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An Energy Efficient Clustering Protocol Using CM-YSGA Optimization Approach in WSN

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Abstract: While dealing with the wireless sensor networks (WSNs), one of the greatest factors that must be taken into consideration is energy consumption of nodes. One of the most effective common way of preserving energy in sensor nodes is clustering technique in which CH selection is of great importance. In this manuscript, an improved energy efficient clustering protocol is proposed in which chaotic mapping algorithm is clubbed along with the advanced variant of Yellow Saddle Goatfish Algorithm (YSGA). The main objective of the proposed model is to reduce the energy consumption of nodes which ultimately prolongs the lifespan of wireless network. Initially, cluster are formed in the network by selecting the nodes randomly. After this, four important parameters which included, residual energy, distance to sink, average distance to CH neighbor node and delay are taken into consideration and on the basis of these factors' fitness value is calculated by the chaotic-YSGA technique. The node whose fitness value came out to be highest of all other nodes, is selected as the CH in that particular cluster. In addition, the Huffman data compression technique is used in the proposed system to reduce energy consumption in nodes. Finally, the performance of the proposed Chaotic-YSGA model is analyzed and compared with conventional energy efficient models in MATLAB software in terms of alive node, dead nodes, throughput, residual energy, FND, HND and LND.
Keywords: WSN, Energy Efficiency, CH selection, Optimization Algorithms.

I. INTRODUCTION

A WSN (Wireless Sensor Network) is a distributed network which consists of huge number of disseminated, independent, small, low powered devices referred as sensor nodes or just nodes. These nodes form a network to considerately gather, process and transmit data to customers and it comprise of limited processing and computing competencies [1]. Basically, sensor nodes are the wireless device which utilizes less amount of energy and perform multiple-functions. In the present time, the wireless network became very famous service due to its technical enhancement in communication, processor and low powered and cost-efficient computing devices. These networks are utilized in various commercial and industrial applications. With the help of sensor nodes, the environmental states such as, humidity, vibration, temperature, sound, pressure, position etc., is monitored. In addition to this, various other tasks such as, smart sensing, discovery of neighbor node, data aggregation, storage and processing of data, tracking of target, synchronization, localization of node, monitoring and controlling, effective routing among nodes and sink are performed by sensor nodes in several real time applications [2]. A typical wireless sensor node comprises of sensing module, processing module and communication module. With the help of sensing unit, the environment is sensed, the sensed data's restricted permutation is computed by the processing unit, and the processed data is exchanged between three neighboring sensor nodes via communication unit. Fig.1. shows the example of a typical WSN in which number of senor nodes are deployed in the sensing region which are connected to the internet via the base station (BS) node.

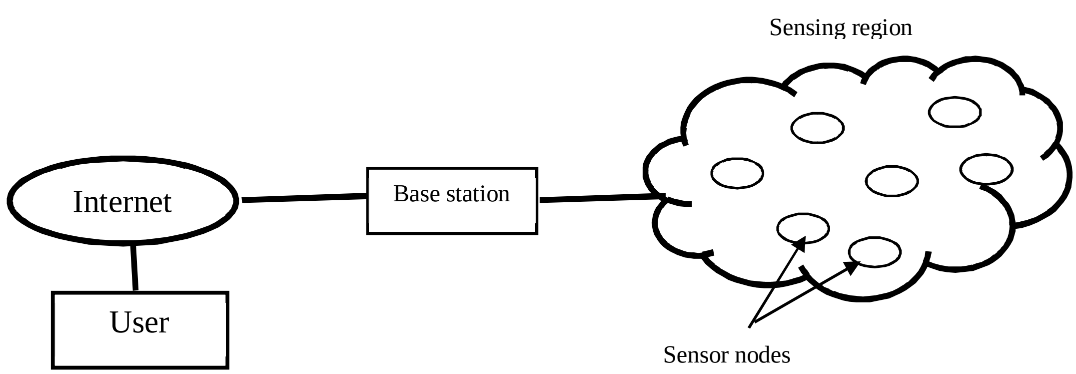

Fig. 1. Typical example of Wireless Sensor Network (WSN)

