

Minimizing Delay in Mobile Ad-Hoc Network Using Ingenious Grey Wolf Optimization Based Routing Protocol

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Abstract – One of the most groundbreaking concepts in wireless networking is the mobile ad hoc network (MANET). It is an ever-shifting network of wireless nodes that may be adaptively and indiscriminately positioned, with the interconnections between nodes constantly changing. Defense networks, in particular, are becoming more prominent, and it is the goal and passion of technology to update and improve its components. There is a significant rise in transmission costs due to the high energy usage. Routing protocols have a critical role in reducing energy utilization. Weak routing protocol leads to exhaustive energy consumption, packet delay and packet loss. Ingenious Grey Wolf Optimization-based Routing Protocol (IGWORP) is proposed in this paper to discover the most efficient path to a destination and reduce the amount of delay and energy spent. IGWORP mirrors the natural tendencies of the grey wolf towards foraging for its prey. IGWORP looks for a global route rather than assembling many local routes. Encircling and hunting characteristics of wolves are used in IGWORP to discover and utilize the route for data transmission. Standard network metrics are used in NS3 to evaluate IGWORP's performance. The findings of IGWORP demonstrate that it reduces delays and energy consumption better than the current routing methods.

Index Terms – Delay, Routing, Optimization, Wolf, Delay, Energy.

1. INTRODUCTION

Wireless network technology is constantly evolving due to the wide variety of devices connected to intelligent systems and wireless data transmission capabilities, such as smartphones, cameras, and automobiles, among other gadgets. It is reasonable to assume that, as technology advances, network size will rise considerably, necessitating greater emphasis on scalability in wireless networks to keep up with current diverse network demands [1]. MANETs (Mobile Ad Hoc Networks) are a collection of mobile wireless devices that

may be used to communicate. Communication in MANETs is decentralized, and nodes can act as both relays and routers without any fixed infrastructure, unlike standard wireless networks. The topology must be flexible enough for self-organization to regularly create and repair communication processes in a mobile network [2].

MANET communication lines are fragile and sensitive to changes in channel characteristics during operation. The establishment and rebuilding stages must be handled with care as part of MANET. The nodes involved in route formation and maintenance must have more dependable connectivity to ensure reliable routing. Developing a responsible routing protocol in MANETs is difficult [3]. Mobility, the strength of the received signal, Node power, and Physical circumstances all affect the reliability of connections. Surveillance Applications and audio/video conferencing need trustworthy nodes in the multicasting network to ensure uninterrupted transmission of high priority and low priority packets. MANET multicast routing protocols fall into the following groups [4].

The routing state is maintained via proactive protocols, whereas reactive protocols lessen the effect of recurrent topology changes by re-creating the routes on demand if necessary. Tree-based routing methods ensure only one path between two nodes [4]–[12]. Link failures cause the entire tree to be re-configured as mobility grows. Protocols that use mesh-based multicast routing build a network of different routes. They are more robust to node failures and connection failures, providing more dependable pathways. When using multipath routing, numerous paths are sought between a source and a destination. Ad hoc networks' unpredictable and dynamic character is mitigated by the availability of several routes. MANET multipath routing systems primarily establish

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redundant routes between source and destination pairs. Still, they only use one of those redundant routes at a time to send data [13].

Disaster recovery, the battlefield, and online education rely on MANET reliability. It is possible that redundant sensing and communication nodes in such applications would increase the dependability of nodes [14]. On the other hand, MANET routing data does not include extra redundancy. Redundancy is an issue in multi-hop mobile networks; hence, routing algorithms must account for it. Therefore, a more robust multicast routing strategy that uses many pathways as backups is presented in this research work.

1.1. Problem Statement

Multipath routing protocols face a major challenge in reducing energy usage. MANETS will be the most important thing when it comes to networks in the future. It is common for nodes in MANETs to be shared for a specific purpose and to have limited power. The multicasting routing system is ideal for MANETs because of its ability to effectively accommodate data transfers. The newest wireless networking technology, multicast routing, is designed to interact with network groups. It is critical to multicast routing for data transmissions between many points of presence or between points of presence and points of presence. There are several advantages of using multicast routing over unicast routing for wireless networks. Due to the ridiculous rapidity with which multicast routing protocols and methods may be integrated or created. In MANET, it is vital to multicast packets from one node to other nodes since doing so increases the likelihood of packet duplication. As a result, MANET's performance suffers. A further problem that may significantly reduce MANET's performance is a link failure.

1.2. Objective

Research work in this paper focuses on developing an improved routing protocol inspired by biological techniques to reduce route failure and boost packet delivery success.

