INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2021, VOL. 67, NO. 3, PP. 437-443
Manuscript received May 17, 2021; revised July, 2021 DOI: 10.24425/ijet.2021.137831

An Innovative Multiple Attribute Based Distributed Clustering with Sleep/Wake Scheduling Mechanism for WSN

Shankar D. Chavan, Shahaji R. Jagdale, Dhanashree A. Kulkarni, and Sneha R. Jadhav

***Abstract*—Wireless sensor network is a dynamic field of networking and communication because of its increasing demand in critical Industrial and Robotics applications. Clustering is the technique mainly used in the WSN to deal with large load density for efficient energy conservation. Formation of number of duplicate clusters in the clustering algorithm decreases the throughput and network lifetime of WSN. To deal with this problem, advance distributive energy-efficient adaptive clustering protocol with sleep/wake scheduling algorithm (DEACP-S/W) for the selection of optimal cluster head is presented in this paper. The presented sleep/wake cluster head scheduling along with distributive adaptive clustering protocol helps in reducing the transmission delay by properly balancing of load among nodes. The performance of algorithm is evaluated on the basis of network lifetime, throughput, average residual energy, packet delivered to the base station (BS) and CH of nodes. The results are compared with standard LEACH and DEACP protocols and it is observed that the proposed protocol performs better than existing algorithms. Throughput is improved by 8.1% over LEACH and by 2.7% over DEACP. Average residual energy is increased by 6.4% over LEACH and by 4% over DEACP. Also, the network is operable for nearly 33% more rounds compared to these reference algorithms which ultimately results in increasing lifetime of the Wireless Sensor Network.**

***Keywords*—advanced distributed energy efficient adaptive clustering, clustering, lifetime, sleep-wake cluster head scheduling, throughput, wireless sensor network**

I. Introduction

THE global pandemic situation of COVID-19 in 2020 largely creates need for technology advancement. Wireless sensor network is a field which can be useful in such medical emergency by remote healthcare monitoring of patients. Depending upon how nodes are placed the WSNs are divided in terrestrial WSN, underground WSN, underwater WSN and mobile WSN [1]. The development in wireless sensor networks was inspired mainly by military applications for battlefield surveillance and now such networks are used in number of industrial and civilian application areas, including industrial monitoring and control, machine maintenance, environment and habitat monitoring, healthcare applications, home automation, and traffic control [2][3]. Another very important application area into which WSN is significant is Disaster Management. Particularly, in this pandemic situation of COVID-19, WSN can play a very important role like robotics to help doctors and nurses in hospitals, drones for monitoring of crowd, IoT for supply chain automation [4]. This creates a need for a vast change in WSN. Energy consumption problem of sensor nodes becomes very challenging for researchers. It becomes important to develop energy efficient routing protocols which help in increasing lifetime of WSN.

Due to low power battery the operation of WSN is limited in terms of its lifetime. Network throughput and network lifetime are always the challenges present in front of WSN in remote monitoring. Routing and clustering are two major fields of WSN [5]. The clustering process deals with grouping of sensor nodes for the data aggregation in which each group consists of optimally located cluster head which transmits aggregated data to base station[6][7]. The Mechanism or technique used for selection of cluster head is very important in any algorithm.

This paper presented advance distributive energy-efficient adaptive clustering protocol along with the cluster scheduling for efficient data management. Load balancing is performed using sleep/wake scheduling mechanism. Clusters with heavy load are assigned with more wakeup time so that they can transmit the data to destination with fast rate. The performance of network is evaluated on the basis of various performance parameters like network throughput, network lifetime, residual energy, packets delivered to base station and cluster heads. It is observed that the proposed algorithm significantly improves the performance of the network in remote application.

The remaining paper is organized as follows: Section I describes the literature review on previous clustering and routing algorithms. Complete description of methodology is given in section III. Section IV depicts about the experimental results and broader discussion on the result. Further Section V gives the conclusion of paper.

