Hybrid Jellyfish Beluga Whale Optimization for Energy Efficient Inter and Intra Cluster based Routing Algorithm for WSN

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Abstract

Clustering is an effective ways to improve energy efficiency by lowering or regulating the energy usage amongst sensor nodes (SNs). The nodes that are closest to the cluster's center are typically selected to serve as Cluster Heads (CH) in earlier cluster-based schemes. Additionally, Member Nodes (MNs) experience uneven energy usage because direct data transfer is typically used for intra-cluster routing when MNs and CH need to communicate. As a result, nodes located further away from CH use more energy to send their data packets than nodes located closer to CH. This unbalanced depletion of energy of MNs causes coverage gaps to emerge and shortens the coverage time. The time, while the initial MN is depleted is known as coverage time, which resulted in partial coverage of the sensing area. This work develops a new Energy aware Clustering framework. The model includes the phases like: Optimal Clustering, Routing and Data Aggregation. Optimal Clustering is the initial phase, where, new Jelly Customized Beluga Whale optimization algorithm (JC-BWOA) is introduced to perform clustering process on considering Delay, Energy, Trust, Intra and Inter Cluster distance. Optimal routing is done via JC-BWOA algorithm on considering link quality and distance.

Keywords: WSN, Optimal Clustering; Routing;Coverage time; JC-BWOAOptimization.

1. Introduction

The Multiple SNs with finite and non-rechargeable energy sources typically make up a WSN [1][2] [3]. The network's SNs [4] [5] were connected to one another for collecting data from the surroundings and transmit it to BS, a specific location. These nodes had limited processing Energy & Environmental Science Page 4 of 32 capacity and power supply batteries [6] [5] [7].The primary responsibility of nodes was to produce various kinds of data and send them via multi or single hop data transmit methods to the sink node. The SNs quickly run out of vitality because they have few supplies. EE was the term used to describe the idea that these elements must be maintained functioning for as long as possible [8] [4] [2]. There were several ways to accomplish EE, including by developing more effective node distribution strategies, data aggregation plans, and creating efficient transport protocols [9] [10] [11]. Each node uses some quantity of energy while processing, detecting, getting, and sending data. Data transfer uses more energy overall than other activities. The most effective method for regulating data transfers was to use cluster-based routing methods [9] [12] [13]. The data had been sent between the servers via multiple steps. Additionally, for transmitting large data loads, nodes close to the sink would deplete their batteries much more rapidly than other nodes [7] [14] [15]. Battery electricity is used by each sensor component for data transmission, computing, and sensing. Since the batteries were the only source of power for the nodes, it was crucial to extend its lifespan and reduce the amount of energy that the sensors used to carry out different network functions [16] [17]. The devices that were used for data transmission used the most energy. As a result, energy aware routing in WSN was significant to improve the lifetime of network [6] [18] [19]. DRL is growing in popularity as it incorporates the benefits of DNNs and RL, [20] [21] [22]. Recently, DRL was used to model complicate IoT system, including flood modeling, application-oriented scheduling for maximizing information freshness, interior air quality monitoring, and resource management [23] [24] [25]. Numerous clustering methods, such as LEACH-M, LEACH, MBC, CRPD, and MODLEACH, and others, were developed to increase network lifespan. They did, however, have drawbacks, including set clustering; insufficient CHS factors, static rounds, etc. Adaptive clustering approach was required to improve CHS and load balancing [12] [26].

The contributions are as follows:

- Introduces EEIICR model, where, optimal clustering is done via a new JC-BWOA optimization on considering Delay, Energy, Trust, Intra Cluster distance and Inter Cluster distance.
- Performs optimal routing via JC-BWOA algorithm on considering link quality and distance.

The review on EEIICR is given in section 2. The system model on EEIICR IN WSN is given in Section 3. Optimal routing and data aggregation via network coding is given in section 4 and 5. The result and conclusion is determined in section 6 and 7.

2. Literature Survey

Related works:

The EIR method was introduced by Niayesh Gharaeiet al. [27] in 2020 for balancing the energy usage of MN throughout a specific period that improved the coverage time. The optimum positions were chosen in the suggested scheme after the MS has arrived at a cluster, taking into account the allotted transit time, so that relocating the MS in those spots resulted in balancing energy usage among MNs. The EIR algorithm significantly improved the network efficiency on various performance assessment metrics, according to the simulation findings.

Anupkumar M. Bongale et al. [9] in 2022 introduced ICA method for WSNs. An energy aware intra cluster data consolidation route was built by ICA from source to its CH. When the message arrive the specific CH node, the packets of data were combined along the aggregation route by intermediary relay nodes. In order to compare the ICA, factors such as count of active nodes, energy usage, and the quantity of data bits attained by BS were taken into account. The results gathered demonstrated that the ICA algorithm outperformed the other protocols.

Y. M. Raghavendra et al. in 2021 [8] introduced latest model, which included the process of efficient clustering in addition to IC-GW. IC-GW relied on PSO-GA, also known as ICGW-PSOGA, when it comes to long distance transmission and the best location of SINKs in WSNs. The data would be collected from the CHs by this IC-GW and delivered to the SINK. For the purpose of determining the best configuration for the Gateway, the PSO-GA reliant estimation of position method and the SINK-reliant network structure had been developed.

A clustering method that chooses CHs using an enhanced ABC algorithm was suggested by Zongshan Wang et al. in 2020 [28]. The clustering issue in WSNs was then resolved by introducing the CH density, network CH energy, CH position, and other related variables into the enhanced ABC model, which depends upon extant ABC model. The enhanced ABC algorithm was used to maximize FCM clustering during the network initialization phase, when all nodes had an identical level of energy. For routing amongst CHs and the BS, they also suggested an energy aware routing method based on an enhanced ACO. They added a polling management method that utilized idle / busy nodes to intra-cluster interaction in the stable transmission phase to increase EE and further increase network performance.

An energy aware routing model by means of FL model was suggested in 2019 by Abhilasha Jain and Ashok Kumar Goel [6]. To create multi-hop paths to BS and for the intellectual selection of CHs, fuzzy decision and fuzzy sets procedures were introduced. The simulated findings demonstrated that FL model performed far better over others on throughput and network lifespan. For networks with a greater node density, the suggested protocol performed even better.

For IoT-enabled WSNs, Gagandeep Kaur et al. [29] suggested an intelligent routing strategy based on DRL in 2021 that would greatly decrease delay and lengthen lifetime of network. The recommended method splits the entire network into a variety of uneven groups based on the data burden that was currently present in the SN, greatly preventing network from failing in advance. To show the effectiveness of the suggested strategy, thorough test was done using ns3 regarding alive nodes, EE, delivery of packet, and transmission delay in the network.

A new energy aware protocol in WSNs for routing relying on the YSGA was suggested by Alma Rodrguez et al. [30] in 2020. The algorithm was designed to extend network lifespan by consuming less energy. The cluster layout of the network takes into account a BS and a compilation of CH. The suggested model decided the quantity of CHs and the choice of the finest CHs, and SNs were allotted to CH that was closest to them. To guarantee an ideal CH spread and shorten the distance, YSGA reconfigured the structure of cluster in network. In contrast to the existing protocols, experiments produced findings that have shown that the suggested routing protocol reduced energy consumption, increases lifespan, and extends the stable period of the network.