1.3. Organization of the Paper

The current section of the paper has given a broad discussion about MANET, routing in MANET, issues in MANET, and the paper's objective. Section 2 discusses the literature related to the problem identified in this research. Section 3 proposes a novel protocol to overcome the energy consumption issues. Section 4 discusses the experimental results. Section 5 concludes the research with the future scope of research.

2. LITERATURE REVIEW

"Neighborhood Compressive Sensing (NCS)" [15] is proposed for compressing the sparse data of neighborhoods using advertisement, trust data, and updates of the table. GloMoSim platform is used to validate the DSR protocol

efficiency, packet dropping ratio, network lifetime, and energy usage. The consumption of resources was reduced, and the data transmitted was reduced in the network. "Multicast algorithm" [16] is proposed to send the packets to the relay nodes using MANET source and destination nodes. Probability is used for sending the packets selected to the other node. Markov chain theoretical architecture features the packet delivery based on a cooperative multicast structure. Analytical expressions for measuring the variance and mean were derived. "Ant Colony Ad-Hoc On-Demand Routing" [17] is proposed to design the cross layers to optimize the data from the Transport, Physical, and Media Access Control and Application layers. For assigning the slot, the Particle Swarm Optimization (PSO) based MAC scheduling mechanism is used while transmitting the data. "Multi-path Enhanced OLSR" [18] is proposed for exploiting the multi-beam transmission's features in Airborne Networks. Multi-Point Relays are used to select the broadcast messages for every node in the network, and social network-based techniques were used to enhance the requirements of LPD. "Decision-Related Event Occurrence Times" [19] is proposed for creating lower and upper bounds and abstracted using case-by-case with mobility structure and decision policies. The neighbour node's mobility and their locations for forwarding the next hop are carried out using the Random Direction mobility framework.

"Enhanced-Ant-AODV" [20] is proposed for selecting the routes for enhancing the Quality of Services (QoS), particularly for MANET. The route which provides the most delicate data delivery is fetched based on the path value. The route value is selected with the highest pheromone value to transmit the packets using end-to-end reliability. "Wormhole Attack Detection" [21] is proposed to mitigate the false alarms in MANET. The resources are protected, and Wormhole Attack Tree is built based on its history of symptoms. The re-establishment of paths is analyzed, and results are demonstrated using a simulator that may be used to reduce the vulnerability and security issues. "Fungi Networks-Based Routing" [22] is proposed to exhibit the MANET optimization and route selection. Different paths are selected parallel based on fungal mycelium and enhanced data flow. Every data package is delivered in appropriate routes, and the quality of the path is enhanced among its source and destination. NS2-2 simulator compares the technique with existing SARA and AODV algorithms. "Efficient Dynamic-Power AODV Routing" [23] is proposed for the optimal delivery of packets in MANET. The transmission range of its dependence is used for enhancement, and when nodes exceed 200 in number, the performance increases. The control overhead and jitter are reduced, and throughput is improvised. "Q-Learning Algorithm" [24] is proposed to improve real-time communication among the control station and its nodes. The delay in the network is reduced using an algorithm called

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Q-FANET. WSNET simulator is used for evaluation, and it is compared with other conventional algorithms for improving packet delivery, which is better than learning-based routing protocols.

"Adaptive Cluster-based Data Scheduling" [25] is proposed for ensembling with Multi-Path Transmission Control Protocol (MPTCP) in the network. The unfamiliar features of the path were selected, and a policy called, Delay-Variation-Based Adaptive Fast Retransmission was applied for exploiting the MAC layers. The overload of the network is reduced dynamically and is compared with conventional algorithms to reduce the load of routing. "Mobility Aware Cross-layer Routing" [26] is proposed to minimize energy consumption in peer-to-peer networks. Cross layers are used for enhancing communication using routing protocols. Better routes and reliable communication are improved for supporting data transmission. Low path stretch is guaranteed by preserving $O(n)$ for every node, and scalability is provided. "Optimized Link-State Routing" [27] is proposed to improve the quantum genetics strategy ensembled with Optimized Link State Routing. The topology in the MANET is modified, and the optimal end-to-end path is determined. The Q-learning technique improves the strategy by embedding it in the network to enable global optimization. "Flexible SDN Prototype" [28] is proposed for dividing the ad hoc network control among data-plane nodes and Software-Defined Networking. The instructions given by the controller are followed up, and performance is upgraded to the conventional Open Flow method. Real tactical ad-hoc network-based datasets are used for evaluation which reduces overhead. "Ad-hoc Network Routing - Review" [29] is proposed to address the network's problems for enhancing its stability and reliability. Trajectory optimization techniques, mobility, and routing protocols were explored, and security issues were solved. Existing communication architecture is used for elaborating the effectiveness of the networks.

