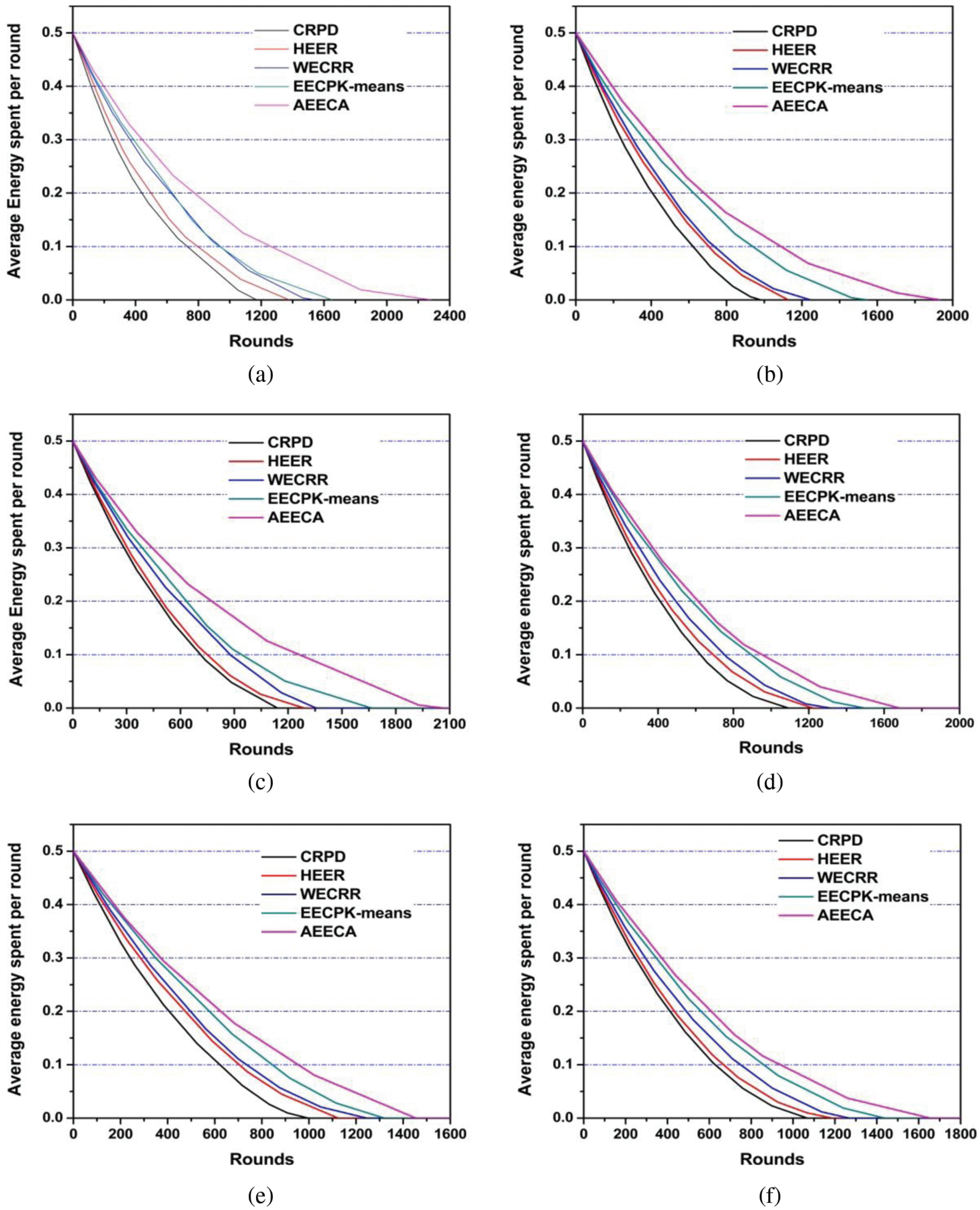


Figure 11: Average Residual Energy for all cases mentioned in the Tab. 2

8 Conclusion

Modified K-means++ algorithm and an Advanced Energy Efficient cluster head selection algorithm for reliable communication are proposed. The cluster head and gateway nodes are used to enhance the lifetime of the network. From the simulation results, the energy depletion of the nodes depends on the distance between the nodes, BS location, density of nodes in network field and the number of transmission. This paper compared the performance of the proposed algorithm against existing methods CRPD, HEER, WECRR and EECPK-means and simulation results shown the proposed algorithm performed better than existing algorithms. The proposed algorithm AEECA is to be tested in mobile sensor environment for analyzing the performance of the networks in future.

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Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

[1] N. Javaid, Z. Ahmad, A. Sher and S. H. Ahmed, “Fair energy management with void hole avoidance in intelligent heterogeneous underwater WSNs,” *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, no. 4, pp. 1–17, 2018.

[2] H. Mohapatra and A. K. Rath, “Fault tolerance through energy balanced cluster formation (EBCF) in WSN,” In *Smart Innovations in Communication and Computational Sciences*, pp. 313–321, 2019.

