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ADAPTIVE HYBRID DRAGONFLY FIREFLY (AHDF) ALGORITHM FOR OPTIMIZED CLUSTER HEAD SELECTION IN WIRELESS SENSOR NETWORKS

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ABSRACT

Wireless Sensor Networks are everywhere around us used in variety of applications such as weather forecasting, military surveillance, health monitoring, agriculture monitoring, and smart IoTs etc. These networks are particularly employed to sense and broadcast the data from source nodes to sink node. Hence, energy consumption becomes one of the most challenging jobs here. Hierarchical clustering-based routing schemes prove to be helpful in such situations. As a result, optimized cluster head selection is essential and key task here. In this paper author has attempted to design an optimized cluster head selection scheme based on Adaptive Hybrid Dragonfly Firefly (AHDF) algorithm on the basis of node energy, corresponding distance and network load and delay parameters. The simulation and comparison results showcase the outperformance of the proposed routing scheme in terms of energy efficiency (121% and 41%), network lifetime (89% and 21%) and data throughput (31% and 23%) in comparison of existing routing schemes SEELCA [15] and CRCGA [16] respectively.

Index Terms – Cluster Head Selection, Network Delay, Energy Efficiency, Attractiveness, Residual Energy, Fitness Function**.**

I. INTRODUCTION

Wireless Sensor Networks (WSN) are specialized networks those have found momentous interest of research owing to their extensive range of applications such as military surveillance, agriculture monitoring, weather forecasting, health monitoring and smart IoTs [1]. These networks are comprised of a large number of very small, low-priced, small storage capacity and restricted battery-operated entities known as sensor nodes to put effort together in order to carry out numerous jobs [2, 3]. In addition, these deployed sensor nodes are going to communicate among themselves within the designed wireless network with intention of collecting and broadcasting an assortment of messages with reference to the respective monitored object to the correspondent sink node commonly known as base station. This base station node is further responsible for the relative data processing and hence accounting this to the consumers finally. Wireless sensor networks are found to be quite flexible, manageable and appropriate implement owing to their variety of salient features

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for instance miniature sized, lower operational cost, their facility to position at a choice of locations exclusive of the impediments found in wired networks in together with the prospects of numbers positioning and arrangements which are not constrained to existing prototype [4].

In addition, as the deployed sensor node are batter operated entities. Hence, battery discharging creates major setbacks such as sensor nodes dead states, network disruptions etc. As a result, the sensor node allocation, source and sink node selection, communication path and overall network lifetime have to be further optimized in order to improvise the network performance [5, 6]. One other significant characteristic is the communication of the deployed nodes with the sink node or base station. In most cases, the sensor nodes simply have a tiny coverage area for data communication. As a result, the routing topologies in together with deployment approach have an effect on the data communication and overall network performance [7]. One such way to optimize the network statistics is use to employ hierarchical routing, where the entire network is divided into smaller areas regarded as clusters [8-10]. A cluster head (CH) node within each individual cluster is selected. This CH node is responsible for data collection from other sensor nodes within the cluster and communication the collected data to the corresponding base station.

In this paper, author has proposed a novel adaptive hybrid dragonfly and firefly (AHDF) scheme based hierarchical routing in order to perform optimized selection of cluster head (CH) node. The cluster head selection is majorly based on node energy, corresponding distance and network load and delay. The communication within the network is carried out in both inter-cluster and intra-cluster fashion to optimize the corresponding network performance parameters such as network residual energy, network lifetime, data throughput etc.

Rest of the paper is organized in following sections. Section-II presents the brief literature review on various latest hierarchical routing schemes. Section-III discusses the energy model and the network model. Proposed work is presented in Section-IV. Section-V demonstrates the simulation setup, simulation results and comparative analysis. The conclusion of the proposed research work has been presented in Section-VI.

II. LITERATURE REVIEW

The selection of cluster head node without consideration of the corresponding distance between sensor node and base station was tried to trounce in [11] while extending the existing standard LEACH algorithm. Here, sensor node with the minimum distance was selected as cluster head node here. This results in improved network lifetime while reducing the overall network energy. In order to optimize the energy expenditure of every individual sensor node particle swarm optimization (PSO) based clustering scheme was proposed in [12]. This scheme results in improved network lifetime and network reliability further. Novel energy efficient clustering schemes DE-LEACH, where cluster head selection was based on distance and energy was proposed in [13]. This scheme was found to be improving the network throughput, lifetime and hence the overall network stability. An energy-efficient E-LEACH scheme was proposed in [14]. This scheme works on selection of multi-hop path technique in order to achieve energy saving with the intention of eliminating a direct communication path of cluster head nodes with the corresponding base station if the distance between them is quite more. This scheme was found to be energy efficient and improving network lifetime.

A sector-based energy efficient lightweight and flexible clustering algorithm (SEELCA) was proposed in [15] in order to trim down the node energy consumption and hence optimize the overall network energy efficiency. This scheme was based on dividing the entire network area into virtual sectors. Furthermore, the sensor nodes priority is evaluated on the basis of node density, residual energy and communication distance in order to select the cluster head. This scheme was found to be energy efficient and achieve improved network lifetime. In [16] a clustering routing scheme by

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means of a chaotic genetic algorithm (CRCGA) was proposed in order to enable load balancing and improving network energy. Here, the chaotic genetic algorithm was employed in order to perform the cluster head selection. This results in improved network energy and load balancing.

The optimal area coverage was accomplished by means of the Gravitational Search Algorithm (GSA) in [17]. In this work the deployed sensor nodes equivalent to corresponding mass elements were prejudiced by Newton's laws of motion, Newton's law of gravity and distance. This scheme was found to be handful to improvise the network lifetime and enable the enhanced network coverage. An optimized routing scheme was proposed in order to discriminate the outlier sensors on the basis of a improved dragonfly optimization (IDO) in [18] in order to achieve enhanced network coverage and energy efficiency. This scheme was found to be energy efficient with improvised network lifetime. Various other schemes such as EE-LEACH [19], EHA-LEACH [20], TEEN [21], DL-LEACH [22], Hybrid Meta-heuristic based optimization [23], Whale optimization scheme [24], MEACBM [25] ME-LEACH [26], RCH-LEACH [27] etc. have also been proposed to optimize the energy consumption and improvise the network lifetime further.

III. NETWORK MODEL & ENERGY MODEL

a. Network Model

For the proposed routing scheme, the implementation has been carried out over an area of a x b dimensions. Total 'n' number of sensor nodes has been placed in this region at random. Furthermore, all the placed sensor nodes are considered to be homogeneous and stationary throughout the network simulation time. These deployed sensor nodes facilitate the flawless and efficient data communication to the subsequent sink node better known as base station assigned for the particular wireless network. In addition, the base station can be located at anyplace either within the network area or exterior to the network area also. The available sensor nodes are characterized by 'S' symbol, where S_i signifies the i^{th} sensor node and the consequent group of available sensor nodes is characterized as $S = S_1, S_2, S_3, \dots S_n$.