"Affinity Propagation-Driven Routing Protocol (APDRP)" [30] is proposed to achieve the best route in MANET via clustering. Map evolution and local optima logic optimize the network's topology. A modified version of Affinity Propagation is utilized to optimize Gauss Markov (GM), which is used to discover the node's movement structure. Nodes and timelines of the propagation technique are represented in an analytical model. It develops before making clustering choices, then further optimized using the GM distribution's temporal dependence. An analytical model explains numerous events that occur over time to understand further how a cluster and a node's APDRP work. Another way to think about it is that the depreciation of the dominant set is the goal of the APDRP clustering algorithm. "Multi-Adaptive Routing Protocol (MARP)" [7] is suggested to identify the most effective route to the destination in an ad-hoc network. Routes that are multi-adaptive pick the most cost-effective

way when the priority of a node changes or fails, which may be caused by issues with nodes or network components. Before transmitting a data packet, multi-adaptive routes verify the network's connection and functionality. Based on fish's natural tendency to look for food in groups, MARP is designed to do the same. A node's priority changes or fails, and MARP is tasked with restoring it as quickly and effectively as possible. Network connectivity and operation are checked before a data packet is sent. MARP, which is based on the natural properties of fish, was developed for IoT-based, ad hoc networks to decrease latency and energy consumption to lengthen a network lifespan. "Adaptive Traffic Routing Approach (ATRA)" [31] is suggested to design a new connection architecture to communicate effectively between sophisticated devices connected to the network. Finding the optimal route in a smart device network is much different from finding the optimal route in other networks, owing to the cloud network's extreme scalability. ATRA supports adaptive management of network traffic and effective load balancing in MANET. One of ATRA's most important features was its capacity to locate various alternative pathways between two nodes and assess the traffic load, stability, and link's cost.

Multiple protocols are being proposed by different researchers for reducing the consumption of energy in MANET. But, still, there exists a need for an advanced routing protocol to find a better route in an optimized manner to enhance the success rate and minimize the energy consumption even more.

3. INGENIOUS GREY WOLF OPTIMIZATION BASED ROUTING PROTOCOL (IGWORP)

In the GWO, social interaction and dominating leadership are modeled by observing the grey wolf pack's natural behaviors and dynamics. A pack of grey wolves prefers to preserve order and discipline by classifying the wolves into four distinct categories, namely:

- Alpha Wolf (Al_Wl): This wolf is the in-charge of making all the group's most important decisions.
- Beta Wolf (Be_Wl): It acts as a backup of Alpha wolf. This type of wolf steps in when the alpha wolf isn't there.
- Delta Wolf (De_Wl): This type of wolf are sentinels, wise wolves and watchdogs of the pack.
- Omega wolves (Om_Wl): These types of wolves are the only ones that are permitted to eat at the end.

It is said that prey hunting is entirely dependent on the alpha, beta, and delta wolves (also known as the "leading hunters"). The three stages of a grey wolf's hunting process:

- (a) Prey detection and pursuit
- (b) Encirclement of prey

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(c) Assaulting the prey

The following are mathematical models for leadership, encirclement, and attack on prey:

3.1. Hierarchy of Leadership

Grey wolves have a hierarchical structure similar to this one. The leading wolves in an optimization issue are Al_WL , Be_WL , and De_WL , the best solutions. Om_WL are the remaining possible solutions to an optimization issue. The solutions of Al_WL , Be_WL , and De_WL lead all Om_WL searches following their instructions.

3.2. Encirclement Behavior

Grey wolves execute encirclement of prey after they have taken the prey position. The prey is halted in its tracks by this encirclement. Several conventional GWO equations are derived from encircling behavior and are shown in Eq.(1) to Eq.(4).

$$P_{f+1} = P_{m,f} - D_f \cdot G_f \tag{1}$$

$$G_f = |U_f \cdot P_{m,f} - P_f| \tag{2}$$

$$D_f = 2 \cdot d_f \cdot b_1 - d_f \tag{3}$$

$$U_f = 2 \cdot b_2 \tag{4}$$

where the position of the wolf at iteration $(f + 1)$ is indicated as P_{f+1} , the position of prey identified at iteration f is represented as $P_{m,f}$. Exploration and exploitation are controlled by the coefficient vector, which is denoted as D_f . Difference vector that determines whether the wolf moves toward or away from prey is denoted as G_f . While D_f fails, the solution space is explored using the coefficient vector U_f . There are two random integers, b_1 and b_2 are evenly distributed with $(0,1)$ intervals.

Eq.(5) is applied to calculate the transition parameter as the number of iterations gets increased eventually.

$$d_f = 2 - 2 \times \left(\frac{f}{F}\right) \tag{5}$$

The current iteration is denoted as f , while the count of maximum iterations is indicated as F .

