CHAPTER - 4

COOPERATIVE DEVICE-TO-DEVICE COMMUNICATION USING JOINT RELAY ASSIGNMENT AND CHANNEL ALLOCATION USING DEEP LEARNING

4.1 Introduction

Modern wireless networks can benefit from relay communication since it enables effective resource utilization. The behavior of the principal users in the cognitive radio network (CRN) will significantly affect the stability of multiple-hop routes connecting cognitive users. This study's deep reinforcement learning-based research proposes a simultaneous channel selection and routing mechanism. Utilizing the improved hunter prey optimization (EnHpo) algorithm, the channel allocation strategy is initially suggested. The classic hunter-prey optimization is combined with an adaptive weighting method in the proposed EnHpo in order to increase convergence and find the optimal solution globally with balanced stages of local search and randomization. The optimal channel allocation is based on the multi-objective fitness function based on parameters like priority, bandwidth, and transmission rate. Then, depending on the channel gain based on the bit error rate, the relay selection is devised using deep reinforcement learning criterion. Here, the efficiency of D2D communication is improved by choosing the relay sub-set using deep reinforcement learning.

4.2 Problem Statement

Femtocells, cooperative networks, intelligent transportation systems, public safety systems, dynamic spectrum access, and smart grid communications are a few examples of CRNs' application domains. However, the model's functioning is still limited by several challenging problems. Researchers have devised a variety of ways for efficient D2D communication among CRN. The loss of information, latency, and enormous consumption of resource were shown to be the limitations of the traditional approaches. The nodes' dynamic nature and the absence of a technique for recovering lost routes are the major reason for the packet loss. Additionally, the network endures a large delay as a result of the new routing paths detected. In order to facilitate effective D2D communication, this chapter presents a combined channel allocation and relay selection method.

4.3 Proposed Methodology for Joint Channel Allocation and Relay Assignment

The cooperative network employs the orthogonal frequency division multiplexing channel (OFDMA) cognitive model with source-destination pairs and numerous relays for joint channel allocation and relay selection. Here, the amount of power used for transmission is fixed, and the device chooses the channel while it is idle to improve communication efficiency between the devices. The channel strength is also thought to be constant for each time slot, and each node is equipped with an antenna. The base station has authority over resource distribution and operational management. The network's latency is initially reduced on the first hop of communication by taking into account variables including bandwidth, priority, and transmission rate. After that, on the second hop, a system for choosing relay nodes based on bit errors is developed to satisfy quality of service specifications. Figure 4.1 presents an example of the two-hop joint channel allocation and relay selection method.

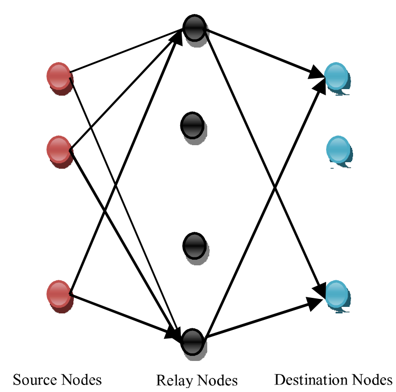


Figure 4.1: System model for the proposed joint channel allocation and relay selection technique

4.3.1 Multi-Objective Fitness Function

The multi-objective fitness function is built with consideration for variables like priority, bandwidth, and transmission rate in order to allocate the optimum channel for D2D communication. In the proposed D2D communication based on joint channel allocation and relay selection, the channels $A_1, A_2,....A_e$ and the bandwidth of $B_1, B_2,...B_e$ are considered.

Priority: Based on the amount of packet loss, the priority of the incoming request is calculated for making the communication more efficient. The node with the quicker packet loss is given a higher priority, and is calculated as follows:

$$A_a = \frac{1}{\min\left\{\frac{D_a - B_a}{D_b}, \frac{C_a - E_a}{S_a}\right\}} \tag{4.1}$$

where, the present size of the data is indicated as E_a, the packets arrives at the node is indicated as S_a, the tolerable delay is notated as D_a, and the device is indicated as a. The delay associated with the node is indicated as B_a, the frames duration is indicated as D_b, and the buffer size is indicated as C_a.

Bandwidth: The bandwidth utilized for making the communication between the devices is notated as B_{G_a}. For making the uninterrupted communication, the bandwidth higher than the B_{G_a} is essential; thus, the requirement of the bandwidth is defined as:

$$A = \left\{A_a \middle| B_a > B_{G_a}\right\} \tag{4.2}$$

Transmission rate: Based on the amount of the data, the transmission time is evaluated, and the best channel allocation is determined by using the highest transmission rate. The estimation of the transmission rate is formulated as:

$$a = \arg\max\left\{g_{a,e} \middle| \frac{f_a}{g_{a,e}} \le T_a\right\} \tag{4.3}$$

where, the transmission rate of device a is indicated as $g_{a,e}$ and available time is indicated as T_a. Thus, the channel allocation's multi-objective fitness function is written as follows:

$$Fit = \{\max(priority, bandwidth, transmission\,rate)\} \tag{4.4}$$

4.3.2 Optimal Channel Allocation using EnHpo

In order to increase convergence rate, the standard hunter prey optimization is combined with an adaptive weighting method to create the suggested Enhanced hunter prey optimization (EnHpo) algorithm. For the purpose of resolving optimization problems, the hunter-prey optimization takes into account the hunting behavior of the prey species. Gazelle, stag, and deer are the prey species taken into account in this optimization, whereas wolves, leopards, and lions are the predator species that employ the suggested algorithm's method of hunting. In order to get the global optimum solution without becoming stuck at a local optimal solution, the best algorithm has balanced randomization and local search capabilities, which is acquired by the EnHpo. The adaptive weighting technique is added to the traditional hunter-prey optimization to strengthen the randomization criterion and prevent the possibility of premature convergence.

4.3.2.1 Mathematical Modeling of EnHpo

The search agents are located in the search space at random manner, and the viability of the solution is determined by estimating multi-objective based fitness for each hunter. Here, the localization of the hunters is represented as $\left(\vec{P}\right) = \left\{\vec{P_1}, \vec{P_2}, ... \vec{P_R}\right\}$. Also, the maximal iterations considered for the algorithm is initialized as $\tau^{\max}$. The following is a representation of the hunter's successful solution during the arbitrary phase's randomization phase:

$$P_k = m(1, L) * (Max_r - Min_r) + Min_r \tag{4.5}$$

where, Min_r and Max_r refers to the minimum and maximum dimension of the solution and the position of the hunter is indicated as P_k and L refers to the variables. The following is the representation of the lowest and maximum dimension of the solution:

$$Min_r = [Min_1, Min_2, ...Min_L] \tag{4.6}$$

$$Max_r = [Max_1, Max_2, ...Max_L] \tag{4.7}$$

Fitness Evaluation: Based on the multi-objective function represented in equation (4.4), the fitness is evaluated.

Randomization: In order to identify the best global best solution for the optimal channel allocation, the hunters explore the prospective areas. In the randomization phase, the hunters' solution is updated as follows:

$$P_{k,h}(\tau+1) = P_{k,h}(\tau) + 0.5\begin{bmatrix}(2HW \cdot N_{v(h)} - P_{k,h}(\tau)) + \\ (2(1-H)W \cdot M_h - P_{k,h}(\tau))\end{bmatrix} \tag{4.8}$$

where, the adaptive parameter is notated as W and the mean of the solutions acquired by the hunters in the present iteration is indicated as M_h. The position updated by the hunters at $(\tau+1)^{th}$ iteration is notated as $P_{k,h}(\tau+1)$ and τ^{th} iteration is notated as $P_{k,h}(\tau)$. The definitions for the W and M_h are expressed as:

$$\begin{gathered} N = \vec{Y_1} < H; \qquad u = (N == 0); \\ W = Y_2 \otimes u + \vec{Y_3} \otimes (\sim u) \end{gathered} \tag{4.9}$$

$$M = \frac{1}{n}\sum_{k=1}^{n} \vec{P_k} \tag{4.10}$$

where, the solution considered as target is represented as N and H is the variable used to get the global best solution by balancing local search criteria with randomization. The random numbers are mentioned as Y_1, Y_2 *and* Y_3 with the limit of $[0,1]$. The value of index is defined as u for $\vec{Y_1}$ that maintains the $(N == 0)$ assumption. Then, the balancing parameter that degrades the value $1 \, to \, 0.02$ throughout the equation is formulated automatically as:

$$H = 1 - \tau\left(\frac{0.98}{\tau_{\max}}\right) \tag{4.11}$$

where, the processing iteration is defined as τ and its highest value is indicated as $\tau_{\max}$.

The prey's location is determined by taking into account the mean of the solution found by each individual hunter and the distance between the prey, which is represented as follows:

$$\overrightarrow{N_v} = \overrightarrow{P_k} \big| k\, is\, index\, of\; Max(End) sort(X) \tag{4.12}$$

The Euclidean distance, this is calculated by considering the mean solution of the hunters and the prey. It is given as follows:

$$X(k) = \left(\sum_{h=1}^{L} \left(P_{k,h} - M_h\right)^2 \right)^{1/2} \tag{4.13}$$

The prey's position is updated if the distance measurement yields a lower outcome. Based on the assumption, the algorithm has tendency to converge slowly when the output is greater. It is defined as:

$$Z = round(H \times q) \tag{4.14}$$

where, The hunters' population is denoted by q, whereas Z represents the distance-limiting factor. In order to increase the algorithm's pace of convergence, the distance limiting factor is gradually reduced from its original value over the course of iterations. The prey's successful solution is described as follows after evaluating the distance limiting factor:

$$\overrightarrow{N_v} = \overrightarrow{P_k} \big| k\; is\; sorted\; X(Z) \tag{4.15}$$

As a result, the definition applies to the solution of the hunters obtained during the randomization phase is formulated as:

$$P_{k,h}(\tau+1) = I_{v(h)} + HW \cos(2\pi Y_4) \times \left(I_{v(h)} - P_{k,h}(\tau)\right) \tag{4.16}$$

The adaptive weighting technique, which is described as follows helps to eliminate the solution's premature convergence during the randomization step. It is formulated as:

$$Y = \left(1 - \tau / \tau_{\max}\right)^{1 - \tan\left(\pi \times (l - 0.5) \times b / \tau_{\max}\right)} \tag{4.17}$$

where, b is added to the hunters' solution when solution updation is not used, is the element that causes the hunters to travel in the direction of the prey. When a solution update is generated by the hunters, however, component b is divided by 2. The adaptive weight factor Y in this instance has a maximum limit of 1 and a minimum value of 0. As a result, utilizing the suggested EnHpo, the hunters' position is updated after adopting the adaptive weighting approach as follows:

$$P_k(\tau+1)_{EnHpo} = Y * P_k(\tau+1) \tag{4.18}$$

where, the solution updation by the proposed EnHpo algorithm is indicated as $P_k(\tau+1)_{EnHpo}$.

Local Search: A local search is designed to find an in-depth solution to the channel allocation problem based on the solution found through randomization. The description of the position update is then given as follows:

$$P_k(\tau+1) = \begin{cases} P_k(\tau) + 0.5[(2 \cdot H \cdot W \cdot N_v - P_k(\tau)) + (2(1-w)W \cdot M - P_k(\tau))] & \text{if } Y_5 < \eta \\ I_v + H \cdot W \cdot \cos(2\pi Y_4) \times (I_v - P_k(\tau)) & \text{otherwise} \end{cases} \tag{4.19}$$

Feasibility Evaluation: The fitness estimation formulated in equation (4.4) is used to assess the viability of the solution found during the local search phase.

Termination: After obtaining the finest possible solution or, the iteration $\tau_{\max}$ comes to an end. Algorithm 4.1 presents the EnHpo algorithm's suggested pseudo-code.

Algorithm 4.1: Pseudo-code for EnHpo algorithm

Pseudo-code for EnHpo **algorithm**	
1	The initialization of parameters $H, \tau^{\max}, \eta, and\ q$ are performed
2	The initialization of parameters Max_v and Min_v are assigned
3	Using equation (4.4) fitness is estimated
4	while
5	{
6	Using equation (4.18) solution accomplished in randomization phase is obtained
7	Using equation (4.19) solution accomplished in local search phase is obtained
8	Re-estimate the feasibility using equation (4.4)

}
$I = I++$
Return the best solution
end

4.3.3 DQL based Relay Selection using channel gain

The DQL is used by the newly devised routing algorithm to determine which relay is the optimal best for making communication between the devices while taking into account the probability of the selected channel. Reinforcement learning helps to solve and improve the problem of the performance of the Markov decision control for the efficient routing. The basic component of reinforcement learning is a learning agent, which is capable of detecting changes in its surroundings and behaving in a way that can have an adverse effect on the controlled environment. In order to improve relay selection performance, the reward signal is specified and instructs the agent to gain larger cumulative values through a trial-and-error process. The well-known reinforcement learning algorithm used Q-learning in its design to address Markov choice issues (Watkins, 1989). As one of the most popular off-policy RLs, q-learning is expected to enhance total reward. Because of this, it is possible to think of the distribution between the given current condition and control action as the ideal value function that guides the formulation of policy. Figure 4.2 illustrates the basic idea that drives Deep Reinforcement Learning.

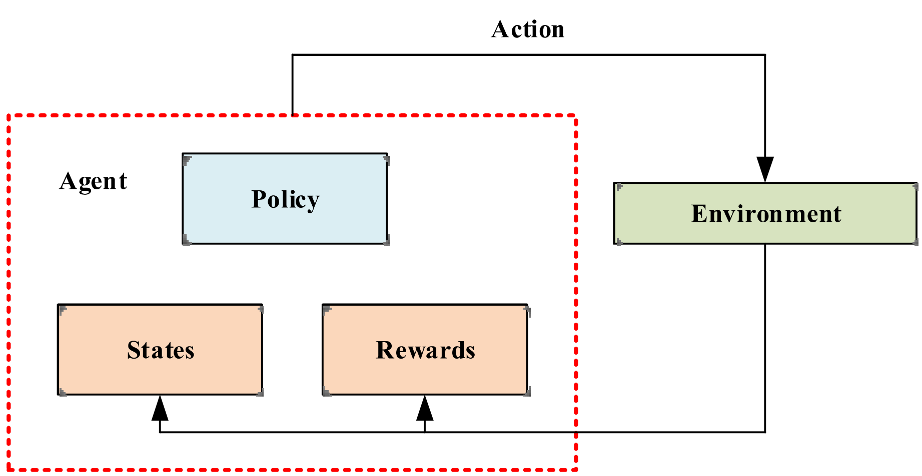


Figure 4.2: Basics architecture of Deep Reinforcement learning

Agent: When making decisions to address problems with uncertainty, the solution is known as the agent. The agent therefore influences the environment (problem). The agent's objective is to maximize rewards since it is essential to do so in order to choose relays with the best efficiency in choosing the available channel assignment.

Action: Actions are the selection best options from many relay for solving the issue. The agent chooses the optimal action out of all the specified actions.

Environment: The newly devised method's relay selection based on channel gain is referred to as the problem since it affects the environment. The environment is changed by the agent's choice in terms of policies, rewards, or states.

Policy: The choice of the right action that contributes to enhancing the reward is the responsibility of the policy.

States: States refer to the collection of parameters that make up the environment.

Rewards: The reward is defined as the feedback of the environment that offers in response to the agent's actions in each state.

4.3.1 Deep Reinforcement Learning

Deep reinforcement learning is the behavior that results from combining reinforcement learning and deep learning. The optimal action is chosen for the relay selection among the different actions that deep reinforcement learning produces for the given state Q . The network parameter is referred to as ϕ in this context. In the proposed D2D communication protocol, the relay is chosen based on the channel gain of the allotted channel using deep reinforcement learning. Figure 4.3 illustrates the Deep Reinforcement Learning architecture.