A. Organization of WSNs

A typical WSN can be organized into five layered framework those are, physical layer, data link layer, network layer, transport layer and application layer. The physical layer is responsible for selecting the frequency, modulate and encrypt the data. the next layer i.e. data link layer acts as alleyway for data stream's multiplexing, identification of data frame, MAC (Medium Access control) and error control. The network layer is responsible for routing data through transport layer by utilizing particular multi-hop wireless routing protocols among sensor and sink nodes. With the help of transport layer, the data's flow is maintained if it is required by the application layer. In the last layer i.e. application layer, the lower layer's hardware and software is made apparent to the users.

B. Challenges in WSN

Despite the number of benefits, WSN face a number of challenges which hinder its wide spread implementation. There are limited resources and generally non-renewable energy supply of sensor nodes, which is the major issue. For prolonging the network lifetime, the protocols should be designed from starting with aim of energy resources' effective management. Fault tolerance, scalability, high production costs, hardware constraints, topology of sensor networks, high power consumption are some of the common challenges that occur in WSN. Among these challenges, energy consumption is the most significant aspect in wireless networks that determine the lifespan of the network. At times, optimization of energy is more intricate in sensor networks as it consists of energy diminution as well as enhancing the network lifetime to maximum extent. By having awareness of energy in all aspects of operation and design, the optimization can be performed. It assures that awareness of energy is also integrated into communicating sensor nodes and whole network and not just in each node. Various algorithms and protocols are analyzed hitherto in order to reduce the sensor network's entire energy consumption [3]. The WSNs lifetime can be enhanced considerably if application layer, operating system, and network protocols are designed as energy aware. The algorithms and protocols must be aware of hardware and should be capable of utilizing special characteristics of transceivers and microprocessors in order to reduce the energy utilization of sensor nodes.

C. Energy efficient routing protocols

The energy efficiency of the system is a primary issue in WSNs. At this moment, networks are expanding, and as a result, the data accumulated is expanding as well. This all consumes a considerable amount of power, resulting in node dying. As a result, a number of energy-efficient protocols have been devised in order to minimize data sampling and collection energy usage and so increase lifetime of the network. Some of the frequently used energy efficient routing protocols are [4]; LEACH (Low-Energy Adaptive Clustering Hierarchy) [5], PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [6], TEEN (Threshold sensitive Energy Efficient sensor Network protocol) [7], HEED (Hybrid Energy-Efficient Distributed Clustering) and so on. in addition to this, there are number of other approaches that were utilized for reducing the energy consumption of nodes and increasing the lifespan of network.

D. Clustering in WSN

The WSN base station must always provide the user with an aggregate value, and adding the information that is transmitted can also help to reduce overhead transmission and energy usage. The nodes can be collected in tiny groups called clusters in order to promote data aggregation in the network. Based on certain mechanisms, clustering may be described as dividing node into groups. It has been shown that clustering enhances network lifespan, a key metric for the performance assessment of a sensor network [8]. Clustering is carried out to attain energy efficiency and network scalability. Also, the cluster formation consists of assignment of the task to the node based on its perimeters. Cluster Head (CH) or the leader is called the coordinator of the cluster which processes, aggregates and transfers the information to the sink, while other nodes that senses and transmits the gathered data to the CH are referred to as Member nodes. Clustering consists of two-tier hierarchy. In the initial phase, the data is sensed by the member nodes and the sensed data is transmitted to cluster head. In other phase, the data is aggregated and processed by the cluster head to transmit it to BS. In comparison with the MN, the CH node loses more energy as it merges on all the gathered information and transmits it to the BS situated far from the cluster site. In WSNs, clustering consists of grouping the nodes into clusters and selecting CH so that, the cluster members can directly communicate with their cluster head and CH can transmit the collected data to central BS via other CHs.

The next section of this paper represents the Literature survey along with some gaps, followed by the Proposed work and its methodology and then Results obtained for the proposed model are discussed and finally conclusion is given.

