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Original Article

Spotted Hyena with Fire Hawk Optimization Algorithm Driven Cluster Based Routing for Wireless Sensor Networks

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Abstract *- A Wireless Sensor Network (WSN) collects data about the environment and transmits it to a central location via distributed Sensor Nodes (SNs). Advancements in sensor equipment, size, interfaces, and cost have led to many WSN applications. Energy effectualness is the most researchable topic of the energy-constrained WSN. Many models are used to handle energy consumption (ECON), and the most promising methods are clustering and routing. The WSN requires a routing protocol to transmit data to the sink via a cost-effective link. A primary issue is detecting the element's constrained energy so that the higher power is utilized consistently over time. Energy-efficient routing can extend lifespan by using less energy. This study develops a spotted hyena with fire hawk optimization algorithm-driven cluster-based routing (SHFHOA-CBR) technique in WSN. The SHFHOA-CBR technique follows two significant processes: energy-efficient clustering and routing. To accomplish this, the SHFHOA-CBR technique includes a spotted hyena optimizer-based clustering approach (SHO-CA) to choose an optimal set of CHs and generate clusters. The SHO-CA technique derives a fitness function (FF) comprised of distance to neighbouring nodes (DTN), residual energy (RE), and trust level (TL). For route selection, the SHFHOA-CBR technique encompasses the fire hawk optimizer-based routing (FHO-R) technique to choose optimal routes to BS. Finally, the FHO-R technique includes three input variables: node degree (ND), RE, and DTN. The investigational evaluation of the SHFHOA-CBR model is conducted using diverse measures, namely ECON, Latency, Packet Delivery Ratio (PDR), Throughput (THRO), Network Life-Time (NLT), End-to-End Delay (EED). The experimental outputs infer that the SHFHOA-CBR technique achieves promising performance over current techniques.*

Keywords *- Wireless sensor network, Residual energy, Sensor nodes, Routing, Cluster head, Fire hawk optimizer.*

1. Introduction

A WSN is an ensemble of sensor devices that transmit in huge quantities over an area to observe the environment and numerous physical assets of the surrounding areas [1]. They are comparatively less expensive devices when compared to other sensor equipment because they are restricted in terms of computing resources [2]. These features make WSN very easy, effective and simple to implement, particularly in areas such as military, health traffic, etc [3]. They are employed as low-cost solutions for numerous real-life states, such as surveillance and following in military and defence-connected services, parameters of traffic, environmental observing for a storm, forest fire recognition, health concerns monitoring, etc. [4]. Usual models are mainly utilized for the last few phases of contact between smartphone devices and wired systems to improve the cellular network in replacement of wired networks [5]. The SNs route the data collection over their transitional nodes connected to wireless gadgets to send data toward the receiver node [6]. However, an appropriate procedure with the optimum track is highly necessary for the transmission of data collection via a few nodes with a routing path of multi-link to have their array over the receiver within them [7]. The tradition of energy is essential to be diminished by considering the optimum decision-making approaches, which centre on rules such as the collection of nodes and routing for executing a perfect routing procedure. SNs organized nearer to the sink node (SK) in multi-link WSN are compulsory for transmitting or forwarding more traffic than other detached SNs [8]. This arithmetical problem creates closer SNs that take their energy quicker than others that generate energy holes. The grade of limited resources modelled by WSN is processing, restricted memory, lower-battery capability, and additional tasks added to WSN due to flexibility and regular variations in network topology [9]. To exceed the resource restraints, numerous energy-effectual routing protocols (RP) have been intended to use the energy of SNs proficiently and increase the system's life period [10]. This study develops a Spotted Hyena with the Fire Hawk Optimization Algorithm Driven Cluster Based Routing (SHFHOA-CBR) method in WSN. The SHFHOA-CBR technique includes a spotted hyena optimizer-based clustering approach (SHO-CA) to pick an optimum set of CHs and build clusters.

The SHO-CA system derives an FF comprised of distance to neighbouring nodes (DTN), residual energy (RE), and trust level (TL). For route selection, the SHFHOA-CBR technique encompasses the fire hawk optimizer-based routing (FHO-R) technique to choose optimal routes to BS. Finally, the FHO-R technique includes three input variables: DTN, node degree (ND), and RE. The performance analysis of the SHFHOA-CBR algorithm can be examined by employing different scenarios.

2. Related Works

Yang et al. [11] suggested a new two-tier fusion swarm intellectual-assisted ranking route protocol (THSI-RP) method. Firstly, the model integrates a hybrid SI method, incorporating the marine predator's algorithm (MPA) and grey wolf optimization (GWO) techniques. Secondly, the routing methods employ a hybrid SI technique dependent upon GWO and the graph model. Initially, the model combines energy and distance parameters by utilizing GWO. Next, a weight cost function was developed and incorporated.

In [12], an energy-efficient RP dependent upon the Tabu search algorithm (TSA) and GWO has been introduced in this study and designated routing model with main objectives comprising clustering and CHS employing GWO with an FF, quality of service (QoS) factors like energy efficiency and reliability, which could be enhanced by determining numerous optimizer paths as well as with the help of TSA choosing the optimum route. Mohan et al. [13] projected an enhanced meta-heuristics-based cluster with a multi-hop routing method called the IMCMR-UWSN approach.

This model integrates chaotic krill head approach (CKHA)-enabled cluster and self-adaptable glowworm swarm optimizer (SA-GSO)-assisted techniques. Also, the SA-GSO model creates an FF that involves four limits. In [14], an enhanced deer hunting optimizer-enabled-MHR (IDHO-MHR) procedure has been developed for WSN. The Nelder mead (NM) idea is incorporated with a customary DHO model using the IDHO technique. Additionally, the model raises an FF by inserting two main variables, distance and RE. In [15], a cryptographic-based cluster design employing the Optimum Privacy-Multi-hop Dynamic Cluster RP (OP-MDCRP) method has been presented. The cause nodes are gathered to generate a cluster in the arbitrary model depending on the region. In addition, this system delivers high data confidentiality by utilizing the elliptic curve incorporated in the Encrypting-Key Provision Model (ECIES-KPM) technique with a tiny critical dimension. In [16], an improved Heterogeneous Gateway-based Energy-Aware-MHR (HMGEAR) has been developed. The routing depends on various nodes; heads are chosen based on the RE. It comprises a multi-hop transmission plan and utilizes an energy-hole removal model. Manikandan and Narasimhan [17] improve an enhanced Rat Swarm Optimizing-Assisted Energy-Aware Multi-Hop Routing (RSOEAMHR) procedure. Then, the IRSO-EAMHR technique originates an FF holding three input parameters for the RP. Mishra and Verma [18] proposed a model based on the Turtle Search Algorithm and Desert Cat Swarm Optimization (TSA-DCSO) with a dual CH selection approach. [19] introduces a hybrid model incorporating swarm optimization with a heuristic model. Muthulakshmi et al. [20] present an Adaptive Wind Driven Optimization-assisted Energy Aware Clustering Scheme (AWDO-EACS) model based on the Wind Driven Optimization (WDO) methodology.