To address the energy and security issues associated with intra-cluster data communication, Anxi Wang et al. [4] in 2019 suggested a novel EEICS for WSNs. Three essential

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components make up the given scheme: novel multi hop route election model for selecting an appropriate relay node for forwarding data to CH, a secured communiqué method for preserving the confidentiality of source node, and an additional layer model, which facilitates self-organization of localized nodes. In the system, the remaining energy of SNs was considered, particularly when choosing the gateway node.

Review

The decrease of energy usage is the main obstacle in a sensor network with limited energy. Nodes use more energy when they are active and when switching between active and dormant states. The difficulty is that nodes should be allowed to sleep for as long as they can, without compromising network efficiency due to packet loss while they remain in sleep. Lower leftover energy nodes could disrupt links. For instance, cluster leaders may use more energy while managing more traffic in a grouped network structure, leaving less energy in reserve. Energy efficient hybrid routing methods have not been put into practice in the real world; therefore additional studies could be done in this field. The majority of the currently used energy efficient routing methods have undergone simulation-based evaluation. It is crucial to evaluate the open problems and efficiency improvements made by the suggested schemes in reality. The efficacy of the suggested methods on the network may be impacted by environmental factors like hardware limitations. Table 1 shows the Review on extant EEIICR schemes in WSN.

Table 1: Review on extant EEIICR schemes in WSN

Author	Adopted scheme	Features	Challenges
(Gharaei et al. 2019)	EIR algorithm	➢ Energy consumed was extremely low and higher coverage duration	➢ It is necessary to improve the network lifetime
(Bongale et al. 2020)	Data aggregation technique	➢ Improved the energy efficiency of the network	➢ Need to assess the proposed model by rising the node count in network
(Bouakkaz and Derdour 2021)	ICGW-PSOGA	➢ Very low amount of energy was consumed and the throughput, network lifetime was improved	➢ The performance was not effective
(Wang et al. 2020)	Improved ABC algorithm	➢ Network life time and throughput had maximized	➢ It is necessary toexpand the study on energy aware protocols
(Jain and Goel 2020)	EEFRP	➢ Higher network lifetime and throughput is acquired	➢ Need to extend the work by summing the trust value to make the method appropriate for secured network.
(Kaur et al. 2021)	DRL scheme	➢ Energy consumed was very low as well as the alive nodes get increased	➢ Need to enhance the reliability of the proposed method with a fault tolerance mechanism.
(Rodríguez et al. 2020)	YSGA	➢ It reduced the transmission distance	➢ Need to enhance the data aggregation schemes to achieve higher energy conservations and network lifetime in WSN
(Wang et al. 2019)	EEICS	➢ Minimal energy was consumed	➢ It is required to carry out well regarding data packets attained at BS.

3. SYSTEM MODEL OF EEIICR

The EEIICR includes BS and T SNs. The SNs are represented by a set $T = T_1, T_2, \ldots T_m$. These SNs were sorted in clusters, and each cluster contains MNs and CH. It is believed that T uniform sensors are distributed uniformly all through the network area. The below assumptions are considered during the performance assessment phase of EEIICR scheme (Gharaei et al. 2019):

In EIR, static and mobile sinks are employed, which reduces data delivery delay and boosts PDR.

ii. Sinks are high-resource gadgets that include a GPS unit.

iii. Each connection channel has enough capability to send data packets over it.

iv. It is not needed to take account of energy utilization as every node generate data at the same rate and the energy lost during data gathering is evenly distributed amongst every node.

v. MNs use direct data transfer to send sensory data to the CH or MS.

vi. Due to the fact that they all offer the similar services, employ the similar wireless technologies, and are tethered to the similar backbone network, all nodes are identical.

vii. This system concerns on outdoor field and flat network, where there were no impediments among SNs.

The recommended EEIICR scheme in WSN is exposed in Fig. 1.

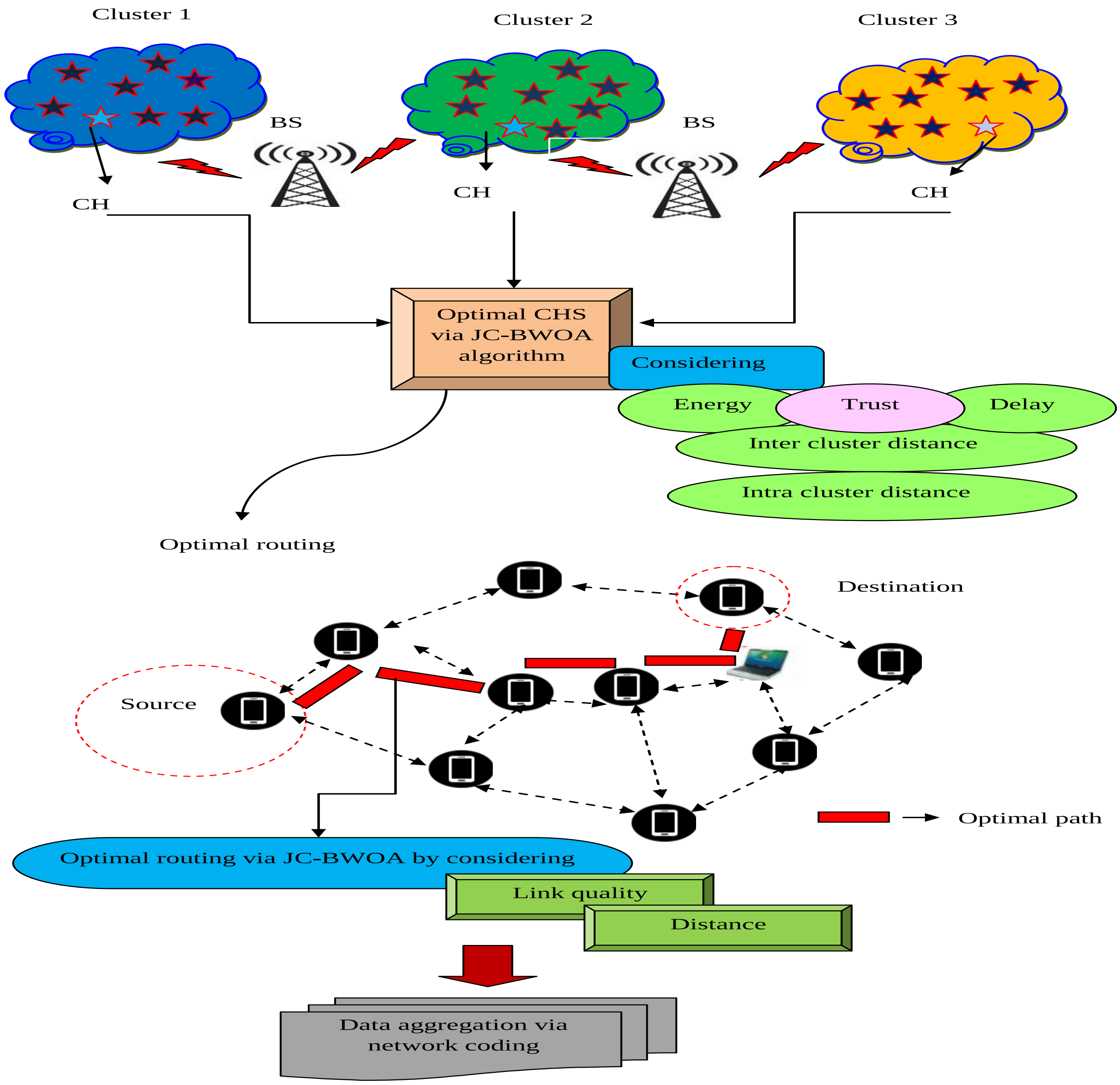

Fig.1. Diagramatic depiction of EEIICR in WSN model

3.1 Optimal CHS via JC-BWOA Optimization

This work chooses optimal CH by means of JC-BWOA. Eq. (1) shows the objective for CHS, which indicates that trust and energy are needed to be higher, whereas, the intra and inter cluster distances and delay should be diminutive. In Eq.

