Research Article

A Minimum Spanning Tree-based Energy Efficient Cluster Head Election in WSN

[1]Saroj Yadav, [2]Subhash Chandra Jat
1Rajasthan college of engineering for women /Department of Computer Science, Jaipur, 835227, India
E-mail: sarojyadav2289@gmail.com
2Rajasthan college of engineering for women /Associate Professor, Jaipur, 835227, India
E-mail: subhashccjat@yahoo.com

Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

Abstract: Over modern decades, both scientific and commercial societies have been seeing progress of Wireless Sensor Networks (WSNs). Clustering is most common form of growing WSN lifetime. The optimal no. of Cluster Heads (CHs) & structure of clusters are the main problems in clustering techniques. The paper focuses on an efficient CH preference mechanism that rotates CH between nodes with a greater energy level than others. Original energy, residual energy as well as the optimum value of CHs is assumed to be used by the algo for the choice of next category capable network cluster heads including ecosystem control, smart cities, or devices. The Fuzzy inference system is used for the clustering algorithm which displays stronger performance than the previous clustering technique. Meanwhile, a minimum spanning tree named Bellmanford algo is also constructed to establish the connection between the nodes for finding the shortest and secure path for data transmission hence resulting in faster data sending and receiving process.

Index Terms: WSN, CH selection (CHS), Residual energy (RE), Lifetime, Energy-efficient (EE).

1. Introduction

The IoT is a system of interrelated autonomous objects, wireless sensors, or individuals that can exchange data independently through the network. Varied studies forecast a massive IoT demand from 157B dollars in 2016 to 457B dollars by 2020. Types of applications using the internet of things technologies include transport and distribution, smart machines, smart supply chains, and smart towns, electric vehicles, the automotive economy, or smart retail. [1].

WSNs, which serves as the digital skin or introduces virtual layers where real-world knowledge can be interpreted by the computer machine, is of significant importance to achieving the IoT dream. WSNs consist of sensors that can gather environmental data independently.

WSNs are ad hoc technology for network surveillance in military applications that appear more than 20 years ago [2]. WSNs frequently consist of large no. of Sensor Nodes (SNs) or actuators (in short nodes describe) that are mainly resource-constricted however may also link to additional network nodes for data transmission. In addition to its potential roles as relay or data fusion nodes, the primary role of every node is to track the atmosphere through on-board sensors. Router to send neighbor data to sink or BS (Base Station) may be applied by each node. BS(s) are applied to process data nearby or to send data to remote machines through the network gateway.

Sensors can create a vast amount of data & have heterogeneous capabilities including computing capacity, memory, and connectivity. If all nodes are identical, for example, they have the same equipment or the same rate of transmission; the WSNs are referred to as homogenous. A non-homogeneous WSN is considered heterogeneous. Devices are usually operated by batteries; it is therefore very necessary to capture WSN data in an energy-efficient manner. Figure 1 illustrates how sensor nodes are installed in a wireless network [3].

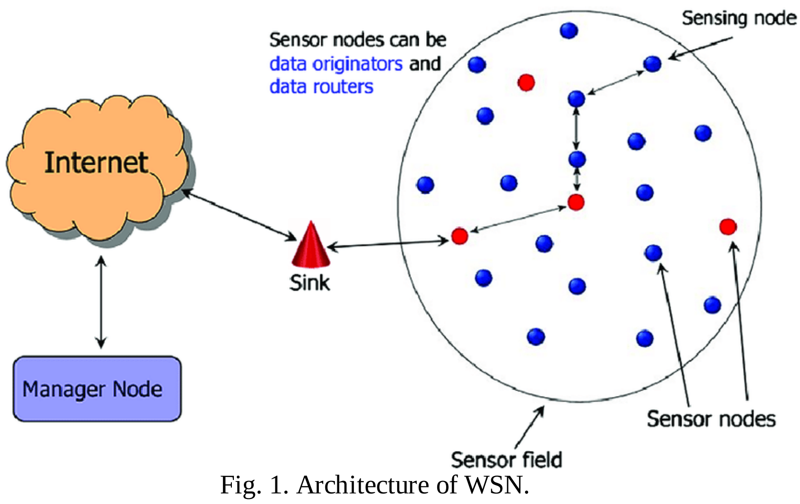

Fig. 1. Architecture of WSN.

