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RESEARCH ARTICLE

Ambient Intelligence-Based Fish Swarm Optimization Routing Protocol for Congestion Avoidance in Mobile Ad-Hoc Network

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Abstract – In mobile ad hoc networks, path stability estimation is a major difficulty because of connection failures that affect network nodes' mobility. In MANETs, path stability estimates must be based on a unified model that accounts for network node mobility and topology-triggered reactive path distribution statistics between surrounding nodes. It is possible to increase the collaboration between nodes in MANET by implementing an effective, trustworthy cum optimization-based routing protocol. This paper proposes the Ambient Intelligence-based Fish Swarm Optimization Routing Protocol (AIFSORP) to find the most efficient route to a destination and decrease the time and energy required. AIFSORP is designed to mimic the ant's innate instincts to forage its food. In AIFSORP, nodes quickly notify their neighbors when they discover a possible route to their target. Only when the route meets the threshold criterion is it picked for data transmission and shared with neighboring nodes. Optimization plays a significant part in AIFSORP towards determining the best route to the destination. AIFSORP's performance is evaluated using NS3s with standard network metrics. Compared to current routing systems, AIFSORP decreases delays and energy usage more effectively.

Index Terms – Routing, Congestion, Delay, MANET, Optimization, Fish-Swarm.

1. INTRODUCTION

Wireless networks are a perfect option for applications that demand rapid operation and services to devices and in any location. It's critical to modify wireless networks because of the need to enable mobile device connectivity without wired technology and drastically reduce network costs by doing away with or lowering infrastructure consumption [1]. There is no demand for a sophisticated infrastructure for communications in the network since these networks may develop dynamically and establish a temporal network based on their application. Because of this, wireless networks have seen quick and prolific growth in real-world use, primarily in real-time scenario applications [2], [3]. There are two types of wireless networks. BS (Base Station) controls communications between devices linked in a wired structure for its data transfer in infrastructure networks, which employ fixed gateways and offer connection from the host. A node's position outside a BS's coverage area is transferred to another, and the network keeps sending data [4].

Wireless Local Area Networks are typical infrastructure-less network applications. Also known as Mobile Ad-hoc Networks (MANETs) are constructed without fixed infrastructure and are solely made up of mobile nodes. A node uses neighbor nodes to route and sends the data to its endpoint network. This node-to-node data transmission is not possible in traditional fixed or wired networks [5]. Examples of network applications that do not require a lot of infrastructures include military applications, rescue operations, search operations, video conferencing systems, device networks, and data networks. People expect to get their hands-on information at any time, from any location. The data collecting processes for hostile territories, where building infrastructure is complicated in real-time, need a temporary network. There are two types of wireless networks which are classified based on the formation of network and architecture, which are (i) infrastructure-based and (ii) infrastructure-less networks [6]–[15].

Through cables, infrastructure-based networks have a fixed base station linked to other base stations. When a mobile node leaves the control of one station and enters the range, significant difficulty arises. For infrastructure-free networks, there are no fixed networks or base stations. The nodes can travel in any direction in the network's links. Networks based on mobile ad hoc networks will be the norm in the future [16]. MANETs are independent networks, meaning they don't

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require any communication infrastructure. Still, they can also take advantage of existing fixed infrastructure networks to interact with other devices if they are available. With its low-cost wireless networking technology and the ability to move about at any moment, MANETs have become more popular. Nodes in a MANET are counted as part of the total number of linked nodes. As long as all the nodes are inside the coverage region, they may communicate. No permanent infrastructure allows a mobile computing device to travel in any direction over radio connections coverage region. It is now possible to create mobile applications utilizing MANETs because of the enhanced short-range communication in wireless technology present in mobile computing devices. Due to its versatility and self-configuration, MANET applications have seen a growth in their use in computing network functions wirelessly [14], [17].

In terms of emerging technologies, wireless communication is the strongest. Connecting the gadgets has become increasingly challenging over the years. To begin, a medium-based comparison of the differences between wired and wireless design is provided. Wired communication uses wires, whereas wireless communication uses air as the medium. A multi-access point system is used when the host connects with others using the same transmission means [18], [19]. Wireless networks can provide point-to-point communication using relatively minimal bandwidth and two directional antennas. Host layer addresses can be detected even if the host moves to a different location as long as a wired link-layer address is used. It is possible to move freely since there is no physical link between networks in wireless. There is a great deal of flexibility regarding where and how you may communicate. Only a wired or wireless connection uses the bottom two levels of the Transmission Control Protocol suite [20].

