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Research paper

ACNM: advance coupling network model sleep/awake mechanism for wireless sensor networks

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Abstract

Wireless Sensor Network (WSN) has attracted many researchers due to its abilities in monitoring remote locations. To gather physical data, such as temperature, humidity, and so on WSNs are utilized. To fulfill the strict constraints like energy consumption and network performance, ongoing wireless sensor networks requires efficient methodologies and practices. The major concern in wireless networks is how to conserve the nodes energy so that network lifespan can be prolonging significantly. The research work focuses on ACNM-DEC (Advance Coupling Network Model-Deterministic Energy-efficient Clustering) protocol i.e. enhancing DEC protocol with sleep awake(S-A) mechanism to utilize energy efficiently. The technique sleep-awake is implemented by simply coupling nodes which are at nearer to one another. The nodes which are paired will switch in two modes i.e. Idle (sleep) and busy (awake). Sleep/wake scheduling is an essential consideration in sensor network applications. Finding an optimal sleep/wake scheduling strategy that would minimize computation and communication overhead, be resilient to node failures, and provide high-quality data service is extremely challenging. In this paper, we present and compare several state-of-the-art algorithms and techniques that aim to address the sleep/wake scheduling issue, which are divided into distributed and centralized manners. The obtained results of the simulation prove that the lifespan of the communication model has been extended in terms of its performance, good energy utility and data transmission.

Keywords: *Energy Efficient; Coupling Network; Base Station; Sleep; Awake.*

1. Introduction

Wireless Sensor Networks (WSNs) brought a comprehensive difference in terms of best use of resources in monitoring remote locations. Applications like temperature monitoring, data center monitoring, and earth sensing etc., can be effectively controlled using such WSN.

WSN is composed of power reserved small sensor nodes placed randomly in the area of networking for the purpose of data collecting and investigations. Various studieshave explained sensor nodes abilities i.e. sensing, processing of data between broadcast units to pick-up units. Most of the sensor nodes are battery powered with storage facilities and limited processing capabilities. In a communication world, WSNs are exposed to external environments that consume more energy which leads to degrading of system performance. To optimize the energy consumption, several authors have developed different protocols [1-6] that suit WSN. Protocols, such as LEACH, DEEC, SEP, DEC, make use of clustering schemes to cooperate with the sensors notably to increase performance in the communication model.

Several studies [2], [3], [7], [8] have used clustering schemes to structure WSNs. Sensing nodes are grouped into 2 categories as cluster heads (CH) and cluster members (CM) once clusters have formed. The main responsibility of Cluster-heads is to gather information from their belonging cluster members, adjust the same by using data compression methods [9-11] and finally submit the cumulative data towards base station (BS). As discussed in [12], cluster-head consumes much energy, since it is acting as a mediator between CM and BS. Rotation of the cluster-heads for every round can save much energy rather than fixing the same sensor node for the entire process. As per earlier studies [1] [13], the optimum election process is not guaranteed since the rotation of cluster-heads is carried out randomly. For a better opting of the cluster heads using election criterion, an energy efficient DEC protocol [7], [14] was introduced, which uses sensor nodes residual energy rather than the initial energies. The present work deterministic energy-efficient clustering protocol along with the Sleep Awake (S-A) mechanism, assures a more desirable election of cluster-heads and good energy utility of sensor nodes. Simulation results of the proposed model show better performance with regards to network lifetime in comparison to the existing DEC protocol and have also achieved the suitable result for WSN.

2. Related work

The idea of clustering yields significantly good results by simply optimizing energy cost in both homogeneous and heterogeneous systems [15], [16]. At the time of clustering, few nodes are chosen as CHs and those nodes will directly connect with the base station for the process of sharing information. The main role of CH is to collect information from their respective cluster members and forward the same towards base station using data aggregation technique. As CH are always contact with CMs and base station that includes long range transmission and data aggregation which makes high energy consumption of cluster heads.