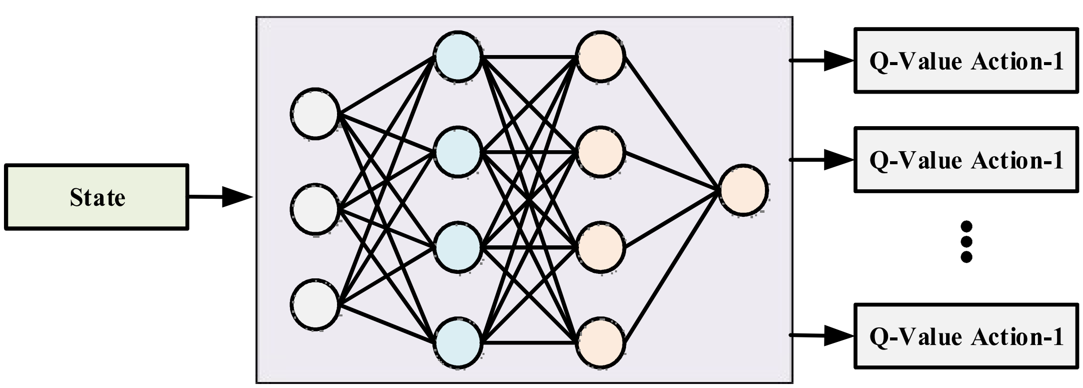


Figure 4.3: Architecture of Deep Reinforcement Learning

Here, the reward $R^h_{Q,Q''}$ serves as the basis for the decision-making process about relay selection concerning the state Q. Depending on the action state pair $B^h_{Q,Q'}$, the likelihood of selecting the relay is devised, where the action is referred as H. The activity is selecting the optimal relay based on its channel gain for the effective D2D communication in the proposed combined channel allocation and relay selection approach.

Reward and Q value Evaluation: Every decision-making action utilizes an estimated reward, and the action with largest reward selects the optimal relay for making the communication between devices. For the source device m_c, the receiver device m_b is considered for the efficient relay selection. Here, the reward for the action is outlined as:

$$R^h_{Q,Q''} = -p - \alpha_1 \left[\left(S_{d,a} \right)_c + \left(S_{d,a} \right)_b \right] + \alpha_2 \left[n(m_c) + n(m_b) \right] \tag{4.20}$$

where, the corresponding action-state pair is notated as $(m\ , f_s)$, punishment factor is defined as p, the weight factors are defined as α_1 *and* α_2 and $R^h_{Q,Q''}$ refers to the factor that defines the reward for the relay selection. If the action fails to choose the optimal relay based on channel gain, the following estimation is devised for choosing its reward function and is described as:

$$R^h_{Q,Q''} = -p \times \eta - \gamma_1 \left(S_{d,a} \right)_c + \gamma_2 n(m_c) \tag{4.21}$$

Here, η and $\left(S_{d,a}\right)_c$ represent the drop case of the relay selection and the channel gain taken into account for communication, respectively. After that, the following is the formula for determining the channel gain depending on the required bit error rate:

$$K_a = \underset{a \in \{M_1, M_2, \ldots M_A\}}{\arg\min} \{S_a\} \tag{4.22}$$

where, the destination device is designated as a, and the set of relays used to communicate with it is denoted as $K_a \in D$. Here, the relay selection is assessed using the channel coefficient in reducing the computational complexity of model, and is written as:

$$S_{d,a} = m_e \exp\left(-c_e \frac{q_{d,a} \left| p_{d,a} \right|}{\sigma^2} \right) \tag{4.23}$$

where, the bit error rate is represented as $S_{d,a}$, the power allocation is stated as $q_{d,a}$, the parameters used for modulation and coding are indicated as c_e and m, and the channel coefficient relating to the dth relay to the destination device is indicated as m_e. Relay selection based on channel gain is essential for effective D2D communication in this case. The estimated reward is described as follows:

$$\text{Re}\,ward = B_Q \times R_m^h + B\left(1 - B_Q\right) \times R_m^h \tag{4.24}$$

where, the initial channel gain varies from $[0,1]$.

Q-Value: To get the largest reward, the estimation of Q is designed as follows:

$$Q - V(Q,h) = \text{Re}ward + \beta\left[Q - V(Q,h) + Max_{h'}\left(Q - V(Q',:)\right)\right] \tag{4.25}$$

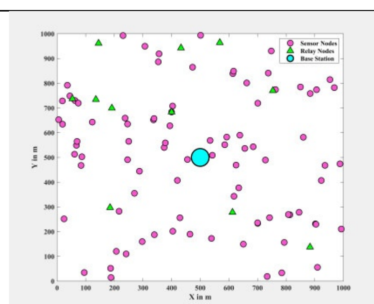
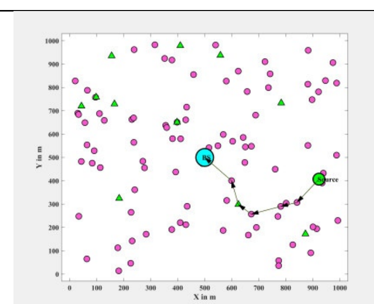
where, the notation of Q-value is represented as $Q - V$ and is exceptionally useful in selecting the most effective relay for D2D communication

4.4. Result and Discussion

Utilizing the MATLAB programming tool and a variety of assessment metrics, the proposed combined channel allocation and relay selection is evaluated. The performance of the suggested routing protocol is compared here using established resource allocation techniques such as the Game based Framework [178], Decode and Forward method [179], Zigbee/WiFi Routing [180], and DDPG Approach [181].

4.4.1 Simulation Outcome

Figure 4.4 illustrates the analysis of the newly devised joint channel allocation and relay selection approach based on the results of the simulation. In this case, the analysis is employed by altering the network scenario's node count.

100Nodes Network scenario with 10 Relay Nodes		

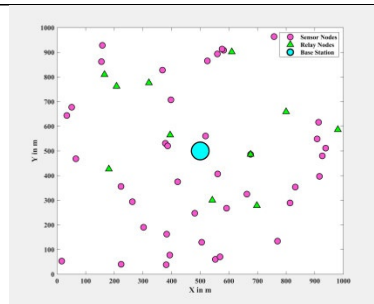
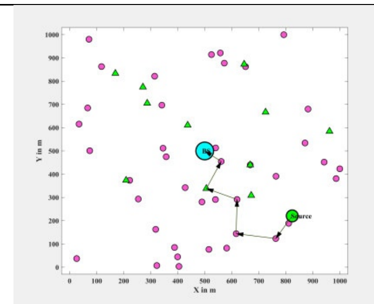
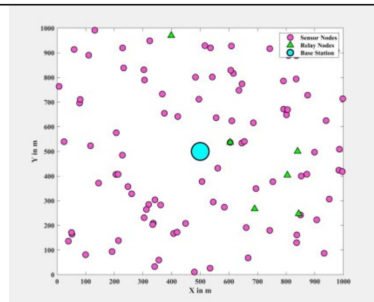
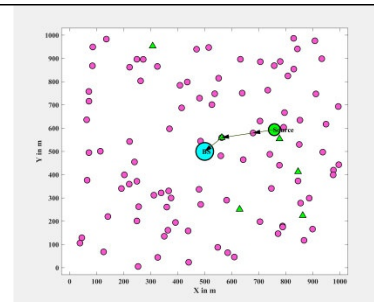
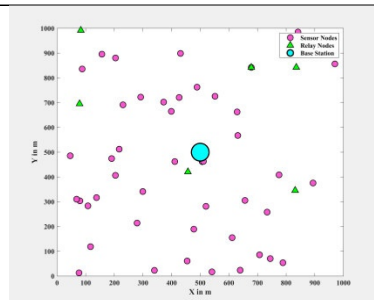
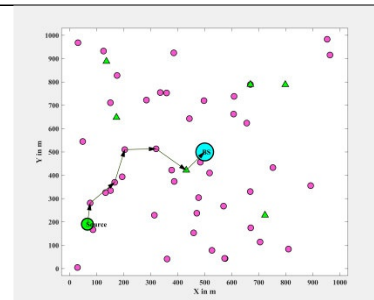
50Nodes Network scenario with 10 Relay Nodes		
100Nodes Network scenario with 5 Relay Nodes		
50 Nodes Network scenario with 5 Relay Nodes		
	(a)	(b)

Figure 4.4: **Simulation Outcome: (a) Network Scenario and (b) Routing**

The experimental results are shown in Figure 4(a) for the network scenario and Figure 4(b) for routing for a variety of network situations including 10 relay and100 nodes, 10 relay and 50 nodes, 5 relay and100 nodes and 5 relay and50 nodes.

4.4.2 Performance Evaluation by varying iteration

The analysis of the proposed EnHpo+DRL by varying the number of nodes in the network for various iterations is elaborated here.

(i) Assessment with 50 Nodes and 5 Relay Nodes

Average Residual Energy: The average residual energy by varying the number of communication rounds and iteration size of the newly devised EnHpo algorithm is shown in Figure 4.5. The average residual energy acquired with 500 round is 0.9148 for 20 iterations, which is further reduced when the round increases to 2500 with the average residual energy of 0.6629. Due to the increase in rounds, a greater amount of energy is consumed. However, the amount of residual energy is improved for the model's performance improvement by the increasing the iterations. For example, the average residual energy estimated with 20 iterations and 1000 round is 0.8456, which is 0.8978 when the iteration increased to 100. The detailed analysis is depicted in Table 4.1.

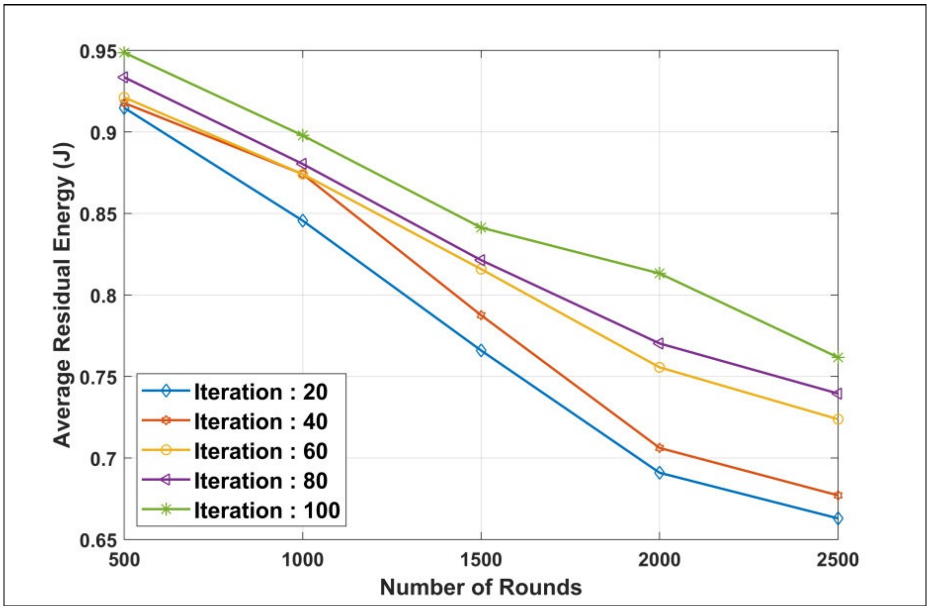


Figure 4.5: Average Residual Energy based on Iteration with 50 nodes and 5 relays

Table 4.1: Average Residual Energy based on Iteration with 50 nodes and 5 relays

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9148	0.8456	0.7659	0.6909	0.6629
Iteration size = 40	0.9177	0.8741	0.7875	0.7062	0.6771
Iteration size = 60	0.9212	0.8742	0.8158	0.7556	0.7238
Iteration size = 80	0.9335	0.8803	0.8213	0.7702	0.7395
Iteration size = 100	0.9486	0.8978	0.8413	0.8132	0.7617

Latency: The latency of the D2D communication depicts the time take for the information to reach the destination from the source. The analysis based on latency by varying the iteration with 50 Nodes and 5 Relay Nodes is portrayed in Figure 4.6. While considering the 20 iterations of EnHpo algorithm with 500 rounds, the latency estimated by the proposed method is 4.197, which is increased to 5.853, when the round is increased to 2500. In contrast, the latency gets minimized with increase in the number of iterations of the algorithm. For example, with 1500 round and 20 iterations, the latency estimated by the newly devised method is 5.434, which is further minimized to 3.637 with 100 iterations. Thus, the increase in iteration elevates the performance and increase in number of rounds limits the performance. The detailed analysis is presented in Table 4.2.

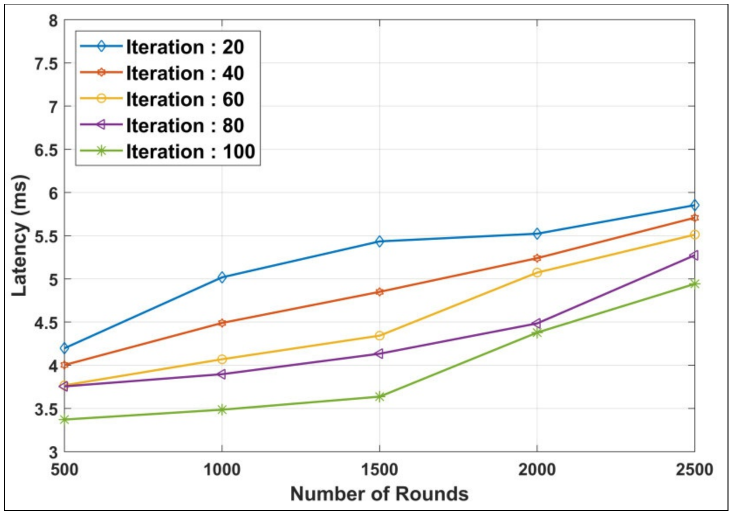


Figure 4.6: Latency based on Iteration with 50 Nodes and 5 Relay Nodes

Table 4.2: Latency based on Iteration with 50 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	4.197	5.018	5.434	5.523	5.853
Iteration size = 40	4.003	4.49	4.85	5.24	5.708
Iteration size = 60	3.768	4.07	4.343	5.073	5.512
Iteration size = 80	3.756	3.897	4.134	4.485	5.274
Iteration size = 100	3.372	3.486	3.637	4.379	4.942

Network Life Time: The network lifetime based analysis with 50 Nodes and 5 Relay Nodes by varying the iteration size is depicted in Figure 4.7. The network lifetime estimated by the newly devised joint channel allocation and relay selection protocol is 93.33 with 20 iteration and 500 rounds. The same is 85.36 with 2500 rounds and 20 iterations, which indicates that the minimal rounds provides the better network lifetime. Also, the network lifetime estimated is 87.41 with 1500 rounds and 20 iterations, which elevates with 91.51 with 100 iterations and 1500 rounds. Here, the analysis indicates the enhanced performance with minimal communication round and higher iteration. The detailed analysis is presented in Table 4.3.

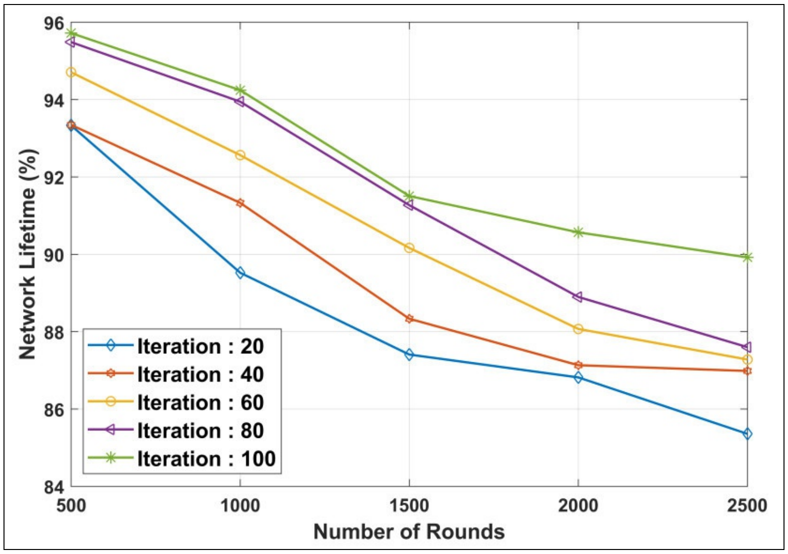


Figure 4.7: Network Life Time based on Iteration with 50 Nodes and 5 Relay Nodes

Table 4.3: Network Life Time based on Iteration with 50 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	93.33	89.52	87.41	86.82	85.36
Iteration size = 40	93.35	91.33	88.33	87.13	86.98
Iteration size = 60	94.71	92.56	90.16	88.07	87.28
Iteration size = 80	95.49	93.95	91.27	88.90	87.60
Iteration size = 100	95.72	94.24	91.51	90.57	89.92

Packet Delivery Ratio: The interpretation of the packet delivery ratio for various iteration sizes of the newly devised EnHpo algorithm of the introduced joint channel allocation and relay selection with 50 Nodes and 5 Relay Nodes is depicted in Figure 4.8. For 20 iterations, the packet delivery ration accomplished by the newly devised protocol is 0.989 with 500 rounds, which is 0.8921 when the round is increased to 2500. In contrast, the packet delivery ratio acquired by the suggested model is 0.932 with 20 iterations and 1000 rounds. Besides, the packet delivery ratio measured by the proposed protocol with 100 iterations is 0.988with 1000 rounds. The detailed evaluation is presented in Table 4.4.