The energy efficiency of multipath routing methods is a serious issue. Regarding networking, MANETS will play a significant role in the near future. Nodes in MANETs are often shared for a particular purpose and have a restricted amount of power, which is typical. The multicasting routing mechanism is appropriate for MANETs since it is able to handle large amounts of data. Multicast routing, the newest wireless networking technique, is intended to communicate with other networks. When several points of presence or points of presence are involved in data transfers, multicast routing is essential. For wireless networks, multicast routing has various benefits over unicast routing. Because multicast routing techniques and procedures may be merged or built at a ridiculously quick pace. Due to the high probability of packet duplication in MANET, it is essential to multicast packets from one node to another. MANET's performance diminishes as a consequence. A broken connection is another issue that might substantially impact MANET's performance. The development of enhanced routing protocols inspired by biological processes is the subject of this paper's research efforts, namely the Ambient Intelligence Based Fish Swarm Optimization Routing Protocol.

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

Numerous issues are present in MANET. A research work cannot focus on the issues present in MANET. This research work has focused on the energy consumption issue present in MANET that leads to reduced network lifetime. This research work has gathered numerous literatures and some of them are discussed are below.

“Fuzzy Clustering Based Secure Routing” [21] is proposed to detect intrusions in MANET. The modelling of the technique is performed in cloud environments, and infrastructures, namely, links, hubs, and routers, are predefined. The routing attacks are detected, and nodes in the network are set to time-dependent structures. The efficiency of the model is improvised through the simulator. “Lightweight Backbone Construction based Routing” [22] is proposed for MANET to store topologically related data in the network. Lightweight Distributed Technique is used for safeguarding the backbone framework in the network, and existing attacks were detected without draining the node’s resources. “Geographic Hopless Opportunistic Routing” [23] is proposed for solving the issues in terms of space and time for routing in MANET. The forwarding priority of the node is measured in distributed order, and the overhead of the protocol is reduced. For data transmission, hop distance and the quality of links were taken into account, and the location of protocols was chosen without regard to their topology. “Jamming-Aware Routing” [24] is proposed for scheduling the friendly nodes and the hidden nodes in MANET. The routing protocols that are jammed and non-jammed are used to detect frozen nodes and are called friendly-jamming-aware routing protocols as JOLSR. Simulation-based results are fetched by comparing with the existing TDMA MAC protocol. “Efficient Stream Region Sink Position Analysis” [25] is proposed to detect congestion-based parameters on the route hops. Cooperative routing is performed for electing the head node, and sink position analysis is performed. Updations were sent to the sink and control nodes, and complete information was tracked for performing different actions.

“Privacy-Preserving Based Routing” [26] is proposed for connecting mobile devices using short-range wireless communication. Every node is programmed to record all other nodes’ locations, and a history table is created. The history table is inspected for detecting different nodes. The optimized nodes were detected for sending the messages. The messages were interchanged by the progression of a message to the destination node. “Imperialist Competitive Algorithm” [27] is proposed using numerical coding to reduce the energy usage to augment routing in the network. The lifetime of the network is increased, and re-clustering minimizes the overhead. Evaluation is carried out to predict the proposed algorithm’s accuracy and efficiency. “Enhanced Certificate Revocation Scheme” [28] is presented to revocate the certification process. The structure’s performance is revealed for protecting the communication in the network, and an increased packet delivery ratio is achieved. The methodology dependency is enhanced, and correctness is ensured using threshold-based techniques for justifying the nodes as cautious nodes. “Predictive Geographic Routing Protocol” [29] is proposed for improving the connectivity in MANET, and each vehicle is ensured for the safety of the drivers with the environment. Messages are sent using inter-vehicle communications, and source-destination routes were built. The weight to its neighbor is given based on the angle and direction to predict the location. A simulation-based model is generated for retrieving the traffic condition. “Optimized Multi-Path Routing” [30] is proposed to estimate the location-based probability in MANET for routing packets. The node position is predicted based on its routing path and spatial and temporal features. Path diversions are defined for probability-based locations, and the protocol’s performance is evaluated.