Clustering has been suggested by the scientific district to collect data from WSN and is one of the energy-efficient alternatives. It creates a variety of clusters. There are a variety of nodes with participants CH in every cluster. It gathers data as of its participants (communication inside cluster). To order to send data to unify BS CHs collaborate CHs).

2. Literature Review

The LEACH [4] is revolutionary routing protocols (RPs) that brought the concept of clustering in WSN[14,15]. LEACH is the best way to do so. In comparison to other clustering protocols, LEACH uses the probabilistic method using residual power for cluster preference[13]. Both cluster heads may interact explicitly with BS, i.e., there is no multi-hop contact. When a node is selected as CH, in next election of cluster, it cannot assume the same position. LEACH proposes a regular CH rotation and grouping of data at each CH.

The clustering protocol HEED [5] creates the same size clusters i.e., that have the same size range. The HEED algo consists of (1) clustering & (2) network processing. through clustering time, CHs are the rest of energy & the nodes of members enter the nearest CH.1 Data messages are forwarded by members to the BS during the network service process. HEED typically stops CHs from being two nodes within the same transmission spectrum.

Sensor nodes near BS, as described in [6], deplete their power faster in respect of distant nodes. This topic is recognized as the question in the hot spot. Indeed, CHs near BS have higher inter-cluster communicative (that is, relay traffic among CHs) when all CH's have same amount of inter-traffic average contact (i.e., traffic within a cluster).

DWEHC is an EE distributed clustering protocol (DWEHC) [7] for WSNs focused on equivalent size clustering. The multi-hop transfer in the clusters optimizes intra-cluster connectivity. DWEHC is performed independently by all sensor nodes to assess if it is a CHs or a node. The forming step of DWEHC is focused on the topology of HEEDs. The resultant configuration of the clusters is compatible and increases network operation.

One of the early solutions for WSNs is EEUC (Energy-Efficient Unequal Clustering) algo [8]. EEUC is focused on assumption that while CH exists in places far from BS, a broader classification will be used, a greater community size should be used, whereas regions nearer to BS should be occupied by a large number of minor clusters.

Unequal HEED clustering algos [9] is a clustering technique unprecedented by WSNs. The concept of the EEUC protocol is introduced into the HEED by UHEED to create clusters of unequal scale. Based on the distance from the BS scale of a cluster CH. difference between CH & BS, larger their strategic power. It means that clusters further from BS have a smaller range than clusters near to BS. UHEED eliminates the issue of hot spots & boosts network longevity relative to HEED & LEACH.

Rotated Unequal HEED [10] utilizes a non-equal-size clustering strategy, which not only fixes the question of a hot spot but also increases the longevity of the network. The RUHEED comprises three steps involving the choosing of CH, the creation of clusters, and the rotation of CH. HEED is utilized to prioritize CHs depends upon their excess energy & contact prices. To create unprecedented clusters, the EEUC concept that is focused on BS-SN distance is applied. New CH chooses the nodes with the lowest energy at the CH rotation stage and designates this explicitly as the next head of the cluster.

ER-HEED [11] is an improved HEED efficiency clustering protocol by incorporating the CH position turning within the clusters. ER-HEED consists of 3 stages: CHS, HEED cluster formation as well as CH rotation. Like RUHEED, CHs designate following CHs with highest energy residual. Principle of CH selection reduces amount of cluster election results within member nodes. Just when one sensor node absorbs its energy can HEED CH be selected absolutely.

DEEC (distributed EE clustering algo for heterogeneous WSNs) [12] is a protocol of the same scale. DEEC CHS is dependent upon assumption that mixture of residual SN energy as well as total network energy is calculated. The CH feature rotates among sensor nodes because of its residual energy. The energy use is consistent across the network. Cluster heads would most definitely be chosen as sensor nodes with the lowest residual and lowest initial energy.

3. Research Methodology

Two methods, the free space interface as well as the multipath fading, were used for energy consumption analysis patterns. Distance b/w receiver & transmitter is depending upon all types. Figure displays radio energy model. Then radio uses a k- packet to relay it at distance d:

$$E_{TX(k,d)} = E_{TX-elec}(K) + E_{TX-amp}(k,d)$$

$$\begin{cases} k * E_{elec} + k * \varepsilon_f * d^2 \\ k * E_{elec} + k * \varepsilon_m * d^4 \end{cases}$$

$$E_{RX}(k) = E_{RX-elec}(K) = k*E_{elec}$$

ETX: energy usage needed for the transfer of packages.
Eelec: is electronic energy that relies on filtering, digital coding modulation, or signal amplification.
ERX: energy usage needed for the reception of packets. d0: is equivalent to the multipath fading sequence square root of the EDA separating the free space model.