In addition, the designed wireless network area is partitioned into multiple regions known as clusters (C_k). Each cluster gets assigned with a special node known as cluster head (CH) denoted by CH_k . This cluster head node facilitates data integration task in order to trim down the well structured and unswerving data availed by the deployed sensor nodes within the cluster area and then processing this data to the subsequent base station genuinely. The cluster head selection is performed by means of adaptive hybrid dragonfly algorithm and firefly algorithm proposed here. The distance between the corresponding cluster head node and base station is denoted by r_{BC} and the distance between the k^{th} cluster head node and any m^{th}ordinary sensor node is given by r_{mk}.

b. Energy Model

One of the major concerns in wireless sensor network design is the energy dissipation. Since, the deployed sensor nodes are battery operated for which recharging is not possible. Hence, in case of full depletion the network will be disconnected due to non-availability of power supply. Here, first order generic radio energy model is being integrated in order to evaluate the designed wireless sensor network. This energy model comprises energy consumption for all of the available sensor nodes for different stages for instance data communication (including both transmission and reception), data sensing and data aggregation for all the deployed sensor nodes. In addition, the radio energy expenditure model by means of data packet communication during transmission phase potential of 'l' bit message and then the data packet communication during reception phase carried out over the distance of 'r' is formulated by equations (1-8).

$$E_{TX}(l,r) = \begin{cases} l * E_c + l * \alpha_{fs} * d^2, & r < r_0 \\ l * E_c + l * \alpha_{mp} * d^4, & r \geq r_0 \end{cases} \quad (1)$$

$$E_{RX}(l) = l * E_c \quad (2)$$

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$$E_{DA}(l) = l * E_{DA} \quad (3)$$

$$E_{Total,ord} = \left(\frac{n}{k} - 1\right) * \left[E_{TX,ord}(l,r) + E_{RX,ord}(l)\right] \quad (4)$$

$$E_{Total,ord} = \left(\frac{n}{k} - 1\right) * \left[2 * l * E_{diss} + l * \alpha_{fs} * {r_{CH}}^2\right] \quad (5)$$

$$E_{Total,CH} = \left(\frac{n}{k}\right) * \left[E_{TX,CH}(l,r) + E_{RX,CH}(l) + E_{DA}(l)\right] \quad (6)$$

$$E_{Total,CH} = \left(\frac{n}{k}\right) * \left[2 * l * E_c + l * E_{DA} + l * \alpha_{mp} * {r_{toBS}}^4\right] \quad (7)$$

$$r_o = \sqrt{\frac{\alpha_{fs}}{\alpha_{mp}}} \quad (8)$$

Where, E_{TX} denotes the transmitter energy, E_{RX} denotes the receiver energy, E_{DA} denotes the data aggregation energy, E_c denotes the consumption energy, $E_{TX,ord}$ denotes the transmitter energy for ordinary node, $E_{TX,CH}$ denotes the transmitter energy for cluster head (CH) node, $E_{Total,ord}$ denotes the total energy for ordinary node, $E_{Total,CH}$ denotes the total energy for cluster head (CH) node, l denotes the number of bits in message, r denotes the distance between receiver and transmitter, α_{fs} denotes the free space loss factor, α_{mp} denotes the multipath loss factor, r_o denotes the threshold crossover distance, r_{toCH} denotes the distance between available sensor node and base station cluster head (CH) node, r_{toBS} denotes the distance between cluster head (CH) node and base station (BS) node, n denotes the total number of sensor nodes deployed and k denotes the total number of cluster head (CH) nodes during ongoing round.

In addition, the adaptive hybrid model of dragonfly and firefly algorithm is extensively employed here in view of four major constraints specifically node distance, node energy, network load and delay. The prime objective here is to minimize the distance between the ordinary node to corresponding cluster head node and cluster head node to subsequent base station, load and delay while maximizing the energy status of cluster head node resulting in the minimal energy consumption by proposing optimized cluster head selection scheme. As a result, the objective function for cluster head selection which has to be minimized is given by equation (9). Furthermore, the regular limits of these factors for distance, energy, load and delay are characterized by μ_1, μ_2, μ_3 respectively. Hence, the cumulative weighted total of all these factors has to rightly maintained and optimized as per equation (10) & (11) while keeping the sum of these factors as unity as shown in equation (12).

$$Z = \xi * z_1 + (1 - \xi) * z_2; \quad 0 < \xi < 1 \quad (9)$$

$$z_1 = \mu_1 * z_{dist} + \mu_2 * z_{en} + \mu_3 * z_{load\_del} \quad (10)$$

$$z_2 = \frac{1}{n} * \sum_{i=1}^{n} \left\| P_i^{ord} - BS \right\| \quad (11)$$

$$\mu_1 + \mu_2 + \mu_3 + \mu_4 = 1 \quad (12)$$

The corresponding fitness function for distance (z_{dist}) is given by as shown in equation (13), where the parameter z_{dist1} denotes the cumulative sum of the distance between ordinary node and corresponding cluster head node and the distance between cluster head node and subsequent base station as given by equation (14) and z_{dist2} denotes the distance amongst all the ordinary nodes which are deployed within the designed wireless network area as given by equation (15).

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$$z_{dist} = \frac{z_{dist1}}{z_{dist}} \qquad (13)$$

$$z_{dist} = \sum_{i=1}^{P}\sum_{j=1}^{k}\left\|P_i^{ord} - CH_j\right\| + \left\|CH_j - BS\right\| \qquad (14)$$

$$z_{dis} = \sum_{i=1}^{P}\sum_{j=1}^{P}\left\|P_i^{ord} - P_j^{ord}\right\| \qquad (15)$$

The corresponding fitness function for energy (z_{en}) is given by as shown in equation (16), where the parameter z_{en} denotes the cumulative sum of the energy deviations corresponding to all of the cluster head nodes as given by equation (17) as per calculated by equation (18) and z_{en2} denotes the energy among the ordinary nodes which are deployed within the designed wireless network area as given by equation (19). As number of cluster head nodes increases, the corresponding energy parameter increases which results in the parameter z_{en} to be greater than unity.

$$z_{en} = \frac{z_{en}}{z_{en2}} \qquad (16)$$

$$z_{en1} = \sum_{i=1}^{CH_k} kE(i) \qquad (17)$$

$$kE(i) = \sum_{\substack{j=1\\ j\epsilon i}}^{P}\left(1 - E\left(P_j^{ord}\right) * E(CH)\right); \;\; 1 \le i < CH_k \qquad (18)$$

$$z_{en2} = CH_k * {}_{i=1}^{CH_k}Max\left(E\left(P_i^{ord}\right)\right) * {}_{j=1}^{CH_k}Max(E(P_j^{ord})) \qquad (19)$$

The corresponding fitness function for delay (z_{load_del}) is given by as shown in equation (20). The load and delay parameter is directly proportional to the total number of nodes available within the specified cluster. Hence reduction in total number of nodes within the cluster results in reduced load and hence reduced delay further. The value of the parameter $z_{load_del}$is ratio and lies between 0 and 1.

$$z_{load\_del} = \frac{{}_{i=1}^{CH_k}Max(CH_i)}{P} \qquad (20)$$

IV. PROPOSED METHODOLOGY

The Adaptive Hybrid Dragonfly Firefly (AHDF) routing methodology has been presented here.

a. Dragonfly Algorithm

The key inspiration of the dragonfly algorithm is adopted from [28]. Further, the significant motivation for this scheme emerges from both static and dynamic social swarming behavior of dragonflies in environment. The two vital and necessary stages of optimization are during exploration and exploitation. These stages are modeled on the basis of social relations of dragonflies during navigation, food search and enemy evasion. Furthermore, as per Reynolds swarms' behavior follow three primeval standards of separation, alignment and cohesion. The prime objective here is survival while attraction towards food source and distraction from evaders. Based on these, total five parameters namely separation, alignment, cohesion, food attraction and enemy interruption are responsible for individual swarm position update given by equation (21-25).