II. LITERATURE REVIEW

Over the years, a significant number of approaches have been proposed for enhancing the lifespan of the wireless sensor networks by reducing the energy consumption by the sensor nodes. Some of the recently published works are discussed briefly here, Alma Rodríguez et al. [9], suggested a novel energy efficient clustering routing protocol that was based on Yellow Saddle Goatfish Algorithm (YSGA) for improving the lifespan of the wireless network. Experiments revealed that the suggested routing protocol consumes less energy, has a longer lifetime and extends the network's stability period when compared to latest clustering routing methods. Nhat-Tien Nguyen [10], suggested an energy-efficient clustering multi-hop routing protocol (EECMR) for balancing the energy usage in sensor nodes which in turn aids in extending the network lifetime. Mohammad Ali Alharbi [11], analyzed and addressed the problems associated with the clustering and routing. The authors proposed an Area-based clustering approach from the transmission range of network nodes for resolving these problems. A. S. Alkalbaniet al. [12], analyzed the Residual Energy Effects on Wireless Sensor Networks (REE-WSN) and proposed an energy conservation method for improving the lifespan of the network. P. T. Theet al. [13], suggested a scheme for enhancing the lifetime of the WSN in which sinks were moving on a fixed path by using Fuzzy clustering algorithm. The performance of the current Cluster head using Fuzzy logic (CHEF) was evaluated and compared with standard datasets in the MATLAB software. Muhammad Faheemet al. [14], proposed a novel multi-mobile sinks-based QoS-aware data collection protocol (MQRP) for WSN-based 5G applications for improving the stability of wireless networks and successful adoption of SGI 4.0. R. Radhikaet al. [15], proposed an improved routing approach for mobile sink nodes wherein they employed Ant colony optimization for selecting the best path. The mobile sink's data collection was made more efficient by employing a clustering strategy that employs an energy-efficient strategy for CH selection. Xiaomin Liet al. [16], presented a highly effective solution for different data gathering tasks with the help of edge computing-enabled WSNs. Kashif Naseer Qureshi, [17], developed a Gateway Clustering Energy-Efficient Centroid- (GCEEC-) where the selection of CHs and gateway nodes was done from each cluster. The simulated results revealed that the proposed methodology performed better than traditional models indicating that WSN-based temperature, humidity and lighting monitoring in agriculture is far more realistic. Roseline R.A et al. [18], introduced and proposed a hybrid routing algorithm referred as Local Clustering and Threshold Sensitive (LCTS), in which TEEN and LEACH protocols were integrated.

From the literature survey conducted it is observed that the performance and efficacy of the wireless sensor networks depends on energy consumption by nodes. Therefore, an effective energy efficient protocol is needed. A substantial number of approaches have been proposed by various researchers for reducing the energy consumption of nodes and enhancing the lifespan. Unfortunately, there are number of limitations in the current energy efficient protocols which affect their performance. One of the biggest limitations in current system is that they considered only limited number of parameters for selecting the Cluster heads (CHs) in the network. Moreover, the algorithms used in current systems had slow convergence rate and they often tend to get stucked in the local minima. Aside from that, it has also been analyzed that the present energy-efficient methods are only dependent on infrastructure-based measures and very few approaches have been given for data layer. So, it is suggested to address the current system's flaws and provide an improved approach for improving energy efficiency.

III.PRESENT WORK

In order to overcome the limitations of the traditional energy efficient protocols, a novel clustering and Cluster head (CH) selection method is proposed in this research that is based on chaotic-map and Yellow Saddle Goatfish Algorithm (YSGA). The main motive of the proposed model is to reduce the energy consumption of the sensor nodes which ultimately will enhance the lifespan of the entire wireless network. To accomplish this task, modifications has been done on two important phases, one is CH selection and second is data compression at data layer. In the proposed work, a yellow Saddle Goatfish Algorithm (YSGA) is clubbed along with the chaotic map algorithm for selecting the CH in the network. The major reason for using the YSGA along with chaotic mapping algorithm is to enhance the global searching ability of YSGA algorithm, enhance the network lifespan and enhance network stability. The Chaotic map algorithm is a nonlinear deterministic system that can deal with complicated, noisy and unexpected behavior, which is why this algorithm was chosen for the improvement. Additionally, due to the non-repetitive nature of chaotic map algorithm, the searching for optimum solution can be carried out at faster rate. On the other hand, YSGA is used in the proposed work because of its ability to maintain balance between exploration and exploitation phases.