3. System Model

3.1. Network Model

It has been expressed depending upon the below-mentioned respects [21]:

- In WSN, all SNs are parallel to every other in an initial energy and processing period.
- Distance among sensors is computed depending upon the formulation of Euclidean distance.
- The SNs are arbitrarily used in the detecting area, and the sensors' locations are static after placing them.
- BS obtains the data near the RE and space from the SNs. Depending on this information, CHs are nominated for all the SNs by employing an effective CHS procedure. Then, the routing procedure is used to get the way among CHs to BS.

3.2. Energy Model

This research evaluates a basic first-order radio method to compute the energy the transmitter and receiver user to send and receive the l-bit packets above the distance d is expressed in Equation (1) and (2) correspondingly.

$$E_{TX}(l,d) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^2 & if\ d \le d_0 \\ l \times E_{elec} + l \times \varepsilon_{mp} \times d^4 & if\ d > d_0 \end{cases} \quad (1)$$

$$E_{RX}(l,d) = l \times E_{elec} \quad (2)$$

The amount of energy degenerating at the receiver or transmitter could be signified as E_{elec}, and the threshold distance was represented by d_0, which was planned using Equation (3), as shown below.

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (3)$$

Where amplification energy for multi-path and free space methods is signified as ε_{mp} and ε_{fs}, individually. These ε_{fs} and ε_{mp} based on the transmitter amplifier method.

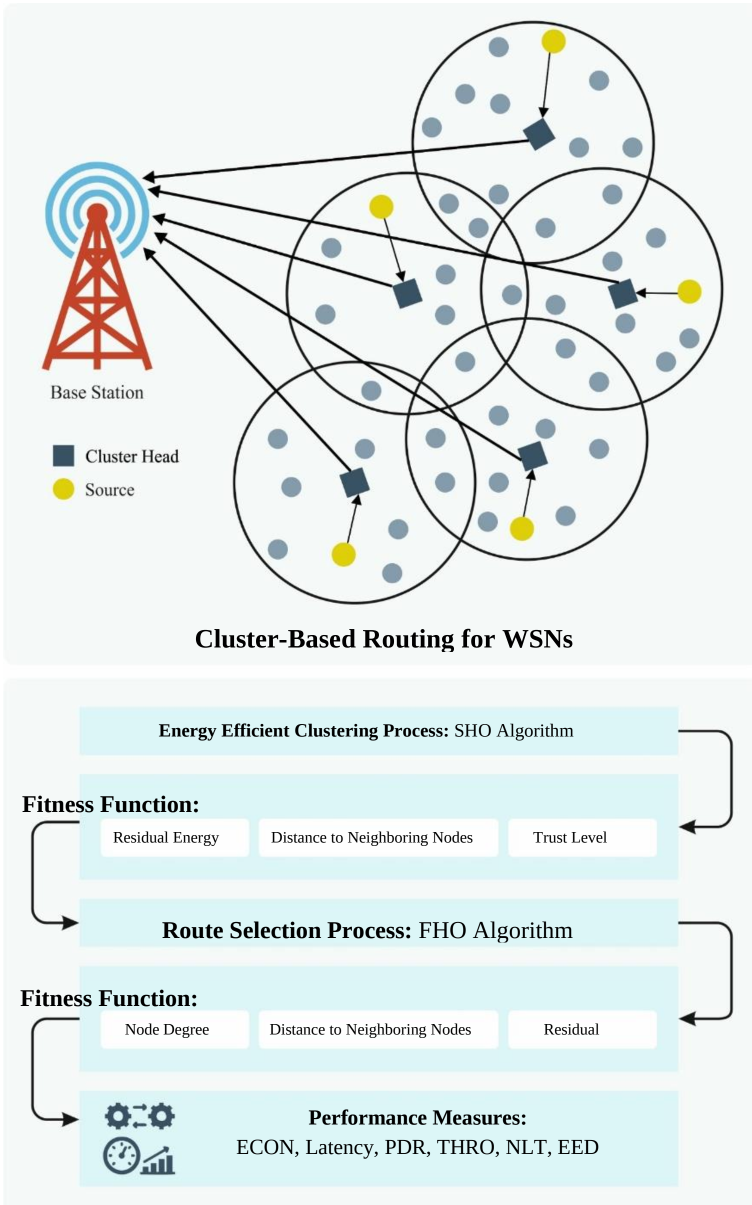

Fig. 1 Overall process of the SHFHOA-CBR technique

4. The Proposed Model

This article mainly concentrated on designing and improving the SHFHOA-CBR technique for energy efficiency in WSN. The technique follows two major processes: energy-efficient clustering and routing. Two major processes are used to accomplish this: SHO-CA-based clustering and FHO-R-based route selection. Fig. 1 depicts the entire procedure of the SHFHOA-CBR technique.

4.1. Stage I: Process Involved in SHO-CA Technique

In the preliminary phase, the SHFHOA-CBR system includes the SHO-CA approach to pick an optimum set of CHs and build clusters. SHO algorithm is derived from the social behaviour of hyena and prey, which became famous control issues that need optimizer approaches in their project owing to the highest ability to attain a suitable outcome [22]. The SHO technique creates a system of four chief stages: attacking, hunting, encircling, and searching demeanours. These stages spotted hyena tracked to search are:

1. Search around for the prey.
2. Chase the prey using a technique to make it drowsy and search effortlessly.
3. Adjacent the prey by a cluster of marked hyenas to grab it at the correct time (prey encircling).
4. Attack the prey in order to grab it by the hyena's cluster.

