Enhancing Network Lifetime using Fuzzy Dynamic Clustering Algorithm in WSNs

M. Kiruthika[1] R. Senthil Kumaran[2]
[1]Student [2]Associate Professor
[1,2]Department of Electronics & Communication Engineering
[1,2]IFET College of Engineering, Villupuram India

Abstract— The main aim of the project is to maximize the network lifetime. In Wireless Sensor Networks, maximizing overall network lifetime and minimizing total energy consumption are the main issues. Fuzzy Dynamic Clustering Algorithm (FDCA) is mainly used to improve the longest survival time of the nodes in the network. The energy consumption of the network can be competently reduced while the nodes are organized in the form of clusters. Based on FDCA, cluster head (CH) are selected for a cluster. By reducing the total energy consumption of the nodes automatically the overall network lifetime will be increased. In the proposed approach the overall network lifetime is increased when compared with Low Energy Adaptive Clustering Hierarchy (LEACH). The FDCA and LEACH protocol are compared based on the network performance analysis such as alive nodes, end to end delay, packet delivery ratio (PDR) and energy consumption. Simulation results reveals that the proposed algorithm outperforms better with the existing LEACH protocol.

Key words: Network Lifetime, Fuzzy Dynamic Clustering Algorithm

I. INTRODUCTION

A Wireless Sensor Networks (WSN) are spatially distributed autonomous sensor for monitoring physical or environmental conditions such as pressure and temperature. A WSN system has a gateway that provides wireless connectivity to the wired world and distributed nodes. The available standard include 2.4 GHz based on IEEE 802.11 standard is mainly used for wireless networks. The development of WSN is motivated by military applications, industrial and consumer applications. A WSN is composed of several number of nodes. In this some of the nodes act as sensor nodes and the other as sink nodes.

- Sensor Node: A sensor node has the capability of performing some processing, collection of sensory information and communicating with other nodes in the network. Sensor nodes are small in size, consumes less energy, adaptive to the environment and operate at high densities. Sensors are categorized as passive-omnidirectional sensor, passive-narrow beam sensors, active sensors. Sink Node- A node which receives data from the sensor node and then store, process and compress the data from the sensor node.

II. RESEARCH METHOD

A. Network and Radio Model

System model has the following properties:

- Sensor nodes are stationary and each one knows its location.
- Communication channel is symmetric (i.e., the same energy required to transmit a message between any two sensor nodes).

In the system, Fuzzy Dynamic Clustering Algorithm is used mainly to increase the overall network lifetime. For this fuzzy inference system is used. A fuzzy membership function is a curve that defines each point in the input space is mapped to a membership value between 0 or 1. Fuzzy logic is an approach of computing based on degrees of truth rather than usual true or false. Fuzzy rules are a collection of linguistic statements that describe how the fuzzy inference system (FIS) should make a decision regarding classifying an input or controlling an output. Fuzzy rules are basically written in the form of "and"/ "or" conditions. For e.g., if temperature is high and humidity is high then room is hot. Once the membership functions (MF) and the input and outputs are defined, then the fuzzy rule base are composed of "if" "then" rules. This rule will derive the output variable from the input variables. Fuzzy Inference System is a system that uses fuzzy set theory to map inputs to outputs. In this algorithm, the values are transformed into five levels based on fuzzy linguistic variables: very low (VL), low (L), medium (M), high (H), very high (VH). Majorly used six steps to compute the output of FIS are,

- Obtaining a set of fuzzy rules.
- By the input membership function, fuzzifying the input.
- According to fuzzy rules to establish a rule strength, the fuzzified inputs are combined.
- By combining the rule strength and the output membership function, the consequence of the rule is obtained.
- To get an output distribution, combine the consequences.
- Defuzzifying the output distribution.

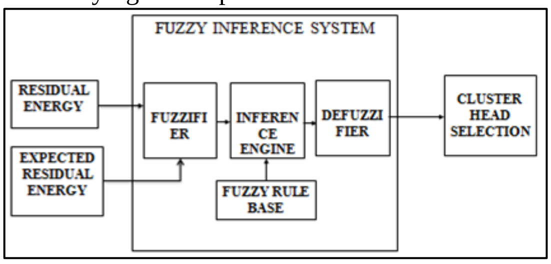

Fig. 1: Proposed Model

- Fuzzification- It is a process of transforming crisp values into grades of membership for linguistic variables using fuzzy rule base. It is a conversion of precise quantity to a fuzzy quantity.
- Defuzzification- It is a process of producing a quantifiable output in crisp logic and conversion of fuzzy quantity to a precise quantity.