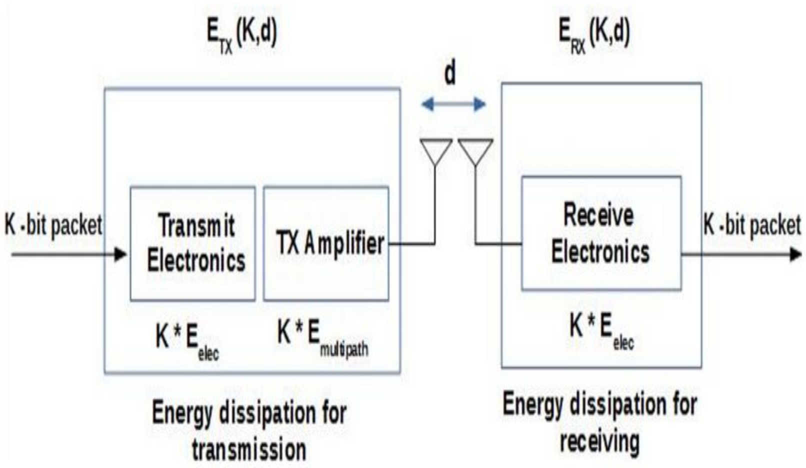

Fig. 2. Radio Model

3.1. Problem Formulation

Three specific problems may be outlined in the disadvantages of the HQCA system. The first problem is CH's inaccurate decision. The second issue has emerged since the sensor nodes within each cluster are unequally distributed. For smaller clusters, the energy usage of the sensor nodes is lower than that of a wide cluster. Since the majority of data is sent by the nodes in smaller clusters. In the constant state process, the third problem is formalized. Within the growing cluster, all sensor nodes are sent continuously. The transfer has been carried out even though the sensed data is not modified. The three problems are why inefficient energy consumption has fallen. This decrease limits the life of the network.

3.2. Proposed Approach

In the proposed work, we have used a new clustering algorithm for overcoming the limitations of previous research work in which HQCA algorithm was used. The new clustering algorithm depends on inter-cluster and intra clustering algorithm. Further, we have decided a strategy for the cluster head (CH) selection process and later the CH nodes are connected by a minimum spanning tree namely Bellmanford tree algo.

3.3. Clustering

The set of cluster centers is denoted by $\bar{Q}$ = {∂^n | n = 1,2,...,k}, where k and ∂^n are no. of clusters and cluster centers, correspondingly. Set of sensors that are not cluster centers is represented by O = {∂i | i = 1,2,...,||Y- $\bar{Q}$|| }, where Y is total no. of clustered sensors & ||Y- $\bar{Q}$ || denotes total no. of nodes but for cluster centers.

$$\bar{Q}=\{\partial^n|n=1,2,3,4,5\}=\{\partial^1\partial^2\partial^3\partial^4\partial^5\}$$

$$Q = \{\partial i \mid i = 1,2,...,95\} = \{\partial_1, \partial_{2,......}\partial_3\}$$

Cluster quality is definite as follows:

$$\partial(k) = \frac{1}{k}\sum_{n=1}^{k} \min_{1\le m\le k: n\ne m}\left\{\frac{l_m+l_n}{\Delta_{mn}}\right\}$$

where l_n shows average similarity b/w cluster center ∂^n as well as all members of cluster Q^m, Δ_{mn} indicates
average similarity between cluster center ∂^m & all members of cluster Q^m , Δ_{mn} is also similarity between ∂^n, and ∂^m clusters, and l_n, l_m, and l_{mn} are defined as follows:

$$l_n = \frac{1}{||Q^n||}\sum_{\partial_i \in Q^n}(\partial_i, \partial^n)$$

$$l_m = \frac{1}{||Q^m||} \sum_{\partial_j \in Q^m} (\partial_j, \partial^m)$$

$$\Delta_{mn} = \sum(\partial^n, \partial^m)$$

where $||Q^n||$ and $||Q^m||$ are no. of nth cluster members as well as no. of mth cluster members, correspondingly, $\sum_{\partial_i \in Q^n}(\partial_i, \partial^n)$and $\sum_{\partial_j \in Q^m}(\partial_j, \partial^m)$are total Euclidean distances of nth & mth cluster sensors by their cluster centers, $\Delta_{mn} = \sum(\partial^n, \partial^m)$ is total Euclidean distance of cluster centers from each other, also Δ_{mn} is similarity b/w m & n clusters. The similarity in terms of euclidean distance to cluster centers depends on their proximity.