II. Related Work

This section emphasizes on the previous work of WSN clustering. et al. have studied distributed, centralized and hybrid clustering methodologies of WSN for the industrial automation and disaster management [8]. Power-Efficient and Adaptive Clustering Hierarchy Protocol (PEACH) for the energy reduction and lifetime improvement have been implemented in [9]. PEACH has no overheads and forms multi-level adaptive clustering. It showed better performance

Shankar Chavan is with Dr. D. Y. Patil Institute of Technology, Pimpri, Pune. (email: sdchavan73@gmail.com).
Shahaji Jagdale is with Dr. D. Y. Patil Institute of Technology, Pimpri, Pune. (email: shahaji.jagdale@dypvp.edu.in).
Dhanashree Kulkarni is with Dr. D. Y. Patil Institute of Technology, Pimpri, Pune. (email: dhanashreek2016@gmail.com).
Sneha Jadhav is with Dr. D. Y. Patil Institute of Technology, Pimpri, Pune. (email: snjadhav44@gmail.com).

in distributed clustering. Energy Driven Adaptive Clustering Hierarchy (EDACH) clustering has been applied to improve network existence with minimum energy consumption. EDACH works more efficiently in the large sized network for the selection of cluster heads based on the distance between CH and nodes [10]. LEACH algorithm has been extended by V. Loscri et al. into two levels LEACH (TL-LEACH) for adaptive clustering of WSN and finding optimized CH. It was designed for monitoring of environment remotely. It resulted in the better distribution of energy among the sensor node and achieved lower energy consumption and better network lifespan for the denser network. TL-LEACH achieved a 20% increase in packet throughput and a 30% increase in network lifespan than LEACH [11]. So, all WSN cluster keep transmitting data even if some nodes dead which increase the network lifetime and performance. Protocol called Secondary Cluster Head (SCH) [12] is used in which a new CH becomes a cluster head simultaneously with the death of the previous CH. It is used in combination with Distance-Based Cluster Head (DBCH) algorithm that results in maximizing the network lifetime, save energy, minimize delay and increase the rate of data transmission. The Differential Evolution Based Clustering and Routing Protocol (DEBCRP) is proposed [13]. The main focus is on the realization of a hierarchical routing protocol which aims to treat the problem of the economic management of energy to increase the life cycle of the network. This protocol achieves a reasonable choice of the appropriate CH for all sensor nodes to prolong their lifetime as much as possible. The authors use the integration of WSN with cloud to store large amount of data generated. In this paper they have proposed a new LBSO (Load Based Self-Organized) [14] clustering technique which helps in load balancing of the node. Three steps are applied here which are selection of Cluster head, formation of cluster and the rotational phase where the CH is reselected. The power optimization algorithm suggests an approach for clustering depending on four attributes CH coverage, CH lifetime, average distance to CH and maximum power of sensor nodes [15]. It reduces energy consumption of nodes effectively. O. Younis et al. [16] have presented Hybrid Energy-Efficient Distributed clustering (HEED) which is the hybrid algorithm used to select the cluster head based on residual energy of sensor node and secondary parameters such as node degree and node proximity. With the appropriate selection of node density, inter and intra cluster distance, the connectivity of the performance of the network has been improved. TEEN is a protocol designed to minimize energy consumption of nodes by transmitting information to base station only when events are recorded. It uses two parameters: hard threshold and soft threshold to measure the appearance of event [17]. APTEEN is advancement in TEEN protocol which transmits both periodic data and detects time critical events [18]. Chirihane Gherbi et al. [19] have presented Distributed Energy efficient Adaptive Clustering Protocol (DEACP) algorithm which reduces the dropping probability and shared the load traffic. They have considered the fix location of the base station and performance decreases for the highly dense mobile network. Heinzelman [20] has presented Low-energy adaptive clustering hierarchy (LEACH) protocol which is a low power algorithm for the cluster formation.

III. Proposed Methodology

This section provides the details about the proposed algorithm which consists of eight phases of the operation. Figure 1 shows the flow diagram of the all phases of Advance DEACP-S/W clustering.

Phase 1: Initialization phase

The proposed methodology consists of eight phases. First phase deals with the initialization of the network and radio model parameters. In the initial phase N number of sensor node are randomly placed over the simulation area of 200 m x 200 m. The base station position is kept at the centre of the simulation area.