Affording to prey position, an optimal solution for the procedure, numerous agents like people and hyenas are tangled to upgrade their locations. The method image of prey enclosing can be defined statistically as below:

$$\vec{D}_h = \left|\vec{B} \times \vec{P}_p(x) - \vec{P}(x)\right| \tag{4}$$

$$\vec{P}(x+1) = \vec{P}_p(x) - \vec{E} \times \vec{D}_h \tag{5}$$

Where x signifies the current iteration, $\vec{D}_h$ represents the space between the marked hyena and the prey. The vectors $\vec{P}_p$ and $\vec{P}$ represent the prey position and marked hyenas correspondingly. The vectors $\vec{B}$ and $\vec{E}$ are co-efficient vectors that are expressed as follows:

$$\vec{B} = 2 \times \vec{r}_{d1} \tag{6}$$

$$\vec{E} = 2\vec{s} \times 2\vec{r}_{d2} - \vec{h} \tag{7}$$

$$\vec{s} = 5 - \left(I_{iteration} \times \frac{5}{\text{Max}_{iteration}}\right) \tag{8}$$

Where, $I_{iteration} = 0,1,$ $\text{Max}_{iteration}$. The vector $\vec{s}$ is evenly decreased from 5 to 0. The vectors $\vec{r}_{d1}$ and $\vec{r}_{d2}$ They are arbitrarily selected not to beat the range value of $[0,1]$. The subsequent equations establish the hunting stage of the SHO system:

$$\vec{D}_h = \left|\vec{B} \times \vec{P}_h - \vec{P}_k\right| \tag{9}$$

$$\vec{P}_k = \vec{P}_h - \vec{E} \times \vec{D}_h \tag{10}$$

$$\vec{C}_h = \vec{P}_k + \vec{P}_{k+1} + \cdots + \vec{P}_{k+N} \tag{11}$$

For the 1st optimal fixed spotted Hyena, the hunter vector can be signified by $\vec{P}_h$, whereas the place of other covered hyenas has been determined by $\vec{P}_k$.

The total quantity of $\vec{P}_h$ is equivalent to N, which is computed as follows:

$$N = Count_{nos}\left(\vec{P}_h\vec{P}_{h+1}, \vec{P}_{h+2}, \ldots, \left(\vec{P}_h + \vec{M}\right)\right) \tag{12}$$

Where, $\vec{M}$ represents the random vector, and its size lies in an array of [0.5, 1]. The entire candidate solution is determined by nos. During attacking stage, which embodies the phase of attacking the prey, can be demonstrated arithmetically by employing the following expression:

$$\vec{P}(x+1) = \frac{\vec{C}_h}{N} \tag{13}$$

Where $\vec{C}_h$ is an optimum solution in the cluster, and N signifies the optimum solution number. The calculation is invented to protect the finest position, $\vec{P}(x+1)$, composed of upgrading the location of other search agents (SAs) linked with an optimal solution. The vector $\vec{E}$ can be larger or lesser than one to ensure the correct agent searches near the prey. The alternative main feature of the procedure that gives to exploration is $\vec{B}$. Rendering to Equation (5), this vector offers arbitrary weightage to prey in its values. Selecting vector $\vec{B} > 1$ in priority to $\vec{B} < 1$ can discover the SHO model's arbitrary performance and clarify an exploit in the space. Figure 2 illustrates the steps employed in the SHO model.

The SHO-CA technique derives an FF comprised of DTN, RE, and TL. The SHO-CA model gains an FF with 3 input variables such as DTN, RE, and TL [23].

Distance to neighbours: Choosing CHs with the least distance between neighbouring vehicles during intra-cluster transmission and sensor vehicle power consumption to CH contact is appropriate. When the space for the neighbouring vehicles is decreased, the power of intra-cluster communication is also reduced.

Objective 1: Minimalize

$$f_1 = \sum_{j=1}^{m} \frac{1}{l_j}\left(\sum_{i=1}^{l_j} dis\left(CH_j, s_i\right)\right) \tag{14}$$

Trust factor (TF): All vehicles are defined as TF being one. An abnormal prediction unit decreases the value of TF once the vehicle performs the anomaly task, and the vehicle is termed malicious.

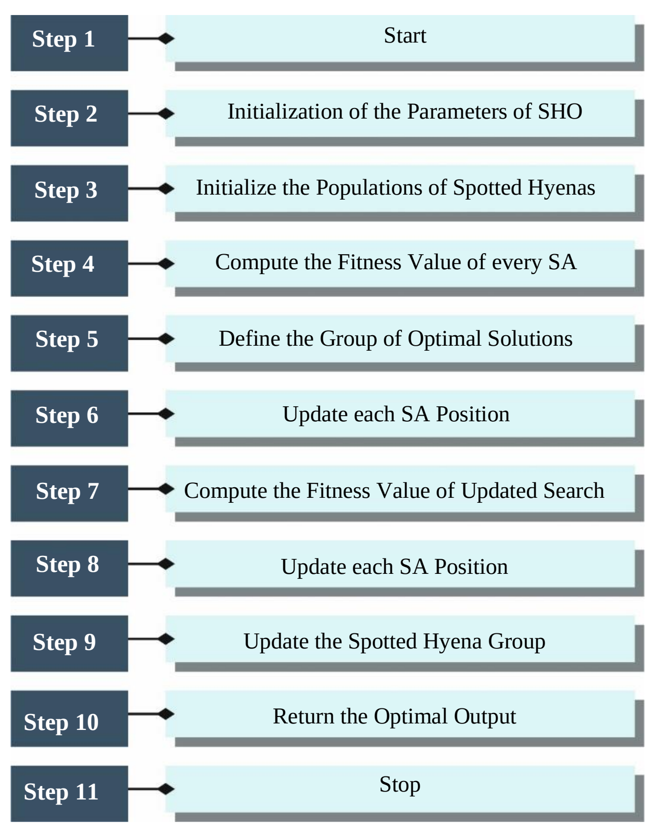

Fig. 2 Steps utilized in the SHO model

Objective 2: Maximalize

$$f_2 = \sum_{j=1}^{m} \frac{1}{m}(TF_j) \quad (15)$$

Energy: The amount of power used as CHs to RE of CHs. When a CH consumes less power usage as procedures, detecting and transmission procedures with high RE are collected as a low energy ratio. Therefore, the CH selection is more likely to be achieved with a low energy ratio.

Objective 3: Minimalize

$$f_3 = \sum_{j=1}^{m} \frac{E_c(CH_j)}{E_R(CH_j)} \quad (16)$$

In the projected SHO-CA method, it could be important to decrease the linear combination of an objective function. So, the potential energy function of the SHO-CA model has been executed by:

$$Minimize\ Potiential\ energy\ function = \alpha_1 \times f_1 + \alpha_2 \times f_2 + \alpha_3 \times f_3 \quad (17)$$

Where $\alpha_1 + \alpha_2 + \alpha_3 = 1, \alpha_2 \geq (\alpha_1 + \alpha_3). Also\ 0 < f_1, f_2, f_3 < 1$.