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$$Separation\ (S_k) = -\sum_{i=1}^{N}(X - X_i) \qquad (21)$$
$$Alignment\ (A_k) = \frac{\sum_{i=1}^{N}(V_i)}{N} \qquad (22)$$
$$Cohesion\ (C_k) = \frac{\sum_{i=1}^{N}(X_i)}{N} - X \qquad (23)$$
$$Food\ Attraction\ (F_k) = \left(X_f - X\right) \qquad (24)$$
$$Enemy\ \text{Interruption}\ (E_k) = (X_e + X) \qquad (25)$$

Where, X is the position of current dragonfly, X_i is the position of neighboring i^{th} dragonfly, N is the number of dragonflies in neighborhood, V_i is the velocity of neighboring i^{th} dragonfly, X_f is the position of food resource dragonfly, X_e is the position of enemy dragonfly.

Furthermore, the overall behavior of dragonflies is evaluated on the basis of above discussed five parameters. In order to update the position of any dragonfly, two vectors namely step vector (ΔX) to track the direction of movement of dragonfly and position vector (X) to obtain the position of dragonfly are evaluated here as per equations (26-31).

$$\Delta X_{r+1} = [(s\text{x}S_k) + (a\text{x}A_k) + (c\text{x}C_k) + (f\text{x}F_k) + (e\text{x}SE_k)]\text{x}(w\text{x}\Delta X_r) \qquad (26)$$
$$X_{r+1} = X_r + \Delta X_{r+1} \qquad (27)$$
$$X_{r+1} = X_r + Levy(n)\text{x}X_r \qquad (28)$$
$$Levy(x) = 0.01\text{x}\frac{n_1\text{x}\sigma}{|n_2|^{\frac{1}{\beta}}} \qquad (29)$$
$$\sigma = \left(\frac{\Gamma(1+\beta)\text{x}\sin\left(\frac{\pi\beta}{2}\right)}{\Gamma\left(\frac{1+\beta}{2}\right)\text{x}\beta\text{x}2^{\left(\frac{\beta-1}{2}\right)}}\right)^{\frac{1}{\beta}} \qquad (30)$$
$$\Gamma(n) = (n-1)! \qquad (31)$$

Where, s is weight of separation, a is weight of alignment, c is weight of cohesion, f weight of food resource, e is weight of enemy, w is weight of inertia, k is k^{th}individual dragonfly, r is ongoing round number. ΔX is the step vector update in position X of the dragonfly. n implies the position vector dimensions, n_1 and n_2 are random numbers, β is Levy function constant and σ is Levy function parameter.

b. Adaptive Firefly Algorithm

The firefly algorithm gets inspiration from their social behavior of flashing light and is a population based stochastic scheme. This flashing light enables features of attraction of the mating associates and caution from marauder. The adaptive behavior of firefly algorithm with alternate search enables the dynamic adjustment of control parameters in order to improve both local global search capabilities in efficient fashion [29]. Since, intensity of light is inversely proportional to the square of the distance. Hence, optimizations are needed for both in light intensity dynamics and attraction proficiently.

The attractiveness similar to the light intensity can be described as Gaussian function as given by equation (32). The distance between two neighboring fireflies can be calculated as Euclidean distance given by equation (33). Based on attractiveness of firefly, current location of firefly and

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random movement, the position of firefly is updated as per given by equation (34). Furthermore, in order to improve the convergence the random movement parameter is updated as per given by equation (35). Also, the attractiveness between two neighboring fireflies becomes constant approaching to zero once algorithm is near convergence and again will be set to value unity for next search which is not useful. Hence, the attractiveness is modified as per given by equation (36) to resolve such issues and enable adaptive behavior within firefly algorithm which is helpful for alternate search further.

$$Attractiveness\ ,\beta\left(d_{ij}\right) = \beta_o \mathrm{x} e^{-\gamma d_{ij}^2} \quad (32)$$

$$d_{ij} = \left\|X_i - X_j\right\| = \sqrt{\sum_{k=1}^{N}\left(X_{ik} - X_{jk}\right)^2} \quad (33)$$

$$X_i(r+1) = X_i(r) + \beta\left(d_{ij}\right)\mathrm{x}\left(X_j(r) - X_i(r)\right) + \alpha \mathrm{x} \varepsilon_i \quad (34)$$

$$\alpha_{k+1} = \alpha_k \mathrm{x}\left(1 - \frac{k}{R_{max}}\right) \quad (35)$$

$$\beta_{opt} = \begin{cases} \beta, & if\ \beta < 1 \\ \beta \mathrm{x} m, & else \end{cases} \quad (36)$$

Where, γ denotes the coefficient of absorption having major impact on algorithm convergence speed, β_o is the attractiveness of the source or attractiveness at $d_{ij} = 0$ level, d_{ij} is the distance between the two neighboring fireflies (X_i and X_j), N denotes number of dimensions, r is ongoing round number, α is random movement coefficient, ε denotes the random number for random movement lying between [0, 1], k is k^{th}individual round number, R_{max} is the maximum number of rounds, m is random number and β_{opt} is the optimal adaptive attractiveness of fireflies.

b. Proposed Adaptive Hybrid Dragonfly Firefly (AHDF) Algorithm

The novel adaptive hybrid dragonfly firefly algorithm is proposed here in order to perform optimized cluster head selection. The hybrid scheme takes away the drawbacks of slow convergence of conventional dragonfly and conventional firefly schemes and hence enabling the enhanced optimization during cluster head selection in together with faster convergence. The basic flowchart for the proposed AHDF scheme is presented in Fig.1 while embedding the concept of adaptive firefly algorithm within dragonfly scheme. To be more precise, when there is no immediate neighborhood available for dragonfly, the position update should work as per conventional dragonfly position update equation (28) as discussed. But in this hybrid scheme, in same scenarios the position update is carried out as per adaptive firefly position update equation (34). The optimized cluster head selection is performed as per following steps –

Step-1: Deploy all the sensor nodes randomly.

Step-2: Construct the clusters and perform initial cluster head selection

Step-3: Evaluate the cluster head selection fitness function based on energy, distance, load and delay

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as per discussed in section-III.

Step-4: Update the cluster head based on evaluated fitness function.