3.4. CH Election

CHs are elected by FL in proposed protocol. FL contains FIS (Fuzzy Inference System), defuzzifier, and rules base. Fuzzy system input usually is crisp value, translated to an appropriate fuzzy variable. Fuzzified values would be submitted to FDB (Fuzzy Decision Block), composed of fuzzy rules and FIS. CHs are chosen depending upon remaining sensors energy, minimum & maximum distances from sensors to BS, lowest & highest energy per cluster of sensors, distribution of sensors in cluster, cluster quality criteria, mean distance of sensors in cluster, as well as cluster density. We offer 4 total energy levels including low, medium, high, as well as very high.

3.5. Sugeno Fuzzy Inference System

As declared earlier, reducing energy among networks is the main goal of clustering in wireless sensor networks. However, repeatedly sending messages from one node towards any other or the BS will reduce the power. Several methods of focus on how to increase energy savings in networks are proposed. In this article, Sugeno fuzzy has an argument for running node clustering procedures on the n/w, which grants cluster-based routing technique, which decreases no. of CH selections, decreases frequency of messages, & increases the power-saving power in a multi-hop network, while routing protocols.

Benefits of the Sugeno Systems:

- Computational flexibility.
- Exertion well through linear methods like PID control.
- Exertion well through optimization as well as adaptive methods.
- Output Surface Guarantee Permanency.
- Suitable for mathematical analysis.

Later minimum spanning tree is formed for establishing the shortest path between the cluster heads for transmitting data.

1) **Bellmanford Algo:** Negative weight edges can at first seem needless, but may clarify other phenomena. Negative weight edges can establish negative weight loops i.e., a loop that reduces the cumulative distance by returning to the same location in figure 3.

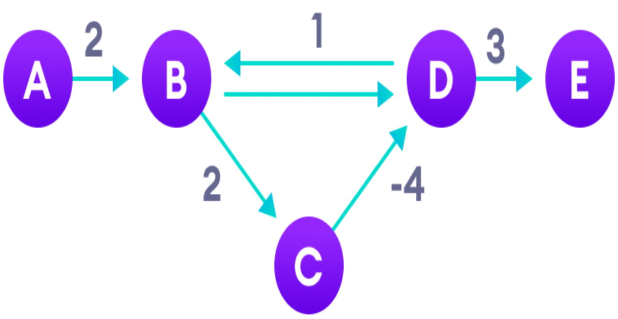

Fig. 3. Negative weight cycle

Such a loop can't be identified by other shortest path Algos because they will go through a negative weight process and minimize the path length.

By overestimating the direction from the beginning vertex to all other vertices, the Bellman-Ford algo functions. This then relaxes these calculations iteratively by discovering different forms which are shorter than the already overestimated conduct. This will guarantee that outcome is optimized on all vertices repeatedly.

step 1 $\forall_b \in B, d[b] \leftarrow \infty$ // set primary distance
step 2 $d[s] \leftarrow 0$ // set distance to initial node as 0
step 3 for i *from* 1 $\rightarrow$ n-1 do
step 4 for $(a, b) \in E$ *do*
step 5 $d[b] \leftarrow \min\{d[b], d[a] + w(a, b)\}$ // update approximation of b
// Negative cycle step
step 6 for $(a, b) \in E$ do
step 7 if d[b] > d[a] +w (a, b) then
step 8 return "Negative Cycle"; // negative cycle discovered
step 9 return $d[b]\ \forall\ b \in B$

4. Results Illustrations

Table 1 defines the network parameters for the MATLAB simulation of the network model. As seen in Figure, 100 nodes are randomly distributed with BS outside network area