(1), the summing up of weights ω_1 - ω_4 is 1, i.e. $\sum \omega_i = 1$.

$$Fit = Min\left[\omega_1 * Dl + \omega_2 * (1-E) + \omega_3 * (1-Tr) + \omega_4 * IAD + \omega_5 * ICD\right] \quad (1)$$

3.2 Energy Model

It is evaluated using the mean of residual energy of CH as exposed in Eq. (2), wherein, (En_{CH}) represents to residual energy of CH.

$$E = Mean\left(En_{CH}\right) \quad (2)$$

3.3 Intra cluster Distance

The distance of all nodes in the cluster to CH is known as total CH (Pal et al. 2012).

$$IAD = \sum_{i=1}^{i=T} Dt(i, CH) \quad (3)$$

Here, $Dt(i,CH)$ refers to distance of a node to CH and T refers to count of nodes in a cluster.

3.4 Inter cluster Distance

The distance among the respective CHs of clusters is known as Inter cluster Distance (Khan et al. 2012). In Eq. (4), k implies cluster count, y_i and y_j implies cluster centre.

$$ICD = Min\left(\left\|y_i - y_j\right\|\right)^2 \quad (4)$$

Here, $i = 1, 2 \ldots k-1$ and $j = i+1, \ldots.k$.

3.5 Delay

Delay is exposed in Eq. (5), in which, Dt indicate distance of node and sink and Sp symbolize speed of 2.1×10^8 meters.

$$Dl = \frac{Dt}{Sp} \quad (5)$$

3.6 Trust

The trust value is evaluated for the chosen CH. There are 2 kinds of trust, such as, Direct and Indirect trust

Direct trust: It is modelled as in Eq. (6), wherein, Er points out residual energy of node Z, $d(Y,Z)$ implies difference in distance among node Y and Z.

$$DT_{(Y-Z)} = \frac{Er}{d(Y,Z)} \quad (6)$$

Indirect trust: It is the quantity of trust value computed by another node. It is modelled in Eq. (7).

$$IDT_{(Y-Z)} = \sum DT_{(Y-H)} * DT_{(H-Z)} \quad (7)$$

Trust is modelled depending upon IDT and DT.

$$Tr_{(Y-Z)} = w * DT_{(Y-H)} + (1-w) IDT_{(Y-Z)} \quad (8)$$

Here, $w = 0.5$ implies weight linked with trust of the node.

This study chooses CH optimally via a new JC-BWOA algorithm.

4. Optimal Routing via JC-BWOA Algorithm

After electing CH optimally, clustering is done, and the nodes are allocated to the suitable clusters. Subsequent to cluster formation, routing is done to transmit data from the source to CH via BS. The routing is done depending upon

1. Link quality
2. Distance

4.1 Objective Function

The objective for optimal routing is specified in Eq. (9) based upon the link quality and distance. Here, $\sum \omega_i = 1$.

$$Fit = Min\left[\omega_1 * Dt + \omega_2 * (1-LQ)\right] \quad (9)$$

4.2 Link quality

The quality of the data packets the receiver has received is represented by the LQI https://www.sciencedirect.com/topics/engineering/link-quality.

4.3 Distance

The distance amongst destination and source is found by means of Euclidean distance as in Eq. (10).

$$Dt_{ixy} = \sqrt{(z_2 - z_1)^2 + (x_2 - x_1)^2} \quad (10)$$

In Eq. (10), the coordinates of node is signified as (z_1, x_1) and the coordinates of MS is signified as (z_2, x_2). Here, the distance is modelled as in Eq. (11).

$$Dt = Sum\left(Dt_{ixy}\right) \quad (11)$$

4.4 JC-BWOA Algorithm: Mathematical Modelling

Solution encoding: The nodes are provided to JC-BWOA as input to facilitate the best CHS. Additionally, JC-BWOA is used for optimum routing. This work (Devagnanam and Elango 2020) develops a combined form of JFO (Chou and Truong 2021) and BWO (Zhong et al. 2022) that helps obtain the best CHS.

Beluga whale behaviors like foraging, gliding, and whale falls are imitated by the JC-BWOA algorithm. Due to the JC-BWOA populace, beluga whales are considered as search agents, and each whale is considered as feasible solution throughout the optimization method. Eq. (12) demonstrates the matrix of search agent position.

$$X = \begin{bmatrix} x_{1,1} & x_{1,2} & \ldots.. x_{1,d} \\ . & & \\ . & & \\ . & & \\ x_{n,1} & x_{n,2} & \ldots.. x_{n,d} \end{bmatrix} \quad (12)$$

The corresponding fitness values of beluga whales are exposed in Eq. (13). The JC-BWOA method moves from the exploration phase to exploitation phase by concerning on the balance factor B_f that lies amongst (0, 1) and is explained as in Eq. (14), wherein, T and $T_{\max}$ implies current and maximal iteration.

$$F_X = \begin{bmatrix} f(x_{1,1}, x_{1,2}, \ldots x_{1,d}) \\ . \\ . \\ f(x_{n,1}, x_{n,2}, \ldots x_{n,d}) \end{bmatrix} \tag{13}$$

$$B_f = B_0(1 - T/2T_{\max}) \tag{14}$$

Exploration: The swimming of Beluga whales is concerned for establishing the JC-BWOA exploration phase. The positions of beluga whale are updated in the same way as in Eq. (15), in which, $X_{i,j}^{T+1}$ implies novel position on j^{th} dimension for i^{th} beluga whale, $X_{r,p1}^{T}$ and $X_{i,pj}^{T}$ implies present position for i^{th} and r^{th} beluga whale, $r_1, r_2 \in (0,1)$ implies arbitrary integer.

$$\begin{cases} X_{i,j}^{T+1} = X_{i,pj}^{T} + \left(X_{r,p1}^{T} - X_{i,pj}^{T}\right)(1+r_1)\sin(2\pi r_2), & j = even \\ X_{i,j}^{T+1} = X_{i,pj}^{T} + \left(X_{r,p1}^{T} - X_{i,pj}^{T}\right)(1+r_1)\cos(2\pi r_2), & j = odd \end{cases} \tag{15}$$

Proposed Exploitation: The mathematical form of exploitative stage of JC-BWOA is depicted as in Eq. (16), wherein, LF implies Levy flight that is provided in Eq. (28), wherein u, v implies arbitrary integers, and $\beta = 1.5$ points out default constant. This is based on the assumption that they could employ the LF method to catch their prey.

$$X_i^{T+1} = r_3 X_{best}^{T} - r_4 X_i^{T} + C_1 \times LF \times \left(X_r^{T} - X_i^{T}\right) \tag{16}$$