In LEACH protocol the selection of CHs are done periodically for every round by role of rotation hence energy drains uniformly.The job of the cluster-head is to collect data from their surrounding nodes and pass it on to the base station. The dynamic nature of LEACH is because of the cluster-head rotation process. The amount of energy depleted in LEACH during data transfer is given by the formula

Transmission costs :(k, d) = $E_{elect}k$ + $\varepsilon_{amp}kd^{\lambda}$

Receiving costs :(k) = $E_{elect}k$

Where k is the length of the message in bits d is the distance between nodes λ taken as path loss exponent
The LEACH network has two phases
The Set-Up Phase: Where cluster-heads are chosen
The Steady-State: Data transmission mode
In LEACH protocol, cluster-heads selection process is done stochastically

$$\mathrm{T(n)} = \begin{cases} \frac{\mathrm{p}}{1-\left(\mathrm{rmod}\frac{1}{(\mathrm{P_x})}\right)*\mathrm{P}} & \text{if } \mathrm{n} \in \mathrm{G}; \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

And n is a random number between 0 and 1
P is cluster head probability and G is set of nodes that weren't cluster heads in the previous rounds
The algorithm is designed such that each node gets a chance to become cluster-head at least once.
To provide good performance in heterogeneous network classification, a protocol named SEP was designed. SEP, which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes and the additional energy factor between advanced and normal nodes.In order to prolong the stable region, SEP attempts to maintain the constraint of well-balanced energy consumption.Advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. SEP solution is more applicable compared to any solution which assumes that each node knows the total energy of the network in order to adapt its election probability to become a cluster head according to its remaining energy. Where the election process while selecting the CH among two type of nodes is not dynamic, which is listed as the drawback of SEP. DEC suitable for both homogeneous and heterogeneous network design. To minimize computational overhead-cost to the self-designed sensor network, DEC protocol follows simple method of illustration.
A generic probabilistic model used by DEC protocols is given in Eq. (2).

$$\mathrm{T(n_x)} = \begin{cases} \frac{\mathrm{p}}{1-\left(\mathrm{rmod}\frac{1}{(\mathrm{P_x})}\right)*\mathrm{P}} \times \mathrm{Q} & \text{if } \mathrm{n} \in \mathrm{G}; \\ 0 \text{ otherwise} \end{cases} \quad (2)$$

Where x could be nrm, int, adv i.e. normal, intermediate or advanced nodes respectively and Q is an additional quantity that can be defined as a function of the ratio of the residual energy of each node or just a constant value.
In DEC, the operation of the clustering process begins with a setup phase for election as CHs. The elected CHs broadcast advertisement message (ADV) using the non-persistent carrier sense multiple access (CSMA MAC) protocol. This message contains the CH's ID and a header that indicates it as an announcement message. The non-elected nodes called cluster members (CMs) determine their cluster by choosing the CH with the minimum communication cost based on the received signal strength of the advertisement message. The cluster members broadcast join-request message to the elected CH using the non-persistent carrier sense multiple access (CSMA MAC) protocol. This message contains the CM-ID (cluster member-ID), CHID (cluster head-ID) and the header that indicates the message as a request. The setup phase ends by the setup of a TDMA by CH for their intra-cluster communication. The steady-state phase begins when sensed data are sent from CMs to CHs and from CHs to BS. The inter-cluster communication is achieved using the direct sequencing spread spectrum (DSSS).
To perform well in multi-level heterogeneous wireless sensor networks and also to increase the stability of the network the existing DEC protocol is enhanced with coupling mechanism [17]. The proposed CNM-DEC enhanced technique, keeping heterogeneous in the notice we tried to improve the performance of WSN in terms of stability period, clustering process and throughput of a network.

3. Proposed ACNM-DEC protocol

Advanced Coupling Network Model (ACNM) is a new routing technique considered for improving network performance in heterogeneous networks. The main aim is to improve network lifetime andstability period by minimizing energy consumption. For the above said reason, the concept of coupling among nearby nodes has been proposed. For the purpose of communication, data sensing and to be energy efficient, sensor nodes which are deployed nearby i.e. placed at a minimum distance will form into pairs. ACNM-DEC protocol, enhance CHs selection process, by opting CHs on basis of residual energy of sensor nodes by considering DEC protocol. More detailed explanation of advanced coupling among sensor nodes was illustrated below.

a) Advance Coupling Network Model (ACNM): Using Global Positioning System, sensor nodes can trace their exact location. After tracing the location, sensor nodes share their location information, Node identity (N-ID) and Application class to the Base Station. To calculate the mutual distance between nodes, the collected information is processed by the BS. Nodes with same application type and with nearby distance from one another in their intracluster transmission regionare coupled in pair by BS as shown in fig.1. Finally, the paired details are shared to all nodes in a network by base station Sensor nodes become alert of their coupled node. At the time of advance coupling, few nodes are left out since they are not in the range of inter cluster transmission of any other node.