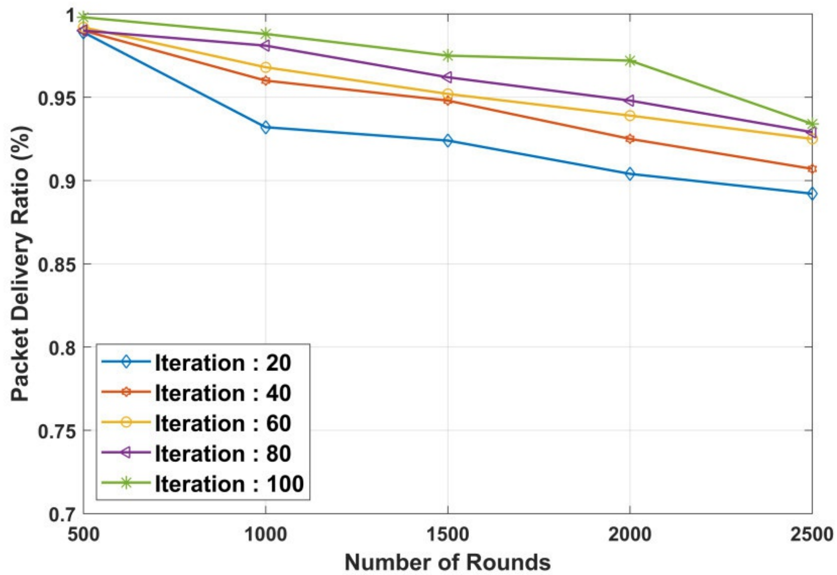


Figure 4.8: Packet Delivery Ratio based on Iteration with 50 Nodes and 5 Relay Nodes

Table 4.4: Packet Delivery Ratio based on Iteration with 50 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.989	0.932	0.924	0.904	0.8921
Iteration size = 40	0.99	0.96	0.948	0.925	0.907
Iteration size = 60	0.992	0.968	0.952	0.939	0.925
Iteration size = 80	0.99	0.981	0.962	0.948	0.929
Iteration size = 100	0.998	0.988	0.975	0.972	0.934

Throughput: The throughput based analysis of the proposed method by varying the iteration of the EnHpo algorithm is depicted in Figure 4.9 with 50 Nodes and 5 Relay Nodes. The throughput estimated by the newly devised protocol with 20 iterations and 500 communications round is 5923, which is 13959 with 2500 rounds. While analyzing the performance with 2000 rounds and 20 iterations, the throughput estimated by the proposed protocol is 11932. When the iteration increased to 100, the throughput estimated is 17908 that depict the better outcome of the model with increase in iteration. The detailed analysis is presented in Table 4.5.

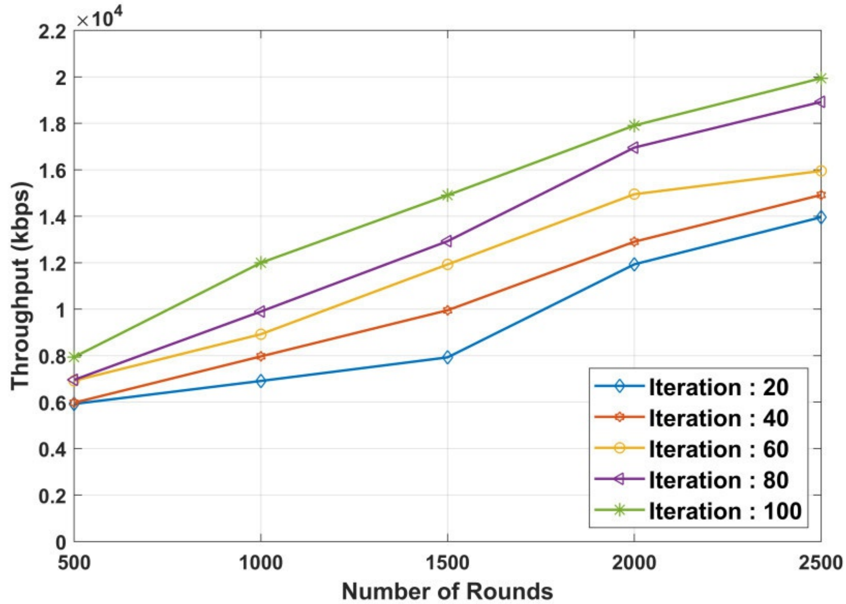


Figure 4.9: Throughput based on Iteration with 50 Nodes and 5 Relay Nodes

Table 4.5: Throughput based on Iteration with 50 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	5923	6911	7927	11932	13959
Iteration size = 40	5974	7968	9954	12905	14919
Iteration size = 60	6919	8923	11926	14949	15951
Iteration size = 80	6958	9900	12928	16957	18924
Iteration size = 100	7940	11996	14906	17908	19941

(ii) Assessment with 100 Nodes and 5 Relay Nodes

Average Residual Energy: The average residual energy by varying the number of communication rounds and iteration size of the newly devised EnHpo algorithm is depicted in Figure 4.10. The average residual energy acquired with 500 round is 0.9292 for 20 iterations, which is further reduced when the round increases to 2500 with the average residual energy of 0.6827. Hence, the elevation in the number of rounds consumes more energy. Still, the increase in iteration elevates the performance of the model by enhancing the amount of residual energy. For example, the average residual energy estimated with 20 iterations and 1000 round is 0.8605, which is 0.9160 when the iteration increased to 100. The detailed analysis is depicted in Table 4.6.

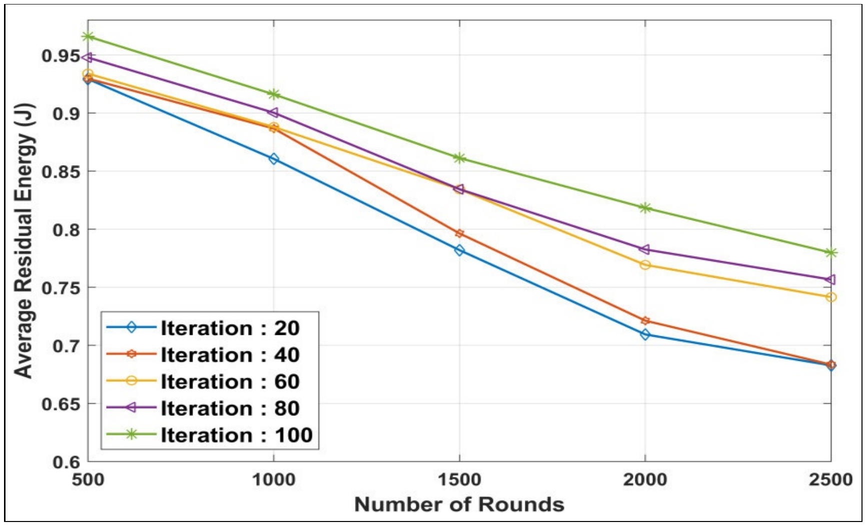


Figure 4.10: Average Residual Energy based on Iteration with 100 Nodes and 5 Relay Nodes

Table 4.6: Average Residual Energy based on Iteration with 100 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9292	0.8605	0.7819	0.7093	0.6827
Iteration size = 40	0.9296	0.8866	0.7962	0.7212	0.6833
Iteration size = 60	0.9338	0.8879	0.8342	0.7692	0.7414
Iteration size = 80	0.9477	0.9002	0.8344	0.7824	0.7565
Iteration size = 100	0.9658	0.9160	0.8611	0.8182	0.7797

Latency: The latency of the D2D communication depicts the time take for the information to reach the destination from the source. The analysis based on latency by varying the iteration with 100 Nodes and 5 Relay Nodes is portrayed in Figure 4.11. While considering the 20 iterations of EnHpo algorithm with 500 rounds, the latency estimated by the proposed method is 4.1874, which is increased to 5.8433, when the round is increased to 2500. In contrast, the latency gets minimized with increase in the number of iterations of the algorithm. For example, with 1500 round and 20 iterations, the latency estimated by the newly devised method is 5.4243, which is further minimized to 3.6276 with 100 iterations. Thus, the increase in iteration elevates the performance and increase in number of rounds limits the performance. The detailed analysis is presented in Table 4.7.

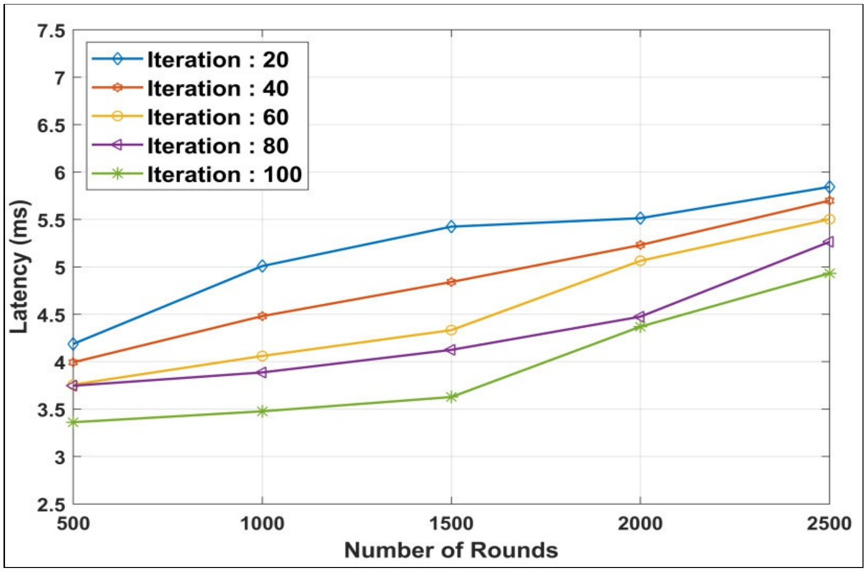


Figure 4.11: Latency based on Iteration with 100 Nodes and 5 Relay Nodes

Table 4.7: Latency based on Iteration with 100 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	4.1874	5.0087	5.4243	5.5133	5.8433
Iteration size = 40	3.9935	4.4809	4.8408	5.2301	5.6988
Iteration size = 60	3.7582	4.0605	4.333	5.0639	5.5026
Iteration size = 80	3.7469	3.887	4.125	4.4752	5.2642
Iteration size = 100	3.3621	3.4769	3.6276	4.3697	4.9322

Network Life Time: The network lifetime based analysis with 100 Nodes and 5 Relay Nodes by varying the iteration size is depicted in Figure 4.12. The network lifetime estimated by the newly devised protocol is 94.50 with 20 iteration and 500 rounds. The same is 86.99 with 2500 rounds and 20 iterations, which indicates that the minimal rounds provides the better network lifetime. Also, the network lifetime estimated is 89.19 with 1500 rounds and 20 iterations, which elevates with 94.10 with 100 iterations and 1500 rounds. Here, the analysis indicates the enhanced performance with minimal communication round and higher iteration. The detailed analysis is presented in Table 4.8.

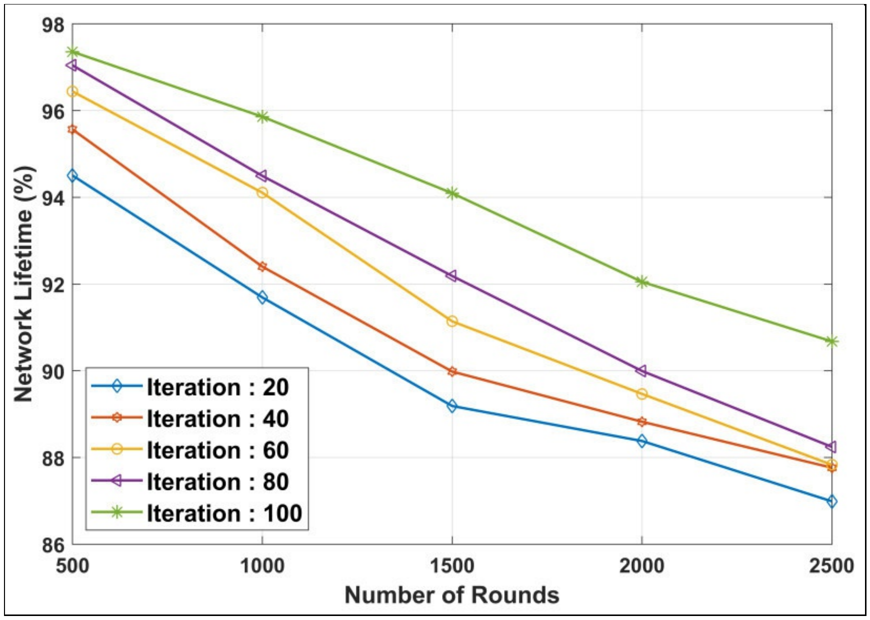


Figure 4.12: Network Life Time based on Iteration with 100 Nodes and 5 Relay Nodes

Table 4.8: Network Life Time based on Iteration with 100 Nodes and 5 Relay Nodes

Rounds	**500**	**1000**	**1500**	**2000**	**2500**
Iteration size = 20	94.50	91.69	89.19	88.38	86.99
Iteration size = 40	95.57	92.40	89.98	88.82	87.76
Iteration size = 60	96.44	94.11	91.14	89.47	87.83
Iteration size = 80	97.04	94.49	92.19	89.99	88.24
Iteration size = 100	97.36	95.86	94.10	92.05	90.68

Packet Delivery Ratio: The interpretation of the packet delivery ratio for various iteration sizes of the newly devised EnHpo algorithm of the introduced protocol with 100 Nodes and 5 Relay Nodes is depicted in Figure 4.13. For 20 iterations, the packet delivery ratio accomplished by the newly devised protocol is 0.9897 with 500 rounds, which is 0.9012 when the round is increased to 2500. In contrast, the packet delivery ratio acquired by the suggested model is 0.9410 with 20 iterations and 1000 rounds. Besides, the packet delivery ratio measured by the suggested protocol with 100 iterations is 0.9908 with 100 rounds. The detailed analysis is presented in Table 4.9.

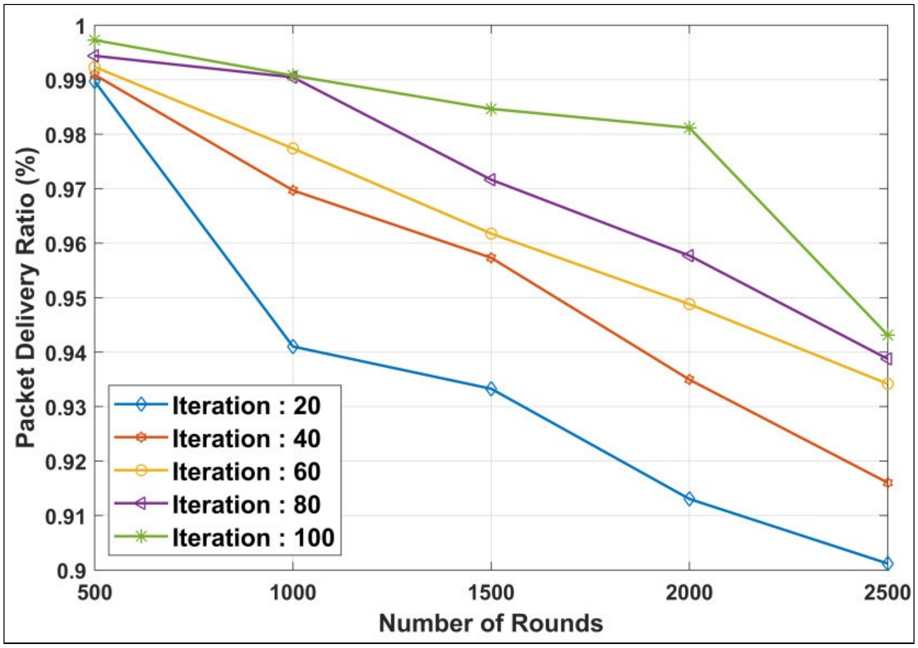


Figure 4.13: Packet Delivery Ratio based on Iteration with 100 Nodes and 5 Relay Nodes

Table 4.9: Packet Delivery Ratio based on Iteration with 100 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9897	0.9410	0.9333	0.9130	0.9012
Iteration size = 40	0.9909	0.9697	0.9573	0.9350	0.9160
Iteration size = 60	0.9923	0.9774	0.9618	0.9488	0.9342
Iteration size = 80	0.9944	0.9904	0.9716	0.9577	0.9388
Iteration size = 100	0.9973	0.9908	0.9847	0.9812	0.9431

Throughput: The throughput based analysis of the newly devised protocol by varying the iteration of the EnHpo algorithm is depicted in Figure 4.14 with 100 Nodes and 5 Relay Nodes. The throughput estimated by the newly devised protocol with 20 iterations and 500 communications round is 6501, which is 15224 with 2500 rounds. While analyzing the performance with 2000 rounds and 20 iterations, the throughput estimated by the proposed protocol is 12536. When the iteration increased to 100, the throughput estimated is 18903 that depict the better outcome of the model with increase in iteration. The detailed analysis is presented in Table 4.10.