As per JC-BWOA, X_i^T in Eq. (16) is determined using the JFO update. The JFO update is given in Eq. (17), in which, $L_i(it)$ signifies jellyfish position, lb and ub signifies lower and higher limits.

$$L_i(it+1) = L_i(it) + \gamma \times ra(0,1) \times (ub - lb) \tag{17}$$

From Eq. (17), find $L_i(it)$ as in Eq. (20).

$$L_i(it) + \gamma \times ra(0,1) \times (ub - lb) = L_i(it+1) \tag{18}$$

$$L_i(it) + \gamma \times ra(0,1) \times ub - \gamma \times ra(0,1) \times lb = L_i(it+1) \tag{19}$$

$$L_i(it) = L_i(it+1) - \gamma \times ra(0,1) \times ub + \gamma \times ra(0,1) \times lb \tag{20}$$

Consider $L_i(it)$ as X_i^T and $L_i(it+1)$ as X_i^{T+1}, i.e.

$$X_i^T = X_i^{T+1} - \gamma \times ra(0,1) \times ub + \gamma \times ra(0,1) \times lb \tag{21}$$

On substituting X_i^T in Eq. (16), we get Eq. (26).

$$\begin{aligned} X_i^{T+1} &= r_3 X_{best}^{T} - r_4 \left[X_i^{T+1} - \gamma \times ra(0,1) \times ub + \gamma \times ra(0,1) \times lb \right] \\ &+ C_1 \times LF \times \left(X_r^{T} - \left[X_i^{T+1} - \gamma \times ra(0,1) \times ub + \gamma \times ra(0,1) \times lb \right] \right) \end{aligned} \tag{22}$$

$$\begin{aligned} X_i^{T+1} &= r_3 X_{best}^{T} - r_4 X_i^{T+1} + r_4 \times \gamma \times ra(0,1) \times ub - r_4 \times \gamma \times ra(0,1) \times lb \\ &+ C_1 \times LF \times \gamma \times ra(0,1) \times ub - C_1 \times LF \times \gamma \times ra(0,1) \times lb \end{aligned} \tag{23}$$

$$\begin{aligned} X_i^{T+1}\left[1 - r_4 + C_1 \times LF\right] &= r_3 X_{best}^{T} + r_4 \times \gamma \times ra(0,1) \times ub - r_4 \times \gamma \times ra(0,1) \times lb \\ &+ C_1 \times LF.X_r^{T} + C_1 \times LF \times \gamma \times ra(0,1) \times ub - C_1 \times LF \times \gamma \times ra(0,1) \times lb \end{aligned} \tag{24}$$

$$X_i^{T+1} = \frac{\begin{bmatrix} r_3 X_{best}^{T} + r_4 \times \gamma \times ra(0,1) \times ub - r_4 \times \gamma \times ra(0,1) \times lb \\ + C_1 \times LF.X_r^{T} + C_1 \times LF \times \gamma \times ra(0,1) \times ub - C_1 \times LF \times \gamma \times ra(0,1) \times lb \end{bmatrix}}{\left[1 - r_4 + C_1 \times LF\right]} \tag{25}$$

$$X_i^{T+1} = \frac{\begin{bmatrix} r_3 X_{best}^{T} + r_4 \times \gamma \times ra(0,1)\left[ub - lb\right] + \\ + C_1 \times LF.X_r^{T} + C_1 \times LF \times \gamma \times ra(0,1)\left[ub - lb\right] \end{bmatrix}}{\left[1 - r_4 + C_1 \times LF\right]} \tag{26}$$

Here,

$$C_1 = 2r_4\left(1 - {T}/{T_{\max}}\right) \tag{27}$$

$$LF = 0.05 \times \frac{u \times \sigma}{|v|^{1/\beta}}; \ \sigma = \left[\frac{\Gamma(1+\beta) \times \sin\left({\pi\beta}/{2}\right)}{\Gamma\left[\frac{(1+\beta)}{2}\right] \times \beta \times 2^{(\beta-1)/2}} \right]^{\beta/2} \tag{28}$$

Whale fall: The beluga whales are probably in the ocean's deep because they relocated or were shot at. To determine the updated position given by Eq. (35) where X_{step} refers to step size of whale fall, $r_5, r_6 r_7$ lies between 0 and 1, C_2 refers to step factor that is illustrated in Eq. (37). The probability (W_f) is assessed as shown in Eq. (38).

$$X_i^{T+1} = r_5 X_i^{T} - r_6 X_r^{T} + r_7 X_{step} \tag{29}$$

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Here,

$$X_{step} = (ub - lb)\exp(-C_2 T/T_{\max}) \tag{30}$$

$$C_2 = 2W_f \times n \tag{31}$$

$$W_f = 0.1 - 0.05T/T_{\max} \tag{32}$$

Algorithm 1: Proposed JC-BWOA
Initializing population T and compute fitness and get finest solution
while $T \le T_{\max}$ do
Accomplish W_f and B_f
for X_i (every whale) do
if $B_f(i) \succ 0.5$
Calculate the dimension arbitrarily $p_j(j = 1,2,...,d)$
Elect the whale randomly X_r
Update position of exploration phase as in Eq. (15)
else if $B_f(i) \le 0.5$
Update LF and C_1
Update position of proposed exploitation using JFO update as in Eq. (26)
end if
Search for novel position limit and calculate fitness
end for
for every X_i do
if $B_f(i) \le W_f$
Update C_2 (step factor)
Calculate X_{step}
Update whale fall position as in Eq. (29)
Search for novel position limit and calculate fitness
end if
end for
Get optimal solution (k^*)
$T = T + 1$
end while

5. Data Aggregation via Network Coding

Data Aggregation is performed via network coding scheme.

Network coding scheme (Wang et al. 2014): It is a network technology, where transferred data is encoded and decoded to boost throughput, decrease delay and to increase the robust of network. The received transmissions are decoded at their destinations. Network coding is alienated into 3 parts:

1. Source node encoding
2. Re-encoding at intermediate node
3. Decoding at receiver node

Network coding is expressed by Eq. (33).

$$(tg)^{-1} tgp = p \tag{33}$$

In Eq. (33), p refers to data matrix, g refers to generator matrix and t refers to transfer matrix. After deploying network coding, p experiences transforms for 3 times. Initially, gp refers to encoding at source node, subsequently, multiplying the resultant of gp by matrix t indicates the re-encoding function at intermediate nodes and at last, multiplying the resultant of $(t(gp))$ by matrix $(tg)^{-1}$ indicates the decoding function at receivers.

6. Results and Discussions

6.1 Simulation set up

The developed JC-BWOA based EEIICR in WSN was done in NS2. Here, analysis was done under varied rounds from 200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800 and 2000. Additionally, the JC-BWOA based EEIICR in WSN was examined for varied nodes from 100 to 300. The JC-BWOA based EEIICR in WSN was assessed over JFO, BWO, ACO, MFO, RHSO and WOA. The parameter set was specified in Table 2.