“Efficient Intrusion Detection” [31] is proposed to detect MANET attacks. The interactions were structured, and the malicious node was detected. The network’s security is reinforced by preserving the node’s resources in the network. Bayesian game strategy is used for finding the defect, and defence strategy is adopted by elaborating the information from the observations. “Dynamic Caching Strategy” [32] is proposed to adopt the cache-based decisions for every content and optimal nodes selected for relocating in old cache nodes. Architecture is built to enhance data availability and reduce traffic, bandwidth usage, and time for data access. Simulation-based results were generated for improvising the performance of the structure. “Mobile Matrix Routing” [33] is proposed for IoT routing to manage mobility without modifying the node’s address. The accelerometer is used for detecting the location with any hardware usage, and analytical-based proofs were provided for evaluation. Group Regularity Mobility Model is used to generate the mobility traces, and a mobility model called Cyclical Random Waypoint is introduced to detect the Movement of nodes. “Trust Management” [34] is proposed to detect network attacks using a typical architecture. The security of data transmission and spectrum sensing was enhanced, and data transmission attacks were detected. The packet drop ratio is reduced, and the transmission rate increases using weighted consensus-based spectrum sensing. The trust values are derived, and the system’s security is improved. “Smart Perception-based Routing” [35] is proposed to solve routing in MANETs. The network is segregated into different zone areas, and a routing table is constructed. PAO is used for selecting the optimal solution, and routes are optimized locally. Physarum Autonomic and Ant Colony Optimization were used for evaluation, and cross-layer perception is used to fetch the ants.

“Affinity Propagation-Driven Routing Protocol (APDRP)” [36] is proposed to overcome the routing issues present in MANET. A combination of map evolution and local optima logic is employed to get the network's structure closer to perfection. By tweaking a modified form of Affinity Propagation, the GM algorithm used to find the node's movement structure may be made even more accurate. Analytical models reflect the propagation technique's nodes and timeframes. “Multi-Adaptive Routing Protocol (MARP)” [37] is proposed to find the best route in MANET. MARP is based on the natural inclination of fish to gather in groups to search for food. MARP is responsible for restoring a node's priority as fast and effectively as feasible if it fails. Before a data packet is delivered through a network, its connection and functioning are verified using multi-adaptive routes. “Ingenious Grey Wolf Optimization-based Routing Protocol (IGWORP)” [38] is suggested to find the most efficient route to an intended destination and to decrease the amount of time and energy consumed in the process of getting there. IGWORP is modelled around the grey wolf's natural foraging behaviors. Instead of building multiple local routes together, IGWORP prefers to focus on a single global route. IGWORP takes advantage of wolf-like behaviors including encirclement and hunting, to find the best path for transmitting data. Power consumption has led to an increase in transmission costs. Reduced energy consumption can only be achieved with the use of routing protocols. “Energy-Efficient Perspicacious Ant Colony Optimization Based Routing Protocol (EEPACORP)” [39] is a proposal for determining the most energy-efficient path for transferring data in MANET. It is based on the ant's natural tendency to search for food that EEPACORP was created. EEPACORP draws inspiration from the ant's inherent need to hunt food. Multi-hop networks need many intermediate sites to relay packets sent by the source host.

To reduce MANET's energy usage, many researchers have suggested various techniques. An improved routing protocol is still required to discover the best path. This research work aims to improve the success rate of packet delivery and reduce energy usage for delivering the packets to the destination.

3. AMBIENT INTELLIGENCE BASED FISH SWARM OPTIMIZATION ROUTING PROTOCOL (AIFSORP)

Many techniques are used to identify the best route in a complicated network, including EEPACORP and IGWORP.

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To move forward in the MANET, conventional optimization algorithms employ predefined threshold information, which may cause inaccuracies. In contrast, the fish swarm optimization (FSO) method makes mobility decisions considering the present position and gives better accuracy.

AIFSORP, an improved version of FSO, is presented in this section for more accurate detection of network communities. One big part of the AIFSORP is called "initializing." The other part is called "movement." A network's parameters were built up at an early stage. Then we utilized our suggested object function based on fish motions to search for communities in a particular network.