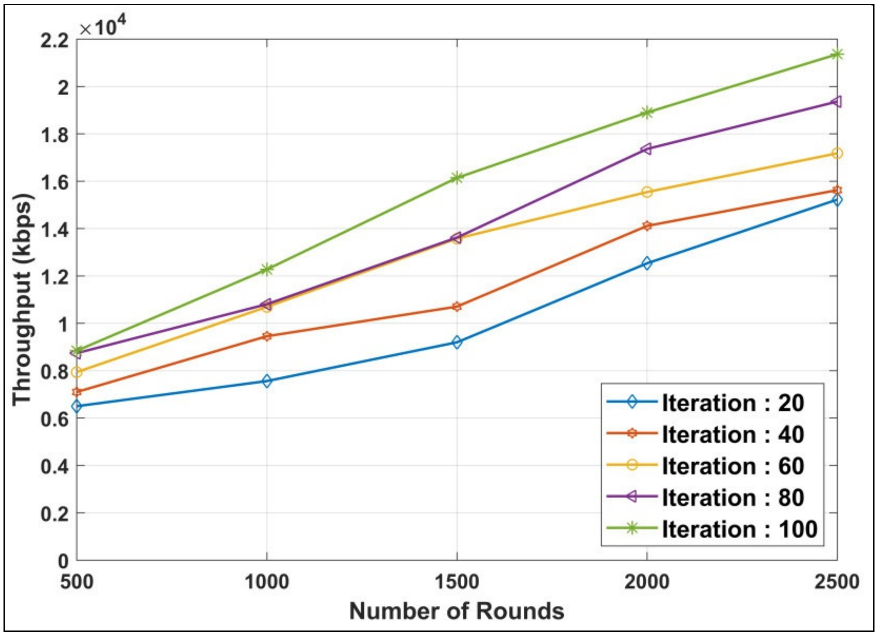


Figure 4.14: Throughput based on Iteration with 100 Nodes and 5 Relay Nodes

Table 4.10: Throughput based on Iteration with 100 Nodes and 5 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	6501	7563	9199	12536	15224
Iteration size = 40	7101	9455	10707	14115	15625
Iteration size = 60	7941	10694	13580	15544	17180
Iteration size = 80	8741	10808	13622	17364	19364
Iteration size = 100	8843	12275	16143	18903	21363

(iii) Assessment with 50 Nodes and 10 Relay Nodes

Average Residual Energy: The average residual energy by varying the number of communication rounds and iteration size of the newly devised EnHpo algorithm is depicted in Figure 4.15. The average residual energy acquired with 500 round is 0.9452 for 20 iterations, which is further reduced when the round increases to 2500 with the average residual energy of 0.7010. Hence, the elevation in the number of rounds consumes more energy. Still, the increase in iteration elevates the performance of the model by enhancing the amount of residual energy. For example, the average residual energy estimated with 20 iterations and 1000 round is 0.8790, which is 0.9529 when the iteration increased to 100. The detailed analysis is depicted in Table 4.11.

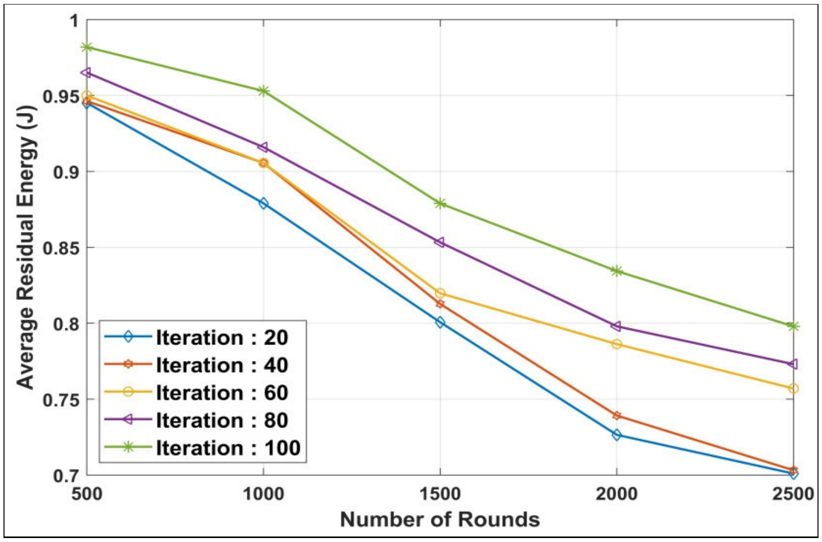


Figure 4.15: Average Residual Energy based on Iteration with 50 Nodes and 10 Relay Nodes

Table 4.11: Average Residual Energy based on Iteration with 50 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9452	0.8790	0.8007	0.7265	0.7010
Iteration size = 40	0.9463	0.9055	0.8127	0.7392	0.7031
Iteration size = 60	0.9500	0.9056	0.8197	0.7862	0.7570
Iteration size = 80	0.9651	0.9160	0.8533	0.7979	0.7730
Iteration size = 100	0.9819	0.9529	0.8789	0.8344	0.7979

Latency: The latency of the D2D communication depicts the time take for the information to attain the destination from the source. The analysis based on latency by varying the iteration with 50 Nodes and 10 Relay Nodes is portrayed in Figure 4.16. While considering the 20 iterations of EnHpo algorithm with 500 rounds, the latency estimated by the proposed method is 3.8283, which is increased to 5.5454, when the round is increased to 2500. In contrast, the latency gets minimized with increase in the number of iterations of the algorithm. For example, with 1500 round and 20 iterations, the latency estimated by the newly devised method is 4.5878, which is further minimized to 3.1874 with 100 iterations. Thus, the increase in iteration elevates the performance and increase in number of rounds limits the performance. The detailed analysis is presented in Table 4.12.

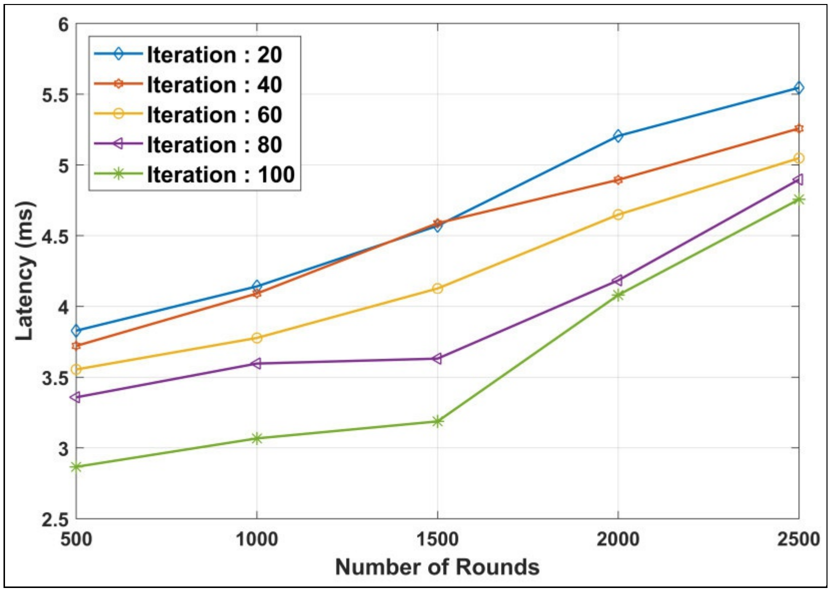


Figure 4.16: Latency based on Iteration with 50 Nodes and 10 Relay Nodes

Table 4.12: Latency based on Iteration with 50 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	3.8283	4.1413	4.5878	5.2049	5.5454
Iteration size = 40	3.7207	4.091	4.5696	4.8944	5.2575
Iteration size = 60	3.5542	3.777	4.1266	4.6486	5.0477
Iteration size = 80	3.3575	3.5962	3.631	4.1844	4.897
Iteration size = 100	2.8663	3.0672	3.1874	4.0808	4.7563

Network Life Time: The network lifetime based analysis with 50 Nodes and 10 Relay Nodes by varying the iteration size is depicted in Figure 4.17. The network lifetime estimated by the newly devised D2D communication protocol is 96.19 with 20 iteration and 500 rounds. The same is 88.65 with 2500 rounds and 20 iterations, which indicates that the minimal rounds provides the better network lifetime. Also, the network lifetime estimated is 90.00 with 1500 rounds and 20 iterations, which elevates with 95.68 with 100 iterations and 1500 rounds. Here, the analysis indicates the enhanced performance with minimal communication round and higher iteration. The detailed analysis is presented in Table 4.13.

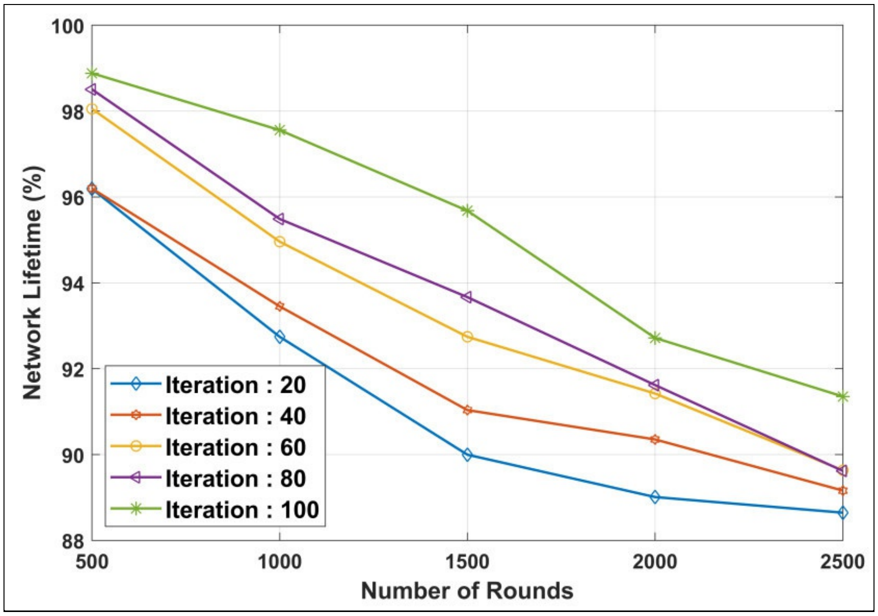


Figure 4.17: Network Life Time based on Iteration with 50 Nodes and 10 Relay Nodes

Table 4.13: Network Life Time based on Iteration with 50 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	96.19	92.74	90.00	89.01	88.65
Iteration size = 40	96.20	93.45	91.04	90.35	89.16
Iteration size = 60	98.05	94.96	92.74	91.42	89.62
Iteration size = 80	98.51	95.49	93.67	91.62	89.63
Iteration size = 100	98.88	97.56	95.68	92.72	91.35

Packet Delivery Ratio: The interpretation of the packet delivery ratio for various iteration sizes of the newly devised EnHpo algorithm of the introduced joint channel allocation and relay selection with 50 Nodes and 10 Relay Nodes is depicted in Figure 4.18. For 20 iterations, the packet delivery ratio accomplished by the newly devised protocol is 0.9929 with 500 rounds, which is 0.9037 when the round is increased to 2500. In contrast, the packet delivery ratio acquired by the proposed model is 0.9547 with 20 iterations and 1000 rounds. Besides, the packet delivery ratio measured by the proposed protocol with 100 iterations is 0.9952 with 100 rounds. The detailed analysis is presented in Table 4.14.

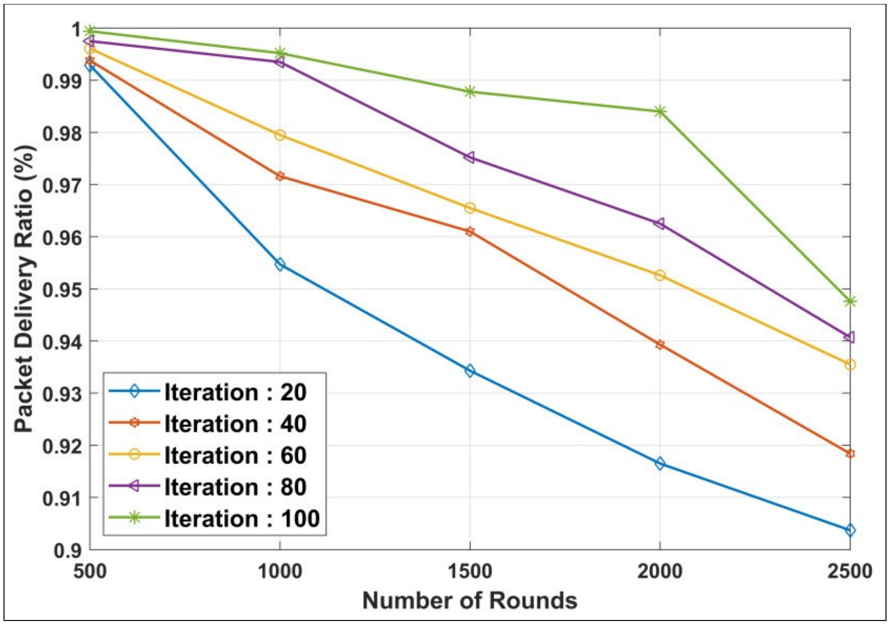


Figure 4.18: Packet Delivery Ratio based on Iteration with 50 Nodes and 10 Relay Nodes

Table 4.14: Packet Delivery Ratio based on Iteration with 50 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9929	0.9547	0.9343	0.9165	0.9037
Iteration size = 40	0.9938	0.9716	0.961	0.9393	0.9184
Iteration size = 60	0.9961	0.9795	0.9655	0.9526	0.9355
Iteration size = 80	0.9975	0.9935	0.9752	0.9625	0.9407
Iteration size = 100	0.9994	0.9952	0.9878	0.984	0.9476

Throughput: The throughput based analysis of the D2D protocol by varying the iteration of the EnHpo algorithm is depicted in Figure 4.19 with 50 Nodes and 10 Relay Nodes. The throughput estimated by the newly devised protocol with 20 iterations and 500 communications round is 7264, which is 15868 with 2500 rounds. While analyzing the performance with 2000 rounds and 20 iterations, the throughput estimated by the proposed protocol is 13427. When the iteration increased to 100, the throughput estimated is 19802 that depict the better outcome of the model with increase in iteration. The detailed analysis is presented in Table 4.15.

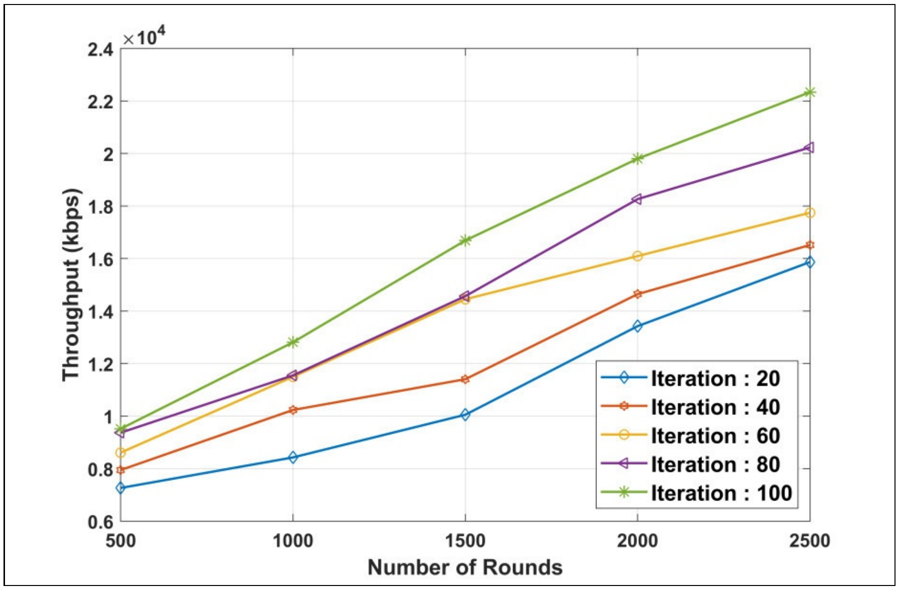


Figure 4.19: Throughput based on Iteration with 50 Nodes and 10 Relay Nodes

Table 4.15: Throughput based on Iteration with 50 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	7264	8428	10053	13427	15868
Iteration size = 40	7947	10234	11406	14646	16515
Iteration size = 60	8610	11498	14450	16097	17744
Iteration size = 80	9369	11551	14567	18263	20231
Iteration size = 100	9516	12811	16687	19802	22335

(iv) Assessment with 100 Nodes and 10 Relay Nodes

Average Residual Energy: The average residual energy by varying the number of communication rounds and iteration size of the newly devised EnHpo algorithm is depicted in Figure 4.20. The average residual energy acquired with 500 round is 0.9625 for 20 iterations, which is further reduced when the round increases to 2500 with the average residual energy of 0.7180. Hence, the elevation in the number of rounds consumes more energy. Still, the increase in iteration elevates the performance of the model by enhancing the amount of residual energy. For example, the average residual energy estimated with 20 iterations and 1000 round is 0.8958, which is 0.9504 when the iteration increased to 100. The detailed analysis is depicted in Table 4.16.