In the next phase of the proposed model, a data compression technique has been implemented at the data layer wherein the data is compressed before transmitting it to the sink node. To do so, a lossless data compression technique named as, Huffman algorithm is employed in the proposed work which compressed the data collected by the sensor nodes before transmitting it to the sink node.

The concept is to give variable-length codes to input characters, whose lengths are determined by the frequency of related characters. The shortest code is assigned to the most frequently occurring word, whereas the largest code is assigned to the least frequently occurring character. Therefore, by implementing the proposed hybrid YSGA and chaotic model, the energy usage of the nodes can be decreased substantially which in turn enhances the lifespan of the network. The detailed description on how the proposed model works is given in the next section of this paper.

A. Methodology

In order to prolong the lifespan of wireless network, a series of steps is followed in the proposed hybrid chaotic-YSGA model that is discussed briefly below;

1) *Step 1:* Initially, a wireless network is initialized in which different parameter like sensing area, no. of deployed nodes, packet size, residual energy etc., are defined. In addition to this, number of other parameters are also defined in the network and are mentioned in table I.

TABLE I
NETWORK INITIALIZATION PARAMETERS

Parameters	Values
Sensing region	100m2
Total no. of sensor nodes (N)	100
Packet size (l)	4000 bits
Energy for 1 bit of data aggregation E_{DA}	5nJ/bit
Energy dissipation for transmitting or receiving 1-bit data E_{dec}	50 nJ/bit
Coefficient of energy dissipation in the free space ε_{fs}	10 pJ/bit/m2
Coefficient of energy dissipation in multi-path attenuation model ε_{mp}	0.0013 pJ/bit/m4
Initial energy of nodes E_o	0.07J

2) *Step 2:* After initializing the network, it's time to deploy the nodes in the sensing area. In the proposed work, a total of 100 node are deployed randomly, each node having an energy of 0.07j.
3) *Step 3:* The next step is to form clusters in the network in which nodes are selected randomly and then the distance from this node to remaining nodes is calculated. The nodes that are close to the selected nodes are grouped together to form a cluster.
4) *Step 4:* Once the clusters are formed in the network, the next step is to select the CH in each cluster. For this, the yellow saddle Goatfish algorithm (YSGA) is initialized wherein different parameters that are mentioned in Table II are defined along with their exact values.

TABLE 2
YSGA INITIALIZATION PARAMETERS

Parameters	Values
Population size	20
Max. Iterations	50
Number of clusters	2
Lower bound	1
Upper bound	no. of cluster members
No. of decision variables	1

5) *Step 5:* In the next phase of the model, the cluster head is selected in the network. For this, residual energy, distance to sink, average distance to CH neighbor node and delay are analyzed by the hybrid chaotic and YSGA algorithm for calculating the fitness function in the network. The fitness function used in the proposed model for selecting the CH in the network is given in equation 1.

$$fitness = 0.6 * energy + 0.4 * \left(\frac{1}{Dsink + Davg + Delay}\right) - - - -(1)$$

The node whose fitness value will come out to be highest will be selected as the CH in the of the particular cluster in the network.

6) *Step 6:* Once the CHs are selected in the network, the communication phase is initiated in the network but before sending the data to BS, a Huffman data compression technique is employed in the proposed work. The Huffman algorithm analyzes the data in every node, compresses it for reducing the energy consumption of nodes. The compressed data is then passed to the BS via the Cluster head (CH) node.
7) *Step 7:* In the final step, the performance of the proposed hybrid chaotic-YSGA approach is evaluated and compared with some state to art methods in terms of various parameters that are explained in the next section of this paper.