Consequence is a phenomenon that follows or caused by some other phenomenon. The input to the fuzzy inference system are the residual energy and the expected residual energy. The inputs are given to the fuzzifier and based on the fuzzy rule base it is processed in the inference engine and the output is directed to the defuzzifier. Based on the output of the defuzzifier the cluster head selection of a cluster is elected. The conditions for the election of the cluster head selection are based on the fuzzy membership function. For the election of CH, the two parameters for the inputs are residual energy and the expected residual energy. It is mainly based on If-then conditions.

B. Residual Energy

The expected residual energy of a node to be a cluster head (CH) after a steady state phase can be represented as,

$$E_{expResidual}(l,d_{toBS},n) = E_{residual}-E_{expConsumed}$$

Where,

$E_{residual}$ = Residual energy of sensor node before CH selection

$E_{expConsumed}$ = Expected consumed energy of a node to be CH after a steady state phase.

This can be represented as,

$$E_{expConsumed} = N_{frame}*(E_{Tx}(l,d_{toBS})+ n* E_{Rx}(l)).$$

$E_{Tx}(l,d)$ = Energy consumed for transmiting '*l*' bits of data to 'd' distance.

$E_{Rx}(l)$ = Energy consumed for receiving '*l*' bits of data.

N_{frame} can be calculated as,

$$N_{frame} = \frac{t_{ss\ phase}}{n^{*}t_{slot}+t_{CH\ to\ BS}}$$

Where,

$t_{ssPhase}$ = time of a node to be a Cluster head.

t_{slot} = time for transmission from members to the CH.

$t_{CH\ to\ BS}$ = time for transmission from CH to base station.

$$E_{TX}(l,d) = \begin{cases} l * E_{elec}^{TX} + l * \varepsilon_{fs} * d^2, d < d_0 \\ l * E_{elec}^{TX} + l * \varepsilon_{mp} * d^4, d \geq d_0 \end{cases}$$

$$E_{RX}(l,d) = l * E_{elec}^{RX}$$

Where,

Threshold value

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$$

ε_{fs} = Energy consumption factor for free space.

ε_{mp} = Energy consumption factor for multipath radio models.

The conditions for selecting the cluster head based on the inputs residual energy and expected residual energy are

1) If(residual energy is very low) and (expected residual energy is very low) then (cluster head selection is very low).
2) If (residual energy is low) and (expected residual energy is very low) then (cluster head selection is very low).
3) If(residual energy is medium) and (expected residual energy is very low) then (cluster head selection is low).
4) If (residual energy is high) and (expected residual energy is very low) then (cluster head selection is low).
5) If (residual energy is very high) and (expected residual energy is very low) then (cluster head selection is medium).
6) If (residual energy is very low) and (expected residual energy is low) then (cluster head selection is very low).
7) If (residual energy is low) and (expected residual energy is low) then (cluster head selection is low).
8) If (residual energy is medium) and (expected residual energy is low) then (cluster head selection is low).

Input		Output
Residual Energy	Expected Residual Energy	Cluster Head Selection
Very Low	Very Low	Very Low
Low	Very Low	Very Low
Medium	Very Low	Low
High	Very Low	Low
Very High	Very Low	Medium
Very Low	Low	Very Low
Low	Low	Low
Medium	Low	Low
High	Low	Low
Very High	Low	Medium
Very Low	Medium	Low
Low	Medium	Medium
Medium	Medium	Medium
High	Medium	High
Very High	Medium	High
Very Low	High	Very Low
Low	High	Low
Medium	High	Medium
High	High	High
Very High	High	Very High
Very Low	Very High	Very Low
Low	Very High	Low
Medium	Very High	Medium
High	Very High	High
Very High	Very High	Very High