4.2. Stage II: Process Involved in FHO-R Technique

For route selection, the SHFHOA-CBR technique encompasses the FHO-R technique to choose the best set of routes to BS. The FHO is enthused by the hunting actions of birds and attempts to transmit fire (black kites, whistling kites, and brown falcons) [24]. These birds use their beaks and claws to grasp smoldering twigs, attempting to spread fire, measured as a sub-versive natural incidence. To handle and attract prey, the birds hold fire twigs and throw them in unfired areas. The prey, including insects, rodents, snakes, etc., is scared by fire and compelled to escape rapidly and anxiously, which makes it significantly easier for hawks to hunt the prey. The primary computation of the FHs and food source's place vector employs several solution candidates (SCs) (X). These preliminary places are defined as follows:

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_i \\ \vdots \\ X_N \end{bmatrix} = \begin{bmatrix} x_1^1 & x_1^2 & \cdots & x_1^j & \cdots & x_1^d \\ x_2^1 & x_2^2 & \cdots & x_2^j & \cdots & x_2^d \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ x_i^1 & x_i^2 & \cdots & x_i^j & \cdots & x_i^d \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ x_N^1 & x_N^2 & \cdots & x_N^j & \cdots & x_N^d \end{bmatrix}, \begin{cases} i = 1,2,\dots,N. \\ j = 1,2,\dots,d. \end{cases} \quad (18)$$

$$x_i^j(0) = x_{\mathrm{i,min}}^j + rand.(x_{i,max}^j - x_{\mathrm{i,min}}^j), \begin{cases} i = 1,2,\dots,N. \\ j = 1,2,\dots,d. \end{cases} \quad (19)$$

The proper SCs are named FHs, and others are said to be prey. The feature is signified as below:

$$PR = \begin{bmatrix} PR_1 \\ PR_2 \\ \vdots \\ PR_k \\ \vdots \\ PR_m \end{bmatrix}, k = 1,2,\dots,m, FH = \begin{bmatrix} FH_1 \\ FH_2 \\ \vdots \\ FH_l \\ \vdots \\ FH_n \end{bmatrix}, l = 1,2,\dots,n \quad (20)$$

The entire distance between the prey and FH is expressed as:

$$D_k^l = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}, \begin{cases} l = 1,2,\dots,n. \\ k = 1,2,\dots,m. \end{cases} \quad (21)$$

In the subsequent algorithm stage, discarding a fiery twig in its allocated area birds to vigour the prey to escape rapidly is expressed as below:

$$FH_1^{new} = FH_1 + (r_1 \times GB - r_2 \times FH_{Near}), l = 1,2,\dots,n \quad (22)$$

Subsequently, the target hides or escapes or accidentally enters into the FH area is conveyed as:

$$PR_q^{new} = PR_q + (r_3 \times FH_1 - r_4 \times SP_1), \begin{cases} l = 1,2,\dots,n. \\ q = 1,2,\dots,r. \end{cases} \quad (23)$$

The prey travelling into FHs regions trying to escape arrest by hiding in a safer place is conveyed as below:

$$PR_q^{new} = PR_q + (r_5 \times FH_{Alter} - r_6 \times SP), \begin{cases} l = 1,2,\dots,n. \\ q = 1,2,\dots,r. \end{cases} \quad (24)$$

The prey actions near the FHs and secure locations external an area is defined by r_5 and r_6. The formulation for SP1 and SP have been displayed in Equation (25).

$$\left. \begin{aligned} SP_1 &= \frac{\sum_{q=1}^{r} PR_q}{r}, & \begin{cases} l = 1,2,\dots,n. \\ q = 1,2,\dots,r. \end{cases} \\ SP &= \frac{\sum_{k=1}^{m} PR_k}{m} & k = 1,2,\dots,m. \end{aligned} \right\} \quad (25)$$

The FHO-R method reduces energy use and increases each SN networking lifetime. Consider $h1$ as an objective function so that CH is selecting next-hop CH with greater RE to path the data so that the system lifetime will be increased; for instance, $h1$ is maximization.

Consider $h2$ an additional foremost function that is the least distance between CH to subsequent hop CH and next-hop CH to BS. Consider $h3$ as the 3rd key function; thus, CH picks the next-hop Cs with lesser node grade. Enhancing the life period of the network requires minimizing h_3, and it is signified as:

$$b_{ij} = \begin{cases} 1 & if\ next-hop(CH_i) = CH_j, \forall_{i,j} 1 \leq i,j \leq m \\ 0 & Otherwise \end{cases} \quad (26)$$

$$Minimize\ F = \frac{1}{h_1} \times \beta_1 + h_2 \times \beta_2 + h_2 \times \beta_3 \quad (27)$$

Exposed to,

$$dis(CH_i, CH_j) \times \leq d_{\max} CH_j \varepsilon \{C + BS\} \quad (28)$$

$$\sum_{j=1}^{m} b_{ij} = 1 \; and \; 1 \neq j \quad (29)$$

$$0 < \beta_1, \beta_2, \beta_3 < 1 \quad (30)$$

4. Results and Discussion

Here, the investigational assessment of the SHFHOA-CBR approach can be investigated under discrete nodes. Table 1 and Figure 3 compare ECON outputs of the SHFHOA-CBR method with existing approaches [25]. The outputs illustrate that the SHFHOA-CBR method attains decreased ECON values. Similarly, the LEACH method accomplishes worse achievement, whereas the fuzzy PSO and SSO models obtain slightly decreased ECON values. Although the MFO and WSN-MCOBA models accomplish reasonable ECON values, the SHFHOA-CBR technique achieves better performance with least ECON of 0.162mJ, 0.225mJ, 0.309mJ, 0.324mJ, and 0.406mJ, respectively. The comparative THRO results of the SHFHOA-CBR technique are related to the present models in Table 2 and Figure 4. With 100 nodes, the SHFHOA-CBR technique attains increasing THRO of 98.99Mbps while the WSN-MCOBA, MFO, SSO, Fuzzy-PSO, and LEACH models offer decreasing THRO of 97.59Mbps, 96.20Mbps, 92.73Mbps, 90.15Mbps, and 87.97Mbps, respectively.

Additionally, on 500 nodes, the SHFHOA-CBR methodology gains boosted THRO of 95.79Mbps; however, the WSN-MCOBA, MFO, SSO, Fuzzy-PSO, and LEACH methodology reducing THRO of 94.52Mbps, 91.64Mbps, 85.69Mbps, 83.39Mbps, and 81.92Mbps, subsequently. Table 3 and Figure 5 show the relational EED outcomes of the SHFHOA-CBR methodology with other systems. The achieved findings specify that the SHFHOA-CBR methodology gets reduced EED values. Simultaneously, the LEACH technique acquires poorer performance. However, the fuzzy PSO and SSO algorithms obtain moderately diminished EED values.

Then, the MFO and WSN-MCOBA approaches accomplish increased EED values; the SHFHOA-CBR technique accomplishes improved performance with minimum EED of 2.66s, 4.85s, 5.79s, 5.92s, and 8.11s, correspondingly. Table 4 and Figure 6 show the relative latency (LAT) analysis of the SHFHOA-CBR technique with other models. The accomplished outputs display that the SHFHOA-CBR technique acquires minimized LAT values. Meanwhile, the LEACH system gets inferior performance, but the fuzzy PSO and SSO methods gain moderately lessened LAT values. While the MFO and WSN-MCOBA methods obtain improved LAT values, the SHFHOA-CBR system attains greater performance with decreased LAT of 2.753s, 2.248s, 3.051s, 4.005s, and 4.779, appropriately.