The suggested AIFSORP method's running computational complexity is linear and calculated as $K(t \times c)W$here t represents the size of the pollutant, and the count of iterations is indicated as c, which is required by protocol to discover and enhance all communities or clusters.

3.1. AIFSORP Operations

AIFSORP is a fish swarm optimization method inspired by nature, which uses information on fish's social behavior. Depending on the fish's needs, they may be able to locate a location that supplies additional food, either alone or with other fish. The ambient intelligence feature is included in AIFSORP to enhance the fish's different movement patterns (AIF). AIFSORP will employ the AIF with all fish motions, including (i) Prey, (ii) Follow, (iii) Swarm, and (iv) Free Movement, to avoid making abrupt turns instead of smooth turns. It is the primary goal of the AIFSORP to determine the quality of the food (i.e., route) in the immediate area and then work to raise the overall consistency of the cluster.

3.1.1. Ambient Intelligence Function.

To account for abrupt changes in fish movement, AIFSORP uses its function (the Ambient Intelligence Function (AIF)). The AIF is utilized to map extensive routing information into a region between zero and one. The curve is created using this function, and it will be in the shape of S. As an alternative, the AIF may be used when a mathematical model can't be found. Eq.(1) represents the mathematical representation of AIF.

$$\mathrm{AIF(i)} = \frac{\mathrm{D}}{1 + \mathrm{h}^{-\mathrm{i},}} + \mathrm{i} \qquad (1)$$

In Eq.(1), the natural logarithm is denoted as h, the maximum value of a curve is indicated as D, and i is indicated to represent an integer that falls between $-\infty$ and $+\infty$.

3.1.2. Node Density

Density measures how many Fish (i.e., nodes) can be seen in a given area. Density ranges from 0 to 1, with 1 being the densest and 0 being the least dense. Computationally, the density of nodes is expressed in Eq.(2)

$$\text{density} = \frac{\text{number of fishes in current cluster}}{\text{total number of fishes present in current cluster}} + \mathrm{AIF(i)} \qquad (2)$$

3.1.3. Fish Movement

Eq.(3) mathematically expresses the Movement of fishes in the swarm. Whenever a fish runs out of food, it will migrate in another direction at random. Furthermore, in the optimization procedure of AIFSORP, a fish may take any estimated path utilizing AIF when it approaches the nearby border.

$$\mathrm{G(f+1)} = \mathrm{G(f)} + \text{ count of step } \times \mathrm{AIF}\,(-1{,}1) \qquad (3)$$

where $\mathrm{G(f)}$ indicates the current position of the fish at the threshold time, count of step represents how much the fish progress from the current position, and a new direction is calculated by applying AIF between -1 and +1.

3.1.4. Prey Movement

There are several places where fishes may obtain additional food, and each fish is always looking for the same. As indicated in Eq.(4), fish first evaluate their visual range for prey. Then, depending on food density, it initiates a movement toward food, and it is mathematically shown in Eq.(5). The AIFSORP considers this Movement as the prey movement.

$$\mathrm{G_s} = \mathrm{G_s} + \text{ visual } \times \text{rand}\,(-1{,}1), \qquad (4)$$

$$\mathrm{G_s(f+1)} = \mathrm{G_s(f)} + \left[\frac{\mathrm{G_w} - \mathrm{Gs(f)}}{\mathrm{distance(s,w)}}\right] \times \text{count of step } \times \mathrm{AIF(0{,}1)}, \qquad (5)$$

where $\mathrm{G_s}$ indicates the current position of individual fish, f indicates the time, count of step indicates the progress in fish movement, and $\mathrm{f+1}$ shows the subsequent Movement of fishes. The distance between two points is measured using the Euclidean distance approach. New directions are calculated using the AIF between -1 and $+1$.