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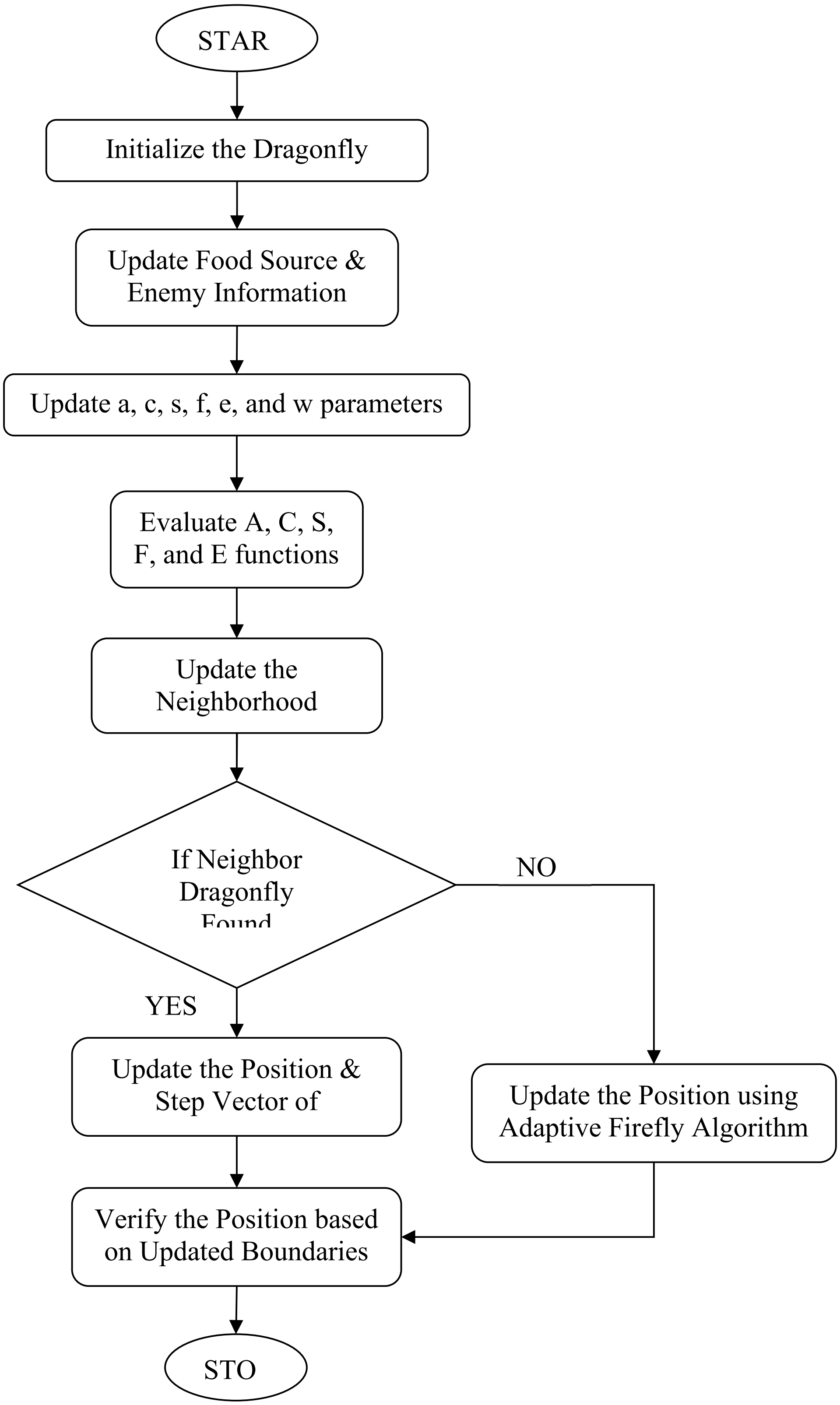

Fig.1. Basic Flowchart for the Proposed AHDF Scheme

4. RESULT AND ANALYSIS

The implementation and simulation for the proposed research work has been performed using MATLAB (MATrix LABoratory) R2015a software by means of MATLAB coding. The common

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network design and simulation oriented parameters utilized during the proposed research work are listed in Table-I. For simplicity, total number of 100 sensor nodes was deployed in 100 x 100 m^2 area randomly. Moreover, the sink node or base station (BS) can be located capriciously anywhere. With the intention of maintaining generalization and simplification, author has assigned base station at the heart or center of the designed wireless sensor network area. The proposed AHDF scheme has been compared with routing schemes presented in SEELCA [15] and CRCGA [16]. A variety of network performance parameters for example data throughput, residual energy, consumed energy, number of alive nodes and dead nodes etc. have been estimated for comparison. Number of dead nodes is evaluated as the number of current state alive nodes subtracted from the total number of deployed sensor nodes originally. Residual energy is the total consumed energy subtracted from the total initial energy of the network. The data throughput is evaluated as the total number of data packets received at corresponding base station effectively divided by the total number of data packets actually got transmitted from individual sensor node.

TABLE-I. Network Parameters used for Simulation

Parameter	**Value**
Area of Network	100m x 100m
Number of Deployed Sensor Nodes	100
Initial Energy of Individual Node	0.5 J
Energy Dissipation during Transmission Phase	50nJ/bit
Energy Dissipation during Reception Phase	50nJ/bit
Data Aggregation Energy	5nJ/bit/message
Amplification factor for Free Space (α_{fs})	10pJ/bit/m^2
Amplification factor for Multi-path (α_{mp})	0.0013pJ/bit/m^4
Data Packet Size	4000 Bits
Maximum Number of Rounds	5000

The network simulation results for proposed work in together with comparison as number of alive nodes, number of dead nodes, network residual energy, network energy dissipated and data throughput are as shown in Fig.2 - Fig.6 respectively. Furthermore, the comparison has also been presented in form of bar chart for better visualization has been presented in Fig.7 – Fig.11. This comparative analysis clearly showcases the superiority of the proposed Adaptive Hybrid Dragonfly Firefly (AHDF) algorithm with respect to various network performance parameters by reasonable margins.