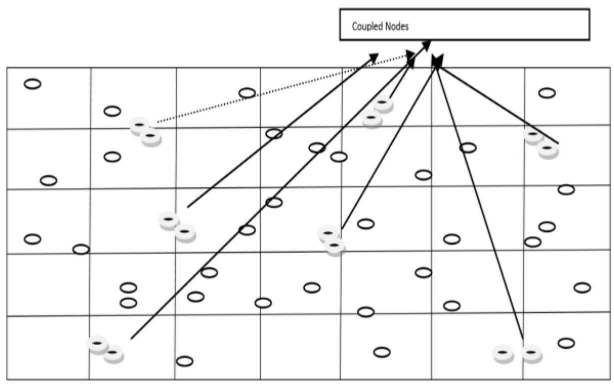

Fig. 1: Illustration of ACNM in WSN.

According to the proposed scheme, for every single communication interval, the nodes shift between"Sleep" and "Awake" fashion. Initially, nodes that are in a pair, switch into Awake-mode if its distance from the BS is less than its coupled node. The node will gather data from surroundings and forward this data to their particular cluster heads in Active-mode. Meanwhile, the transceiver of the paired node will remain switched off. Sleep-mode nodes can only sense the status of the network. In next round of communication, nodes in Sleep-mode switch into Active-mode and Awake-mode nodes switches into Sleep-mode. In this direction, energy consumption can be minimized as sensor nodes in Sleep-modes cease their energy without communicating and by avoiding overhearing with the cluster heads. For every round unpaired nodes in the network always remain in Active-mode till their energies are totally drained.

b) Setup Phase (SP)

The Setup phase of ACNM-DEC is same as DEC Protocol. In proposed ACNM technique, only Active-mode nodes can take participation in CH election process. According to the Eq. (2), present nodes which are active is determined to be CH for every round$r$, the sensor node opts a random number in the range 0 and 1. If this is lower than the threshold limit for node nT(n)the sensor node will be a CH. The probability of becoming as CH represented by P_x, G indicates non-chosen cluster members. The concept of heterogeneity can be considered with help of parameter P_x mainly to enhance the lifespan of a network model.

According to LEACH, DEC and other cluster based protocols, the clustering phase always begins with a setup phase i.e. CH electing process based on indicator function. To transmit advertisement message (ADV), elected CHs follows non-persistent carrier-sense multiple access (CSMA MAC) protocol of networking model. The ADV contains the header and CH's ID.Based on minimal distance and signal strength of the advertisement message, the non-elected nodes, discover their cluster by choosing the cluster head. To generate join-request between CMs and their elected CH data communication protocol CSMA MAC [18] is used. Once a communication link is generated between CH-CMs, data exchange will be done using TDMA principle for the intra-cluster communication that ends the setup phase.

c) Network Transmission Phase (NTP)

In NTP, CH assigns TDMA slots for cluster members and receives sensed data from all nodes that are Awake. Sleep nodes do not participate in NTP, hence save their energy by turning OFF their transceivers. CHs follow data aggregation technique mainly to aggregate the collected data from all awake nodes in their particular clusters and forward to BS. Using data aggregation technique an apparent volume of energy is reserved.

To calculate the average number of sensor nodes in each cluster $\left(\frac{N}{K}-1\right)$ where N represents the total number of nodes and k denotes the optimal number of CHs.

In order to broadcast data, cluster members dissipate ETX to run the source circuitry and $Eamp$ for transmit amplifier to attain Signal-to-Noise Ratio (SNR) in anacceptable mode. So, for broadcasting L_C bit message a non-CH node expands:

$$E_{ClusterMember}=\left(\frac{N}{K}-1\right)\left(E_{T_x}\times L_C\times E_{amp}\times L_C\times d^2_{to\ CH}\right) \quad (2)$$

The radio unit of cluster head in each cluster receives data from a non-CH node using:

$$E_{received}=\left(E_{R_x}\times L_C\right)\left(\frac{N}{K}-1\right) \quad (3)$$

Here, E_{R_x} is energy dissipating by receiver circuitry to receive information.