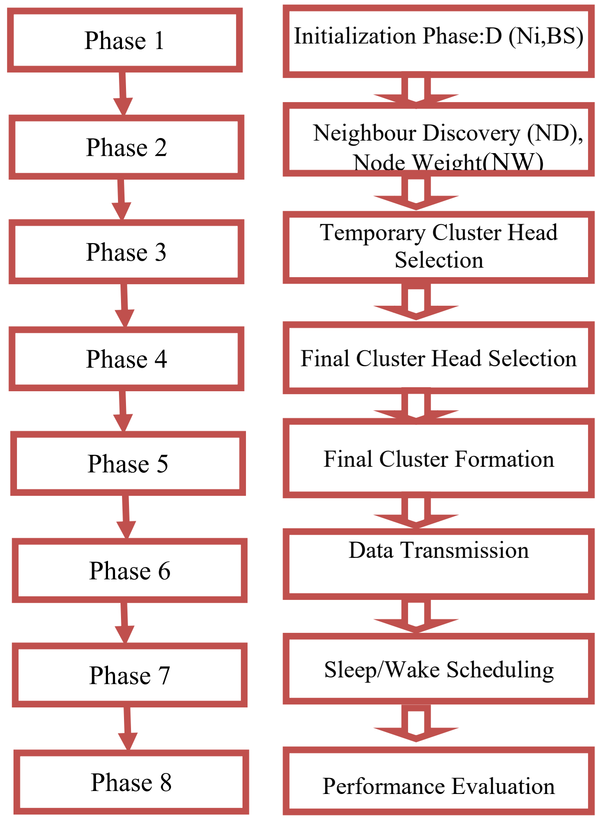

Fig.1. Advance DEACP-S/W clustering

Phase 2: Neighbouring node and Node Weight calculation

This phase performs the neighbour finding (N_D) and node weight calculation (N_W). Early calculation of N_W makes transmission of data faster by knowing good quality links. Good quality links are discovered with the help of neighbour table. The neighbours are discovered by sending broadcast message to all neighbouring nodes and depending upon the received signal strength distance between node and its neighbouring node is calculated [21]. The node weight is equal to the total number of neighbouring nodes in the range of current node. Neighbour table is calculated after calculation of node weight and neighbouring node.

Phase 3: Temporary cluster head selection

The condition for temporary cluster selection (Pch) depends upon the four factors of the current node and its neighbouring node as:

(i) Factor one β1 is function of the distance between the current node and the Base Station.

(ii) Factor two β2 is function of the distance between the current node neighbours and node weight which is the measure of number of neighbouring nodes to current node.

(iii) Factor three β3 is function of the residual energy of current node and its neighbours.

The factor β1 is computed using following "(1)" and is the function of distance between node and BS.

$$\beta1(i,j) = 1 - \alpha1 * (1 - D_{BS,i}/D_{BS,j}) \quad (1)$$

Where, $D_{BS,i}$ and $D_{BS,j}$ is the distance between current node i to base station (BS) and neighbour node j to BS respectively.

The factor β2 is computed using "(2)", which is function of weight of nodes, which is obtained by computing the distance between node and its neighbour node.

$$\beta2(i,j) = 1 - \alpha2 * (1 - Nw_i/Nw_j) \quad (2)$$

Where, Nw_i and $Nw_j$are the weights of current and neighbouring node respectively.

The factor β3 is computed using "(3)",which is function of residual energy of nodes. It is obtained by computing the residual energy of current node and its neighbour node.

$$\beta3(i,j) = 1 - \alpha3 * (1 - E_i/E_j) \quad (3)$$

Where, E_i and E_j are the residual energies of current and neighbouring node.

Here, α1, α2 and α3 are the small constants having values is in between 0 to 1.

The final temporary cluster head selection condition value Pch depends upon all calculated factors β1, β2 and β3 and is given in "(4)".

$$Pch_{(i,j)} = \text{Max}\ [1 - \sum_{i,j=1}^{N} \beta1(i,j), \beta2(i,j), \beta3(i,j)] \quad (4)$$

If the Pch value of current node is greater than the Pch value of its neighbouring node then it is elected as the cluster head and neighbouring node will be treated as cluster member. In this way temporary clusters are formed. Number of temporary cluster heads depends upon the radius of the cluster. More is the radius then more number of temporary clusters generated.

Phase 4: Final cluster selection

In this phase, temporary CH sends advertising message to the neighbouring node. When the node receives the message, it calculates the distance between sender and receiver node. If the distance is less than the threshold distance and sender node Pchvalue is greater than the receiver node then sender node is selected as final CH and receiver node is selected as cluster member. This phase helps to reduce the cluster number in the network.

Phase 5: Cluster formation phase

The final CH advertises the message to the neighbouring nodes and upon receiving the advertising message ordinary nodes joins the cluster to form the cluster. The condition for joining the cluster is given in "(5)".

$$\text{JoinCond}_{(chj)} = \max\left(1 - Pch_j/(D_{i,chj} + D_{chj,BS})\right) \quad (5)$$

Where, $D_{i,chj}$ is the distance between node to cluster head and $D_{chj,BS}$ is the distance between CH and base station.