3.3. Hunting

It is presumed that all of the pack's leadership wolves can hunt prey. As a result, both of these leads may be utilized in combination to estimate the location of prey, according to a mathematical model of hunting tactics, and it is shown in Eq(6) to Eq.(8).

$$G_{\delta,f} = |U_{\delta,f} \cdot P_{\delta,f} - P_f| \tag{6}$$

$$G_{\gamma,f} = |U_{\gamma,f} \cdot P_{\gamma,f} - P_f| \tag{7}$$

$$G_{\theta,f} = |U_{\theta,f} \cdot P_{\theta,f} - P_f| \tag{8}$$

The three most prominent hunting positions during the f th iteration are denoted as $P_{\delta,f}$, $P_{\gamma,f}$ and $P_{\theta,f}$. By utilizing Eq.(4), random numbers $U_{\gamma,f}$, $U_{\delta,f}$ and $U_{\theta,f}$ are defined. The updated state of the grey wolf for the $(f + 1)^{th}$ iterations are calculated using Eq.(9) to Eq.(12), but after computing the difference vectors $G_{\delta,f}$, $G_{\gamma,f}$ and $G_{\theta,f}$.

$$Q_1 = P_{\delta,f} - D_{\delta,f} \cdot G_{\delta,f} \tag{9}$$

$$Q_2 = P_{\gamma,f} - D_{\gamma,f} \cdot G_{\gamma,f} \tag{10}$$

$$Q_3 = P_{\theta,f} - D_{\theta,f} \cdot G_{\theta,f} \tag{11}$$

$$P_{f+1} = (Q_1 + Q_2 + Q_3)/3 \tag{12}$$

Eq.(3) is applied to compute $D_{\delta,f}$, $D_{\gamma,f}$ and $D_{\theta,f}$. The encirclement and hunting methods of grey wolves might be repeated to address the optimization issues.

3.4. Exploitation and Exploration

It is obvious in search equations that D_f and U_f vectors are provided to keep the algorithm's exploitation and exploration distinct from one another. Predators use search areas when $|D_f|$ and U_f are less than 1, which is similar to the chase of prey. There exists no stagnation in the pack at local optima because of the exploration that occurs when $|D_f|$ and U_f are greater than 1. Grey wolves similarly attack their prey; therefore, this is a good representation of that behavior. When half of F iterations have been completed, then the coefficient D_f takes use of the solution space. By using the coefficient U_f , GWO keep the algorithm explored. In GWO, the diminishing nature of the transition parameter D_f keeps the operator's exploitation and exploration in balance. According to the traditional GWO search equation, only the leading wolves influence search direction. It is very uncommon for the top wolves to be caught by local solutions, especially in multimodal issues with several valleys. Because the search is dependent on leading wolves, when the pack is caught at these local optimizations, it is hard for the group to escape. It is the stalemate at local optimum points that leads to premature convergence. Wolf-to-wolf information transmission may assist in relieving these challenges from the optimization technique by speeding up its search for solutions.