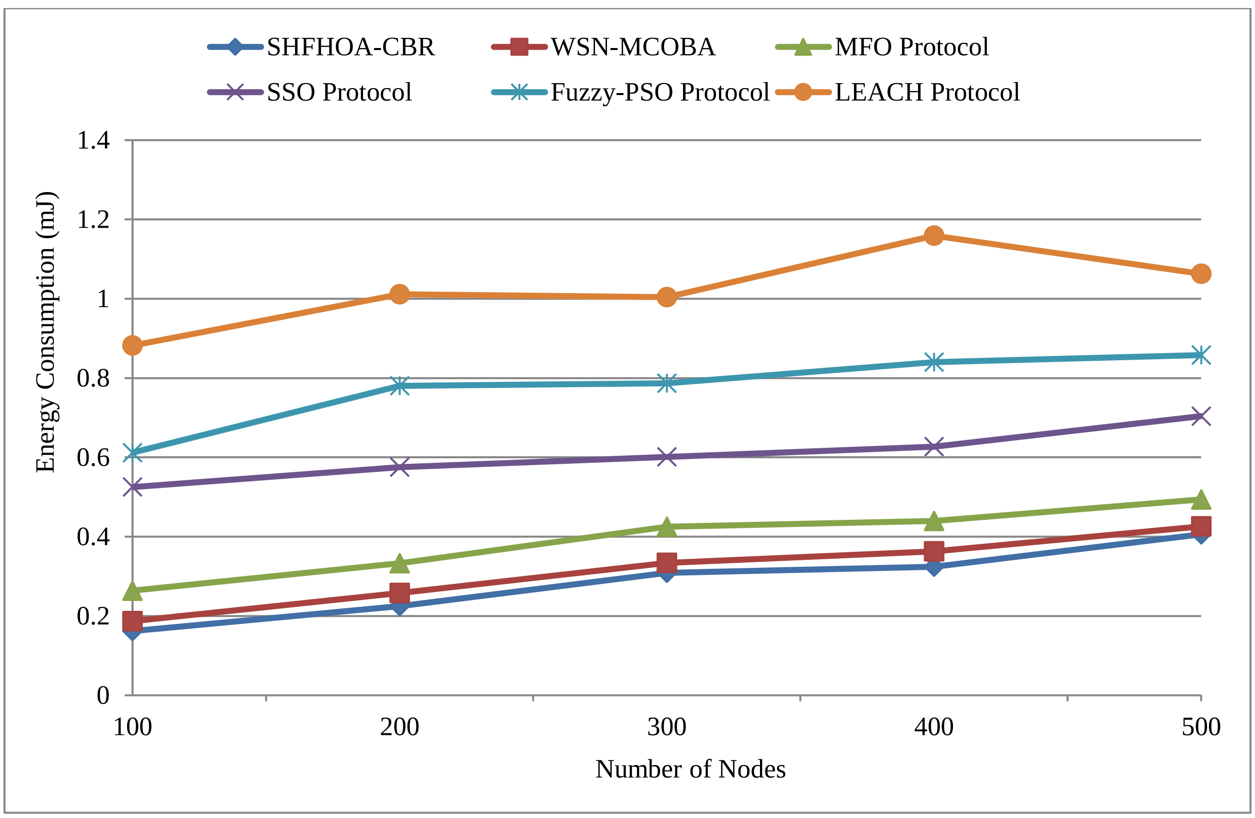

Fig. 3 ECON analysis of the SHFHOA-CBR model under varying nodes

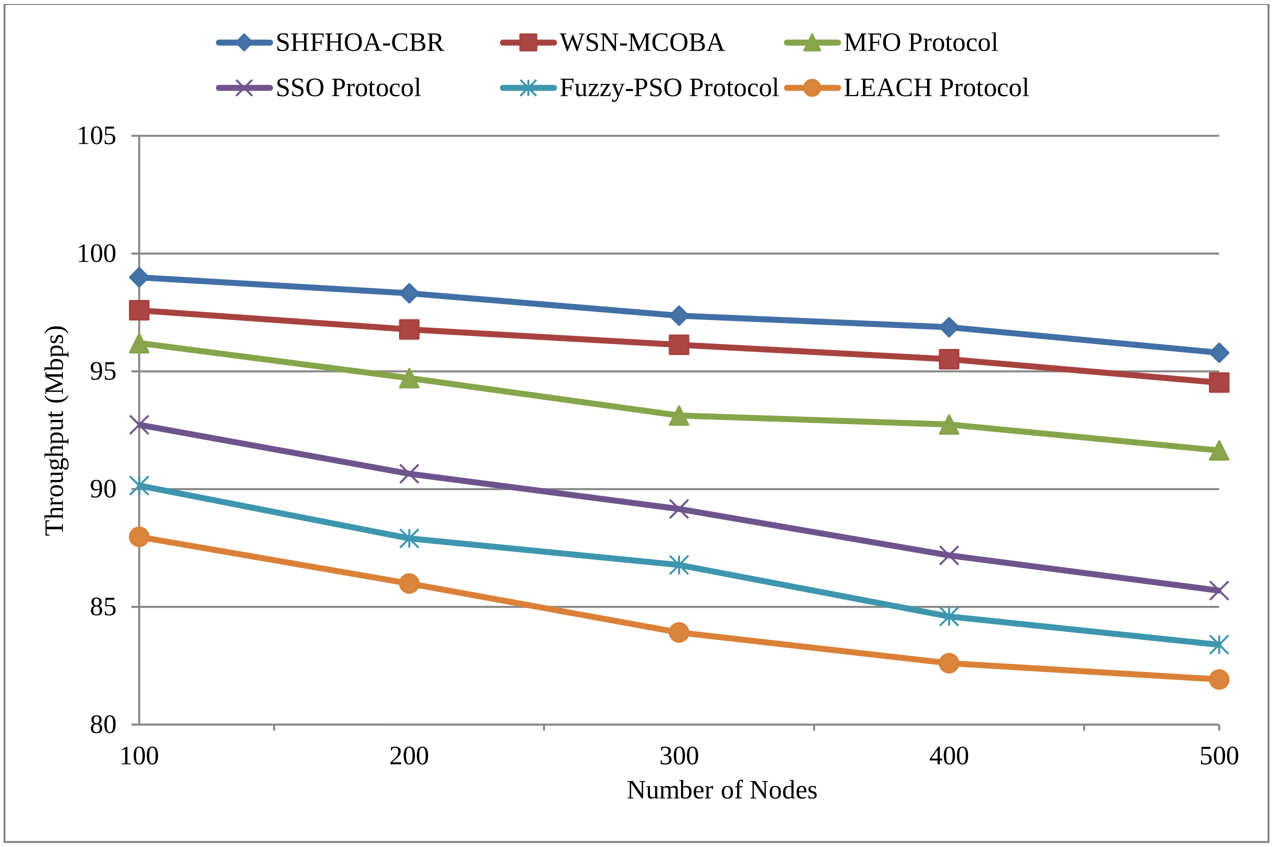

Fig. 4 THRO analysis of the SHFHOA-CBR model under varying nodes

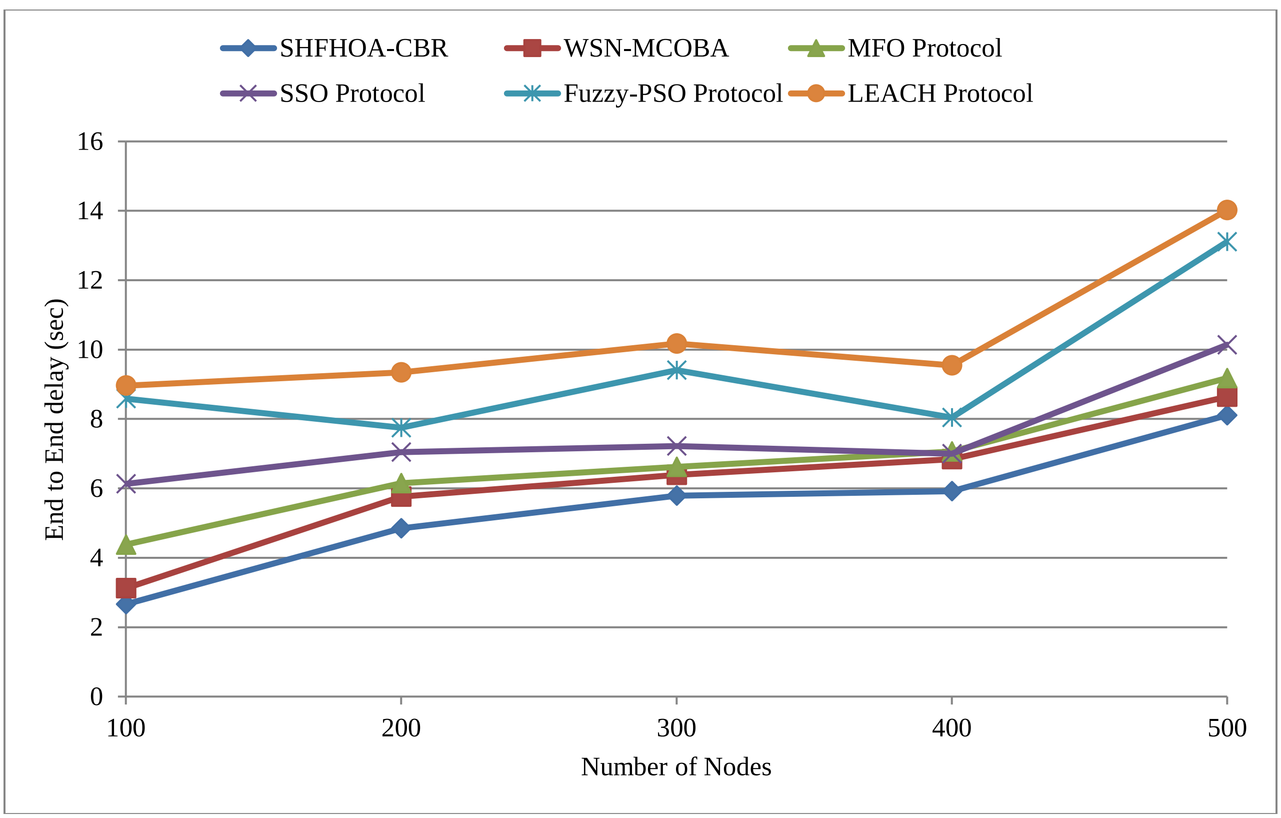

Fig. 5 EED analysis of the SHFHOA-CBR model under varying nodes

Table 1. ECON outcome of the SHFHOA-CBR model with other methods under varying nodes

ECON (mJ)						
Node Count	**SHFHOA-CBR**	**WSN-MCOBA**	**MFO Protocol**	**SSO Protocol**	**Fuzzy-PSO Protocol**	**LEACH Protocol**
100	0.162	0.187	0.264	0.525	0.612	0.882
200	0.225	0.258	0.333	0.575	0.780	1.011
300	0.309	0.334	0.425	0.601	0.787	1.004
400	0.324	0.363	0.440	0.627	0.840	1.159
500	0.406	0.426	0.494	0.704	0.858	1.063

Table 2. THRO outcome of the SHFHOA-CBR model with other methods under varying nodes

THRO (Mbps)						
Node Count	**SHFHOA-CBR**	**WSN-MCOBA**	**MFO Protocol**	**SSO Protocol**	**Fuzzy-PSO Protocol**	**LEACH Protocol**
100	98.99	97.59	96.20	92.73	90.15	87.97
200	98.32	96.78	94.72	90.65	87.91	85.99