To receive aggregated data from associate nodes towards CH.

$$E_{AGR}=\left(E_{AD}\times L_C\right)\left(\frac{N}{K}\right) \quad (4)$$

For transmitting aggregated information to the BS, ET (Transmission energy) dissipates by CH is given as

$$ET = ETX \times LA \times Eamp \times LA \times dtoBS2 \quad (5)$$

Where aggregated information is represented by L_A and $d_{to}{}^2{}_{BS}$ is the distance between BS and CH.

Total energy dissipation of a Cluster head per round is:

$$ECH = Erec + EAGR + ET \quad (6)$$

Hence total energy dissipate by CH is obtained with the summation of energy dissipated in the reception of data from its associated nodes, aggregation of received data and transmission of that data to the BS.

D. Node Mode Setup Phase

In this mode, for each round, the coupled nodes decide whether to switch in awake mode or sleep mode. Awake-mode node first checks whether it can become CH or not. If no chance to be CH then it is shifted to sleep mode by simply turnoff its transceiver. If it is selected as CH, it will continue to be awake for the next round also. Sleep-mode nodes will turn on transceiver only if their paired partner has not elected as CH. Nodes which are unpaired will remain active through its lifetime.

The following theory is explained in flowchart as shown in Fig.2.

4. Simulation and analysis

ACNM-DEC protocol is verified using MATLAB.

Table 1: Specifications

Parameters	Values
$Eelec$	50nJ/bit
E_{DA}	5nJ/bit/message
E_0	0.5J
Size of packets	4000 bit
$popt$	0.1
ϵ_{fs}	10pJ/bit/m^2
ϵmp	0.0013pJ/bit/m^4
n	100

Simulation results for ACNM- DEC protocols have generated using MATLAB using the following parameters listed in table I: Consider 100m*100m size field with randomly deployed 100 sensor nodes. For heterogeneity energies ranging from 0.5J to 2.25J and BS sited at the center of the communication model. The total energy of a network taken as 102.5J. In ACNM- DEC, heterogeneity implications are 50% were equipped with 0.5J of energy. 20% of the nodes were loaded with 2J and 30% taken as 1.25J.

Deployment of nodes in ACNM-DEC:

In the below fig.3

'*' indicates the base station (BS).

'o' indicates normal nodes(pink),intermediate nodes (green),super nodes (orange)

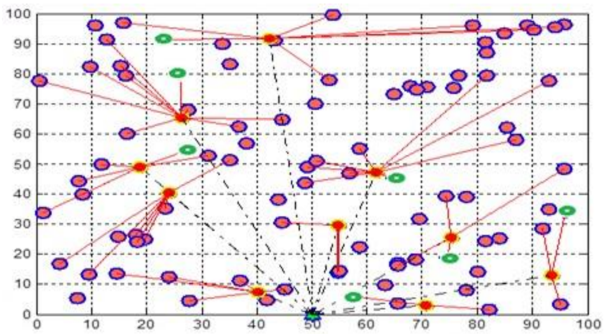

Fig. 3: Deployment of Nodes.

a) Cluster-heads analysis

In fig.4 the solid line represents the fixed number of CH nodes in 100 nodes deployment in a given networking area. It shows the line falls suddenly at the round 2385, i.e. all the nodes energy nearly comes to end (stage of falling to dead). Hence cluster head nodes become normal nodes at the final stage of rounds and they individually communicate with the sink. So they fall suddenly at the end of the network.

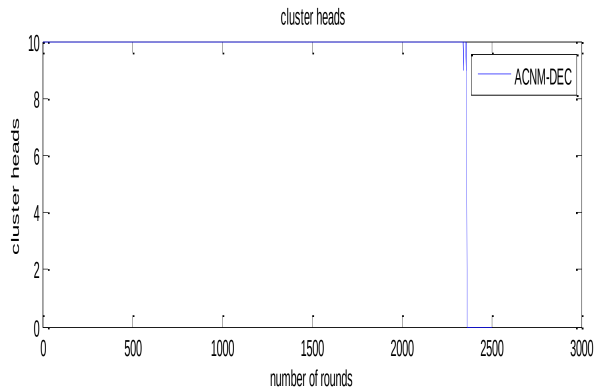

Fig. 4: Count of Cluster Heads per Round.

b) Stability Period (Analysis of alive nodes) in the ACNM

Fig.5 shows the number of rounds the network is alive before no nodes are alive in the network. In