IV. RESULTS AND DISCUSSION

In this section, the results attained for the proposed hybrid chaotic-YSGA model are evaluated. The simulation of the proposed approach is analyzed in the MATLAB software and is validated by comparing with few state of art models in terms of dead nodes, alive nodes, residual energy and throughput.

A. Performance Evaluation

Initially, the performance of the proposed hybrid chaotic-YSGA model is analyzed and compared with traditional DEEC and YSGAP models in terms of dead nodes after each iteration. Fig. 2 represents the comparison graph for the proposed chaotic-YSGA model and traditional DEEC and YSGAP model in terms of the dead nodes. After analysing the above graph, it is observed that the nodes start dying after performing just 180 and 230 rounds in traditional DEEC and YSGAP model and are communicating effectively till 330th and 450th iterations. On the other hand, in proposed hybrid chaotic-YSGA model all nodes are working effectively till the 250th round after which they begin to die. Nonetheless, the model is still able to communicate until the 550th iteration is performed.

Moreover, the efficacy of the suggested hybrid chaotic-YSGA model is validated by comparing it with the traditional DEEC and YSGAP models in terms of residual energy, and is shown in Fig. 3.

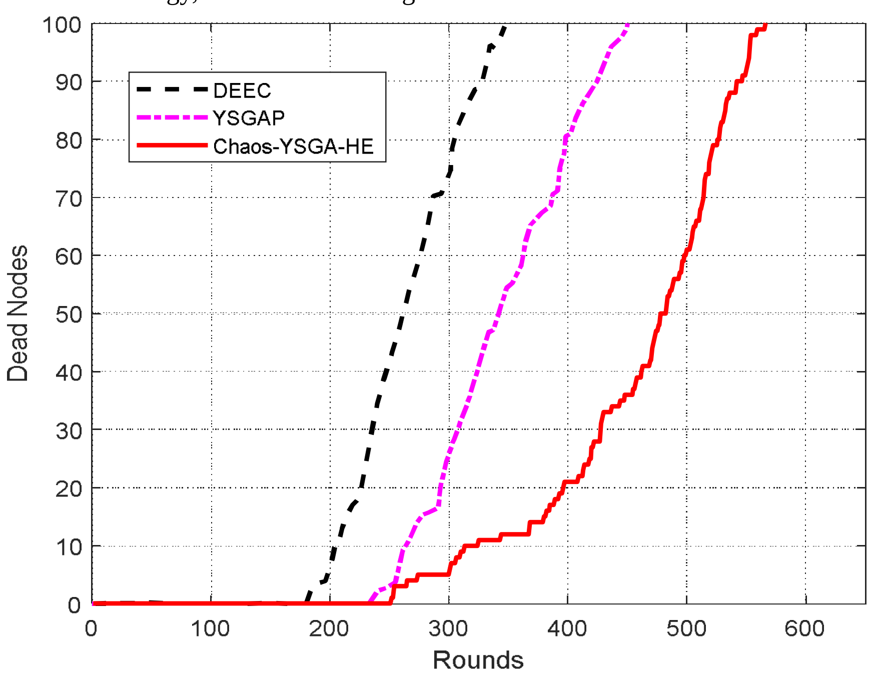