Table. 1. Simulation Parameters

Network diameter	**100 meters2**
Number of nodes	100 nodes
Network size (monitoring area)	100 ∗ 100
Eelec	50 nJ/bit
Energy dissipation: receiving (Emp)	0.0013 pJ/bit/m4
Energy dissipation: free space model (Efs)	10 pJ/bit/m2
Initial energy	0.5 j
Energy dissipation: aggregation (EDA)	5 nj/bit/signal

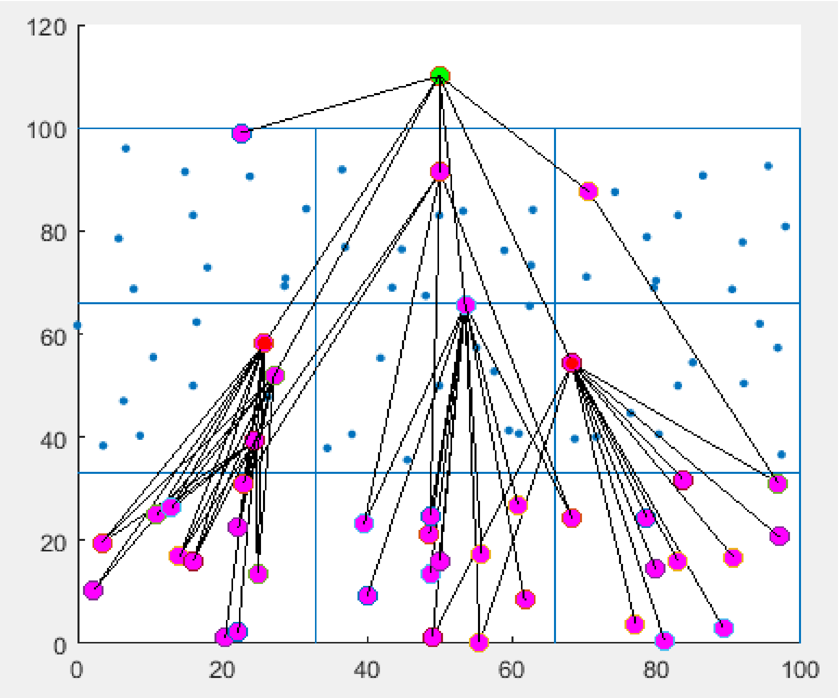

Fig. 4. Node deployment based on tree using Bellmanford algorithm

The above figure is the schematic view of tree construction using Bellman-ford algorithm where the sink node is connected with cluster head node and has constructed a connection with each cluster for the faster routing process.

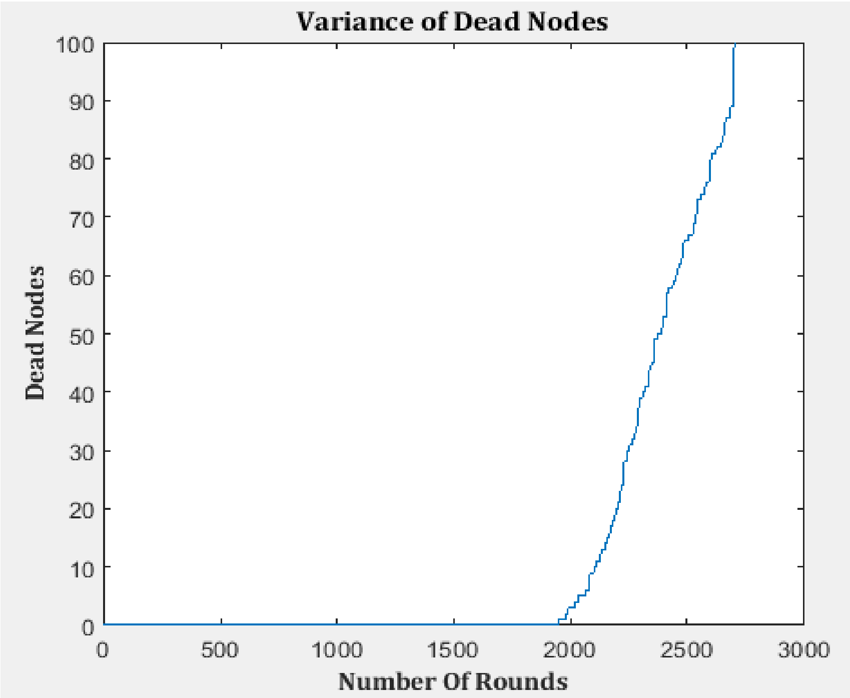

Fig. 5. Variance of dead nodes by previous technique.