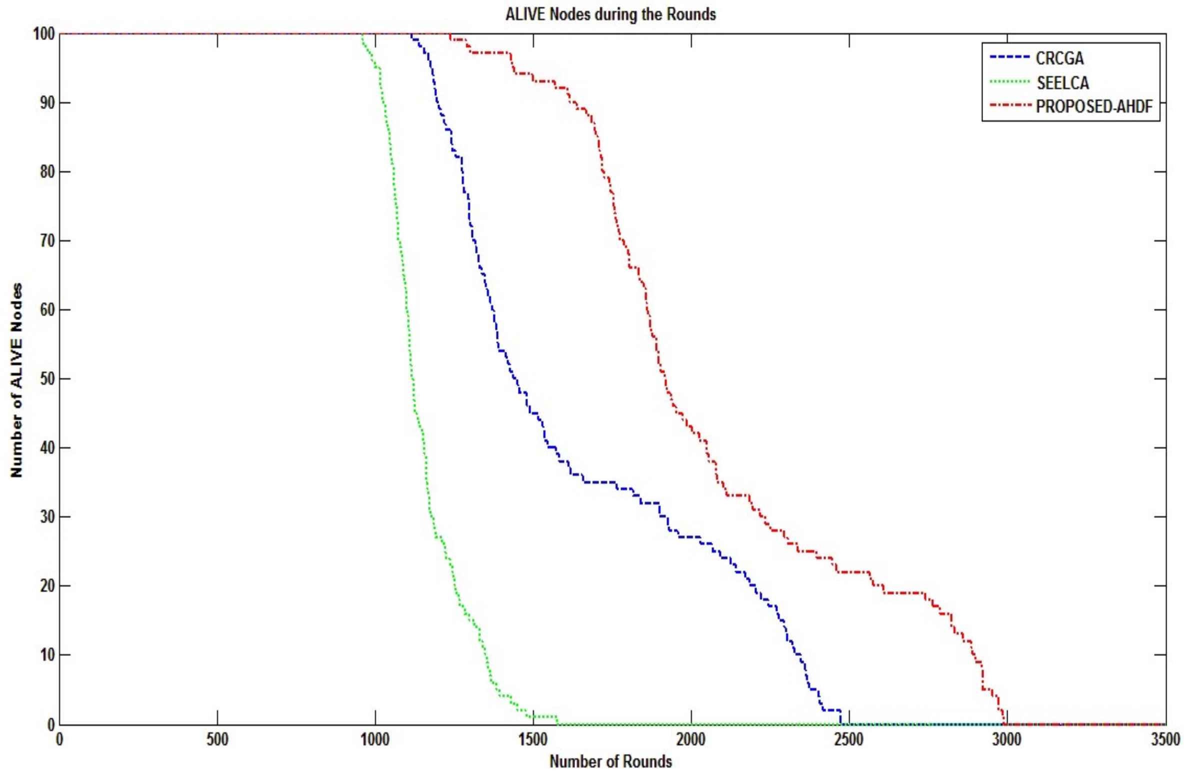

Fig.2 – Number of Alive Nodes during Each Round

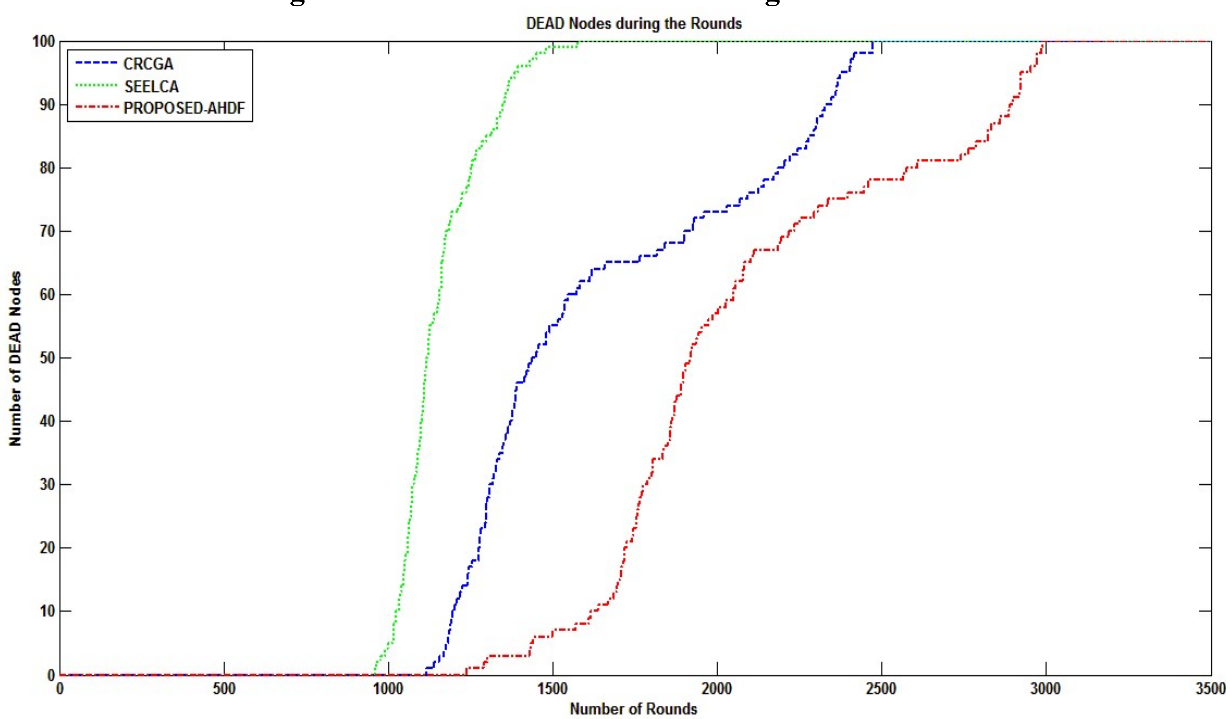

Fig.3 – Number of Dead Nodes during Each Round

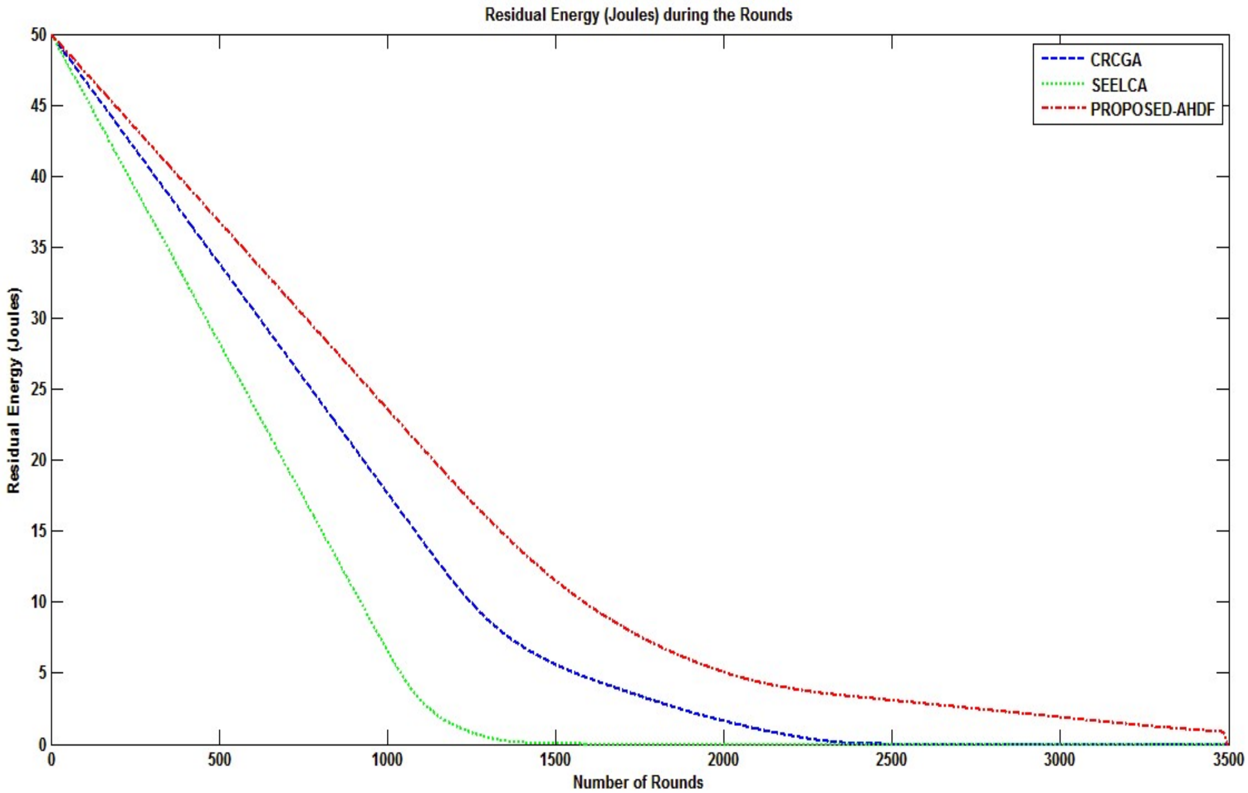