300	97.36	96.12	93.13	89.16	86.78	83.91
400	96.87	95.51	92.75	87.18	84.59	82.61
500	95.79	94.52	91.64	85.69	83.39	81.92

Table 3. EED outcome of the SHFHOA-CBR system with other methods under varying nodes

EED (sec)						
Node Count	**SHFHOA-CBR**	**WSN-MCOBA**	**MFO Protocol**	**SSO Protocol**	**Fuzzy-PSO Protocol**	**LEACH Protocol**
100	2.66	3.12	4.38	6.13	8.59	8.96
200	4.85	5.76	6.15	7.04	7.75	9.34
300	5.79	6.39	6.62	7.22	9.41	10.17
400	5.92	6.84	7.06	7.00	8.04	9.55
500	8.11	8.64	9.18	10.14	13.11	14.02

Table 4. LAT outcome of the SHFHOA-CBR system with other methods under varying nodes

LAT (sec)						
Node Count	**SHFHOA-CBR**	**WSN-MCOBA**	**MFO Protocol**	**SSO Protocol**	**Fuzzy-PSO Protocol**	**LEACH Protocol**
100	2.753	3.133	3.838	5.361	7.044	8.346
200	2.248	2.838	4.740	6.546	8.038	9.153
300	3.051	3.331	5.079	7.039	8.947	10.138
400	4.005	4.135	6.217	8.046	9.731	10.116
500	4.779	5.089	7.108	8.339	10.041	12.115

Table 5. PDR outcome of the SHFHOA-CBR model with other methods under varying nodes