Table 2: Simulation Parameters

Parameters	**Values**
"Initial nodal energy	0.5J
Network area	100×100
Total node count	300 nodes
Energy dispersed per bit	100nJ/bit
Predetermined percentage of CH	0.05"

6.2 Analysis on Alive nodes

This section give explanation on EEIICR in WSN based on JC-BWOA over other schemes as JFO, BWO, ACO, MFO, RHSO and WOA on alive node. The CAN should be high for better transfer of data. The analysis on CAN is exposed in Fig. 2 for varied nodes from 100 to 300. In Fig. 2, the CAN is analysed for 2000 rounds. In case of 100 nodes, at beginning rounds, the CAN is high. That is, from 0 to 1600 rounds, the CAN is high, after 1600th round, the CAN is lessened and when the round is 1800, less CAN is obtained. From 1800th round, the CAN for JC-BWOA is around 24. The CAN using JFO is low around 15 for 100 nodes. In case of 200 nodes, the CAN is high at beginning rounds. That is, from 0 to 1700 rounds, the CAN is high, after 1700th round, the CAN is lessened and when the round is 1800, less CAN is obtained. From 1800th round, the CAN using WOA is low around 12 for 200 nodes. However, when evaluated over JFO, BWO, ACO, MFO, RHSO and WOA, the CAN for JC-BWOA is high around 30. Similarly, for 300 nodes, the CAN is high using JC-BWOA over JFO, BWO, ACO, MFO, RHSO and WOA. The CAN for proposed work is better as the suggested EEIICR in WSN model uses JC-BWOA to carry out CHS. In addition, optimal routing guarantees the high CAN during transmission.

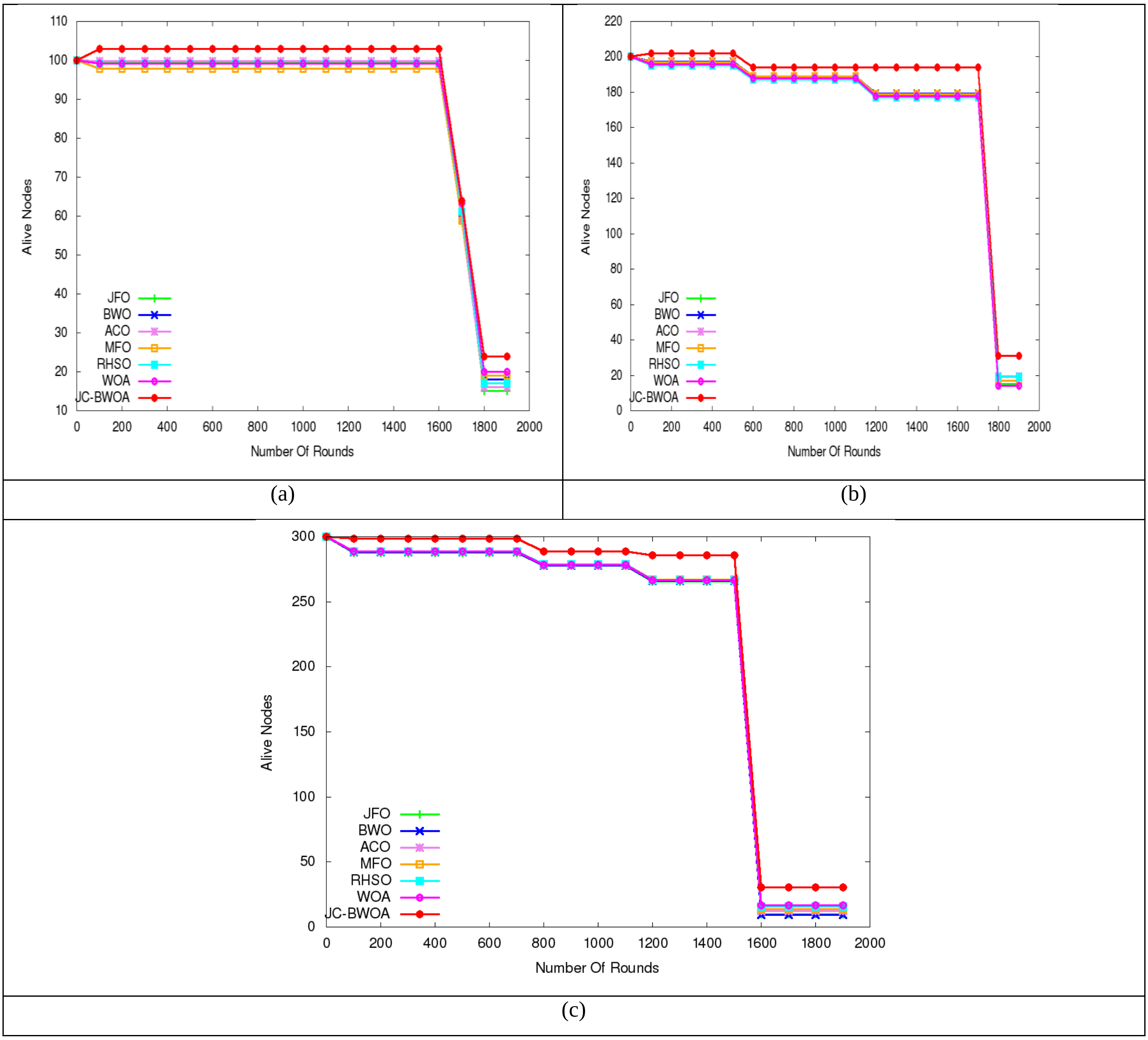
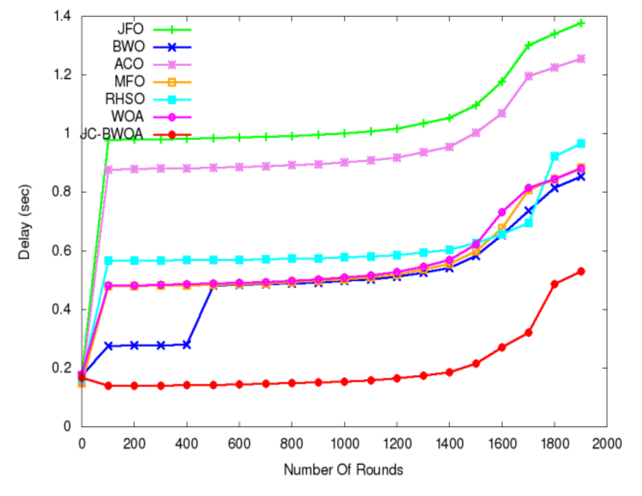


Fig.2. Alive node analysis for EEIICR in WSN for nodes (a) 100 (b) 200 and (c) 300

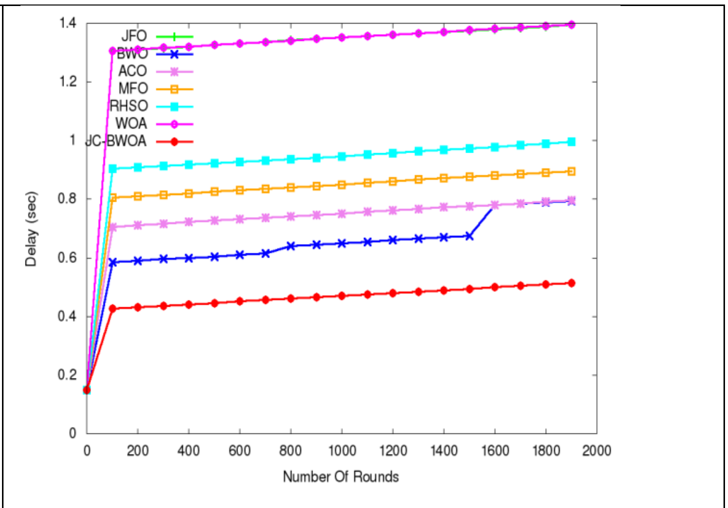
6.3 Analysis on Delay

The description on EEIICR in WSN based on JC-BWOA over other schemes as JFO, BWO, ACO, MFO, RHSO and WOA on delay is given here. The delay should be less for faster transfer of data. The analysis on delay is exposed in Fig. 3 for varied nodes from 100 to 300. In Fig. 3, the delay is analysed for 2000 rounds. In case of 100 nodes, at beginning rounds, the delay is less. That is, from 0 to 1200 rounds, the delay is less, after 1600th round, the delay is high and when the round is 1900, high delay is obtained. At 1900th round, the delay for JC-BWOA is around 0.55. The delay using JFO is high around 1.4 for 100 nodes at 1800th round. In case of 200 nodes, the delay is less at beginning rounds. That is, from 0 to 50 rounds, the delay is less, after 50th round, the delay is high and when the round is 1800, high delay is obtained. From 1800th round, the delay using