Fig.4 – Residual Energy during Each Round

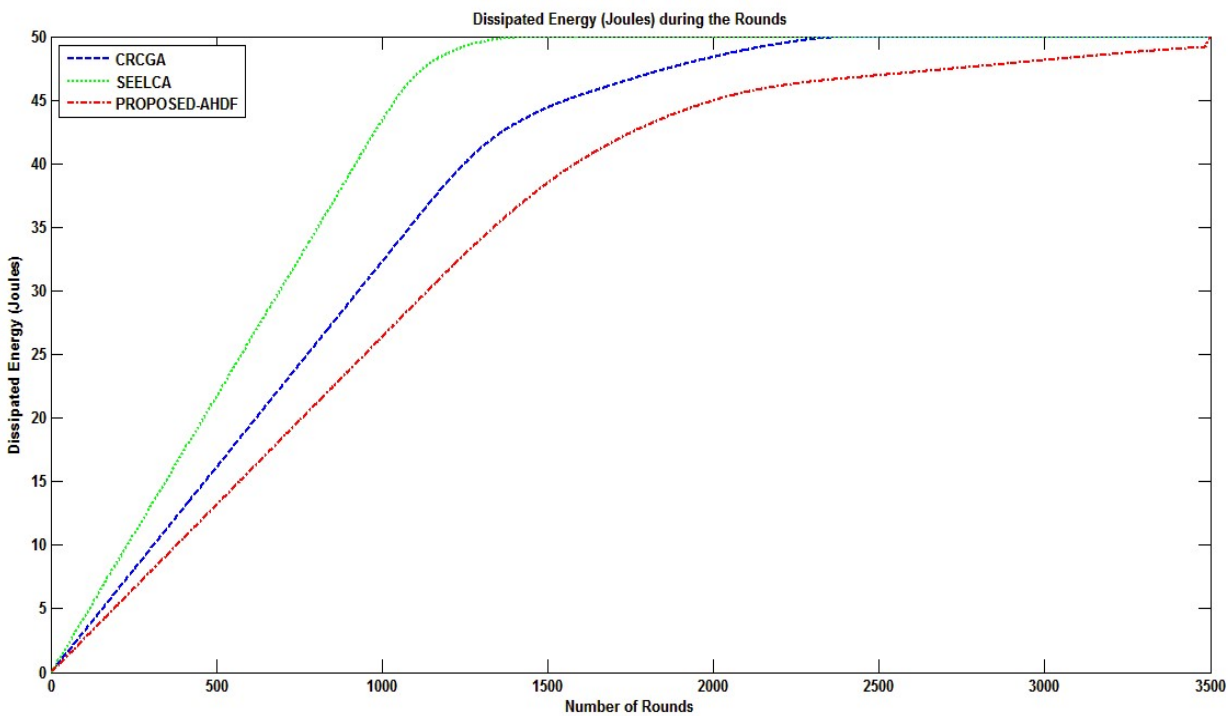

Fig.5 – Dissipated Energy during Each Round

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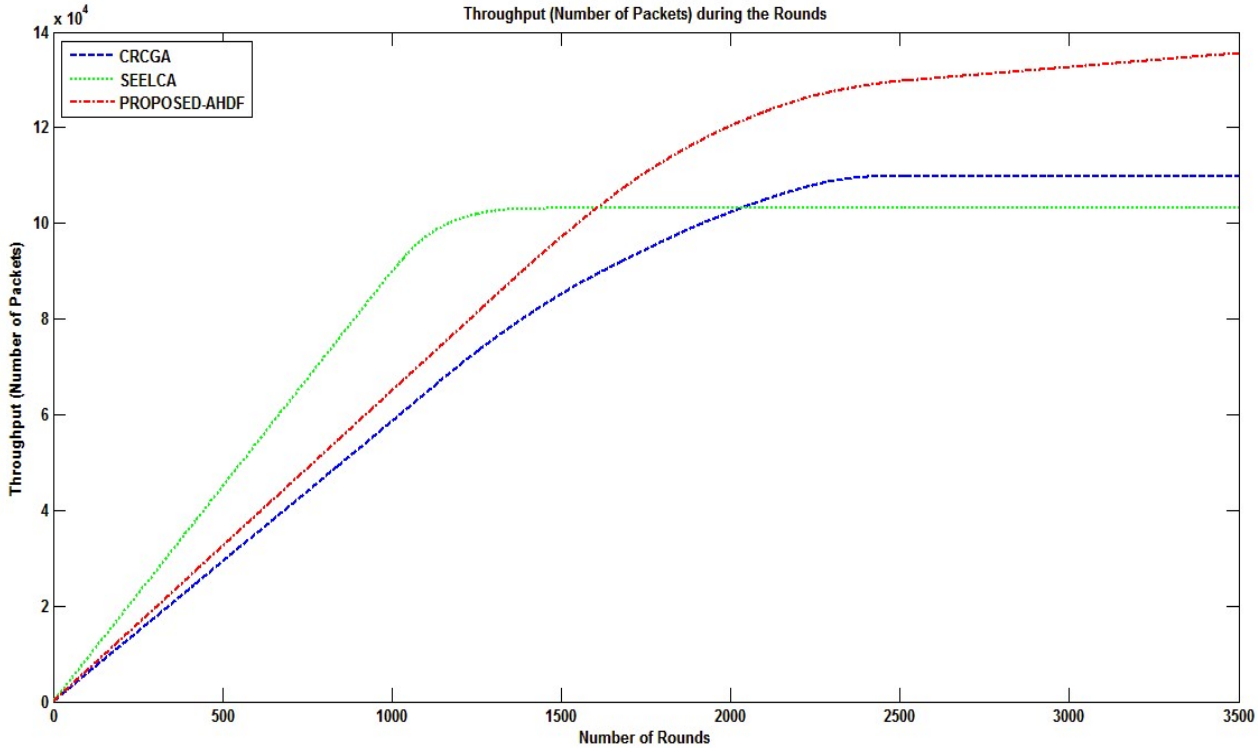