Phase 6: Data transmission

This phase deals with the parameters of radio model which are used for data transmission and scheduling. For the scheduling, the nodes nearer to the base station are overloaded because of higher traffic. Here, continues tracking of residual energy of the CH nearer to the BS is done and when energy level is below sufficient value, data traffic is routed to the substitute route. For the transmission of L bits the energy consumption is given in "(6)".

$$E_{Tx} = \begin{cases} L * E_{elec} + L * E_{fs} * d^2, & \text{if } d < d_o \\ L * E_{elec} + L * E_{mp} * d^4, & \text{if } d \geq d_o \end{cases} \quad (6)$$

Where, L is number of bits, E_{Tx} is energy consumed for transmission of L bit, E_{fs} is amplification factor for free space, E_{mp} is amplification factor for multipath channel, d_o is threshold distance, and $E_{elec}$is energy dissipated per bit. If the distance is less than the threshold distance then less energy will be consumed than distance which is greater than threshold distance.

The total energy consumed for receiving L bit is given by "(7)".

$$E_{Tx} = L * E_{elec} \quad (7)$$

Phase 7: Sleep/Wake scheduling

This is the vital phase in the algorithm. As the CHs nearer to base station are overloaded, they are assigned more wakeup time to reduce traffic congestion at CHs and to maintain continuous delivery of data packets to base station. Here, the complete region is divided in to three regions based on the distance of CHs from the base station as shown in Figure 5. During the wake time, nodes sense the message and transmit/receives the data. The wake up time is kept inversely proportional to the distance of the CH from the BS. Lesser is the distance of CH from the BS, larger is the wake time of CH [22].

Phase 8: Performance evaluation

This phase deals with the performance evaluation of the proposed algorithm on the basis of different network parameters such as live nodes per round, dead nodes per round, throughput, average residual energy of nodes and total number of packets transmitted to the BS and CH. It is required that, all parameters should show improved results compared to basic reference algorithms such as LEACH (Low Energy Efficient Adaptive Clustering Hierarchy) and DEACP (Distributive Energy Efficient Adaptive Clustering Protocol). All network parameters are compared with these two algorithms and then performance is evaluated.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed algorithm is implemented using MATLAB software. The performance of the system is estimated on the basis of network lifespan, packet throughput and energy consumption. The network parameters and their specifications used for network scenario for the implementation of system are given in Table I.

Table I

Network scenario simulation parameters

Parameter	Specification
Network Area	200 m X 200 m
Number of Sensor Nodes	100
Number of Wind Nodes	5,10,15,20, 25 etc.
Initial Energy of each node	0.5J
Traffic Patterns	CBR (Constant Bit Rate)
MAC Protocol	802.11
Threshold Distance(do)	$\sqrt{E_{fs}/E_{mps}}$
Energy Dissipated per bit (E_{elec})	50 nJ /bit
Transmission Power Dissipation (E_{Tx})	50 nJ /bit
Receiver Power Dissipation (E_{Rx})	50 nJ/bit
Message bits (K)	2000 bits

The network scenario used for the simulation is shown in figure 2. The simulation is performed over the area of 200m x 200m and base station position is kept at the centre of simulation area for the simplification. The formation of temporary clusters is shown in figure 3. It can be seen that total 56 numbers of clusters are formed.