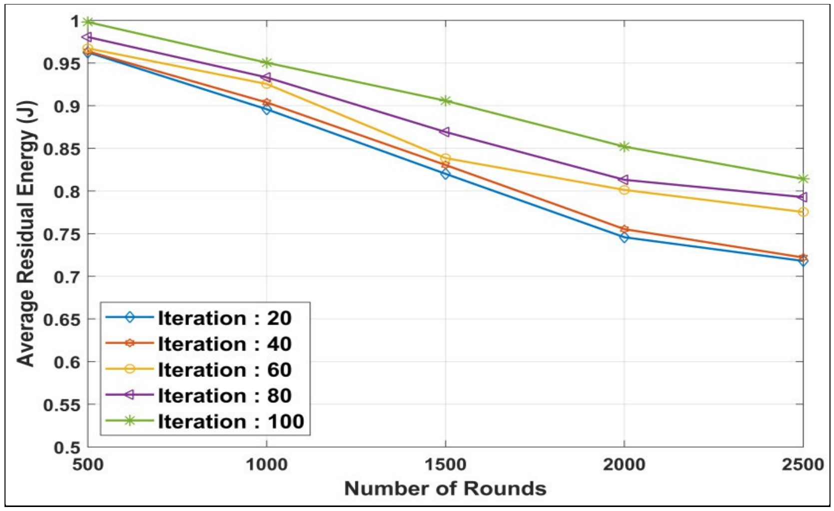


Figure 4.20: Average Residual Energy based on Iteration with 100 Nodes and 10 Relay Nodes

Table 4.16: Average Residual Energy based on Iteration with 100 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9625	0.8958	0.8201	0.7457	0.7180
Iteration size = 40	0.9637	0.9038	0.8305	0.7553	0.7220
Iteration size = 60	0.9672	0.9254	0.8385	0.8013	0.7754
Iteration size = 80	0.9805	0.9331	0.8691	0.8131	0.7928
Iteration size = 100	0.9980	0.9504	0.9058	0.8520	0.8142

Latency: The latency of the D2D communication depicts the time take for the information to reach the destination from the source. The analysis based on latency by varying the iteration with 100 Nodes and 10 Relay Nodes is portrayed in Figure 4.21. While considering the 20 iterations of EnHpo algorithm with 500 rounds, the latency estimated by the proposed method is 3.5006, which is increased to 5.1638, when the round is increased to 2500. In contrast, the latency gets minimized with increase in the number of iterations of the algorithm. For example, with 1500 round and 20 iterations, the latency estimated by the newly devised method is 4.6526, which is further minimized to 3.461 with 100 iterations. Thus, the increase in iteration elevates the performance and increase in number of rounds limits the performance. The detailed analysis is presented in Table 4.17.

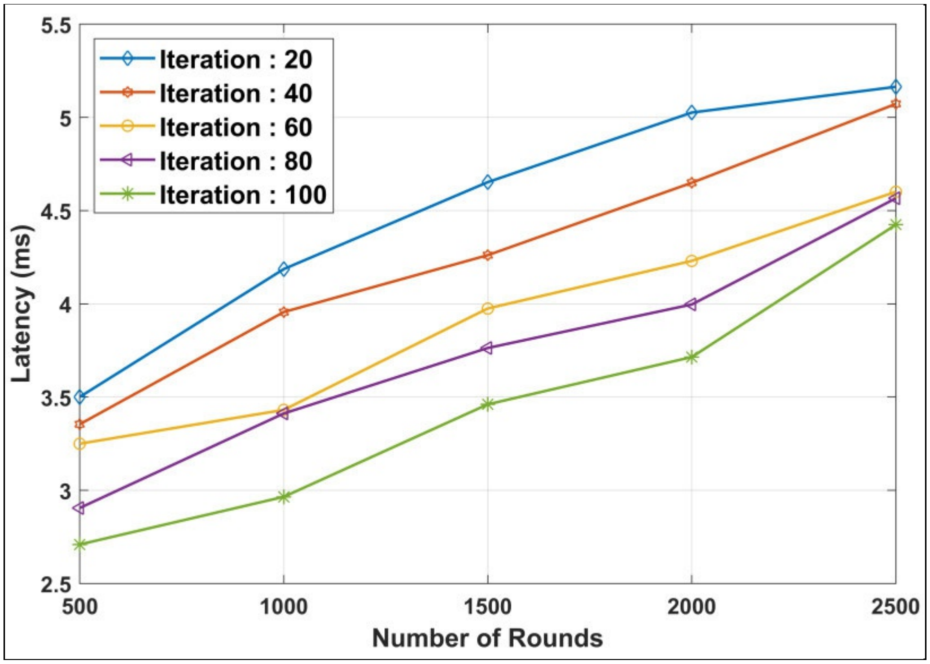


Figure 4.21: Latency based on Iteration with 100 Nodes and 10 Relay Nodes

Table 4.17: Latency based on Iteration with 100 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	3.5006	4.1863	4.6526	5.0259	5.1638
Iteration size = 40	3.3541	3.956	4.261	4.6494	5.0722
Iteration size = 60	3.2498	3.4312	3.975	4.2303	4.6007
Iteration size = 80	2.9051	3.412	3.7632	3.9966	4.5661
Iteration size = 100	2.7094	2.9649	3.461	3.7147	4.4243

Network Life Time: The network lifetime based analysis with 100 Nodes and 10 Relay Nodes by varying the iteration size is depicted in Figure 4.22. The network lifetime estimated by the newly devised protocol is 96.95 with 20 iteration and 500 rounds. The same is 90.06 with 2500 rounds and 20 iterations, which indicates that the minimal rounds provides the better network lifetime. Also, the network lifetime estimated is 91.40 with 1500 rounds and 20 iterations, which elevates with 96.31 with 100 iterations and 1500 rounds. Here, the analysis indicates the enhanced performance with minimal communication round and higher iteration. The detailed analysis is presented in Table 4.18.

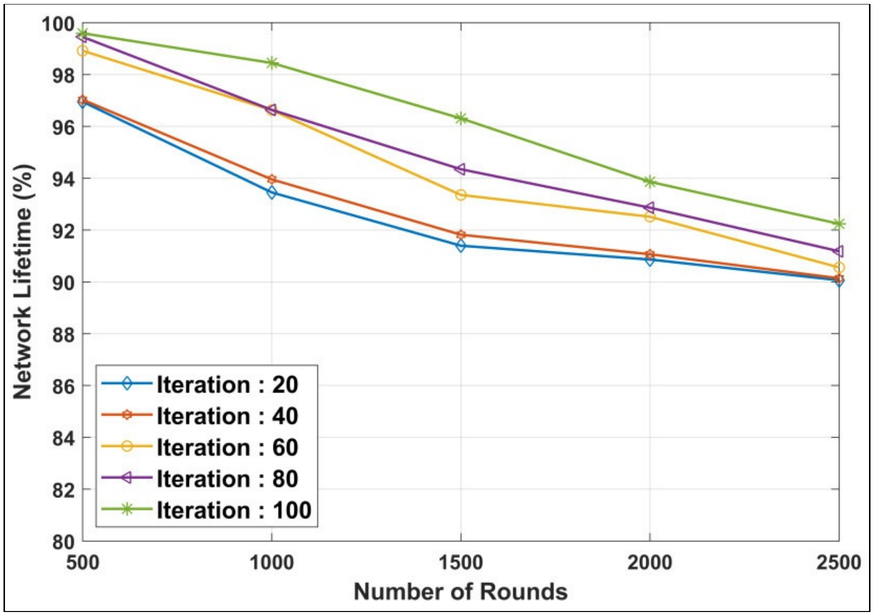


Figure 4.22: Network Life Time based on Iteration with 100 Nodes and 10 Relay Nodes

Table 4.18: Network Life Time based on Iteration with 100 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	96.95	93.45	91.40	90.86	90.06
Iteration size = 40	97.03	93.95	91.82	91.07	90.14
Iteration size = 60	98.92	96.62	93.35	92.51	90.56
Iteration size = 80	99.45	96.64	94.35	92.86	91.18
Iteration size = 100	99.59	98.45	96.31	93.86	92.24

Packet Delivery Ratio: The interpretation of the packet delivery ratio for various iteration sizes of the newly devised EnHpo algorithm of the introduced joint channel allocation and relay selection with 100 Nodes and 10 Relay Nodes is depicted in Figure 4.23. For 20 iterations, the packet delivery ration accomplished by the newly devised protocol is 0.9950 with 500 rounds, which is 0.9053 when the round is increased to 2500. In contrast, the packet delivery ratio acquired by the proposed model is 0.9581 with 20 iterations and 1000 rounds. Besides, the packet delivery ratio measured by the proposed protocol with 100 iterations is 0.9990 with 100 rounds. The detailed analysis is presented in Table 4.19.

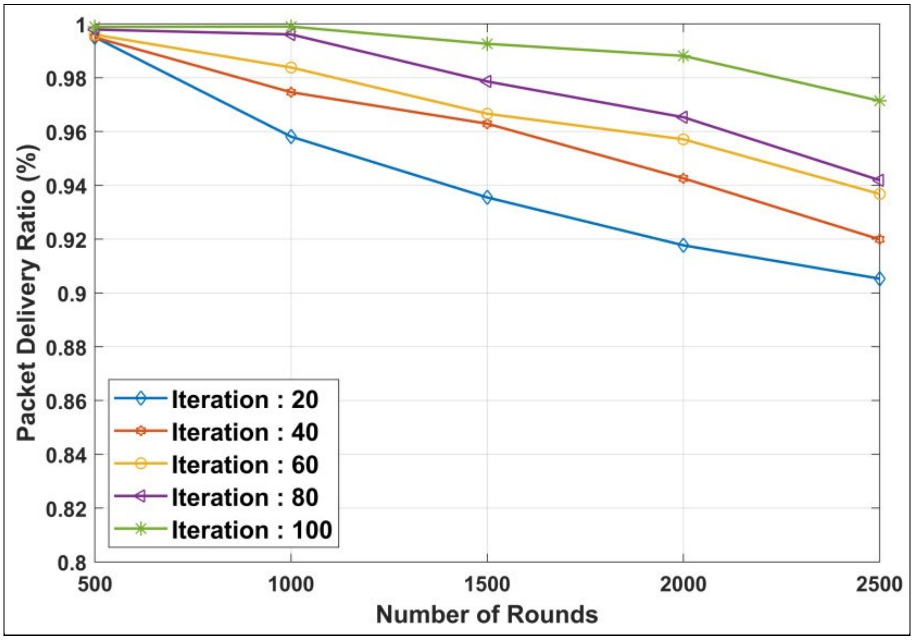


Figure 4.23: Packet Delivery Ratio based on Iteration with 100 Nodes and 10 Relay Nodes

Table 4.19: Packet Delivery Ratio based on Iteration with 100 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	0.9950	0.9581	0.9355	0.9177	0.9053
Iteration size = 40	0.9951	0.9746	0.9629	0.9426	0.9199
Iteration size = 60	0.9960	0.9838	0.9666	0.9571	0.9368
Iteration size = 80	0.9979	0.9961	0.9786	0.9653	0.9419
Iteration size = 100	0.9989	0.9990	0.9926	0.9881	0.9714

Throughput: The throughput based analysis of the D2D protocol by varying the iteration of the EnHpo algorithm is depicted in Figure 4.24 with 100 Nodes and 10 Relay Nodes. The throughput estimated by the newly devised protocol with 20 iterations and 500 communications round is 8023, which is 16588 with 2500 rounds. While analyzing the performance with 2000 rounds and 20 iterations, the throughput estimated by the proposed protocol is 14222. When the iteration increased to 100, the throughput estimated is 20497 that depict the better outcome of the model with increase in iteration. The detailed analysis is presented in Table 4.20.

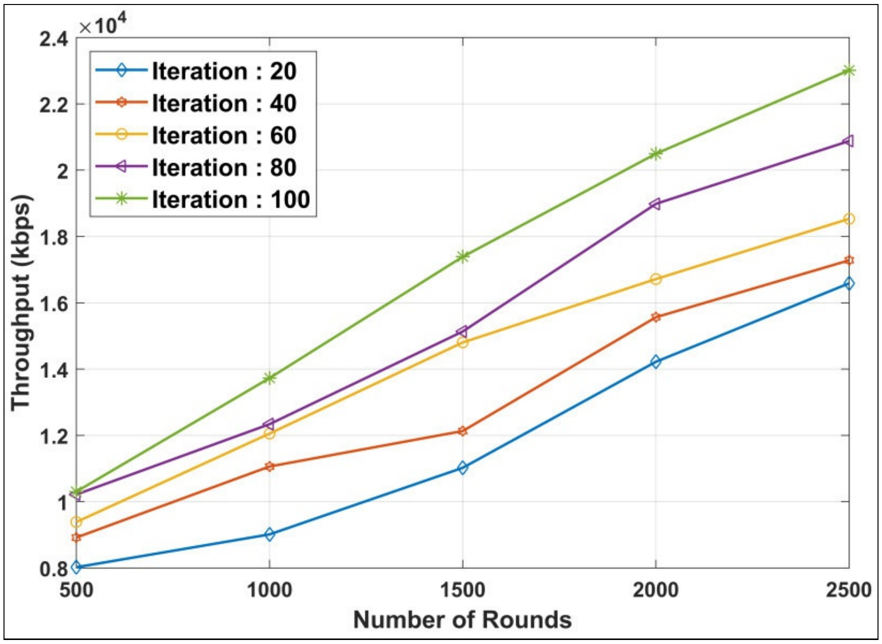


Figure 4.24: Throughput based on Iteration with 100 Nodes and 10 Relay Nodes

Table 4.20: Throughput based on Iteration with 100 Nodes and 10 Relay Nodes

Rounds	500	1000	1500	2000	2500
Iteration size = 20	8023	9013	11022	14222	16588
Iteration size = 40	8918	11062	12132	15565	17282
Iteration size = 60	9387	12054	14804	16716	18534
Iteration size = 80	10216	12338	15134	18985	20881
Iteration size = 100	10303	13728	17389	20497	23015

4.4.3 Comparative Assessment

The comparative assessment is devised by comparing the newly devised joint channel allocation and relay selection protocols for the D2D communication along with the conventional communication protocols like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach methods to indicate the superiority of the proposed model.

(i) Using 50 Nodes and 5 Relays

Average Residual Energy: The assessment based on the average residual energy is depicted in Figure 4.25 with 50 Nodes and 5 Relays. The average residual energy evaluated by the newly devised protocol is 0.9148 with 500 rounds, which is 021.96%, 21.29%, 18.00%, and 11.46% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the average residual energy evaluated by the newly devised protocol is 0.6629, which is 44.47%, 43.29%, 39.89%, and 10.06% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.21.