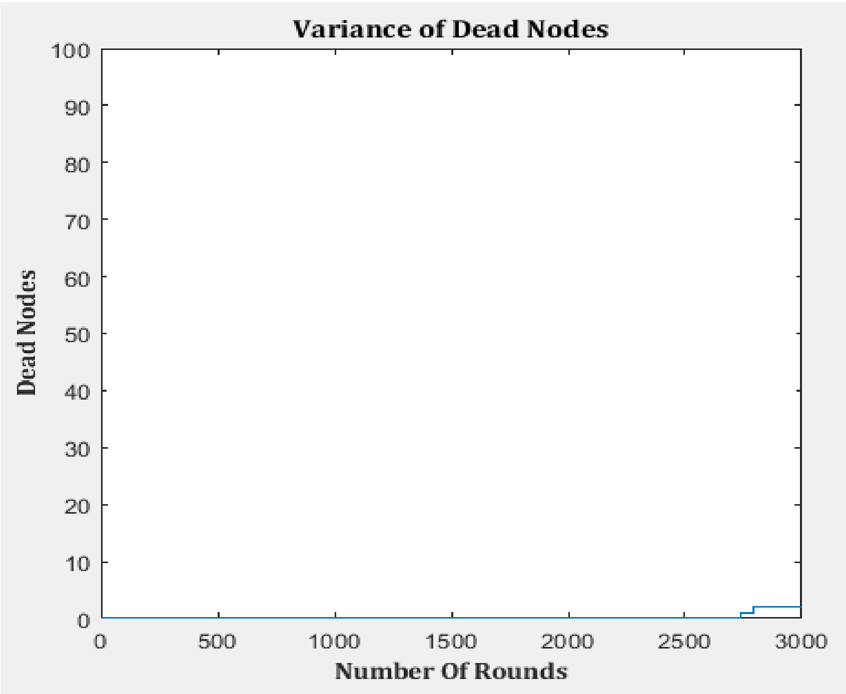

Fig. 6. Variance of dead nodes by FIS-Bellmanford technique.

Figures 5 and 6 visualize the network lifetime of both the research work which shows the first node dead (FND) rounds duration of base results is in 1948, whereas in proposed work it is improved with the improvement in the first dead node time at 2740.

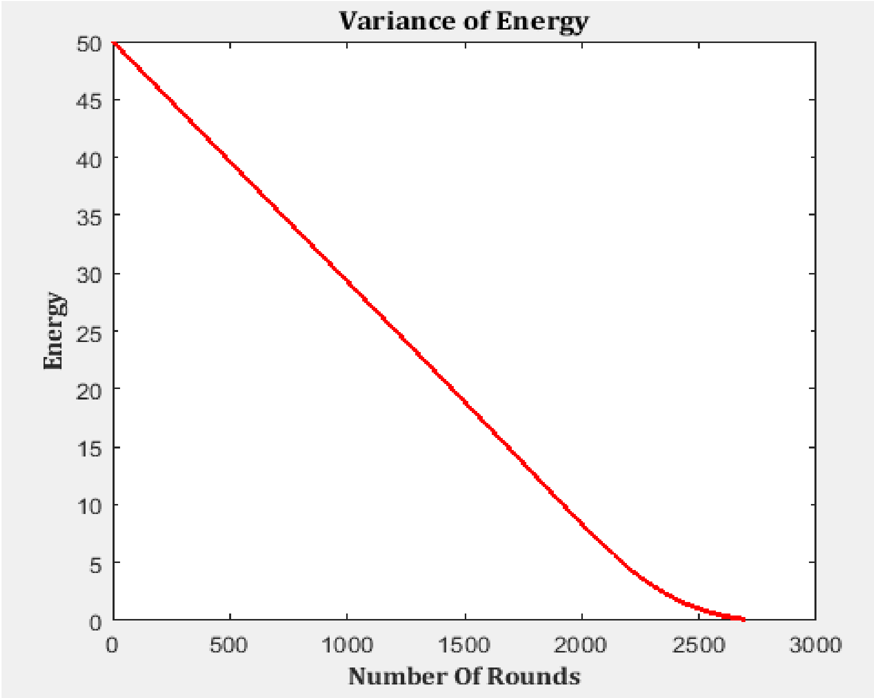

Fig. 7. Residual Energy in previous work.