Table 1: Leach-FDCA

9) If (residual energy is high) and (expected residual energy is very low) then (cluster head selection is low).
10) If (residual energy is very high) and (expected residual energy is very low) then (cluster head selection is medium).
11) If (residual energy is very low) and (expected residual energy is medium) then (cluster head selection is low).
12) If (residual energy is low) and (expected residual energy is medium) then (cluster head selection is medium).
13) If (residual energy is medium) and (expected residual energy is medium) then (cluster head selection is medium).
14) If (residual energy is high) and (expected residual energy is medium) then (cluster head selection is high).
15) If (residual energy is very high) and (expected residual energy is medium) then (cluster head selection is high).
16) If (residual energy is very low) and (expected residual energy is high) then (cluster head selection is very low).
17) If (residual energy is low) and (expected residual energy is high) then (cluster head selection is low).
18) If (residual energy is medium) and (expected residual energy is high) then (cluster head selection is medium).
19) If (residual energy is high) and (expected residual energy is high) then (cluster head selection is high).
20) If (residual energy is very high) and (expected residual energy is high) then (cluster head selection is very high).

21) If (residual energy is very low) and (expected residual energy is very high) then (cluster head selection is very low).
22) If (residual energy is low) and (expected residual energy is very high) then (cluster head selection is low).
23) If (residual energy is medium) and (expected residual energy is very high) then (cluster head selection is medium).
24) If (residual energy is high) and (expected residual energy is very high) then (cluster head selection is high).
25) If (residual energy is very high) and (expected residual energy is very high) then (cluster head selection is very high).

From the fuzzy membership function, based on the residual energy the nodes which have higher priority should be elected as cluster head. The conditions for the fuzzy rule base are composed of "if - then" rules.

III. Results and Analysis Simulation Parameters

A. *Simulation tool used: Network Simulator2*

Parameters	Values
Number of nodes	100
Initial energy	2 joules
Simulation area	1000 m * 1000 m
Energy consumed for transmitting / receiving per bit	50 nJ/ bit
Free space energy consumption factor	10 pJ/bit/ m^2
Energy consumption factor for multipath radio models	0.0013 pJ/bit/m^2

Table 1: Simulation tool used: Network Simulator2

The simulation results shows the comparison between LEACH and LEACH-FDCA in the performance metrics such as alive nodes, packet delivery ratio, delay and the energy consumption. If the number of nodes increases then the number of alive nodes will get decreased. In the proposed system, the number of alive nodes get decreased is less when compared with the LEACH protocol. This is shown in the following graph Fig 2.

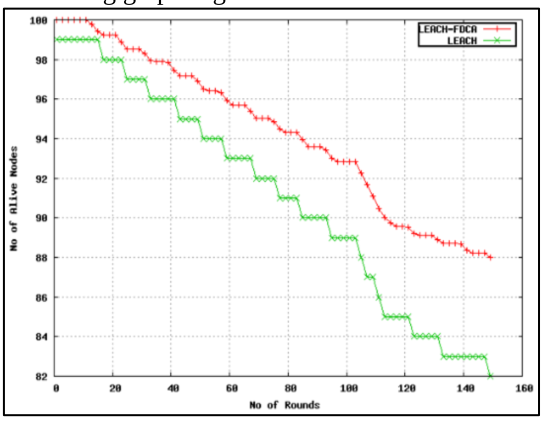

Fig. 2: Rounds Vs Number of Alive Nodes

If the number of rounds is increased then the average end to end delay will also get increased. When compared with LEACH protocol the proposed system is better. This is shown in Fig 3.

In LEACH protocol the PDR will get decreased if the number of rounds increased. But in the LEACH FDCA, the Packet Delivery Ratio (PDR) will be constantly maintained. This is shown in Fig 4.