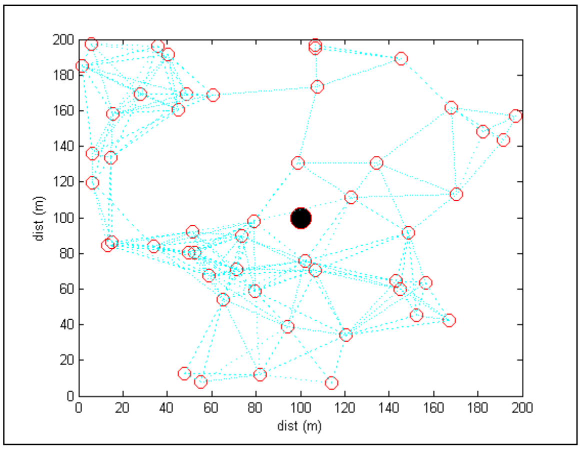

Fig. 2. Network scenario with 100 nodes

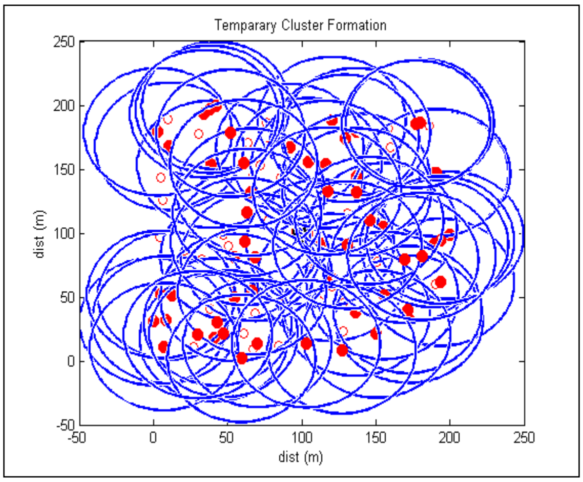

Fig. 3: Temporary cluster formation (Number of temporary clusters = 56)

Figure 4 shows the final cluster head selection procedure. The numbers of final clusters formed are reduced to 11 from 56 temporary clusters. It has significance in reducing overall traffic congestion.

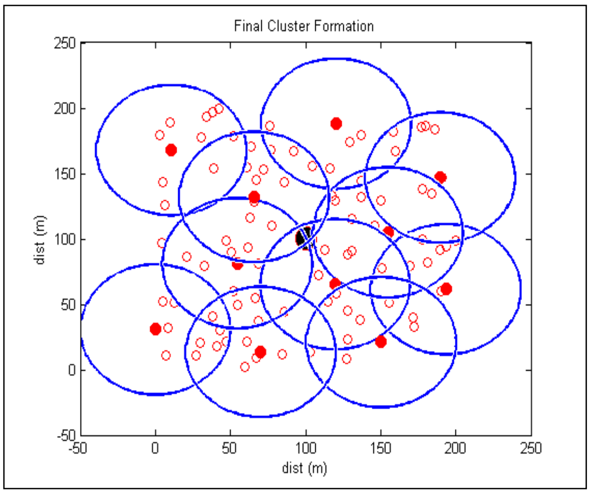

Fig. 4. Final cluster formation (Number of final clusters = 11)

The network area is split in to three regions based on the distanceof CHs from the BS. Splitting is performed for the sleep/wake scheduling process as shown in figure 5. Different wakeup time is assigned to clusters presented in different regions. It is shown in the figure 6. More wake time is assigned to the CHs near to the base station to avoid the traffic overloading.

The clusters near destination possess heavy traffic load as they have large data to send. So, packets get queued at these CHs and there is delay in data transmission. If the time required to serve such packets is large many of them are dropped, ultimately resulting in the lower throughput. If large wake up time is assigned to these Cluster heads, it can serve large number of packets with reduced dropping probability.

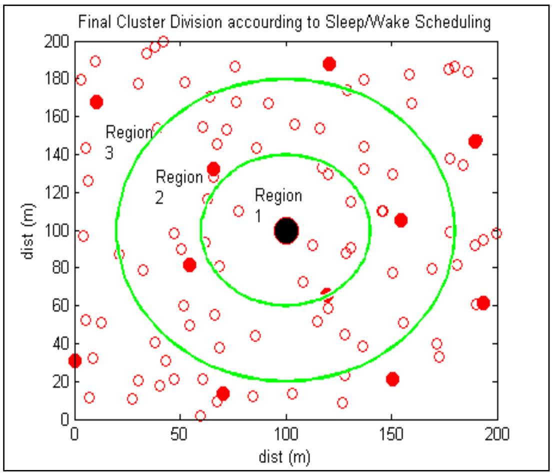

Fig. 5. Grouping of CHs for the sleep/wake scheduling

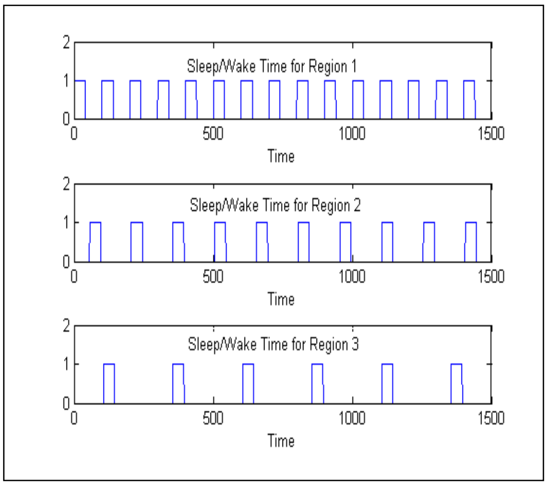

Fig. 6. Sleep/wake time for different regions

The performance of the proposed algorithm is compared with the DEACP (Distributive Energy Efficient Adaptive Clustering Protocol) and standard LEACH (Low Energy Efficient Adaptive Clustering Protocol). Dead nodes per round are shown in figure 7 and live nodes per round are shown in figure 8. To exhaust all nodes, nearly 300 more rounds are required in proposed algorithm compared with DEACP and LEACH protocol. Hence, lifetime of the network is improved.