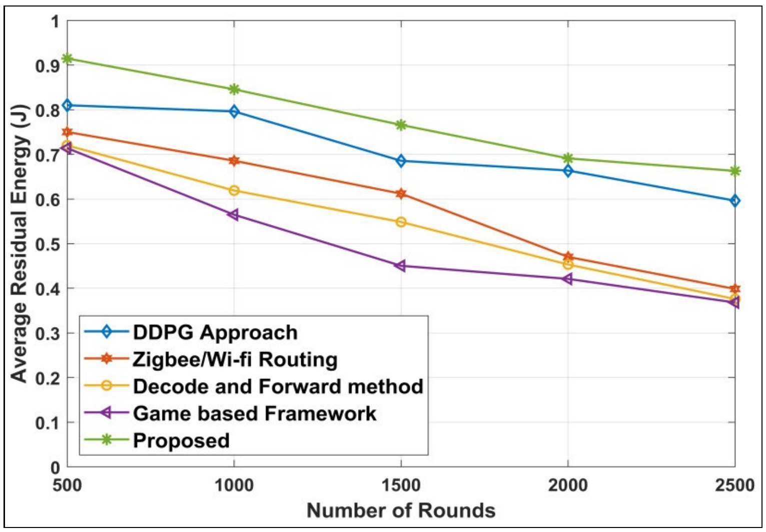


Figure 4.25: Average Residual Energy with 50 Nodes and 5 Relays

Table 4.21: Average Residual Energy with 50 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.81	0.7501	0.72	0.7139	0.9148
1000	0.7962	0.6857	0.619	0.5647	0.8456
1500	0.6855	0.6119	0.5485	0.4503	0.7659
2000	0.6637	0.4702	0.4532	0.421	0.6909
2500	0.5962	0.3985	0.3759	0.3681	0.6629

Latency: Figure 4.26 depicts the latency analysis of the proposed method by considering 50 Nodes and 5 Relays. While considering the 500 rounds, the latency evaluated by the newly devised protocol is 3.372 that is 957.99%, 47.73%, 45.96%, and 13.68% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. Also, the latency estimated by the newly devised protocol is 4.942 with 2500 rounds that is 58.58%, 54.31%, 47.10%, and 40.99% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.22.

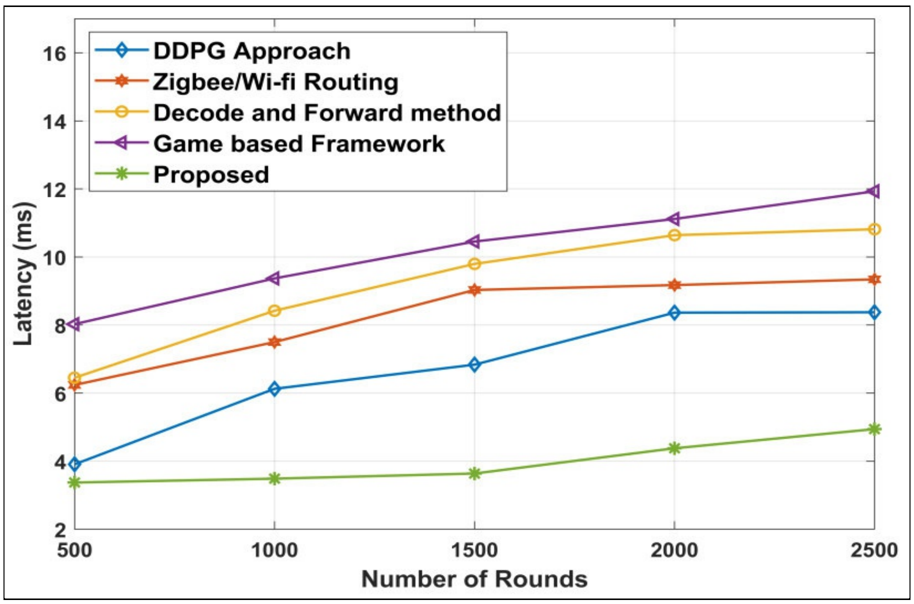


Figure 4.26: Latency with 50 Nodes and 5 Relays

Table 4.22: Latency with 50 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	3.9063	6.2395	6.4506	8.0265	3.372
1000	6.127	7.4992	8.42	9.3706	3.486
1500	6.836	9.0311	9.7966	10.454	3.637
2000	8.3643	9.1743	10.6417	11.117	4.379
2500	8.3755	9.343	10.8161	11.9313	4.942

Network Life Time: The network lifetime analysis is portrayed in Figure 4.27 and its detailed analysis is presented in Table 4.23. In this, the newly devised protocol accomplished the higher network life time of 95.7195; still the conventional methods like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach accomplished degraded network life time of 11.00%, 9.58%, 6.77%, and 5.68% respectively with 500 rounds. Here, the newly devised protocol accomplished 89.9195 Network lifetime with 2500 rounds, which is 15.30%, 13.21%, 11.60%, and 8.85% elevated outcome as compared to the existing like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach.

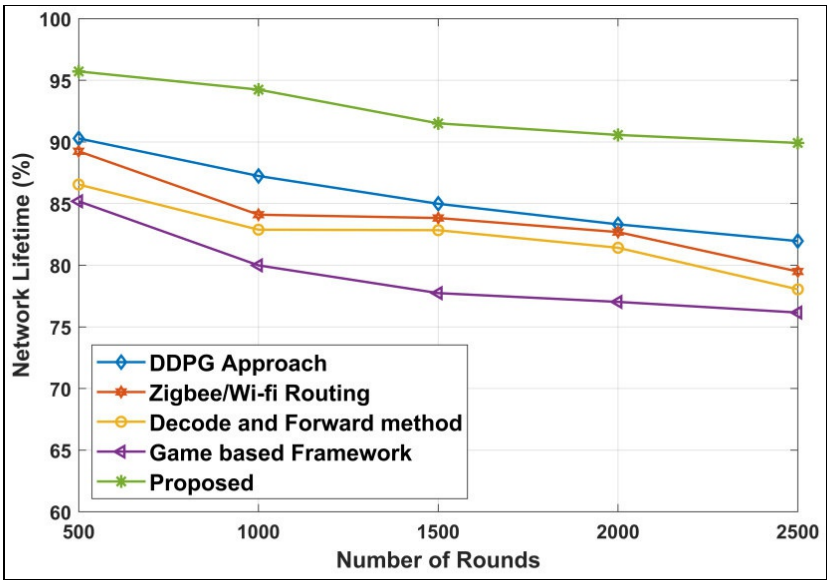


Figure 4.27: Network Life Time with 50 Nodes and 5 Relays

Table 4.23: Network Life Time with 50 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	90.2853	89.2435	86.5465	85.1869	95.7195
1000	87.2405	84.0981	82.8833	79.9888	94.2445
1500	84.9824	83.8301	82.8419	77.7384	91.5069
2000	83.3158	82.6898	81.4155	77.0263	90.5669
2500	81.958	79.4913	78.0443	76.1605	89.9195

Packet Delivery Ratio: The reception amount of information depicts the measure of packet deliver ratio; thus the higher value indicates the better outcome. The analysis of the packet delivery ratio with 50 Nodes and 5 Relays is depicted in Figure 4.28, wherein the newly devised protocol acquired the superior outcome. For example, the newly devised protocol acquired the packet delivery ratio of 0.998 with 500 rounds; still the conventional methods Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach acquired 24.48%, 11.81%, 10.19%, and 7.77% degraded outcome. Here, the newly devised protocol acquired the packet delivery ratio of 0.934 with 2500 rounds, which is 59.46%, 51.00%, 43.17%, and 37.92% superior concerning the Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approaches. The detailed analysis is presented in Table 4.24.

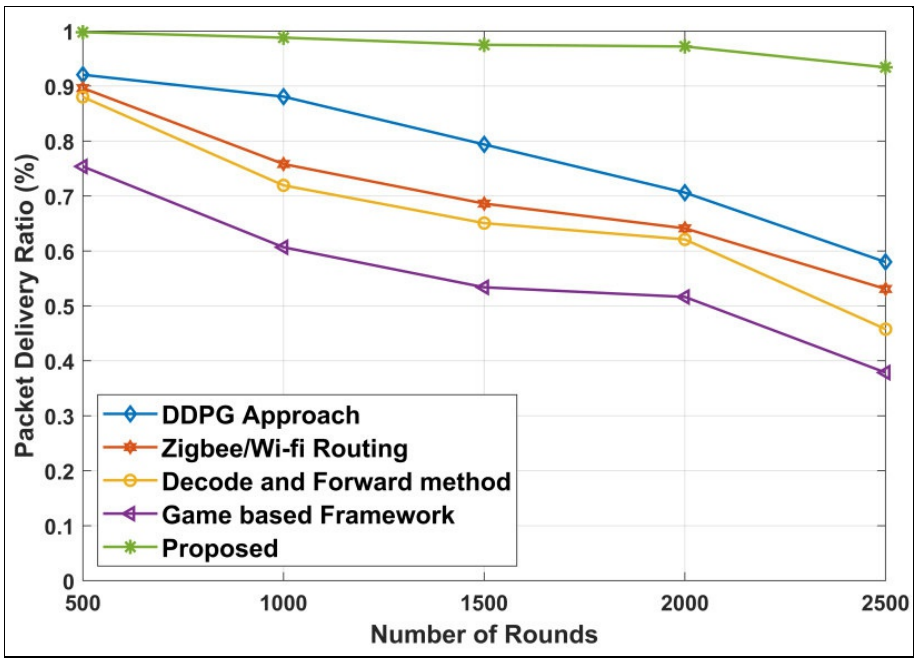


Figure 4.28: Packet Delivery Ratio with 50 Nodes and 5 Relays

Table 4.24: Packet Delivery Ratio with 50 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.9205	0.8963	0.8801	0.7537	0.998
1000	0.8807	0.7581	0.7193	0.6067	0.988
1500	0.7937	0.6861	0.6506	0.5338	0.975
2000	0.7061	0.6411	0.6209	0.5163	0.972
2500	0.5798	0.5308	0.4577	0.3786	0.934

Throughput: The throughput based interpretation with 50 Nodes and 5 Relays is portrayed in Figure 4.29. The throughput evaluated by the newly devised protocol is 7940 with 500 rounds, which is 2.19%, 25.35%, 27.14%, and 61.05% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the throughput evaluated by the newly devised protocol is 19941, which is 6.92%, 29.02%, 32.19%, and 32.61% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.25.

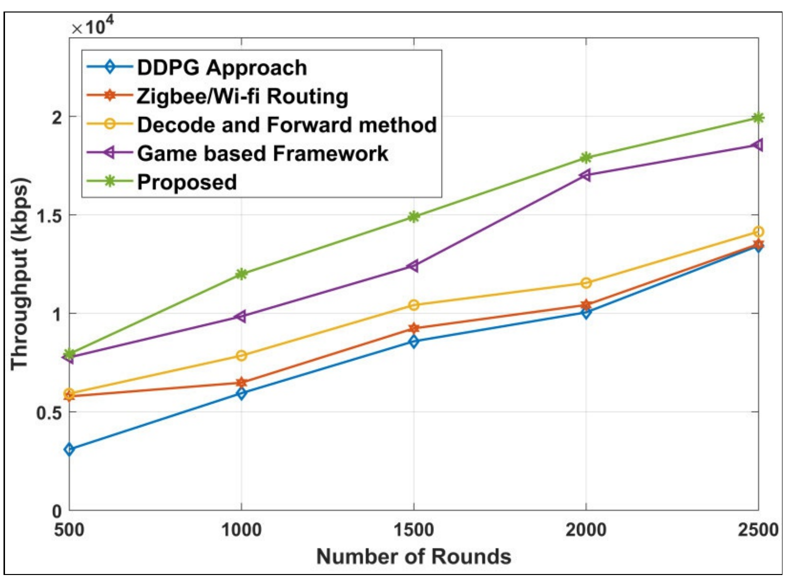


Figure 4.29: Throughput with 50 Nodes and 5 Relays

Table 4.25: Throughput with 50 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	3093	5785	5927	7766	7940
1000	5950	6481	7856	9850	11996
1500	8585	9241	10426	12418	14906
2000	10056	10431	11547	17026	17908
2500	13439	13521	14154	18562	19941

(ii) Using 100 Nodes and 5 Relays

Average Residual Energy: The assessment based on the average residual energy is depicted in Figure 4.30 with 100 Nodes and 5 Relays. The average residual energy evaluated by the newly devised protocol is 0.9658 with 500 rounds, which is 13.32%, 11.65%, 6.54%, and 3.81% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the average residual energy evaluated by the newly devised protocol is 0.7797, which is 40.17%, 37.33%, 34.26%, and 16.11% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.26.

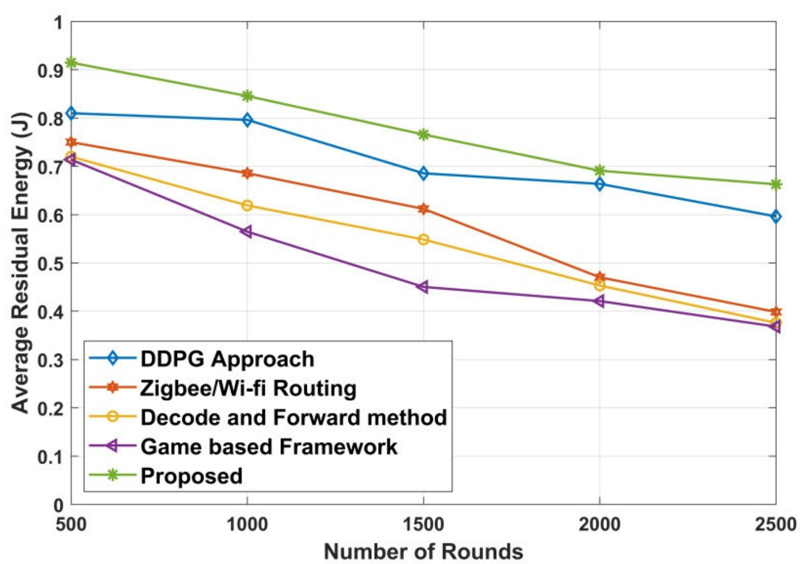


Figure 4.30: Average Residual Energy with 100 Nodes and 5 Relays

Table 4.26: Average Residual Energy with 100 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.929	0.9026	0.8533	0.8372	0.9658
1000	0.892	0.826939	0.6881	0.6387	0.916
1500	0.80191	0.69487	0.6239	0.571	0.8611
2000	0.75696	0.5641	0.5203	0.503	0.8182
2500	0.65407	0.5126	0.4886	0.4665	0.7797

Latency: Figure 4.31 depicts the latency analysis of the proposed method by considering 100 Nodes and 5 Relays. While considering the 500 rounds, the latency evaluated by the newly devised protocol is 3.3621 that is 45.13%, 44.25%, 36.78%, and 9.13% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. Also, the latency estimated by the newly devised protocol is 4.9322 with 2500 rounds that is 56.88%, 50.97%, 44.66%, and 37.25% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.27.

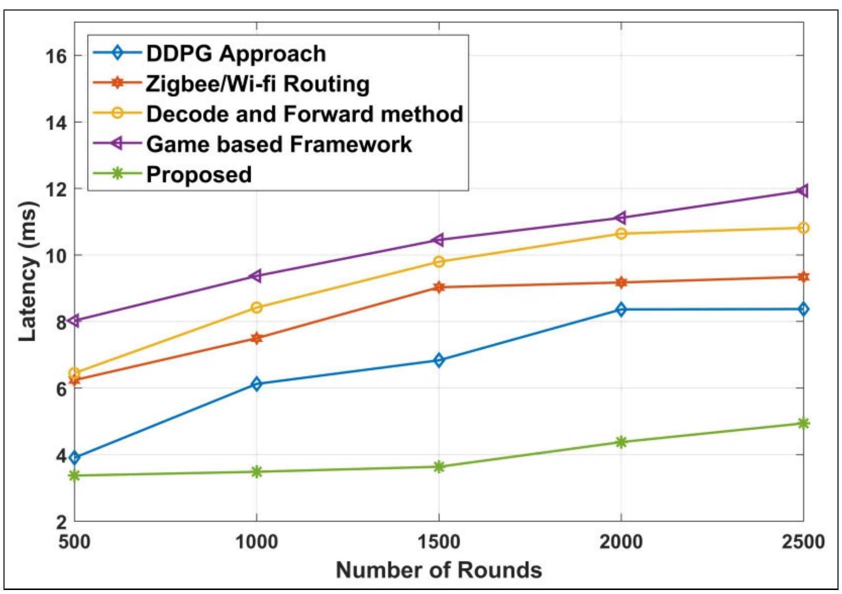


Figure 4.31: Latency with 100 Nodes and 5 Relays

Table 4.27: Latency with 100 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	3.7	5.3184	6.0306	6.1275	3.3621
1000	4.475	6.0644	7.124	7.4176	3.4769
1500	5.731	7.4258	8.1839	9.2048	3.6276
2000	6.9562	8.0865	9.2284	10.2142	4.3697
2500	7.8607	8.912	10.06	11.4379	4.9322

Network Life Time: The network lifetime analysis is portrayed in Figure 4.32 and its detailed analysis is presented in Table 4.28. In this, the newly devised protocol accomplished the higher network life time of 97.3561; but the conventional methods like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach accomplished the degraded outcome of 7.23%, 6.17%, 4.43%, and 1.85% respectively. Here, the newly devised protocol accomplished the higher network life time of 90.6763, which is 8.58%, 8.19%, 7.34%, and 6.53% elevated outcome as compared to the existing like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach.