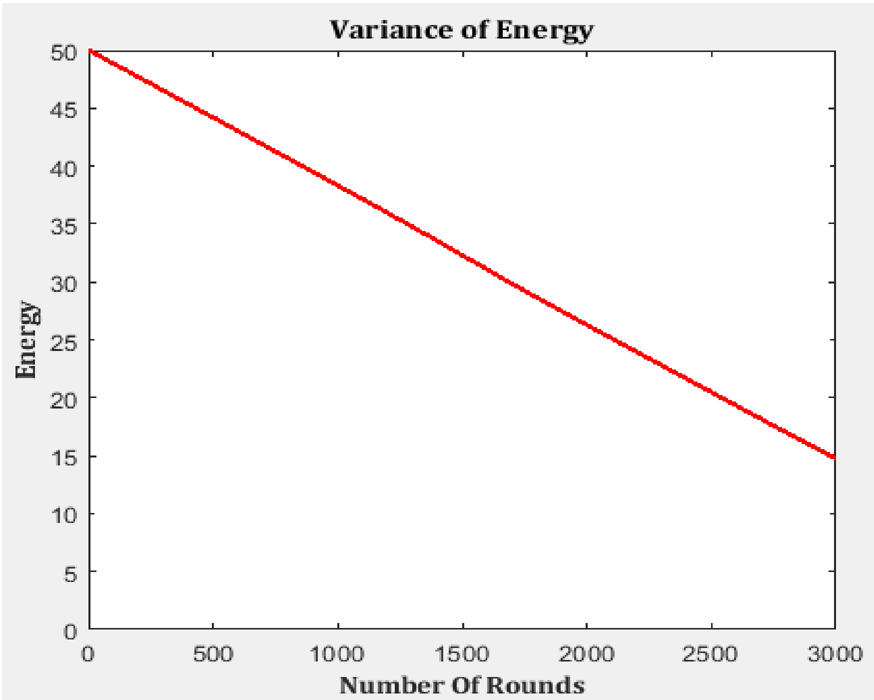

Fig. 8. Residual Energy in current work.

HQCA consumes residual energy faster than FIS-Bellmanford algorithm. This paper proposes an updated CH selection algo to prolong a network existence by monitoring the energy dissipation of the network. The findings of the simulation indicate increased network efficiency for metrics like residual electricity, packets sent to BS, output & lifespan. Research currently underway may be expanded by exploring more CH selection parameters in the network of mobile nodes that regularly shift location.

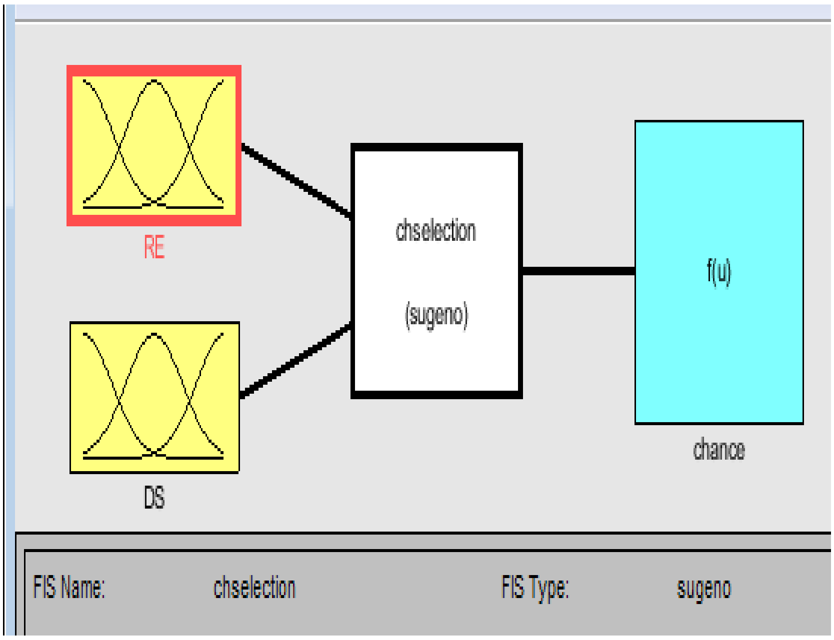

Fig. 9. Sugeno FIS parameters.

Figure 9 represents the role of FIS Sugeno using residual energy (RE) and distance (DS).