PDR (%)						
Node Count	**SHFHOA-CBR**	**WSN-MCOBA**	**MFO Protocol**	**SSO Protocol**	**Fuzzy-PSO Protocol**	**LEACH Protocol**
100	99.09	97.81	96.65	93.49	90.19	88.17
200	98.40	97.13	95.18	91.51	88.13	86.17
300	97.87	96.65	96.39	89.53	87.18	85.23
400	97.63	96.26	93.25	87.68	84.70	82.57
500	97.68	96.29	93.46	88.01	84.80	82.57

Table 6. NLT evaluation of the SHFHOA-CBR system with other methods under varying nodes

NLT (rounds)						
Node Count	**SHFHOA-CBR**	**WSN-MCOBA**	**MFO Protocol**	**SSO Protocol**	**Fuzzy-PSO Protocol**	**LEACH Protocol**
100	1722	1570	1346	1327	1350	1150
200	1901	1747	1423	1463	1414	1396
300	2226	2012	1720	1725	1659	1292
400	2520	2331	1826	1801	1929	1571
500	2600	2429	2201	2035	2152	1958

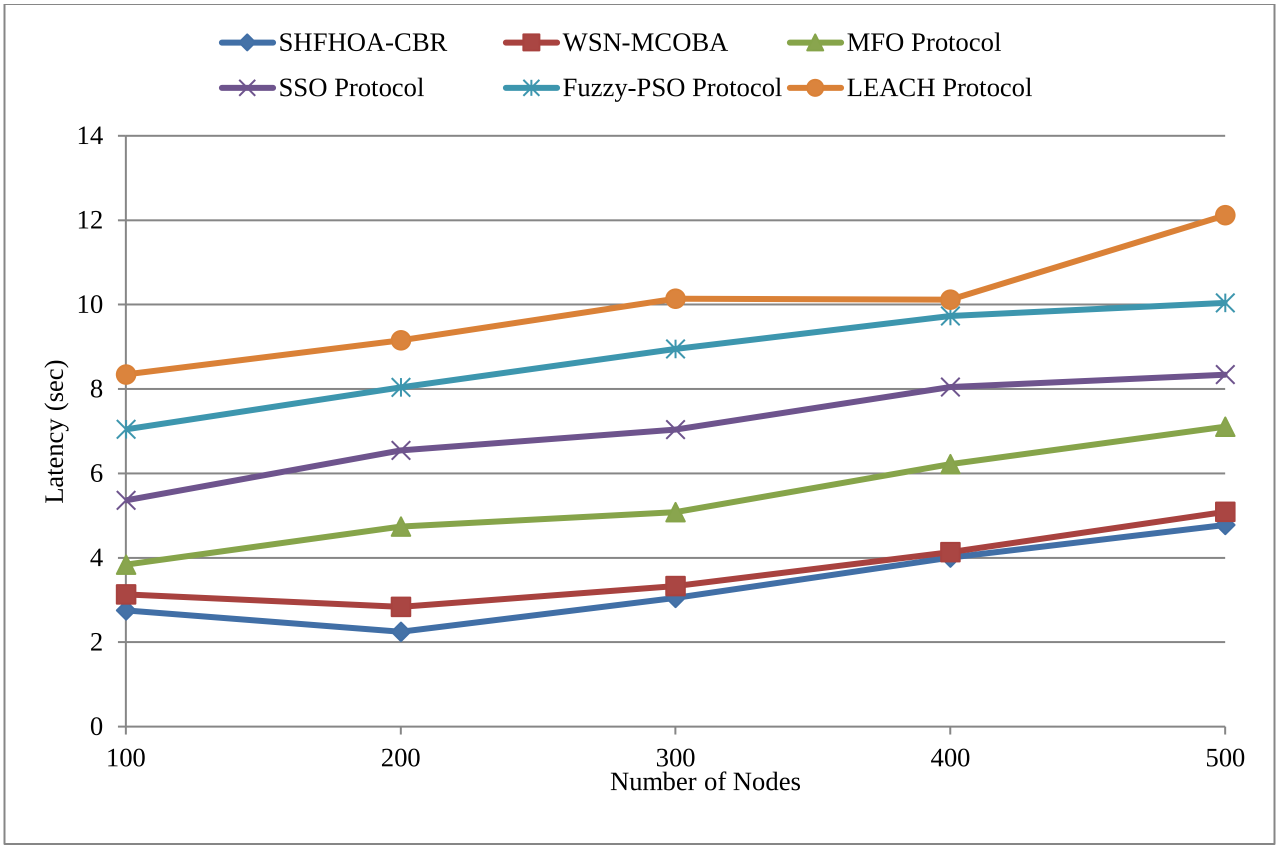

Fig. 6 LAT outcome of the SHFHOA-CBR model under varying nodes

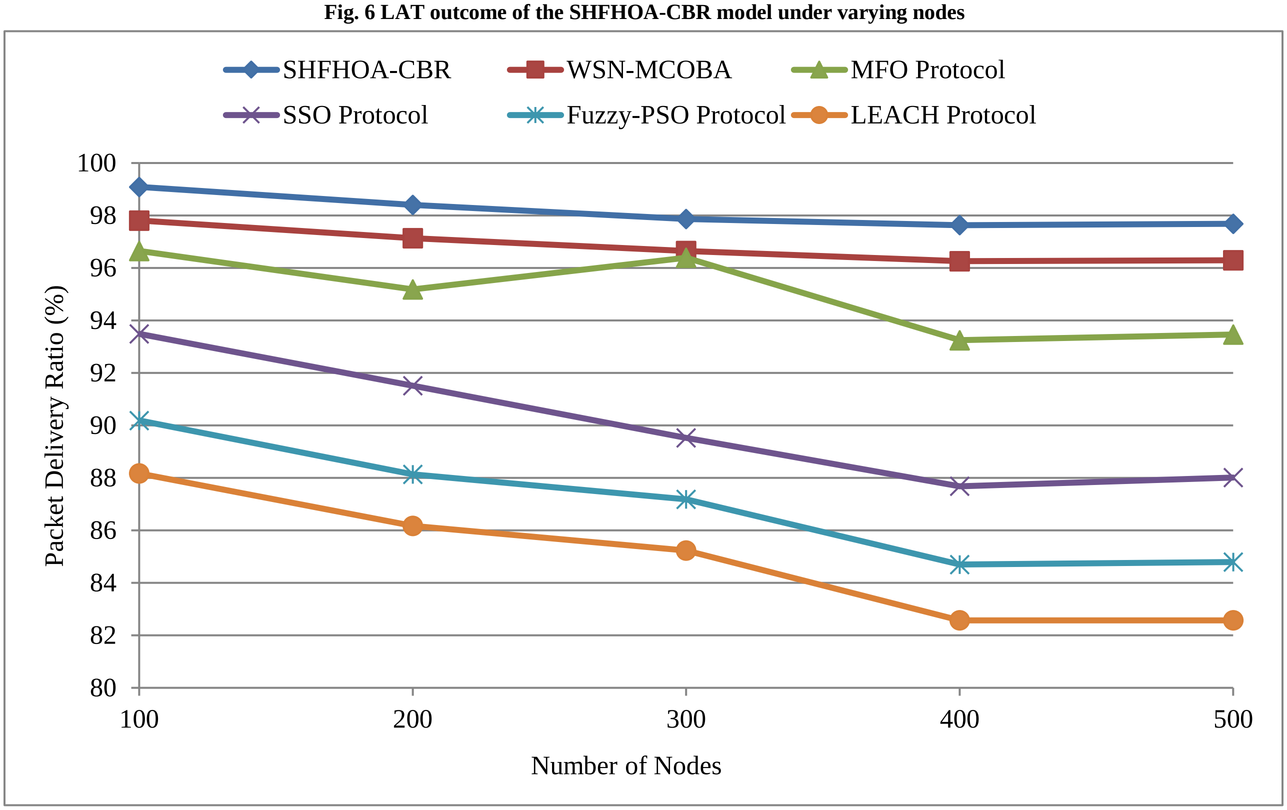

Fig. 7 PDR outcome of the SHFHOA-CBR model under varying nodes

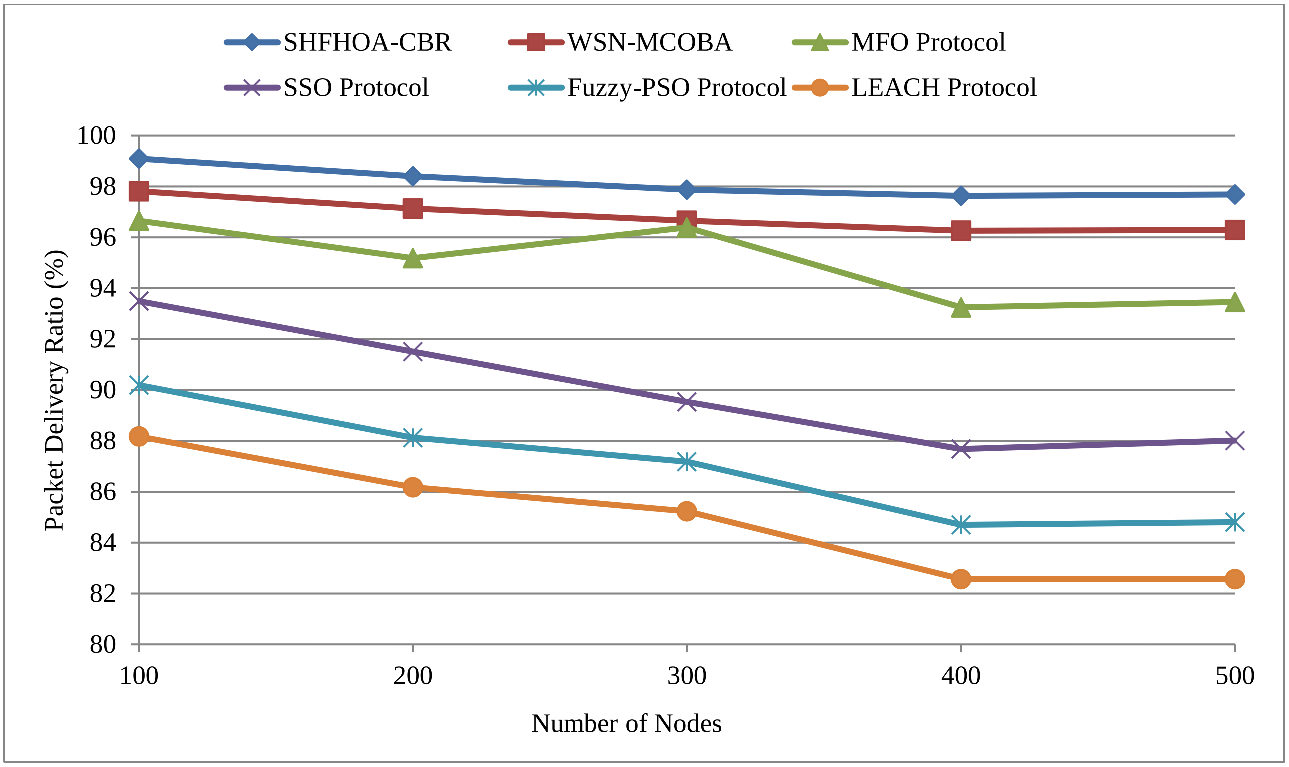

Fig. 8 NLT analysis of the SHFHOA-CBR model under varying nodes

The comparative PDR analysis of the SHFHOA-CBR system can be compared with other systems in Table 5 and Fig. 7. According to 100 nodes, the SHFHOA-CBR system gains increasing PDR of 99.09% while the WSN-MCOBA, MFO, SSO, Fuzzy-PSO, and LEACH methods offer to decrease PDR of 97.81%, 96.65%, 93.49%, 90.19%, and 88.17%. Similarly, with 500 nodes, the SHFHOA-CBR technique acquires boosted PDR of 97.68%, whereas the WSN-MCOBA, MFO, SSO, Fuzzy-PSO, and LEACH