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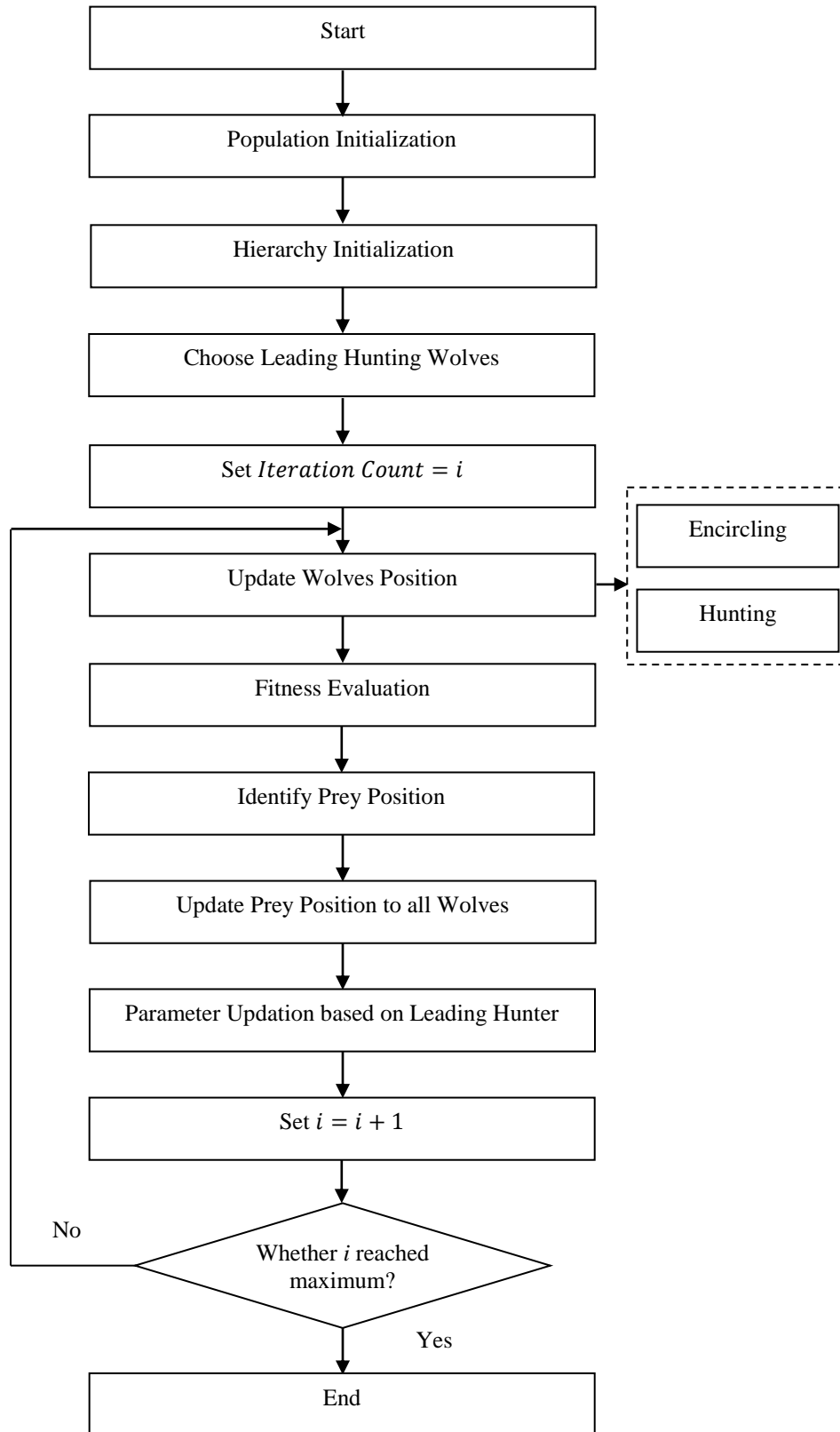


Figure 1 IGWORP Architecture

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This is why the suggested method incorporates the personal best history of each wolf into the search process, enhancing the pack's collective power and allowing each wolf to contribute their unique expertise to the search. Thus, in the suggested method, leading and intellectual best direction are combined to explore the solution space's most promising and elite parts. The method suggested in the study is referred to as IGWORP.

The suggested IGWORP method combines wolves' best personal and pack information at the same time throughout the search to increase wolf cooperation and move the search forward in promising directions. The GWO employs four distinct techniques, which may be stated as follows:

- (a) By using each wolf's particular best knowledge in hunting mechanism.
- (b) A novel search equation is presented with the personal best direction and random wolves to increase the pack's collective strength.
- (c) Crossover is done between positions gained by improved hunting mechanisms and positions achieved through personal best guiding.
- (d) Greedy selection is used to recover information about promising regions of the search space.

A modification to the encirclement mechanism is necessary to begin the hunting process. The following Eq.(13) explains how the encirclement mechanism was modified:

$$P_{f+1} = P_{\delta} - D_f \times |U_f \times P_{\delta} - P_{pbest}| \tag{13}$$

Where P_{pbest} represents the wolf P 's personal best state till the iteration f . GWO's standard symbols are used for the other symbols. Alpha, beta, and delta wolves serve as the primary search guides when the encircling system is in place. The prey's position is approximated using the equation shown above. An individual wolf's best knowledge of visited solution regions is believed to be shared by all wolves in the newly suggested improved hunting mechanism. Eq.(14) is used to describe the new hunting process that IGWORP has come up with:

$$I_{s,f+1} = \frac{Q_1 + Q_2 + Q_3}{3} \tag{14}$$

Where $Q_1, Q_2,$ and Q_3 are calculated using Eq.(15) to Eq.(17).

$$Q_1 = P_{\delta} - D_{\delta,f} \times |U_{\delta,f} \times P_{\delta} - P_{spbest}| \tag{15}$$

$$Q_2 = P_{\gamma} - D_{\gamma,f} \times |U_{\gamma,f} \times P_{\gamma} - P_{spbest}| \tag{16}$$

$$Q_3 = P_{\theta} - D_{\theta,f} \times |U_{\theta,f} \times P_{\theta} - P_{spbest}| \tag{17}$$

Where P_s wolf updated position during hunting is represented as $I_{s,f+1}$. Best state of P_s wolf in iteration f is indicated as P_{spbest} . The rest of the symbols are identical to those in the standard GWO definition. A unique search has been suggested to explore and exploit the personal best states of wolves and to simulate the concept that every wolf has complete hunting knowledge about the prey, and Eq.(18) provides the same.