Fig. 2. Comparison for dead nodes

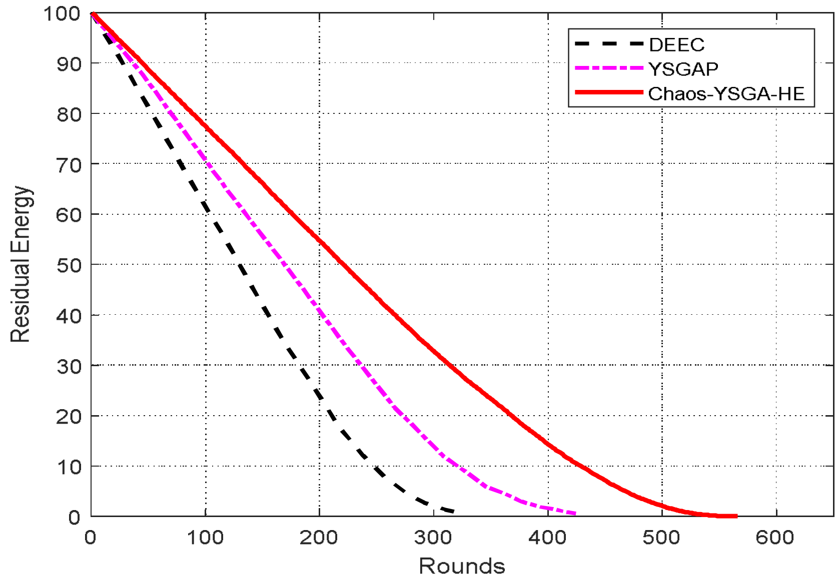

Fig. 3. Comparison graph for residual energy

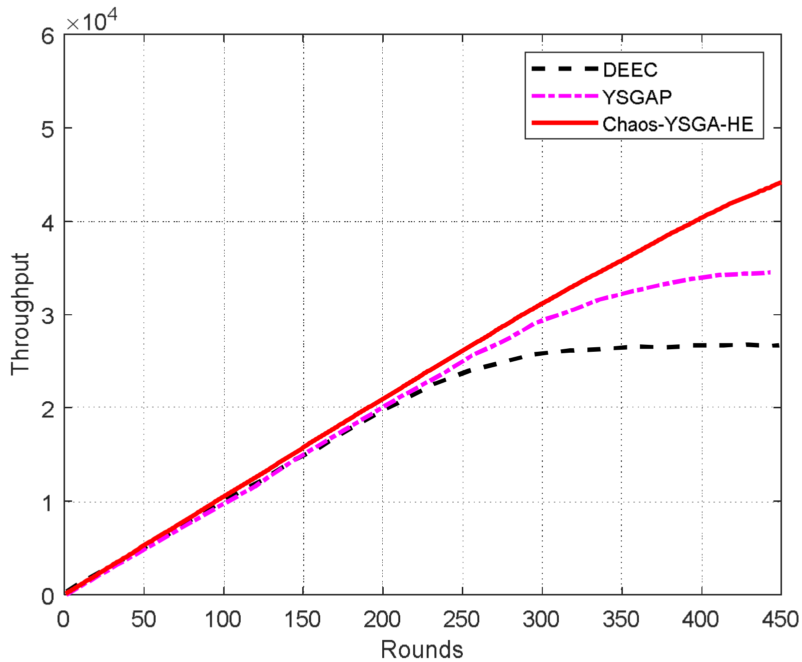

Fig. 4. Comparison graph for throughput

Above graph (see Fig. 3) illustrates the comparison between proposed hybrid model and traditional DEEC and YSGAP model in terms of their residual energy. From the given graph, it is concluded that the residual energy is lowest in conventional DEEC model which last only up to 300 rounds, followed by traditional YSGAP model in which residual energy last up to only 410 rounds. While as, in case of proposed hybrid chaotic-YSGA model the energy of nodes last till 550th iteration is performed, clearly showing its dominance.

Additionally, the efficiency of the proposed chaotic-YSGA approach is analyzed and compared with the standard DEEC and YSGAP models in terms of throughput. The graph for the same is shown in Fig. 4. After examining the above graph, it can be concluded that the proposed hybrid chaotic-YSGA model is outperforming traditional DEEC and YSGAP models in terms throughput. The conventional DEEC and YSGAP systems obtained throughput of only 2.8 ×104 and 3.5×104 respectively, however the proposed Chaotic-YSGA approach achieves throughput of 4.2×104, which itself is considerably better than traditional systems.