Fig.6 – Data Throughput during Each Round

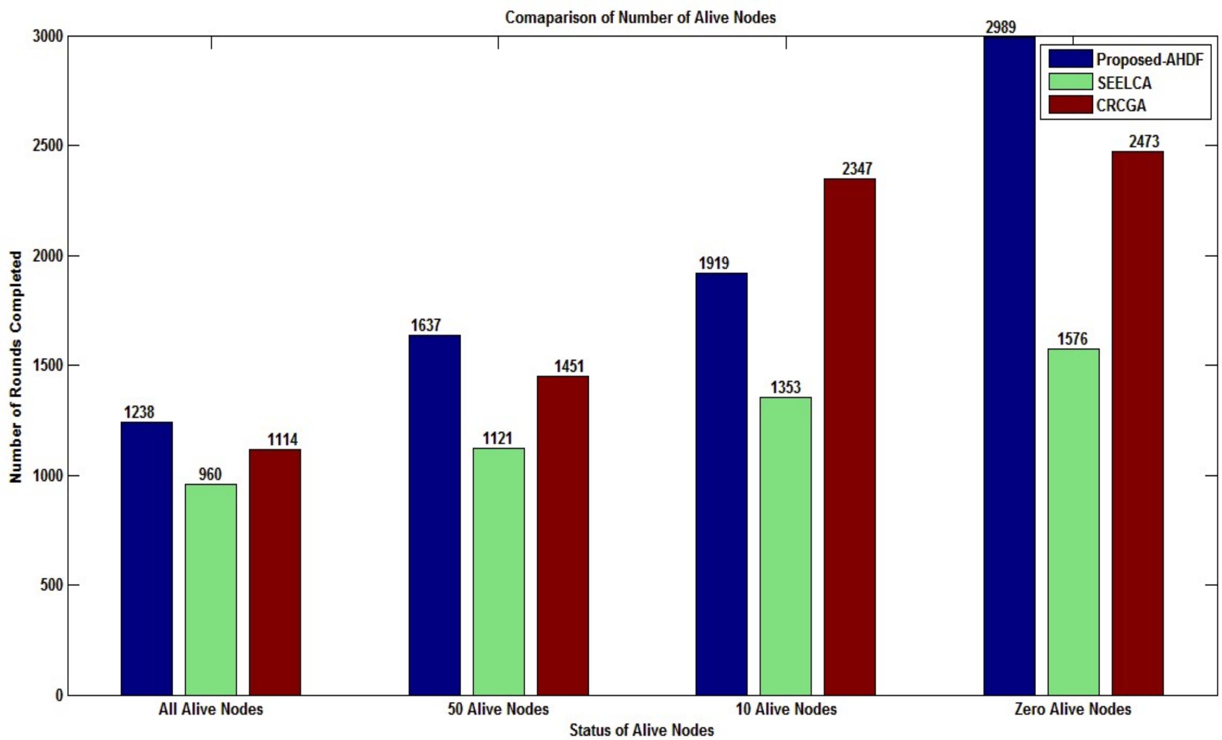

Fig.7 – Comparison of Number of Alive Nodes

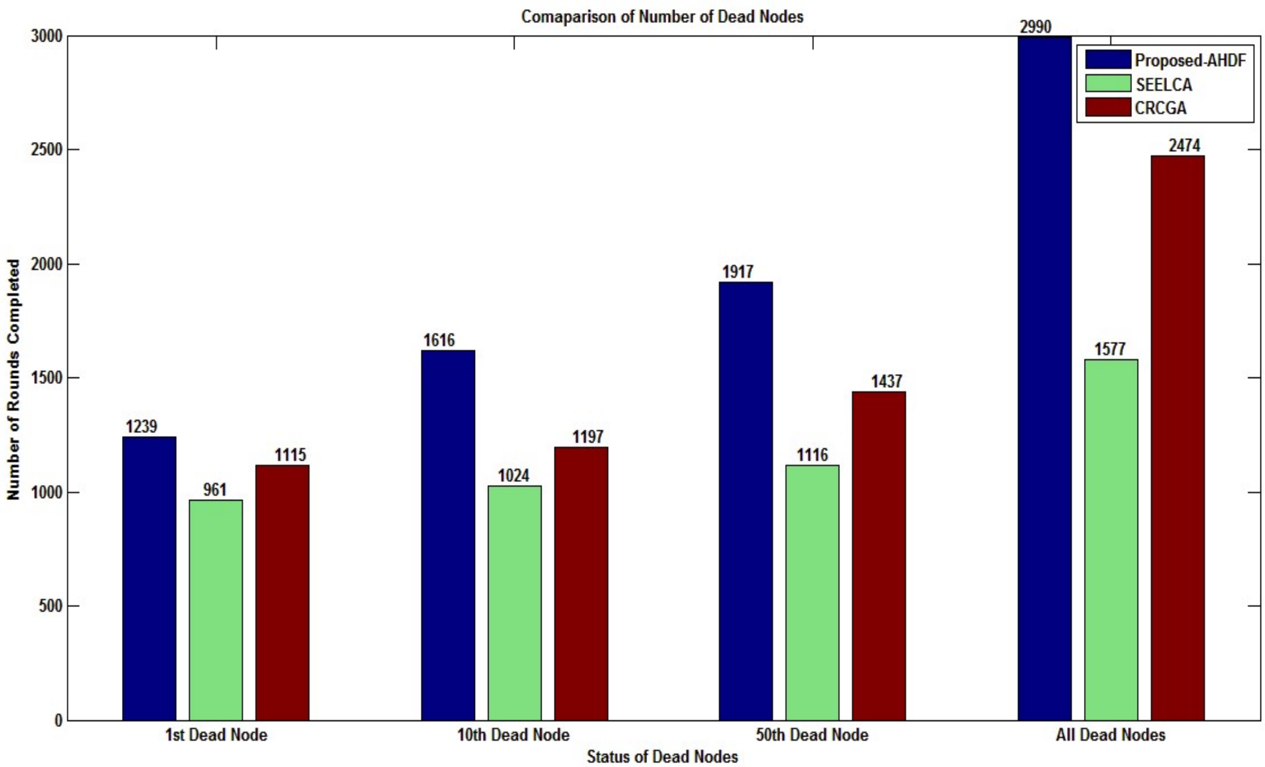

Fig.8 – Comparison of Number of Dead Nodes

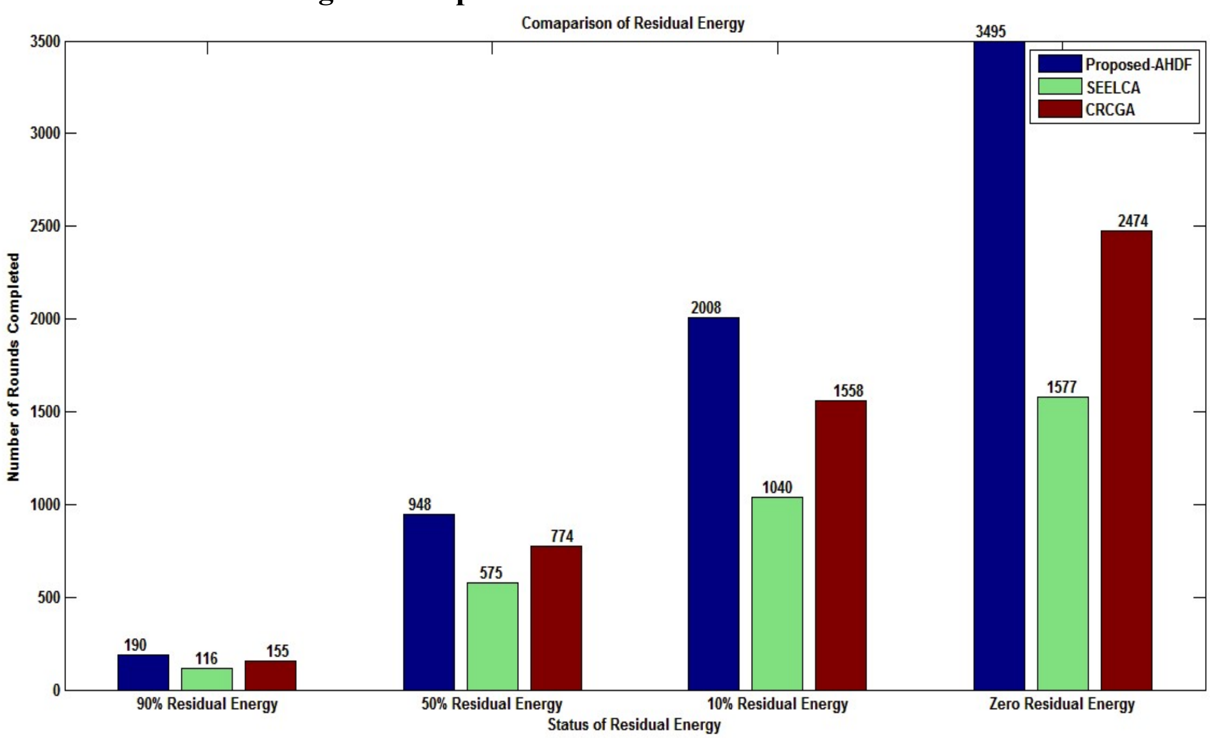

Fig.9– Comparison of Residual Energy

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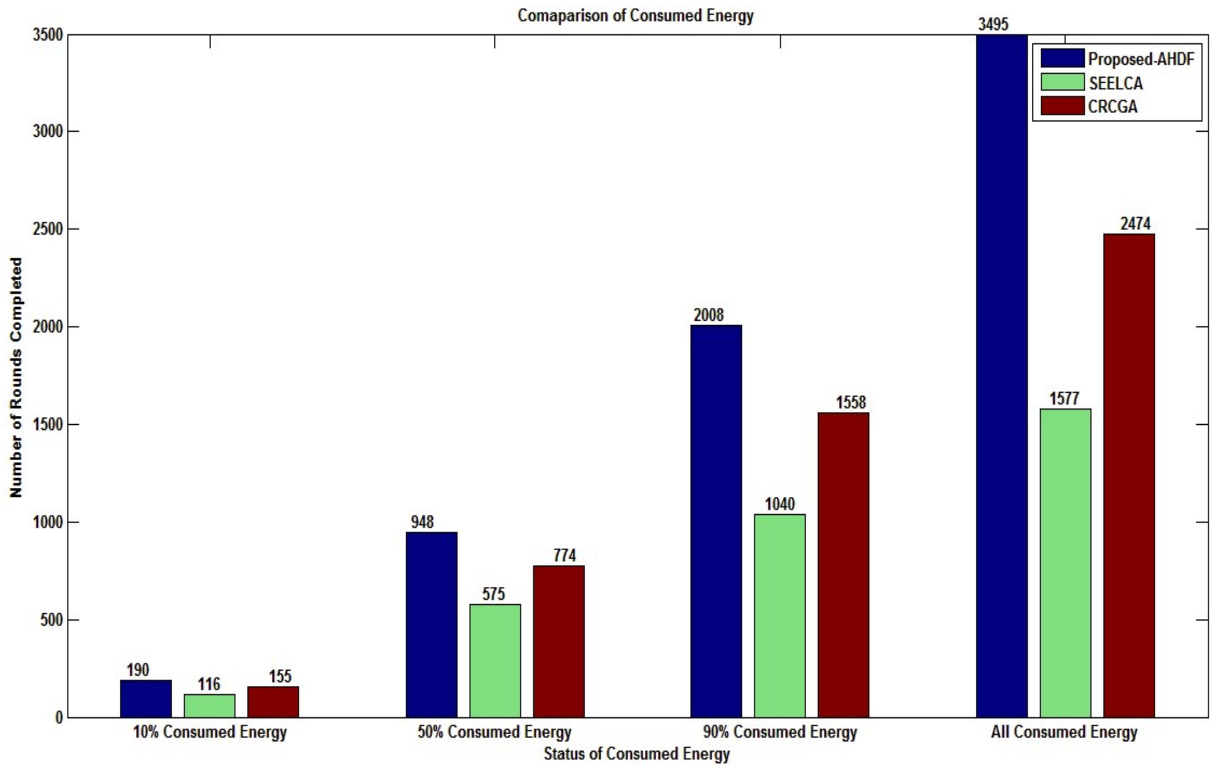

Fig.10 – Comparison of Dissipated Energy

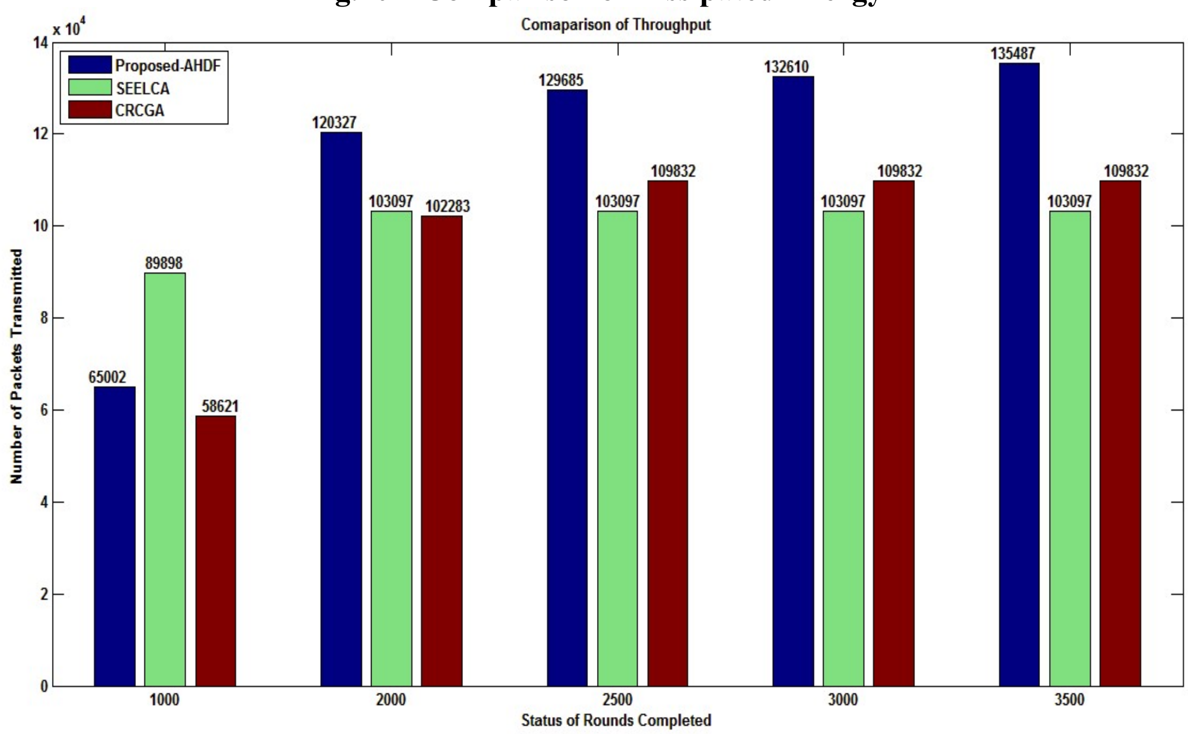

Fig.11 – Comparison of Data Throughput

5. CONCLUSION

A novel and optimized cluster head selection scheme based on Adaptive Hybrid Dragonfly Firefly (AHDF) methodology has been presented here. The cluster head selection is majorly based on node energy, corresponding distance and network load and delay parameters. The hybrid scheme helps to achieve the faster convergence here while optimizing most of the corresponding network

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performance parameters such as network residual energy and dissipation energy, number of alive nodes and dead nodes, data throughput etc. The simulation and comparison results demonstrate the dominance of the proposed routing scheme with respect to network residual energy, data throughput and network lifetime in comparison of latest existing algorithms.

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