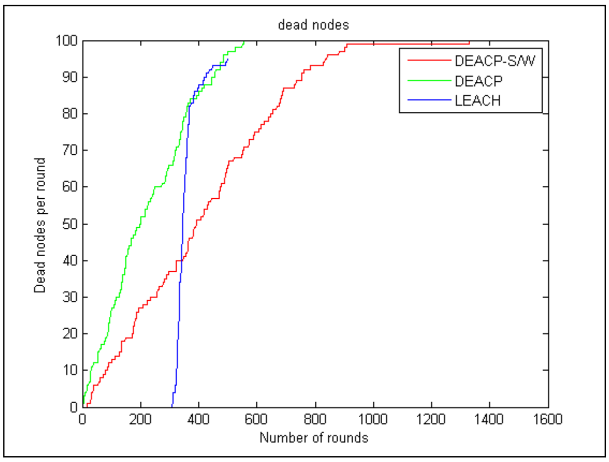

Fig. 7. Dead Nodes per round

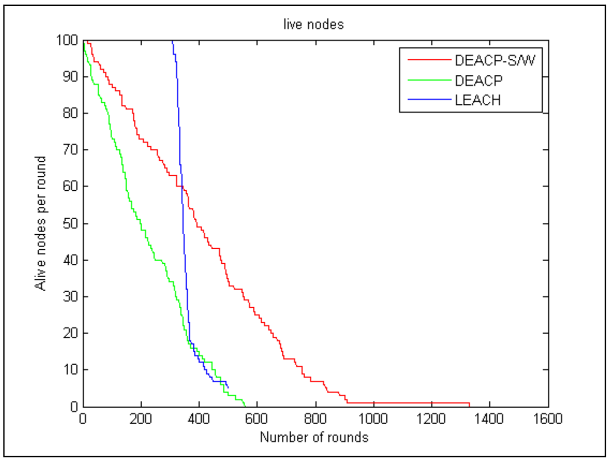

Fig. 8. Live nodes per round

The total numbers of packets transmitted to the base station per round are given in the figure 9. It can be seen that, the total packets transmitted to base station are more in proposed algorithm compared with other two algorithms. Distributive clustering technique and cluster head scheduling mechanism results in the better packet delivery to the base station. Distributive and adaptive selection of the cluster heads enhances the network life and thus delivery of packet to CH increases as shown in figure 10.

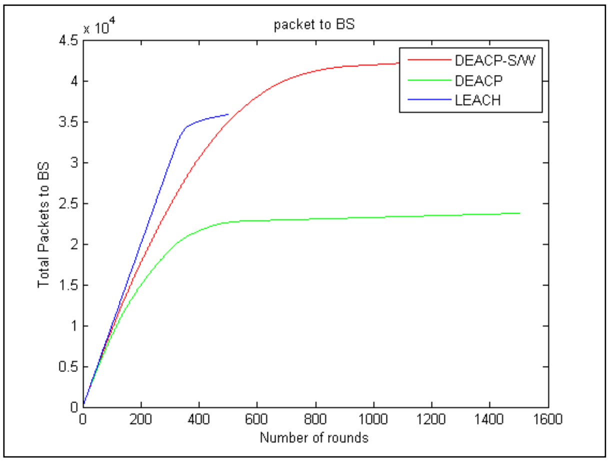

Fig. 9. Total number of packets to base station (BS)

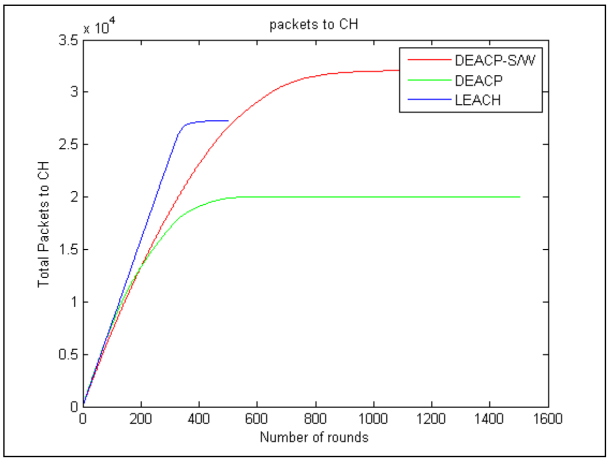

Fig.10. Number of packets to CH

Increase in the packet delivery to CH and BS along with increase in the network lifetime and total throughput of the network is shown in figure 11. Increasing the number of rounds increases the data transmission rate, decreases the number of active nodes in the network and increases the amount of energy dissipation. Average residual energy is the amount of remaining energy of all the sensor nodes of the network as shown in figure 12.