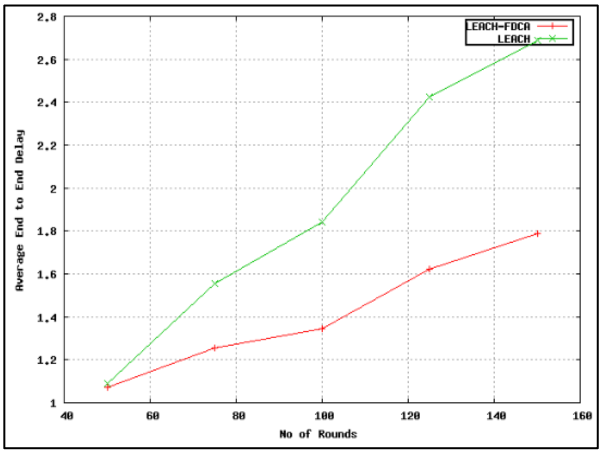

Fig. 3: No. of Rounds Vs Delay

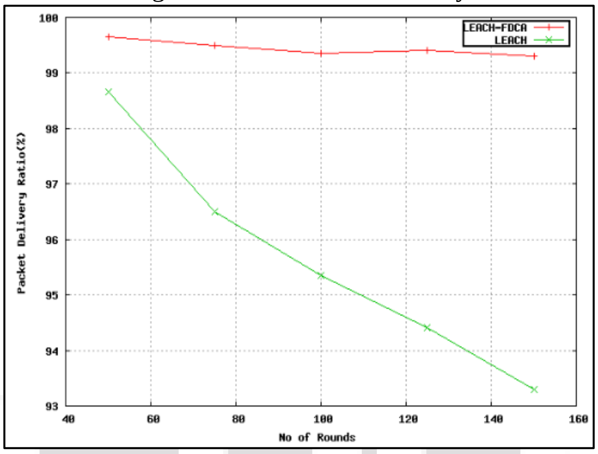

Fig. 4: No. of Rounds Vs PDR

In LEACH protocol, if the number of rounds get increased then the remaining energy will get decreased. When compared with LEACH, the remaining energy in the proposed system is high. This is shown in Fig 5.

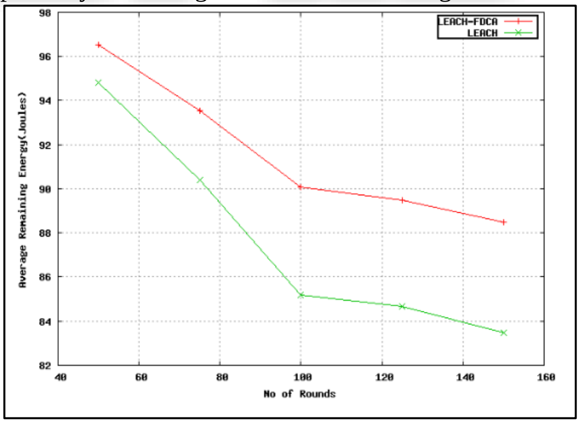

Fig. 5: No. of Rounds Vs Remaining Energy

IV. Conclusion

Thus the proposed Fuzzy Dynamic Clustering Algorithm (FDCA) in Wireless Sensor Networks is used to enhance the network lifetime. FDCA based approach is proposed in order to maximize the network lifetime based on the cluster head elected for a cluster. The result obtained by the proposed system shows that the network lifetime is maximized and the energy consumption of the nodes are reduced. The output of proposed FDCA and LEACH are compared and generated in the form of graph. The performance analysis of the proposed system is better when compared with the existing system. It has high PDR, energy consumption and low end to end delay. Hence the network lifetime is improved in WSNs.

REFERENCES

[1] D.Jia, H.Zhu, S.Zou, and Po Hu, "Dynamic Cluster Head Selection for Wireless Sensor Networks," IEEE Sensors Journal, Vol.16, no. 8, April 15, 2016.

[2] Y. Han and Y. Tianming, "Adaptive energy optimized clustering algorithm for wireless sensor network routing," Appl. Res. Comput., Feb. 2015.

[3] S.Pino-Povedano, R.Arroyo-Valles, and J.Cid-Sueiro,"Selective forwarding for energy-efficient target tracking in sensor networks," Signal Process., vol.94, pp. 557–569,Jan.2014.

[4] S.M.Hosseinirad,M.A.Mohammadi, S.K.Basu, and A.A.Pouyan,"LEACH routing algorithm optimization through imperialist approach," Int. J. Eng., Trans. A, Basics, vol. 27, no.1, pp. 39–50, 2014.

[5] H. Fotouhi, M. Alves, M. Zuniga Zamalloa, and A. Koubaa, "Reliable and fast hand-offs in low-power wireless networks," IEEE Trans. Mobile Comput., vol. 13, no. 11, pp. 2620–2633, Nov. 2014.