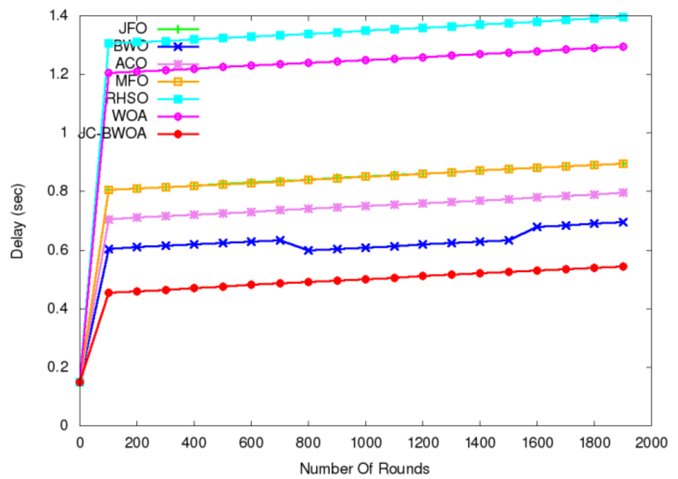
WOA is high around 1.4 for 200 nodes. However, when evaluated over JFO, BWO, ACO, MFO, RHSO and WOA, the delay for JC-BWOA is less around 0.5. Similarly, for 300 nodes, the delay is less using JC-BWOA over JFO, BWO, ACO, MFO, RHSO and WOA. The delay for proposed work is less as the suggested EEIICR in WSN model uses optimal routing via JC-BWOA. JC-BWOA guarantees the CHS during transmission that lessened the delay.



(a)



(b)



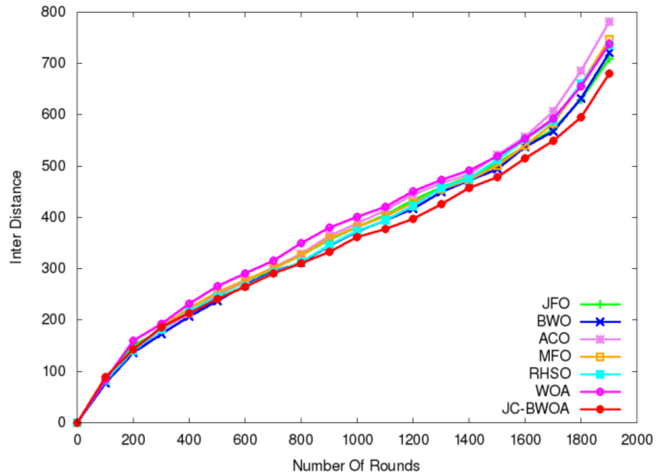
(c)

Fig.3. Delay analysis for EEIICR in WSN for nodes (a) 100 (b) 200 and (c) 300

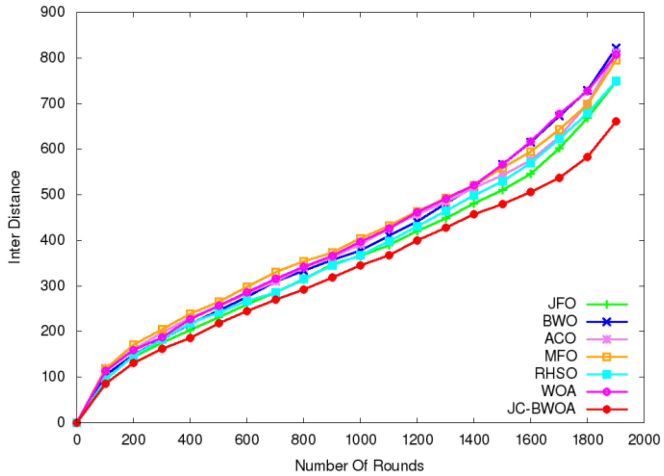
6.4 Analysis on Inter cluster and Intra cluster distance

The study on inter and intra cluster distances for JC-BWOA based EEIICR in WSN over JFO, BWO, ACO, MFO, RHSO and WOA for 300 nodes is displayed in Fig. 4 and 5. The distance amongst nodes should be less, so that it could be chosen as CH. In assessment over JFO, BWO, ACO, MFO, RHSO and WOA, the suggested JC-BWOA model includes lesser distances. In case of 100 nodes, at beginning rounds, the inter cluster and intra cluster distances are less. That is, in Fig. 4(a) at 0^{th} round, the inter cluster distance is less. After 0^{th} round, the inter cluster distance is high and when the round is 1900, high inter cluster distance is obtained. At 1900^{th} round, the inter cluster distance for JC-BWOA is around 690. The inter distance using JFO is high around 790 for 100 nodes at 1800^{th} round. In case of Fig. 5, the distance is less at beginning rounds for 200 nodes. As rounds increases, the intra cluster distance also increases. At 1800^{th} round, the intra distance using MFO is high around

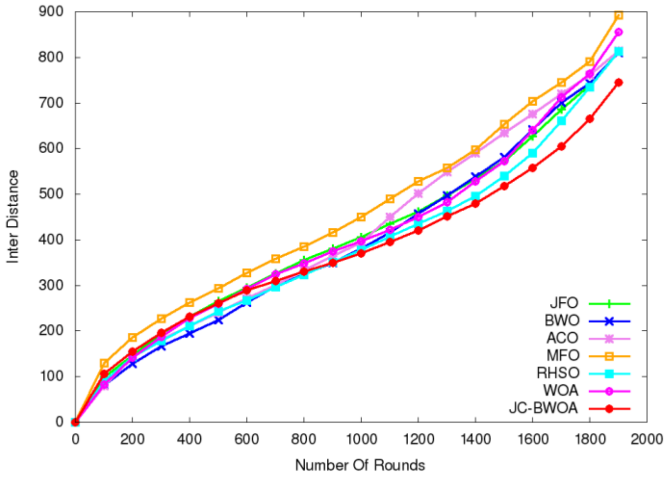
730 for 200 nodes. However, when evaluated over JFO, BWO, ACO, MFO, RHSO and WOA, the distances for JC-BWOA is less. Similarly, for 300 nodes, the distances are less using JC-BWOA over JFO, BWO, ACO, MFO, RHSO and WOA. The distances for proposed work are less as the suggested EEIICR in WSN model uses optimal routing via JC-BWOA. In addition, JC-BWOA aids in CHS that lessened the cluster distances during transmission.