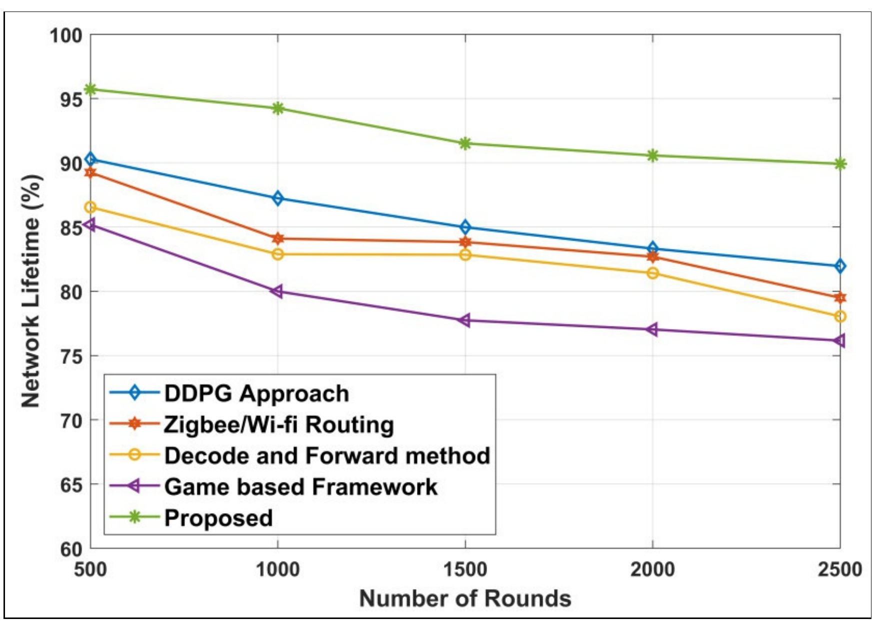


Figure 4.32: Network Life Time with 100 Nodes and 5 Relays

Table 4.28: Network Life Time with 100 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	95.5598	93.0434	91.3457	90.3181	97.3561
1000	93.9258	91.3379	88.9753	88.4894	95.8592
1500	91.1016	88.3035	87.0861	85.8486	94.0952
2000	87.9435	86.2365	85.207	84.7813	92.0501
2500	84.7531	84.0249	83.2525	82.8952	90.6763

Packet Delivery Ratio: The reception amount of information depicts the measure of packet deliver ratio; thus the higher value indicates the better outcome. The analysis of the packet delivery ratio with 100 Nodes and 5 Relays is depicted in Figure 4.33, wherein the newly devised protocol acquired the superior outcome. For example, the newly devised protocol acquired the packet delivery ratio of 0.9973 with 500 rounds; but the conventional methods Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach acquired the 17.45%, 8.59%, 7.92%, and 4.57% degraded outcome. Here, the newly devised protocol acquired the packet delivery ratio of 0.9431, which is 48.51%, 35.76%, 33.78%, and 28.25% enhanced outcome concerning the conventional Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is presented in Table 4.29.

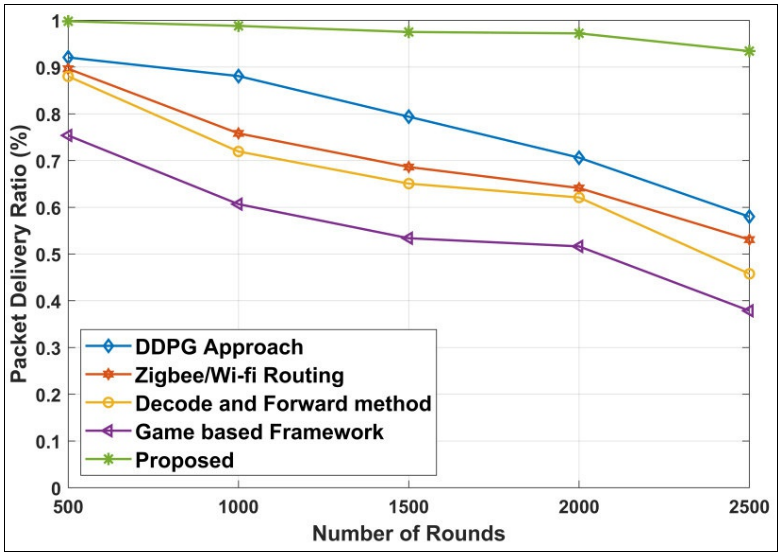


Figure 4.33: Packet Delivery Ratio with 100 Nodes and 5 Relays

Table 4.29: Packet Delivery Ratio with 100 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.9517	0.9183	0.9116	0.8233	0.9973
1000	0.9065	0.8355	0.7897	0.683	0.9908
1500	0.8885	0.7475	0.6817	0.6357	0.9847
2000	0.8463	0.7247	0.6298	0.6128	0.9812
2500	0.6767	0.6245	0.6059	0.4856	0.9431

Throughput: The throughput based interpretation with 100 Nodes and 5 Relays is portrayed in Figure 4.34. The throughput evaluated by the newly devised protocol is 8843 with 500 rounds, which is 12.18%, 32.98%, 34.58%, and 65.02% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the throughput evaluated by the newly devised protocol is 21363, which is 13.11%, 33.75%, 36.71%, and 37.09% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.30.

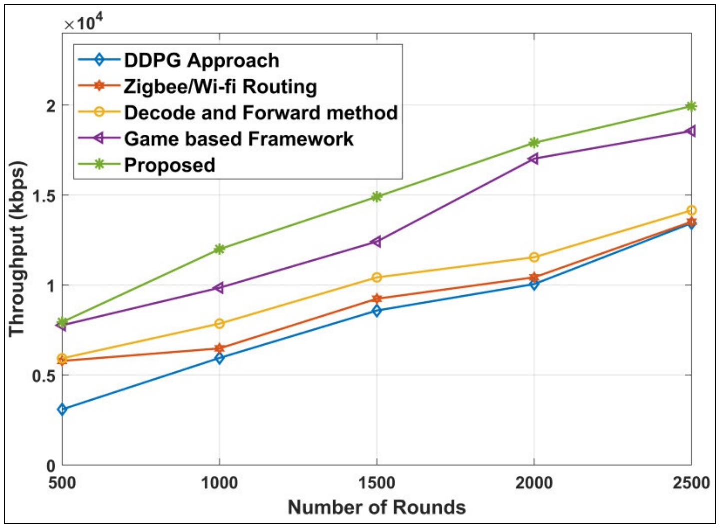


Figure 4.34: Throughput with 100 Nodes and 5 Relays

Table 4.30: Throughput with 100 Nodes and 5 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	3093	5785	5927	7766	8843
1000	5950	6481	7856	9850	12275
1500	8585	9241	10426	12418	16143
2000	10056	10431	11547	17026	18903
2500	13439	13521	14154	18562	21363

(iii) Using 50 Nodes and 10 Relays

Average Residual Energy: The assessment based on the average residual energy is depicted in Figure 4.35 with Using 50 Nodes and 10 Relays. The average residual energy evaluated by the newly devised protocol is 0.9819 with 500 rounds, which is 7.93%, 5.06%, 4.99%, and 4.86% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the average residual energy evaluated by the newly devised protocol is 0.7979, which is 17.67%, 14.70%, 7.38%, and 6.27% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.31.

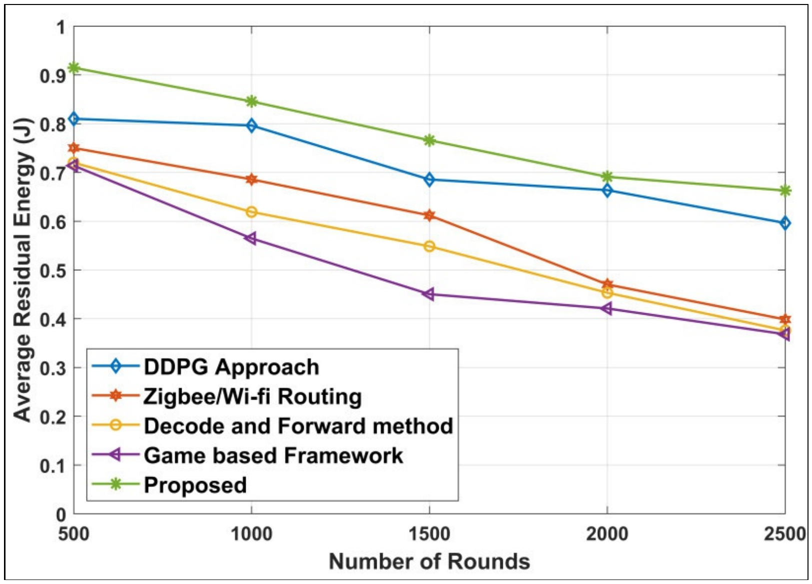


Figure 4.35: Average Residual Energy with 50 Nodes and 10 Relays

Table 4.31: Average Residual Energy with 50 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.9342	0.9329	0.9322	0.904	0.9819
1000	0.8919	0.8802	0.8661	0.8415	0.9529
1500	0.8237	0.8062	0.7745	0.7743	0.8789
2000	0.7738	0.7683	0.7232	0.7146	0.8344
2500	0.7479	0.739	0.6806	0.6569	0.7979

Latency: Figure 4.36 depicts the latency analysis of the proposed method by considering 50 Nodes and 10 Relays. While considering the 500 rounds, the latency evaluated by the newly devised protocol is 2.8663 that is 50.39%, 40.01%, 33.38%, and 27.95% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. Also, the latency estimated by the newly devised protocol is 4.7563 with 2500 rounds that is 50.30%, 48.53%, 43.61%, and 28.84% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.32.

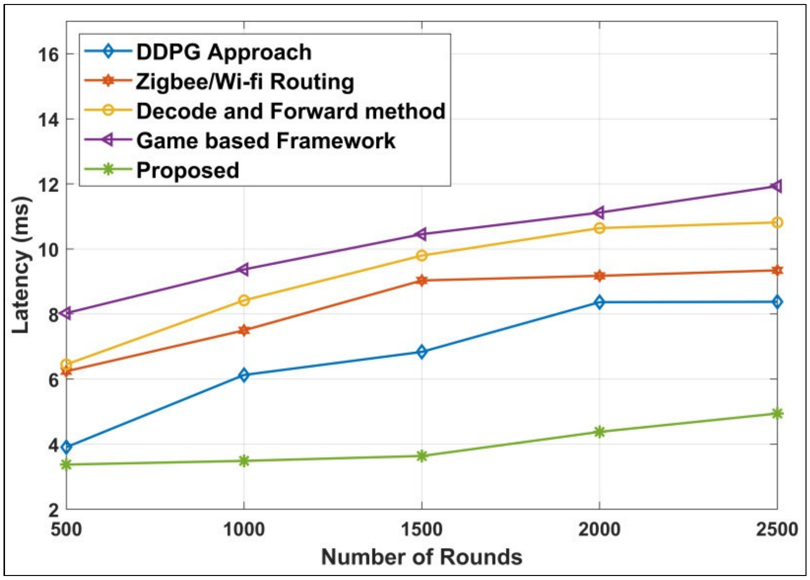


Figure 4.36: Latency with 50 Nodes and 10 Relays

Table 4.32: Latency with 50 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	3.978	4.3025	4.7779	5.7771	2.8663
1000	4.7018	5.0849	5.9417	6.7119	3.0672
1500	5.521	5.9668	6.8569	7.2727	3.1874
2000	5.9921	6.6605	8.213	8.7616	4.0808
2500	6.6839	8.4346	9.2414	9.5705	4.7563

Network Life Time: The network lifetime analysis is portrayed in Figure 4.37 and its detailed analysis is presented in Table 4.33. In this, the newly devised protocol accomplished the higher network life time of 98.8817; but 9.67%, 7.26%, 4.51%, and 0.55% degraded outcome is accomplished by the conventional methods like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach with 500 rounds. Here, the newly devised protocol accomplished the higher network life time of 91.3525, which is 9.28%, 6.46%, 5.57%, and 3.26% elevated outcome as compared to the existing like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach with 2500 rounds.

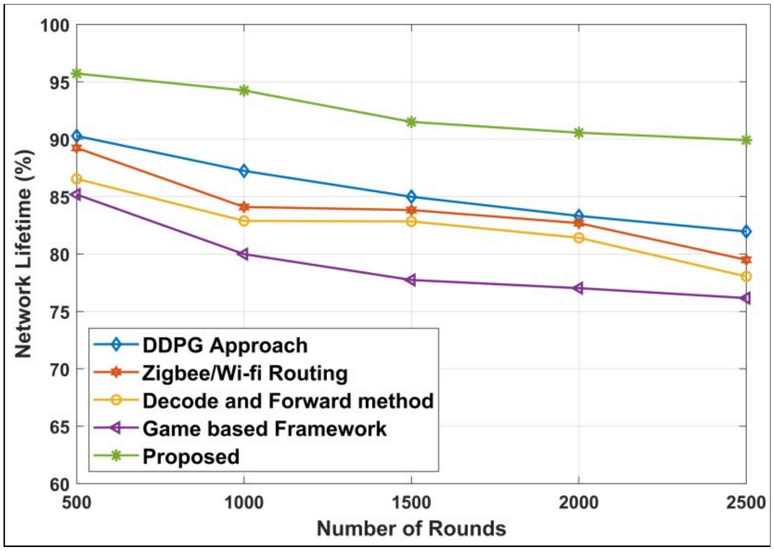


Figure 4.37: Network Life Time with 50 Nodes and 10 Relays

Table 4.33: Network Life Time with 50 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	98.3384	94.4185	91.7076	89.3176	98.8817
1000	92.5049	90.703	89.5894	88.6218	97.5573
1500	91.4707	88.8	88.3979	87.1463	95.6793
2000	90.4793	88.3374	87.0163	85.6733	92.7156
2500	88.3726	86.2596	85.455	82.8747	91.3525

Packet Delivery Ratio: The reception amount of information depicts the measure of packet deliver ratio; thus the higher value indicates the better outcome. The analysis of the packet delivery ratio with 50 Nodes and 10 Relays is depicted in Figure 4.38, wherein the newly devised protocol acquired the superior outcome. For example, the newly devised protocol acquired the packet delivery ratio of 0.9994 with 500 rounds; but 3.29%, 2.26%, 4.23%, and 1.72% superior compared to the conventional methods like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. Here, newly devised protocol acquired the packet delivery ratio of 0.9476 with 2500 rounds that accomplished the performance enhancement of 34.90%, 30.86%, 27.26%, and 12.47% concerning the Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is presented in Table 4.34.

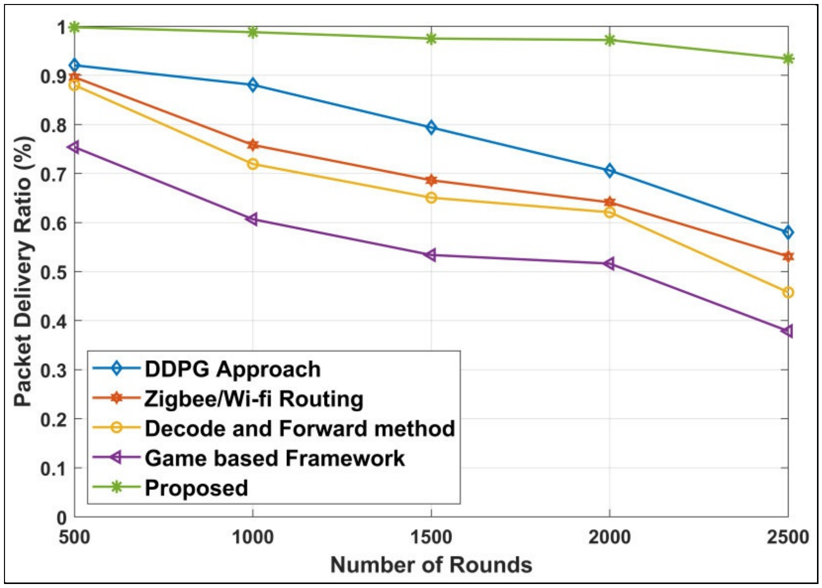


Figure 4.38: Packet Delivery Ratio with 50 Nodes and 10 Relays

Table 4.34: Packet Delivery Ratio with 50 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.9822	0.9571	0.9768	0.9665	0.9994
1000	0.9328	0.8703	0.8451	0.7581	0.9952
1500	0.8826	0.8283	0.7587	0.732	0.9878
2000	0.8699	0.8213	0.7319	0.6445	0.984
2500	0.8294	0.6893	0.6552	0.6169	0.9476

Throughput: The throughput based interpretation with 50 Nodes and 10 Relays is portrayed in Figure 4.39. The throughput evaluated by the newly devised protocol is 9516 with 500 rounds, which is 1.54%, 9.52%, 16.49%, and 23.67% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the throughput evaluated by the newly devised protocol is 22335, which is 9.42%, 20.56%, 26.06%, and 28.95% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.35.