5. Conclusion

Since the design of every WSN routing protocol is limited to various major restrictions, energy or lifetime are very relevant. The target was achieved. It is challenging to use an energy effective routing method to uniformly spread the load throughout the system. From the above results visualizations, we can conclude how the new approach of clustering discovered in this work is more efficient, less time consuming, more power-saving, and having large duration of network lifetime.

The Bellmanford algorithm established a tree that has evolved new clustering criteria through which we can easily do the routing process and also our data remain secure with this process of clustering. In future, we can go for a fuzzy-based clustering using minimum spanning tree.

References

1. D. Cacciagrano, R. Culmone, M. Micheletti, & L. Mostarda, "Energy-Efficient Clustering for Wireless Sensor Devices in the Internet of Things," *EAI/Springer Innovations in Communication and Computing*, pp. 59–80, 2018.
2. Shahraki, et al., "Clustering Objectives in Wireless Sensor Networks: A Survey and Research Direction Analysis, Computer Networks," pp. 107-376, 2020.
3. A. Abbasi, & M. Younis, "A survey on clustering algos for wireless sensor networks", *Computer Communications*, vol. 30, no. 14, pp. 2826–2841, 2007.
4. W.R. Heinzelman, A. Chandrakasan, H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," *Proceedings of the 33rd Hawaii International Conference on System Sciences, HICSS '00 (IEEE Computer Society, Washington, DC, 2000*), vol. 8, pp. 80-20.
5. M.A. Alsheikh, S. Lin, D. Niyato, H.P. Tan, "Machine learning in wireless sensor networks: algos, strategies, and applications," *IEEE Commun. Surv. Tutorials*, vol. 16, no.4, pp. 1996–2018, 2014.
6. O. Younis, S. Fahmy, "Heed: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks." *IEEE Trans. Mob. Comput*., vol. 3, no.4, pp. 366–379, 2004.
7. P. Ding, J. Holliday, A. Celik, "Distributed energy-efficient hierarchical clustering for wireless sensor networks," Proceedings *of the First IEEE International Conference on Distributed Computing in Sensor Systems, DCOSS'05 (Springer, Berlin/Heidelberg),* pp. 322–339, 2005.
8. P. Liu, T.l. Huang, X.Y. Zhou, G.X. Wu, "An improved energy-efficient unequal clustering algo of the wireless sensor network," *2010 International Conference on Intelligent Computing and Integrated Systems (ICICIS)*, pp. 930–933, 2010.
9. E. Ever, R. Luchmun, L. Mostarda, A. Navarra, P. Shah, "Uheed - an unequal clustering algo for wireless sensor networks," *SENSORNETS*, 2012.

I. N. Aierken, R. Gagliardi, L. Mostarda, Z. Ullah, “Ruheed-rotated unequal clustering algo for wireless sensor networks,” *29th IEEE International Conference on Advanced Information Networking and Applications Workshops*, AINA 2015 Workshops, Gwangju, 24–27 March 2015, pp. 170–174.
10. Z. Ullah, L. Mostarda, R. Gagliardi, D. Cacciagrano, F. Corradini, “A comparison of heed-based clustering algos – introducing er-heed,” *2016 IEEE 30th International Conference on Advanced Information Networking and Applications (AINA*), pp. 339–345, 2016.
11. L. Qing, Q. Zhu, M. Wang, “Design of a distributed energy-efficient clustering algo for heterogeneous wireless sensor networks,” *Comput. Commun*, vol. 29, no. 12, pp. 2230–2237, 2006.
12. Mrityunjay Singh, Niranjan Lal, "A Tree Based Routing Protocol for Mobile Sensor Networks (MSNs)" International Journal on Computer Science Engineering (IJCSE) Vol. 02, No.01S, 2010, (pp. 55-60)
13. Niranjan Lal et al. "Prospects for Handling 5G Network Security: Challenges, Recommendations and Future Directions" Journal of Physics: Conference Series, Volume 1714, 2nd International Conference on Smart and Intelligent Learning for Information Optimization (CONSILIO) 2020 24-25 October 2020, Goa, India, 2021 J. Phys.: Conf. Ser. 1714 012052.
14. Niranjan Lal, Shamimul Qamar "Power Efficient Data Collection in Wireless Sensor Networks" International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8 Issue-6C, pp. 133-137, April 2019.