(a)

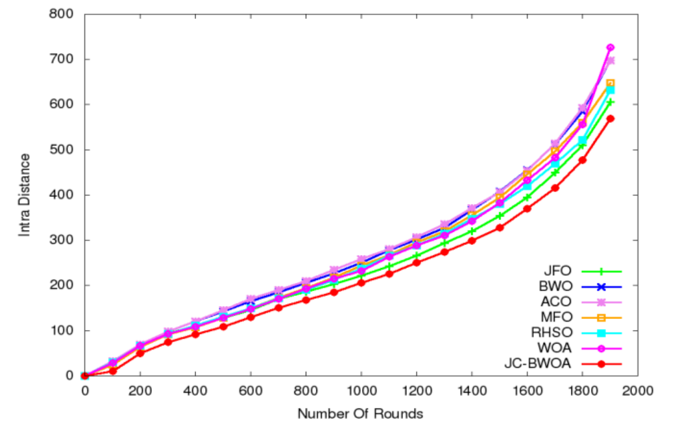


(b)

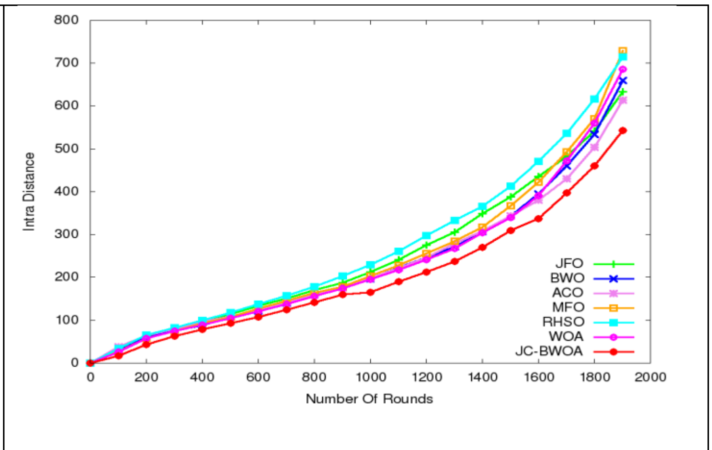


(c)

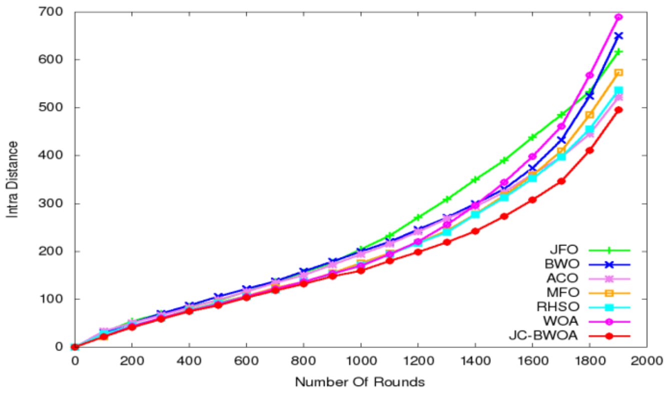
Fig.4. Inter cluster distance analysis for EEIICR in WSN for nodes (a) 100 (b) 200 and (c) 300



(a)



(b)

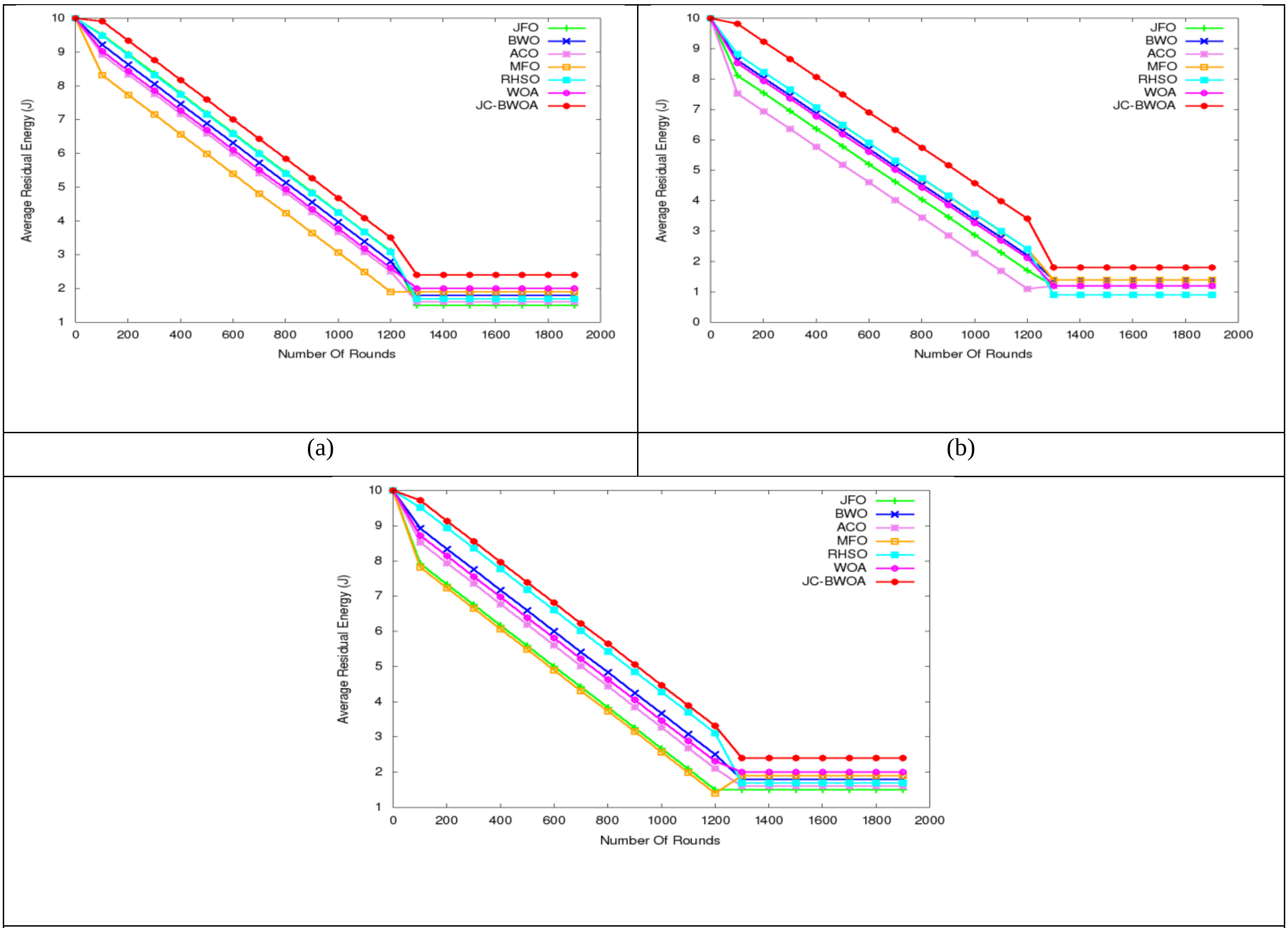


(c)

Fig.5. Intra cluster distance analysis for EEIICR in WSN for nodes (a) 100 (b) 200 and (c) 300