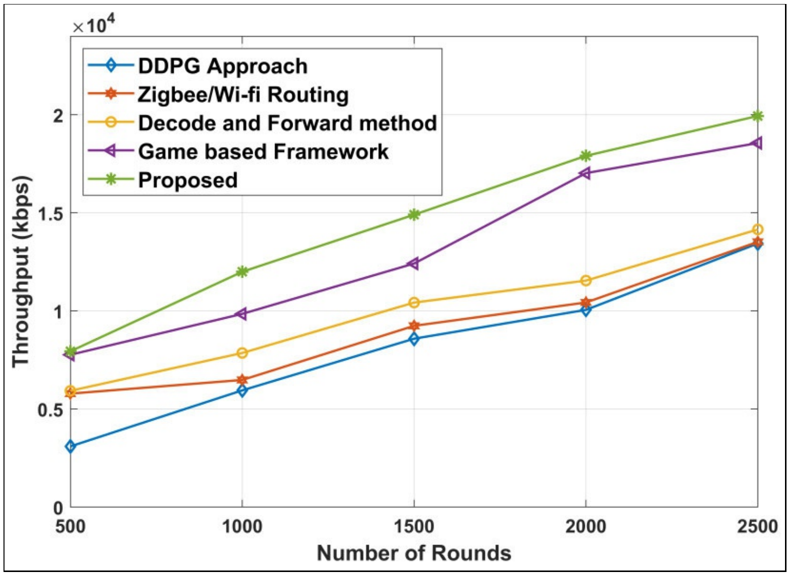


Figure 4.39: Throughput with 50 Nodes and 10 Relays

Table 4.35: Throughput with 50 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	7264	7947	8610	9369	9516
1000	8428	10234	11498	11551	12811
1500	10053	11406	14450	14567	16687
2000	13427	14646	16097	18263	19802
2500	15868	16515	17744	20231	22335

(iii) Using 100 Nodes and 10 Relays

Average Residual Energy: The assessment based on the average residual energy is depicted in Figure 4.40 with 100 Nodes and 10 Relays. The average residual energy evaluated by the newly devised protocol is 0.9980 with 500 rounds, which is 8.51%, 7.86%, 5.74%, and 3.73% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the average residual energy evaluated by the newly devised protocol is 0.8142, which is 15.97%, 13.56%, 9.10%, and 7.04% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.36.

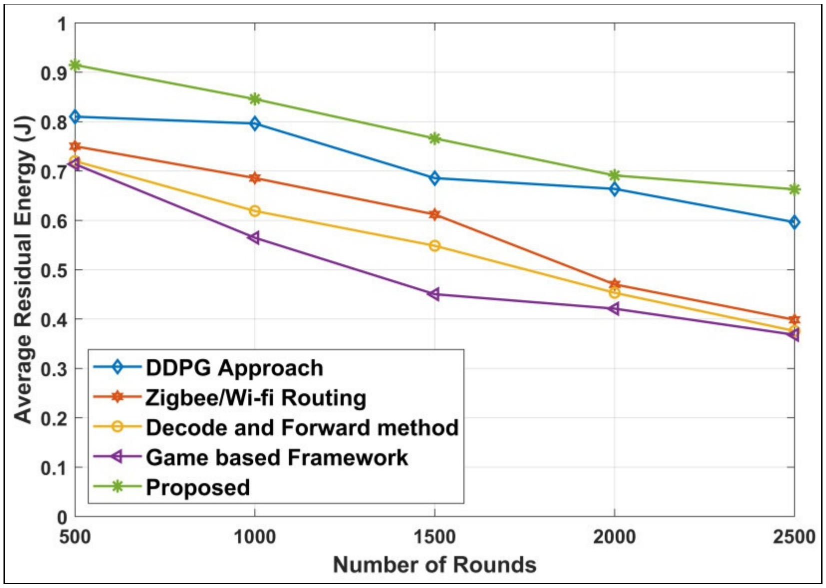


Figure 4.40: Average Residual Energy with 100 Nodes and 10 Relays

Table 4.36: Average Residual Energy with 100 Nodes and 10 Relays

Rounds/ Methods	**DDPG Approach**	**Zigbee/Wi-fi Routing**	**Decode and Forward method**	**Game based Framework**	**Proposed**
500	0.9608	0.9407	0.9196	0.9130	0.9980
1000	0.9145	0.8926	0.8718	0.8565	0.9504
1500	0.8396	0.8233	0.8068	0.7805	0.9058
2000	0.7977	0.7881	0.7444	0.7175	0.8520
2500	0.7569	0.7401	0.7038	0.6842	0.8142

Latency: Figure 4.41 depicts the latency analysis of the proposed method by considering 100 Nodes and 10 Relays. While considering the 500 rounds, the latency evaluated by the newly devised protocol is 2.7094 that is 41.02%, 35.55%, 40.35%, and 33.73% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. Also, the latency estimated by the newly devised protocol is 4.4243 with 2500 rounds that is 52.72%, 48.01%, 42.87%, and 28.62% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.37.

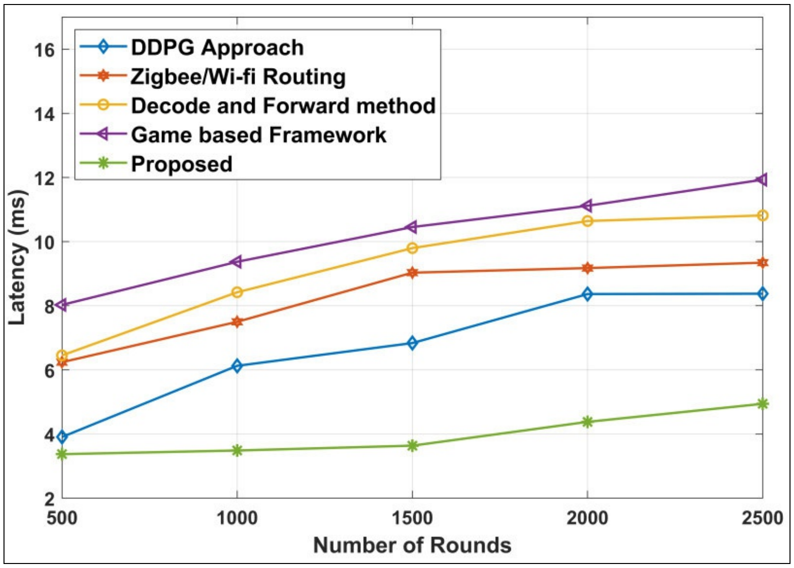


Figure 4.41: Latency with 100 Nodes and 10 Relays

Table 4.37: Latency with 100 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	4.0885	4.5424	4.2042	4.5938	2.7094
1000	4.5363	4.8508	5.6339	5.5944	2.9649
1500	5.2472	6.4409	6.7365	7.5583	3.461
2000	5.941	7.6243	8.2066	8.5718	3.7147
2500	6.198	7.7445	8.5104	9.35791	4.4243

Network Life Time: The network lifetime analysis is portrayed in Figure 4.42 and its detailed analysis is presented in Table 4.38. In this, the newly devised protocol accomplished the higher network life time of 99.5921; it is 6.62%, 4.66%, 2.67%, and 2.37% superior compared to the conventional methods like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach with 500 rounds. Here, the newly devised protocol accomplished the higher network life time of 92.2384; it is 22.88%, 13.24%, 12.59%, and 11.16% superior compared to the conventional methods like Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach with 2500 rounds.

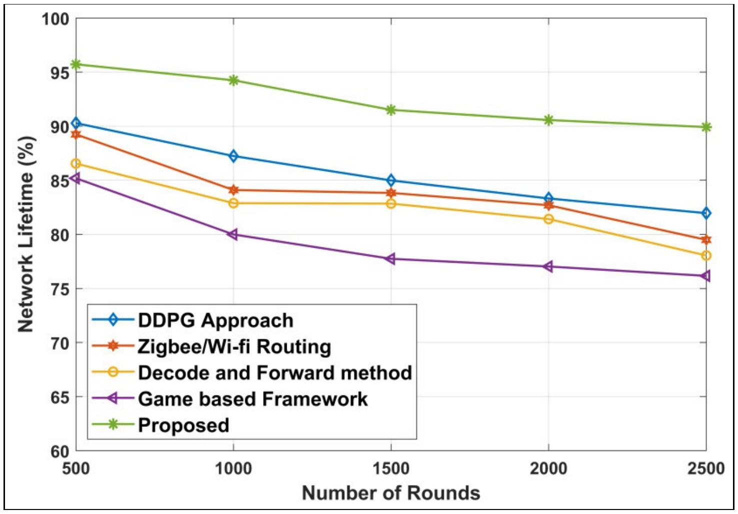


Figure 4.42: Network Life Time with 100 Nodes and 10 Relays

Table 4.38: Network Life Time with 100 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	97.2319	96.9377	94.9471	92.9992	99.5921
1000	94.2967	90.7627	89.3988	83.1402	98.4475
1500	87.2829	85.7078	83.6951	80.0235	96.3095
2000	83.7207	81.8668	80.7718	76.8964	93.8597
2500	81.9402	80.6293	80.0269	71.1314	92.2384

Packet Delivery Ratio: The reception amount of information depicts the measure of packet deliver ratio; thus the higher value indicates the better outcome. The analysis of the packet delivery ratio with 100 Nodes and 10 Relays is depicted in Figure 4.43, wherein the newly devised protocol acquired the superior outcome. For example, the newly devised protocol acquired the packet delivery ratio of 0.9989 with 500 rounds, which is 8.04%, 6.16%, 6.04%, and 1.09% better than the conventional methods Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. Here, newly devised protocol acquired the packet delivery ratio of 0.9714, which is 23.40%, 21.41%, 13.37%, and 9.87% better than the conventional methods Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach with 2500 rounds. The detailed analysis is presented in Table 4.39.

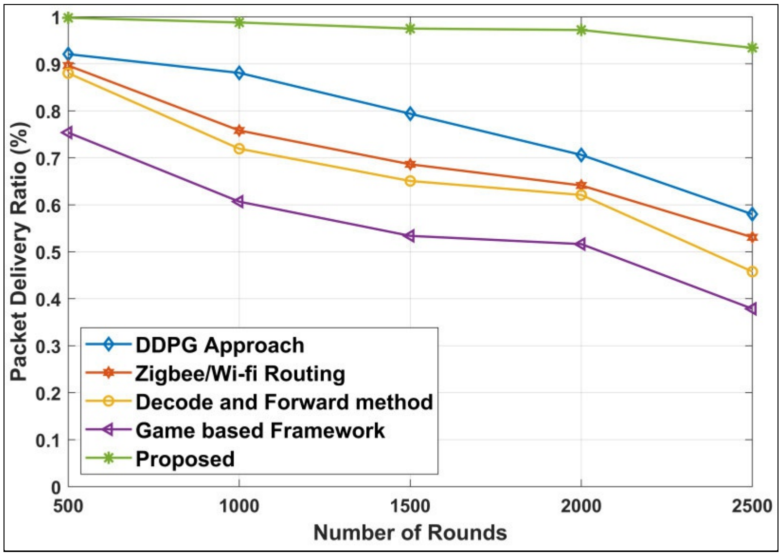


Figure 4.43: Packet Delivery Ratio with 100 Nodes and 10 Relays

Table 4.39: Packet Delivery Ratio with 100 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	0.988	0.9386	0.9374	0.9186	0.9989
1000	0.9338	0.9191	0.9054	0.852	0.999
1500	0.8989	0.8878	0.8524	0.8065	0.9926
2000	0.8783	0.8684	0.804	0.7646	0.9881
2500	0.8755	0.8415	0.7634	0.7441	0.9714

Throughput: The throughput based interpretation with 100 Nodes and 10 Relays is portrayed in Figure 4.44. The throughput evaluated by the newly devised protocol is 10303 with 500 rounds, which is 34.29%, 42.01%, 42.77%, and 64.37% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. For 2500 rounds, the throughput evaluated by the newly devised protocol is 23015, which is 8.00%, 29.98%, 41.63%, and 54.73% improved outcome compared to the existing Game based Framework, Decode and Forward method, Zigbee/WiFi Routing, and DDPG Approach. The detailed analysis is depicted in Table 4.40.

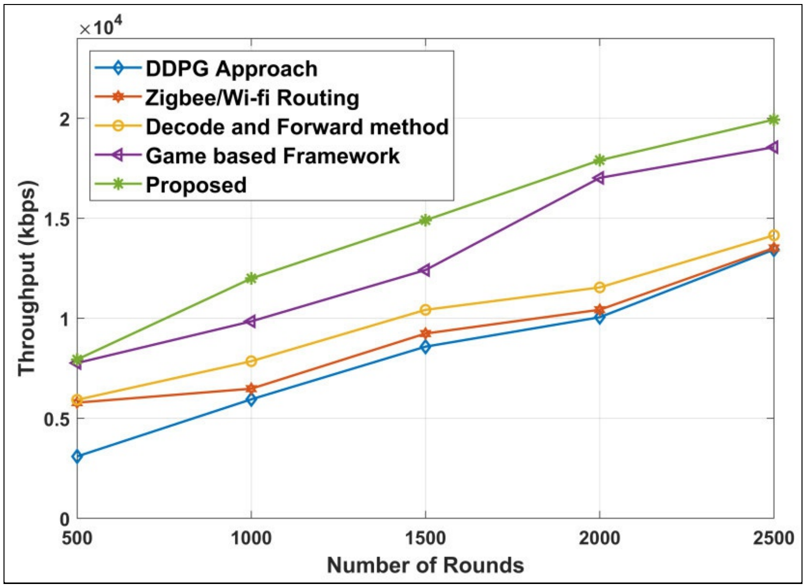


Figure 4.44: Throughput with 100 Nodes and 10 Relays

Table 4.40: Throughput with 100 Nodes and 10 Relays

Rounds/ Methods	DDPG Approach	Zigbee/Wi-fi Routing	Decode and Forward method	Game based Framework	Proposed
500	3671	5896	5975	6770	10303
1000	3719	7713	9545	9824	13728
1500	5437	9171	11098	13863	17389
2000	7002	11275	13986	17986	20497
2500	10418	13433	16114	21173	23015

4.4.4 Discussion

The assessment based on several evaluation criteria illustrates the superiority of the suggested approach. The introduction of a combined channel allocation and relay selection mechanism is what makes the performance better. By taking into account the priority, bandwidth, and transmission rate, the suggested optimum channel allocation approach selects the best channel. In addition, the model's aptitude for balanced local and global search assures the fastest convergence rate and the best overall solution. Utilizing deep reinforcement learning criteria, the relay is chosen once the best channel has been found. Here, the relay selection approach is used with a minimally computationally intensive channel increase based on bit error rate. As a result, the analysis shows the better result.

4.5 Summary

With the use of deep reinforcement learning, this study presented a deep learning technique for joint channel allocation and relay selection. Using the suggested EnHpo algorithm and many fitness functions, including priority, bandwidth, and transmission rate, the channel allocation is originally determined like this. The adaptive weight method is combined with the traditional hunter-prey optimization in the proposed EnHpo to increase convergence and the acquisition of the optimal global solution. Then, using deep reinforcement learning, the channel gain based on bit error rate is taken into consideration while choosing the relay. So, in comparison to the traditional cooperative routing strategies, the suggested strategy achieved greater results. The evaluation using Average Residual Energy, Latency, Network Life Time, Packet Delivery Ratio, and Throughput obtained values of 0.998, 2.709, 99.592, 0.999, and 23015, respectively.