$$\hat{P}_{s,f+1} = P_{spbest} + a \times (P_{b_1} - P_{b_2}) \tag{18}$$

Where P_{b_1} and P_{b_2} represents the wolves randomly selected from the group of wolves, i.e., pack. The difference vector's influence is scaled using the value a . Exploration is encouraged by larger k values, whereas exploitation is encouraged by lower k values. Parameter a is chosen as a variable that reduces linearly from one value to zero in this study. This parameter value controls the difference vector, expressed as Eq.(19).

$$P_{s,f+1}^w = \begin{cases} I_{s,f+1}^w & \text{if } b_3 < CR \\ \hat{P}_{s,f+1}^w & \text{otherwise} \end{cases} \tag{19}$$

The crossover probability CR is set at 0.5 in our IGWORP, and the locations $I_{s,f+1}$ and \hat{P}_{f+1} are determined by Eq.(14) to Eq.(18), respectively. b_3 represents a distributed randomly generated number but uniformly within (0,1). A greedy selection algorithm is implemented when Eq.(19) updates each wolf in a pack. The architecture of IGWORP is provided in Figure 1.

4. EXPERIMENTAL RESULTS

4.1. Simulation Setting

Table 1 Simulation Settings and Parameters

Parameters	Values
Simulator	Network Simulator version 3
Number of nodes	250
Area Size of Simulation	1250 × 1750 m ²
Mobility Speed	5 m/s to 32 m/s
Packet Size	256 kb
Initial level of Energy	12 Joules
Range of Transmission	480 m
Traffic Type	CBR
Channel Type	Wireless
MAC	802.16
Model of Mobility	Randomway Point

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MANET routing protocols can be tested on a variety of simulators. As a result, the performance of MANET's protocol modeling and implementation in various contexts remains a mystery to academics. NS3 has been used in this current research to compare the proposed IGWOP to the existing routing protocols in use. In this study, IGWOP is compared to current routing protocols. A discussion of how NS2 simulations are used to evaluate the IGWOP is given in this section. The NS3 simulator used in this study is written in C++. The simulated environment shown in Table 1 was used to test the proposed technique.

4.2. Performance Metrics

Measuring IGWOP's performance against the current routing protocols is done using the performance metrics listed below.

- Packet Delay(PD)is the time data packets consume to travel from their origin to their destination.
- Packet Delivery Ratio(PDR) is the proportion of packets that are received at the destination node compared to the count of data packets that are sent by the source node.
- Packet Loss Ratio (PLR) measures sent packets that did not reach the intended node.
- Throughput (TP) represents the pace at which data is processed and moved from sending node to the end node (i.e., destination node) in a defined time.
- Energy Consumption (EC) denotes the utilized energy to roam from source to destination.

4.3. Results and Discussion

4.3.1. Packet Delay (PD) Analysis

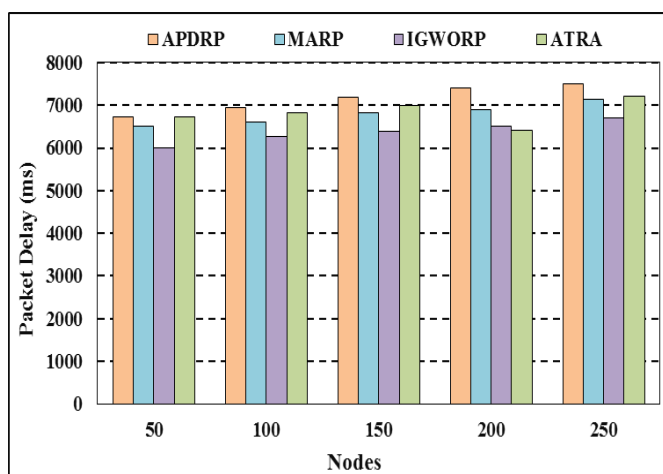


Figure 2 PD Vs Protocols

Figure 2 highlights the PD faced by the proposed routing protocol IGWOP and the existing routing protocols APDRP,

MARP, and ATRA. From Figure 2, it is possible to understand that IGWOP faces low delay than the existing routing protocols. IGWOP attempts to find the best route to the destination in a bio-inspired optimization manner, i.e., IGWOP utilizes the wolf's natural foraging characteristics. IGWOP analyses the identified routes using the bio-inspired optimization strategy and then selects them for data transmission. The existing routing protocols attempt to find the shortest route in a short duration without focusing on the route quality, which fails route and retransmission and finally with increased PD. Data for Figure 2's numerical results are shown in Table 2. The average PD for routing protocols is shown in Table 3.