methods provide diminishing PDR of 96.29%, 93.46%, 88.01%, 84.80%, and 82.57%, correspondingly. The comparative NLT result of the SHFHOA-CBR method can be compared with other approaches in Table 6 and Fig. 8. Based on 100 nodes, the SHFHOA-CBR method archives raised NLT of 1722 rounds but the WSN-MCOBA MFO, SSO, Fuzzy-PSO, and LEACH models give lessening NLT of 1570, 1346, 1327, 1350, and 1150 rounds. Likewise, on 500 nodes, the SHFHOA-CBR method obtains improved NLT of 2600 rounds while the WSN-MCOBA, MFO, SSO, Fuzzy-PSO, and LEACH models offer reduced NLT of 2429, 2201, 2035, 2152, and 1958 rounds, subsequently.

5. Conclusion

This study mainly concentrated on designing and improving the SHFHOA-CBR technique for energy efficiency in WSN. SHFHOA-CBR technique follows two major processes: energy-efficient clustering and routing. To accomplish this, the SHFHOA-CBR technique includes two major processes: SHO-CA-based clustering and FHO-R-based route selection. The SHO-CA technique derives an FF comprised of DTN, RE, and TL.

For route selection, the SHFHOA-CBR technique encompasses the FHO-R technique to elect an optimal set of routes to BS. Finally, the FHO-R technique includes three input variables: RE, ND, and DTN. The performance validation of the SHFHOA-CBR model has been tested by employing different scenarios. Experimental results infer that the SHFHOA-CBR technique achieves promising performance over recent approaches.

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