6.5 Analysis on Energy and throughput

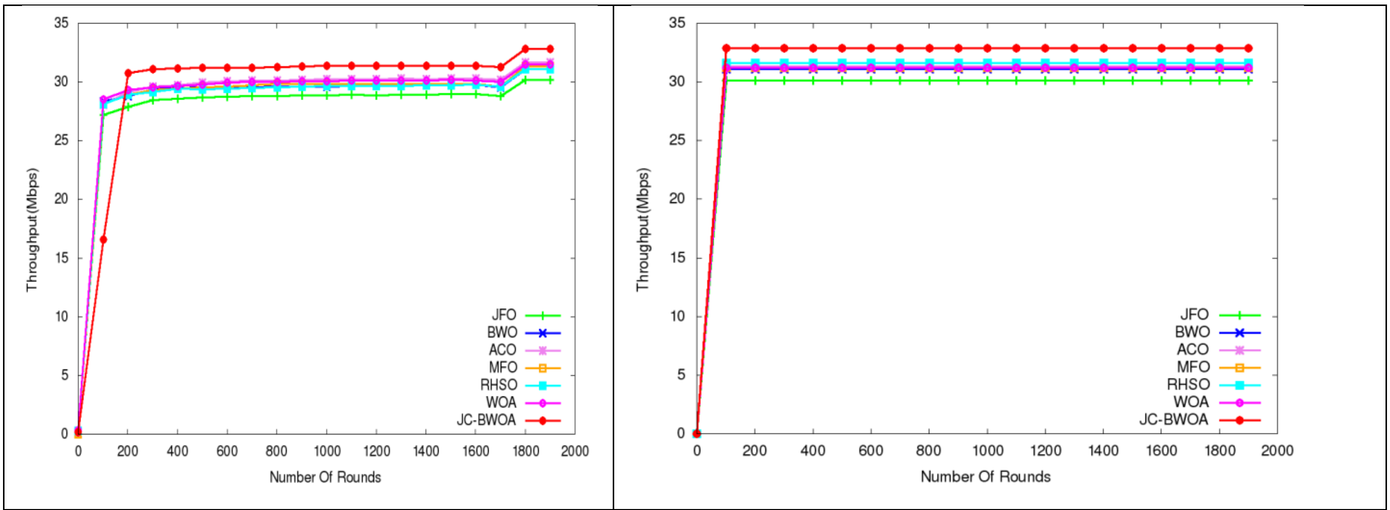
Fig. 6 and 7 describe theenergy and throughput examination of JC-BWOA based EEIICR in WSN over JFO, BWO, ACO, MFO, RHSO and WOAfor300 nodes. Energy and throughput are crucial parameters for transmission of data. The throughput as well as residual energy should be higher. The suggested JC-BWOA model includes higher energy and throughput. The residual energy lessens with increase in rounds, however, In case of 100 nodes, at beginning rounds, the energy is high. That is, in Fig. 6(a) at 0^{th} round, the energy is high, after 0^{th} round, the energy is less and when the round is 1900, less energy is obtained. At 1900^{th} round, the energy for JC-BWOA is around 2.4. However, when evaluated over JFO, BWO, ACO, MFO, RHSO and WOA, the energy for JC-BWOA is less. The throughput is less at beginning rounds; however, with increase in rounds, throughput is high due to optimal routing via JC-BWOA.



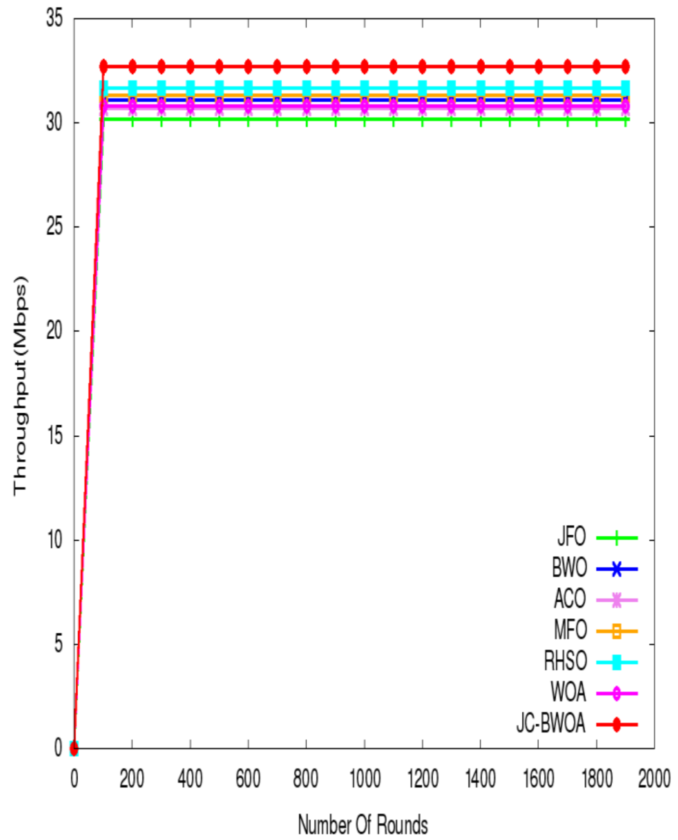
(a) (b)

(c)

Fig.6. Energy analysis for EEIICR in WSN for nodes (a) 100 (b) 200 and (c) 300



(a) (b)



(c)

Fig.7. Throughput analysis for EEIICR in WSN for nodes (a) 100 (b) 200 and (c) 300

6.6 Statistical study

Table 3 showsstatistical study of presented JC-BWOA based EEIICR in WSN over JFO, BWO, ACO, MFO, RHSO and WOA. The analysis is done for 300 nodes. The adopted scheme for maximum case scored a lesser value of 0.823805. The fitness of JC-BWOA based EEIICR in WSN is less, whereas, the existing models have exposed high fitness. As optimum CHS is done based upon suggested JC-BWOA along with optimal routing; the fitness is satisfied for suggested EEIICR in WSN.

Table 3: Statistical Analysis of EEIICR in WSN

Methods	Maximum	SD	Mean	Minimum	Median
JFO	2.01193	0.164411	1.06945	0.175554	1.00137
BWO	0.92077	0.181836	0.51106	0.174082	0.497103
ACO	1.29945	0.133272	0.970433	0.15	0.901702
MFO	1.47414	0.154083	0.574682	0.15	0.502895
RHSO	0.99938	0.136605	0.631228	0.165015	0.577636
WOA	0.991861	0.149076	0.578328	0.179248	0.508402
JC-BWOA	0.823805	0.126145	0.216476	0.138396	0.154648

7. CONCLUSION

This work introduced a new EEIICR framework. The model included the phases like: Optimal Clustering, Routing and Data Aggregation. Optimal Clustering was the initial phase, where, JC-BWOA optimization was introduced to perform clustering process on considering delay, energy, trust, intra and inter cluster distance. Optimal routing was done via JC-BWOA algorithm on considering link quality and distance. From analysis, at 0^{th} round, the inter cluster distance was less. After 0^{th} round, the inter cluster distance was high and when the round is 1900, high inter cluster distance was obtained. At 1900^{th} round, the inter cluster distance for JC-BWOA was around 690. The inter cluster distance using JFO was high around 790 for 100 nodes at 1800^{th} round. In case of intra cluster distance, the distance was less at beginning rounds for 200 nodes. At 1800^{th} round, the distance using MFO was high around 730 for 200 nodes. In future, life span of network should be analysed.

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