Table 2 Result Values of PD Analysis

Nodes	APDRP	MARP	IGWOP	ATRA
50	6721	6498	5999	6715
100	6942	6607	6266	6827
150	7198	6820	6396	7003
200	7413	6899	6511	6419
250	7499	7135	6704	7200

Table 3 Average PD

Routing Protocols	AveragePD(ms)
APDRP	7154.6
MARP	6791.8
IGWOP	6375.2
ATRA	6832.8

4.3.2. Packet Delivery Ratio (PDR) and Packet Loss Ratio (PLR) Analysis

Figure 3 and Figure 4 focus on comparing PDR and PLR of proposed and existing routing protocols (i.e., APDRP, MARP, and ATRA). From Figure 3 and Figure 4, it is illustrated that the IGWOP have superior performance in terms of PDR and PLR. The significant reason for getting superior performance by IGWOP is the novel search for the best route in the entire network. Encirclement behavior present in IGWOP identifies the best route with a very low rate for getting failure. Due to this reason, IGWOP has increased PDR and decreased PLR than the existing routing protocols. No analysis before utilization to send data packet is the root cause for facing more route failure leading to poor PDR and greater than PLR. Table 4 provides the numerical results seen in Figure 3. A routing protocol's average PDR and PLR are shown in Table 5.

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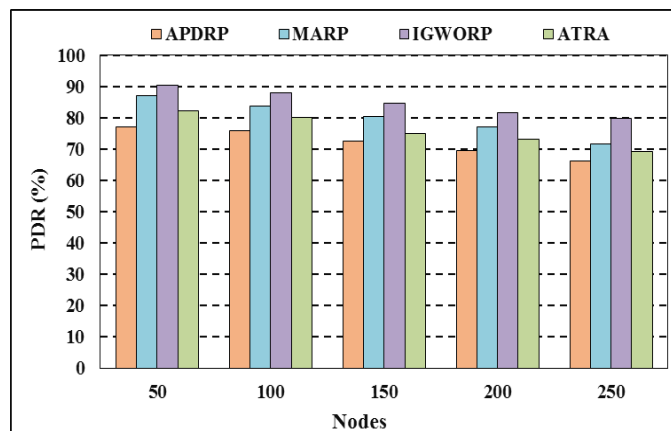


Figure 3 PDR Vs Protocols

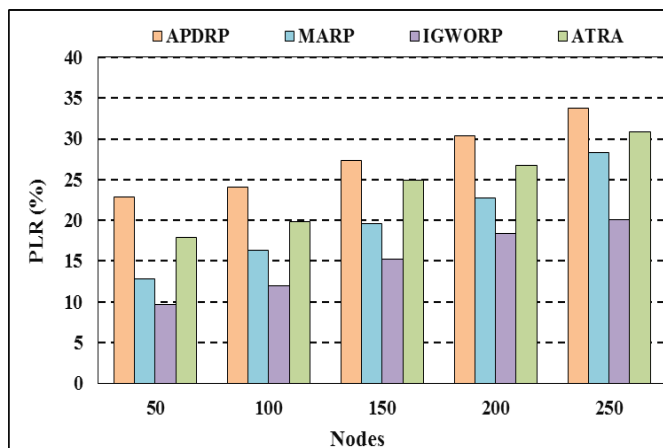


Figure 4 PLR Vs Protocols

Table 4 Result Values of PDR and PLR Analysis

Nodes	PDR				PLR			
	APDRP	MARP	IGWORP	ATRA	APDRP	MARP	IGWORP	ATRA
50	77.119	87.177	90.326	82.124	22.881	12.823	9.674	17.876
100	75.955	83.697	88.054	80.147	24.045	16.303	11.946	19.853
150	72.701	80.420	84.800	75.123	27.299	19.580	15.200	24.877
200	69.589	77.265	81.659	73.212	30.411	22.735	18.341	26.788
250	66.248	71.732	79.908	69.147	33.752	28.268	20.092	30.853

Table 5 Average PDR and PLR

Routing Protocols	Average PDR	Average PLR
APDRP	72.322	27.678
MARP	80.058	19.942
IGWORP	84.949	15.051
ATRA	75.951	24.049

4.3.3. Throughput (TP) Analysis

Figure 5 analyses the throughput of the *IGWORP* against the existing routing protocols *APDRP*, *MARP*, and *ATRA*. From Figure 5, it is observed that *IGWORP* gives a better throughput with a varying number of nodes than the existing protocols. Also, it is observed that the throughput of all protocols gets down when the count of nodes increases.

IGWORP provides better throughput in all considered varying numbers of nodes, and the main reason for that is the presence of the exploration and exploitation phase. The exploration and exploitation phase enhances the efficiency of routing in *IGWORP*. The root cause for low throughput by *APDRP*, *MARP*, and *ATRA* is selecting the available route without analyzing its quality, leading to the ultimate number of

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unexpected route failures. Data for Figure 5's numerical results are included in Table 6. The average *TP* for routing protocols is shown in Table 7.