ACNM-DEC protocol the election of cluster heads (CH's) depends on comparing the RE of each individual node after completing each round. The nodes with high RE will have more chances of becoming a cluster head .While comparing the RE of each node the same CH can continue as cluster head if RE of present CH is more. In such scenario, the nodes which are active in paired nodes continue to be active. Let us consider that the RE of present CH is less compare to cluster members. In such case cluster member with highest RE will become CH and also the sleeping nodes in the paired configuration switches to the Active mode by simply switching the present active nodes to sleep mode. In each cluster, the elected CH gathers the data from respective cluster members and sends the data to base station. Fig.5 shows that ACNM-DEC has an extend stability period when compared to the existing DEC protocols. In existing DEC, the first node dies around 1860 round whereas for ACNM-DEC it is 1968 round. Hence Stability period of ACNM-DEC is almost 5.8% greater than DEC.

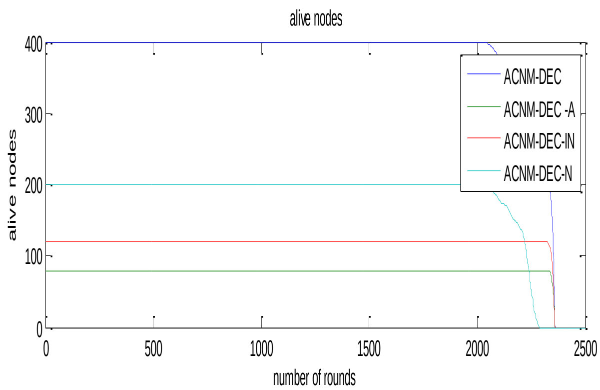

Fig. 5: Analysis of Alive Nodes in ACNM-DEC.

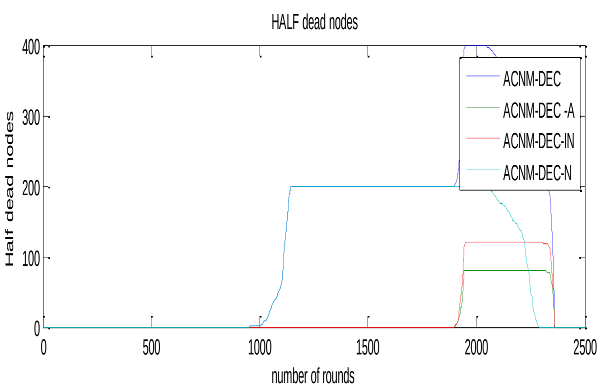

Fig. 6: Analysis of Half Dead Nodes in ACNM-DEC.

Fig. 6 gives the information about 50 percent energy dissipated heterogeneity sensor nodes i.e. half dead nodes per each round. The no. of half dead count of nodes increases as the number of rounds gradually increases. The energy dissipation varies in heterogonous nodes.

C. Performance analysis of Average Energy and Residual energy in DEC and ACNM-DEC Fig.7 and Fig.8 shows the evaluation of residual energy and average energy for protocols DEC and ACNM-DEC. Table II compares results of existing DEC protocol and ACNM-DEC generated through simulation. The obtained results shows that for the round 2265 the total energy of DEC protocol reaches to zero while ACNM-DEC exists still with energy 1.11J.The network services of ACNM-DEC degrades at round 2385.ACNM- DEC out performs DEC by increasing the number of rounds. ACNM-DEC found to be superior in performance up to when 5.28% compared to the existing DEC protocol.

Table 2: Comparison of Residual Energy and Average Energyfor DEC and ACNM

Rounds	Residual energy		Average Energy	
	DEC	ACNM-DEC	DEC	ACNM-DEC
0	102.5	102.5	1	1
500	79.15	82.53	0.791	0.799
1000	55.42	57.79	0.560	0.575
1500	33.13	34.54	0.331	0.352
2000	9.647	10.05	0.102	0.125

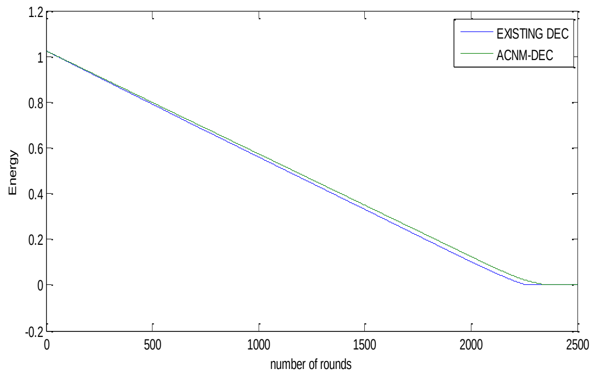

Fig. 7: Performance Evaluation of Existing DEC and Proposed ACNM-DEC.