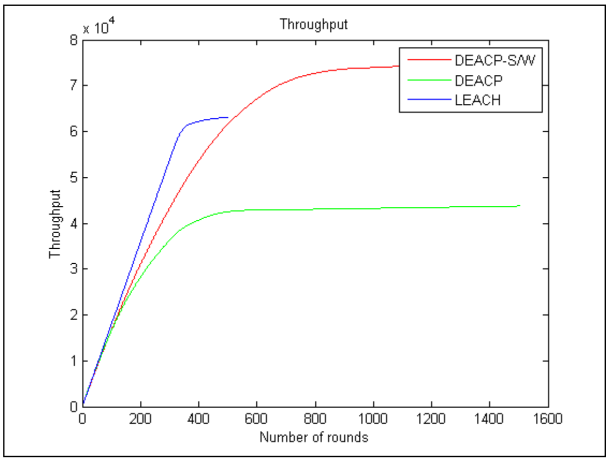

Fig. 11. Throughput vs number of rounds

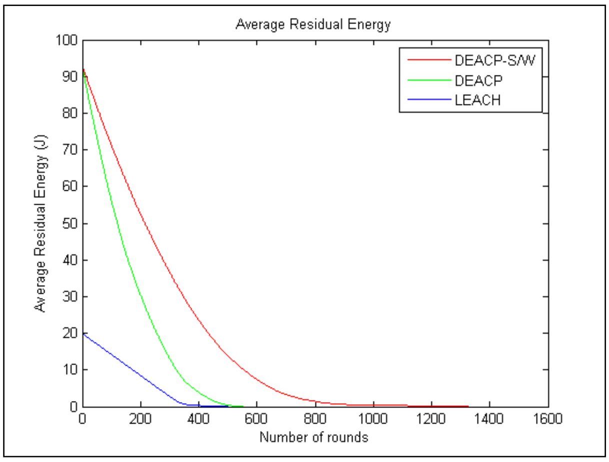

Fig. 12. Average residual energy per round

CONCLUSION

It is very important to get rid from node energy exhaustion which may lead to the incapacity of successfully achieving the network mission. More improvised routing protocols need to develop to solve above mentioned problem. This research work, the advance distributive energy efficient adaptive clustering protocol with the CH scheduling (DEACP-S/W) is presented. Scheduling is done to efficiently manage the traffic load at sensor nodes. Sleep/wake scheduling mechanism allows comparatively more wake up intervals to CHs which are nearer to base station as they possess more working load. It helps to minimize end to end delay and transmission latency. Also, scheduling helps to serve packets at the CH at fast rate. Thus less number of packets is dropped. It increases the throughput of the network. The performance of the proposed algorithm is evaluated on the basis of the network lifetime, throughput, packet transmission to BS, packet transmission to the CH and average residual energy. It is observed that, it gives better results than the existing baseline algorithms such as LEACH and DEACP. Throughput is improved by 8.1% over LEACH and by 2.7% over DEACP. Average residual energy is increased by 6.4% over LEACH and by 4% over DEACP. Also, the network is operable for nearly 33% more rounds compared with these baseline algorithms which ultimately increases the lifetime of wireless sensor network.

REFERENCES

[1] K. Sohraby, D. Minoli, T. Znati, “Wireless sensor networks: technology, protocols, and applications,” John Wiley & Sons, 2007.

[2] K. Pavai, A. Sivagami and D. Sridharan, "Study of Routing Protocols in Wireless Sensor Networks,” 2009 International Conference on Advances in Computing, Control and Telecommunication Technologies, Trivandrum, Kerala, 2009, pp. 522-525.

[3] D. Goyal and M. R. Tripathy, "Routing Protocols in Wireless Sensor Networks: A Survey,"2012 Second International Conference on Advanced Computing & Communication Technologies, Rohtak, Haryana, 2012, pp. 474-480.