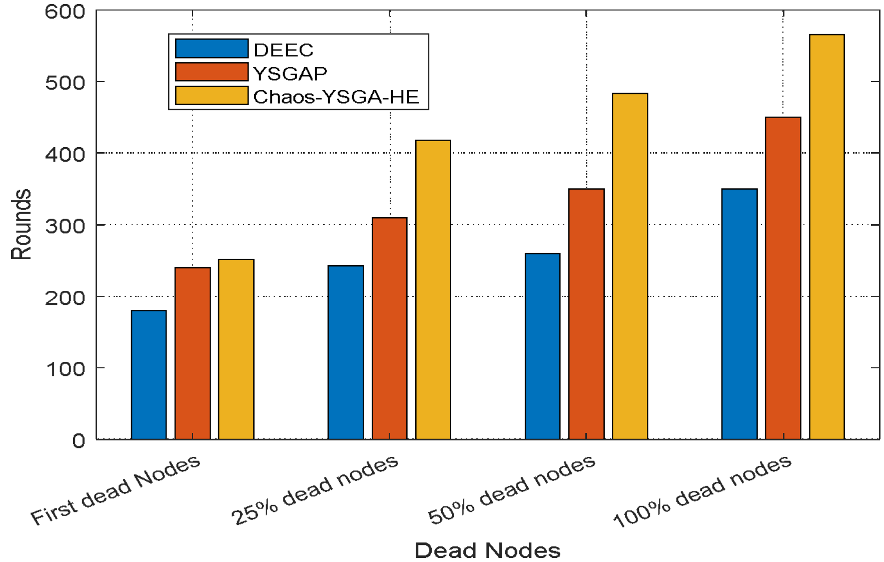

Fig. 5. Lifetime evaluation of proposed hybrid model and traditional models

In addition to this, the effectiveness of the proposed chaotic-YSGA approach is analyzed and validated by comparing it with the conventional DEEC and YSGAP models in terms of lifetime evaluation. Fig. 5 represents the comparison graph for the same. From the given graph, it is observed that in conventional DEEC scheme the death of first node, 25% nodes, 50% nodes and last node occurs after performing just 180, 243, 260 and 350th iterations. Whereas, in standard YSGAP model the death of first node occurs after performing 240th iteration, 25% and half nodes dies at 310 and 250 rounds and the death of last node occurs at 450th iteration. While as, in case of proposed chaotic-YSGA model the very first node dies after performing 252th iterations and the 25% and 50% nodes die around 418th and 483th iterations respectively. Additionally, the last node dies in the proposed hybrid chaotic-YSGA model after performing 566th simulating rounds, which indicates that the model is able to communicate till 566th round. . The exact values are recorded in tabular form and is shown in Table III.

TABLE III
COMPARISON TABLE FOR LIFETIME EVALUATION

Technique	FND	DN25%	DN50%	LND
DEEC	180	243	260	350
YSGAP	240	310	350	450
Chaotic-YSGA	252	418	483	566

The above given graphs and tables prove the efficacy and stability of the proposed chaotic-YSGA model in terms of enhanced network lifespan, stability and reduced energy consumption.

V. CONCLUSION

In this paper, an efficient and effective model is proposed for improving the lifespan of the network that is based on chaotic map and Yellow Saddle Goatfish Algorithm (YSGA). The performance of the suggested hybrid approach is analyzed and validated by comparing it with the state of art methods in the MATLAB software. The simulated outcomes were determined in terms of dead nodes, alive nodes, residual energy, FND, HND and LND. After analyzing the results, it is concluded that the nodes in standard DEEC and YSGAP models begin to die just after performing 180th and 230th simulation round. While as in case of the proposed hybrid chaotic-YSGA model the nodes are working and communicating effectively till the 230th iteration is performed. Likewise, the performance of the standard DEEC and YSGAP model is evaluated in terms of its lifetime evaluation in which the value of FND came out to be 180 and 240, HND at 260 and 350 and last node died at 350 and 450th iteration respectively.

On the other hand, the first node dies in the proposed hybrid chaotic-YSGA model after performing 252th iteration while as the half nodes died at 483th iteration and value of LND also came out to be 566 iteration, thereby proving its supremacy. In addition to this, the proposed chaotic-YSGA model outperforms conventional DEEC and YSGAP model in terms of residual energy and throughput as well to prove its superiority over these algorithms.