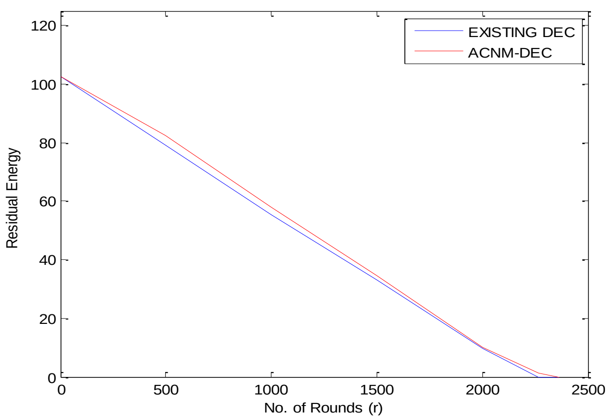

Fig. 8: Evaluation of Residual Energy in Existing DEC and Proposed ACNM-DEC.

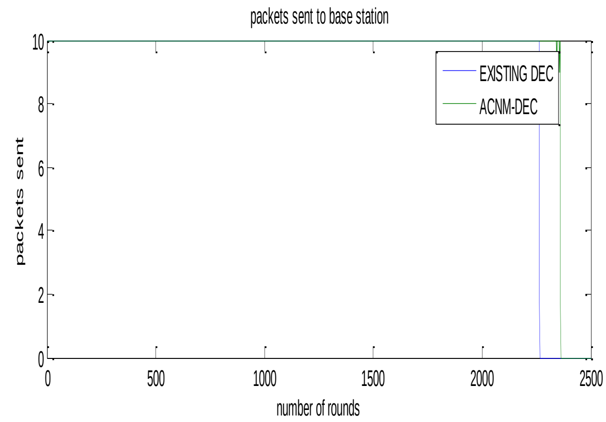

Fig. 9: A. Packet Sent To BS.

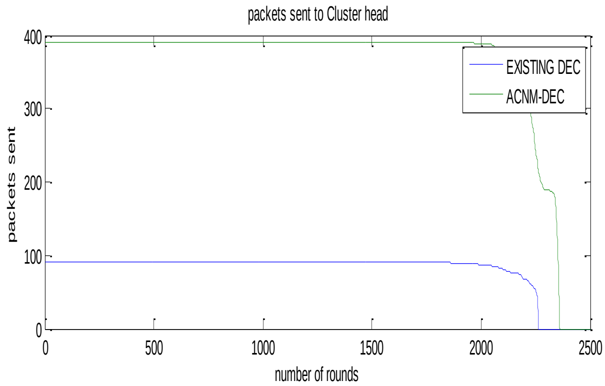

Fig. 9: B. Packet Sent from Cluster Members to Cluster Head.

From fig.9 it clearly implies that the packet delivery process mainly depends on the performance of a protocol. In DEC protocol the packet flow from different CHs to BS processes healthy till 2265 rounds whereas ACNM-DEC performs till 2385 rounds. The simulation result clearly implies that ACNM-DEC outperforms existing DEC protocol by extending 120 more rounds in its process.

5. Conclusion and future direction

The present research work on ACNM-DEC introduces a deterministic protocol to utilize energy in WSN in a better process. The solutions of ACNM-DEC are very advantageous since they match with ideal characteristics. The simulation results prove that deterministic based network ACNM-DEC to be more stable and robust in characteristics to that of the probabilistic-based network models by guaranteeing election of fixed number of cluster heads at the end of each round. At the end of each round the cluster head election is based on the local information of residual energy of nodes within the cluster.Finally, ACNM-DEC along with advance nodes coupling improves the life of WSN, which is noteworthy when compared to the existing DEC. The main advantage of both DEC and ACNM-DEC protocol is to consider the residual energy of nodes for effective use of energy levels and the energy consumption among the nodes is distributed. In a proposed work, which will be carried out by the same authors, it's planned to extend ACNM-DEC protocol to a multi-level and multi-hierarchy system where the communication method is multi-hop instead of a single-hop.

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