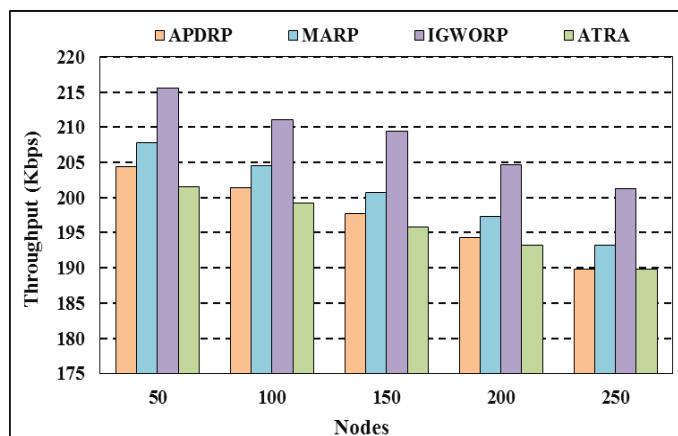


Figure 5 TP Vs Protocols

Table 6 Result Values of TP Analysis

Nodes	APDRP	MARP	IGWORP	ATRA
50	204.372	207.804	215.617	201.48
100	201.395	204.478	211.068	199.24
150	197.697	200.695	209.410	195.87
200	194.332	197.264	204.708	193.21
250	189.876	193.191	201.306	189.77

Table 7 Average TP

Routing Protocols	Average TP
APDRP	197.534
MARP	200.686
IGWORP	208.422
ATRA	195.914

4.3.4. Energy Consumption (EC) Analysis

Figure 6 compares the energy consumed by *IGWORP* against *APDRP*, *MARP*, and *ATRA* for transmitting during the entire simulation. Figure 6 clearly illustrates that the proposed routing protocol *IGWORP* consumes a low level of energy than the *APDRP*, *MARP*, and *ATRA*. Even though the count

of nodes gets varied in simulation, *IGWORP* has consumed a low energy level to deliver the data to the destination. *IGWORP* creates the opportunity to identify a better route to the destination even when the count of nodes increases. At the same time, *APDRP*, *MARP*, and *ATRA* face more congestion obstacles, leading to the degradation of selecting the best route. Due to this specific reason, energy consumption increases by *APDRP* and *MARP*. Table 8 provides the numerical results of Figure 6. The average *TP* for routing protocols is seen in Table 9.

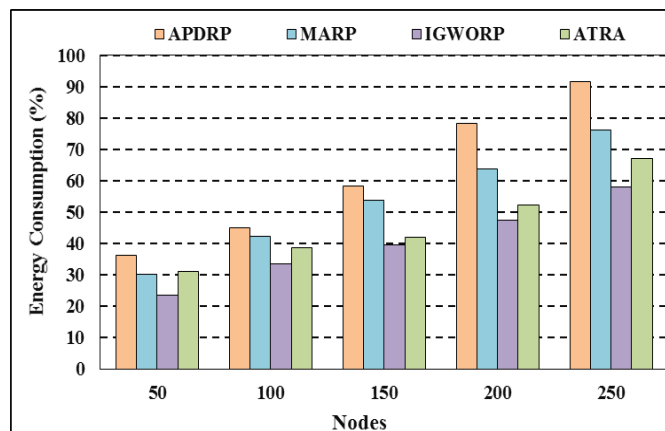


Figure 6 EC Vs Protocols

Table 8 Result Values of EC Analysis

Nodes	APDRP	MARP	IGWORP	ATRA
50	36.175	30.262	23.451	31.147
100	45.014	42.381	33.672	38.563
150	58.442	53.686	39.504	42.132
200	78.427	63.935	47.390	52.367
250	91.789	76.119	57.980	67.214

Table 9 Average EC

Routing Protocols	Average EC
APDRP	61.969
MARP	53.277
IGWORP	40.399
ATRA	46.285

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5. CONCLUSION

Network architecture is dynamically created by the cooperation of mobile and self-organizing nodes in a Mobile Ad-Hoc Network (MANET). As a result of these limitations and environmental sensitivity, the wireless links are particularly susceptible to failure, and the network architecture is subject to frequent shifts. To find the most efficient route to a destination, this paper has proposed the Ingenious Grey Wolf Optimization-based Routing Protocol (IGWORP). The proposed routing protocol IGWORP is designed to mimic the natural hunting habits of the grey wolf. IGWORP focuses on a single global route rather than a collection of smaller ones. To compare IGWORP's performance to that of other routing protocols, NS3 simulations are conducted. Results show that IGWORP consumed 40.399% of energy, while APDRP, MARP and ATRA consumed 61.969%, 53.277% and 46.285% of total energy. IGWORP's future course can be determined by experimenting with various bio-inspired tactics that utilize less energy.

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