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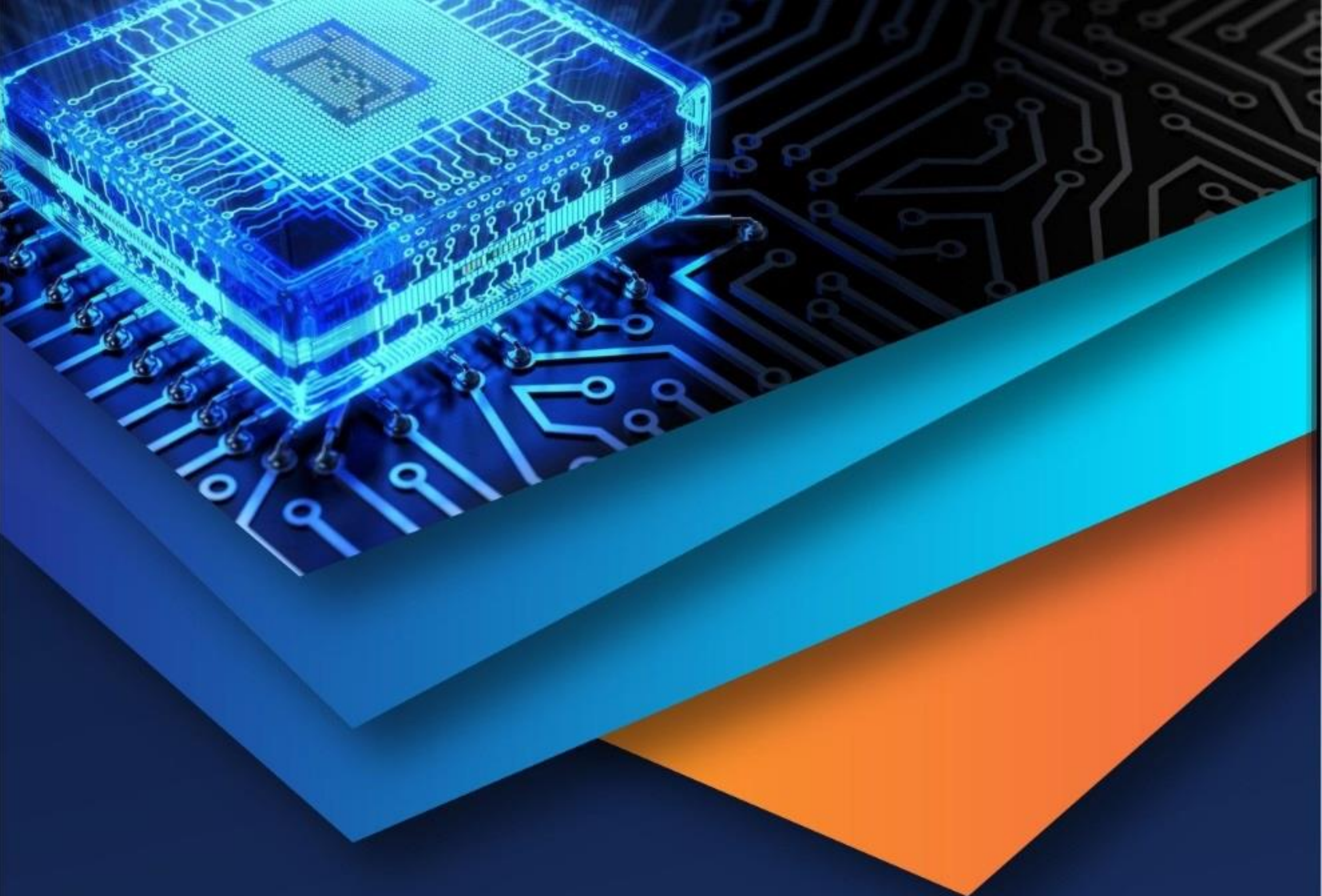

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