[6] N. Javaid, M. Waseem, Z. A. Khan, U. Qasim, K. Latif, and A. Javaid, "ACH:Away cluster heads scheme for energy efficient clustering protocols in WSNs," in Proc. Saudi Int. Electron., Commun. Photon. Conf., Piscataway, NJ, USA, 2013, pp. 1–4.

[7] C.-S.Fan, "Rich:Region-based intelligent cluster-head selection and node deployment strategy in concentric-based WSNs," Adv. Elect. Comput. Eng., vol. 13, no. 4, pp. 3–8, 2013.

[8] S. Tyagi and N. Kumar, "A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks," J. Netw. Comput. Appl., vol. 36, no. 2, pp. 623–645, Mar. 2013.

[9] D.D.Geeta, N.Nalini, and R.C. Biradar, "Fault tolerance in wireless sensor network using hand-off and dynamic power adjustment approach," J.Netw.Comput. Appl., vol. 36, no. 4, pp. 1174–1185, Jul. 2013.

[10] Hosseinirad, S. and Basu, S., "Imperialist approach to cluster head selection in WSN," Special Issue of International Journal of Computer Applications on Wireless Communication and Mobile Networks , No.1,1-5, 2012.

[11] W. K. Lai, C. S. Fan and L. Y. Lin, "Arranging cluster sizes and transmission ranges for wireless sensor networks," Information Sciences, vol. 183, no. 1, pp. 117-131, Jan. 2012.

[12] Bhawnesh Kumar, Vinit Kumar Sharma, " Distance based Cluster Head Selection Algorithm for Wireless Sensor Network",InternationalJournal of Computer Applications (0975 – 8887) Volume 57– No.9, November 2012.

[13] Guo, J., Fang, J. a. and Chen, X., "Survey on secure data aggregation for wireless sensor networks," in Service Operations, Logistics, and Informatics (SOLI), 2011 IEEE International Conference on, 138-143, 2011.

[14] Liang, J., Wang, J., Zhang, X. and Chen, J.,"An adaptive probability broadcast-based data preservation protocol in wireless sensor networks," in Communications (ICC), IEEE International Conference on, IEEE. 1-5, 2011.

[15] F.A. Aderohunmu, J.D. Deng, and M.K. Purvis, "A Deterministic Energy-efficient Clustering Protocol for Wireless Sensor Networks," Int.l Conf. on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), pp. 341-346, Dec. 2011.

[16] Samarah, S., Al-Hajri, M., Boukerche, A., "A Predictive Energy-Efficient Technique to Support Object-Tracking Sensor Networks, " IEEE Transactions On Vehicular Technology, Vol. 60, NO. 2, pp. 656–663, 2011.

[17] Ademola P. Abidoye, Nureni A. Azeez, Ademola O. Adesina, Kehinde K. Agbele, " ANCAEE: A Novel clustering algorithm for Energy Efficiency in Wireless Sensor Networks", Wireless Sensor Network, 2011, 3, pages 30- 312.

[18] H. Pan, H. F. Zhang, and Y. Li, "Energy efficient target tracking algorithms in wireless sensor networks," J. Comput. Res. Develop., vol. 47, no. 2, pp. 64–68, 2010.

[19] G. Fan, R. Wang, H. Huang, L. Sun and C. Sha, "CoverageGuaranteed Sensor Node Deployment Strategies for Wireless Sensor Networks," Sensors, vol. 10, no. 3, pp. 2064-2087, Mar. 2010.

[20] Guo, M, Olule, E, Wang, G, Guo, S.,"Designing energy efficient target tracking protocol with quality monitoring in wireless sensor networks", [J]. The Journal of Supercomputing, pp.131−148, 2010.

[21] Stanislava Soro, Wendi B. Heinzelman "Cluster head election techniques for coverage preservation in wireless sensor networks" Elseiver journal Ad Hoc Networks 7 (2009) 955–972.

[22] T. H. Arampatzis, J. Lygeros, and S. Manesis, "A survey of applications of wireless sensors and wireless sensor networks," in Proc. 13th Medit. Conf. Control Autom., Limassol, Cyprus, pp. 719–724, Jun. 2005.