[4] NasirSaeed, Ahmed Bader, T.Y. Al-Naffouri, Mohamed-slim Alouini, “When Wireless Communication Faces COVID-19: Combating the Pandemic and Saving the Economy,” Research Gate Journal, May 2020.

[5] Jitendra Singh, Rakesh Kumar, “Clustering algorithms for wireless sensor networks: A review,” 2nd International Conference on Computing for Sustainable Global Development, May 2015.

[6] S. Misra and R. Kumar, "A literature survey on various clustering approaches in wireless sensor network," IEEE 2nd International Conference on Communication Control and Intelligent Systems (CCIS), Mathura, 2016, pp. 18-22.

[7] S. Mishra, R. Bano, S. Kumar and V. Dixit, "A literature survey on routing protocol in wireless sensor network," IEEE International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), Coimbatore, 2017, pp. 1-4.

[8] Kalyani Wankhede, Sumedha Sirsikar, “Review of Clustering Algorithms in Wireless Sensor Networks,” International Journal of Advance Foundation and Research in Computer (IJAFRC), Volume 1, Issue 11, November 2014, pp.126-133.

[9] Sangho Yi, Junyoung Heo, Yookun Cho and Jiman Hong b, “PEACH: Power-efficient and adaptive clustering hierarch protocol for wireless sensor networks,” Computer Communications, ELSEVIER, 23 June 2007, pp. 2842–2852.

[10] K. T. Kim and H. Y. Youn, “Energy-Driven Adaptive Clustering Hierarchy (EDACH) for Wireless Sensor Networks,” International Federation of Info. Processing, vol. 3823, Dec. 2005, pp. 1098–1107.

[11] V. Loscri, G. Morabito and S. Marano, “A Two-Level Hierarchy for Low-Energy Adaptive Clustering Hierarchy(TL-LEACH),” IEEE Proceedings of Vehicular Technology Conference, vol. 3, 2005, pp. 1809-1813.

[12] S. Nasr, M. Quwaider, “LEACH Protocol Enhancement for Increasing WSN Lifetime,” 2020 11th International Conference on Information and Communication Systems (ICICS), April 2020, pp. 102-107.

[13] M. Kaddi, Z. Khalili, M. Bruchra, “A Differential Evolution Based Clustering and Routing Protocol for WSN,” 2020 International Conference on Mathematics and Information Technology, March 2020, pp. 190-195.

[14] G. Malshetty, B. Mathapati, “Efficient Clustering in WSN-Cloud using LBSO (Load Based Self Organised) technique,” Third International Conference on Trends in Electronics and Informatics(ICOEI), October 2019, pp. 1243-1247.

[15] K. Dubey, A. Yadav, P. Kumar, P. Shekar, P. Rajput, S. Kumar, “Power Optimization Algorithm for Heterogeneous WSN using Multiple Attributes,” Proceedings of Third International Conference on Computing Methodologies and Communication (ICCMC), August 2019, pp. 294-299.

[16] O. Younis, S. Fahmy, “HEED: A Hybrid Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks,” IEEE Transactions on mobile computing, vol. 3(4) , 2004, pp. 1-36

[17] A. Manjeshwar, D. P. Agrawal, “TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,” 15th International Workshop on Parallel and Distributed Processing Symposium (IPDPS), 23–27 April 2001, pp. 2009–2015.

[18] A. Manjeshwar, D. P. Agrawal, “APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless

Sensor Networks,” 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing,” April 2002, pp. 195–202.

[19] Chirihane Gherbi, Zibouda Aliouat, Mohamed Benmohammed, “A Novel Load Balancing Scheduling Algorithm For Wireless Sensor Networks,” Journal of Network And Systems Management (2019) 27, pp. 430–462.

[20] Heinzelman W,Chandrakasan A and Balakrishnan H, "Energy-Efficient Communication Protocols for Wireless Microsensor Networks," Proceedings of the 33rd Hawaaian International Conference on Systems Science (HICSS), January 2000.

[21] JiuqiangXu, Wei Liu, Fenggao Lang, Yuanyuan Zhang, Chenglong Wang, “Distance Measurement Model Based on RSSI in WSN,” Scientific Research Journal on Wireless Sensor Network, August 2010, pp. 606-611

[22] Nazir Babar, Hasbullah Halabi & Madani Sajjad, “Sleep/wake scheduling scheme for minimizing end-to-end delay in multi-hop wireless sensor networks,” EURASIP Journal on Wireless Communications and Networking, 2011. 92. 10.1186/1687-1499-2011-92.