[3] S. Katyara, M. A. Shah, B. S. Chowdhary, F. Akhtar and G. A. Lashari, “Monitoring, control and energy management of smart grid system via WSN technology through SCADA applications,” *Wireless Personal Communications*, vol. 106, no. 4, pp. 1951–1968, 2019.

[4] S. A. Butt, K. A. Bakar and M. A. Mujahid, “Exploiting layered multi-path routing protocols to avoid void hole regions for reliable data delivery and efficient energy management for IoT-enabled underwater WSNs,” *Sensors*, vol. 19, no. 3, pp. 510, 2019.

[5] H. H. R. Sherazi, L. A. Grieco and G. Boggia, “A comprehensive review on energy harvesting MAC protocols in WSNs: Challenges and tradeoffs,” *Ad Hoc Networks*, vol. 71, pp. 117–134, 2018.

[6] K. K. Vyas and A. Pareek, “IOT enabled energy efficient wireless sensor network & services–A pathway towards green engineering-part 4 (Energy efficient WSN with suitable protocol),” *International Journal on Recent Technologies in Mechanical and Electrical Engineering*, vol. 5, no. 12, pp. 01–04, 2018.

[7] M. Faheem, R. A. Butt and V. C. Gungor, “Energy efficient and reliable data gathering using internet of software-defined mobile sinks for WSNs-based smart grid applications,” *Computer Standards & Interfaces*, vol. 66, no. 1, pp. 1–16, 2019.

[8] G. Jayaraman and V. R. Dhulipala, “FEECS: Fuzzy-based energy-efficient cluster head selection algorithm for lifetime enhancement of wireless sensor networks,” *Arabian Journal for Science and Engineering*, pp. 1–11, 2021.

[9] Y. Zhang, H. Gao, S. Cheng and J. Li, “An efficient EH-WSN energy management mechanism,” *Tsinghua Science and Technology*, vol. 23, no. 4, pp. 406–418, 2018.

[10] D. Deng and H. Yuan, “Energy management of WSN-based charge measurement system of ultra high-voltage direct-current transmission line,” *Wireless Networks*, vol. 24, no. 5, pp. 1667–1681, 2018.

[11] S. Kassan and J. Gaber, “Autonomous energy management system achieving piezoelectric energy harvesting in wireless sensors,” *Mobile Networks and Applications*, vol. 25, no. 1, pp. 1–12, 2018.

[12] A. -Q. a. Abu-Isbeih, “Energy efficiency management system using WSAN: Investigation of energy consumption of buildings,” *Wireless Networks*, vol. 2, no. 1, pp. 1–14, 2018.

[13] K. S. Adu-Manu and N. Adam, “Energy-harvesting wireless sensor networks (EH-WSNs): A review. ACM,” *Transactions on Sensor Networks (TOSN)*, vol. 14, no. 2, pp. 1–10, 2018.

[14] S. Chen, J. Zhou and X. Zheng, “Energy-efficient data collection scheme for environmental quality management in building,” *IEEE Access*, vol. 6, pp. 57324–57333, 2018.

[15] A. Zahedi and A. Arghavani, “Energy efficient reservation-based cluster head selection in WSNs,” *Wireless Personal Communications*, vol. 100, no. 3, pp. 667–679. 2018.

[16] M. Omar, I. Belalouache, S. Amrane and B. Abbache, "Efficient and energy-aware key management framework for dynamic sensor networks," *Computers & Electrical Engineering*, vol. 72, pp. 990–1005, 2018.

[17] S. Din, A. Paul, A. Ahmad and J. H. Kim, "Energy efficient topology management scheme based on clustering technique for software defined wireless sensor network," *Peer-To-Peer Networking and Applications*, vol. 12, no. 2, pp. 348–356, 2019.

[18] S. Wang, J. Yu, M. Atiquzzaman, H. Chen and L. Ni, "CRPD: A novel clustering routing protocol for dynamic wireless sensor networks," *Personal and Ubiquitous Computing*, vol. 22, no. 3, pp. 545–559, 2019.

[19] D. Yi and H. Yang, "HEER–A delay-aware and energy-efficient routing protocol for wireless sensor networks," *Computer Networks*, vol. 104, pp. 155–173, 2016.

[20] K. Haseeb, K. A. Bakar, A. Ahmed, T. Darwish and I. Ahmed, "WECRR: Weighted energy-efficient clustering with robust routing for wireless sensor networks," *Wireless Personal Communications*, vol. 97, no. 1, pp. 695–721, 2017.

[21] A. Ray and D. De, "Energy efficient clustering protocol based on K-means (EECPK-means)-midpoint algorithm for enhanced network lifetime in wireless sensor network," *Iet Wireless Sensor Systems*, vol. 6, no. 6, pp. 181–191, 2016.

[22] A. Y. Barnawi and I. M. Keshta, "Energy management in wireless sensor networks based on naive Bayes, MLP, and SVM classifications: A comparative study," *Journal of Sensors*, vol. 1, no. 1, pp. 1–12, 2016.