3.1.5. Swarming Movement

One of the characteristics of fish as a swarm is that they tend to work together to accomplish their objectives (i.e., identifying the food). The swarming behavior of fish allows them to achieve their goal more rapidly but without being dispersed. Fish uses Swarm movement to accomplish objectives such as searching for food. Fishes collectively move in a swarm, which is a term for this Movement. While in movements, the fish first determines its central location and then maintains its position until the desired outcome is achieved. Calculating the swarm midpoint is mathematically

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expressed in Eq (6). Eq.(7) mathematically depicts the Movement of the swarm towards food.

$$G_{center} = \frac{1}{T}\sum_{s=0}^{T} G_{s,} \tag{6}$$

$$G_s(f+1) = G_s(f) + \frac{G_{Center} - G_s(f)}{\text{distance } (s, \text{center})} \times \text{count of step} \times \sum \text{AIF}(0,1), \tag{7}$$

f in Eq.(7) represents the midpoint of the swarm.

3.1.6. Following Movement

It is not uncommon for individual fishes to alter their course in search of food while the swarm is moving in search of it. If that's the case, the fish around them will follow them, searching for other food. The term "following movement" refers to this technique. To stay up with its surroundings, fish keeps an eye out for better food options than it currently has. Here is the formula for the following Movement:

$$G_s(f+1) = G_s(f) + \frac{G_t - G_s(f)}{\text{distance}(s,t)} \times \text{count of step} \times \text{AIF}(0,1), \tag{8}$$

In Eq.(8), G_s represents the count of fishes in the nearby positions. Algorithm 1 provides the pseudocode of AIFSORP.

Input: count of iteration, visual range, step distance, count of minimum number of steps

Output: Different solution represents a different segment of network with routes

Optimization:

1: Begin
2: Perform Normalization using Min–Max strategy
3: Initialize the Propagation of Label
4: Set Iteration=i
5: Foreach iterations →1 till maximum iteration do
6: Foreach fishno →1 to total number of initialized fish do
7: Current neighbor of fish → 0
8: Current neighbor of fish → Fishes present in visual range
9: If neighbors = 0
10: Next movement → AIF(Movement in random direction)
11: Break loop and go to step-1
12: Else
13: If (crowed factor + better food consistency)< fish density
14: Subsequent movement → AIF(Prey Movement)
15: Else
16: Subsequent Movement → AIF(Rand(Swarming Movement, Follow Movement))
17: End if
18: Iteration = Iteration +1
19: End foreach
20: End foreach
21: Apply modularity in identified solution
22: End

Algorithm 1 Pseudocode of AIFSORP

4. EXPERIMENTAL RESULTS

4.1. Simulation Setting

An examination of AIFSORP will be discussed in this part utilizing NS3 simulations. Analysis of different MANET routing protocols may be done with various simulation tools. A comparison of the proposed AIFSORP routing protocol to current routing protocols was carried out using the NS3. It's no secret that MANET's protocol simulation and implementation characteristics have long baffled researchers, especially regarding the network's overall performance. Analysis of AIFSORP and other routing protocols is performed. According to this study, C++ is the best programming language for the NS3 simulator. Table 1 shows how the suggested technique (i.e., AIFSORP) was evaluated in a computer-simulated 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

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MAC	802.16
Model of Mobility	Randomway Point

4.2. Performance Metrics

The metrics provided below is used to compare AIFSORP's performance against the existing routing protocols.

- Delay is the time taken for a packet to go from sender to receiver.
- Packet Delivery Ratio measures delivered packets compared to the total number of packets that were initially transmitted.
- Packet Loss Ratio indicates the number of data packets that fail to reach the intended destination.
- Throughput indicates the data quantity that is transmitted from source to destination in a threshold period.
- Energy Consumption represents the amount of energy required to transfer a data packet from a sender node to a receiver node.

5. RESULTS AND DISCUSSION

5.1. Packet Delay Analysis

Figure 1 highlights the delay faced by the packet in every protocol with different node densities. In Figure 1, the X-axis represents the node density, whereas the Y-axis represents the delay, measured in milliseconds. Figure 1 shows that the proposed routing protocol AIFSORP has a minor delay from any present routing protocol, which is easy to comprehend. AIFSORP employs a sharing strategy to take advantage of the most efficient path. AIFSORP uses the current position of nodes to find a better route rather than utilizing the old position of nodes. The considered current routing protocols use the previous position of nodes rather than the updated position of nodes, which ends them facing more delay. Table 2 provides the result values of Figure 1 and its average values.

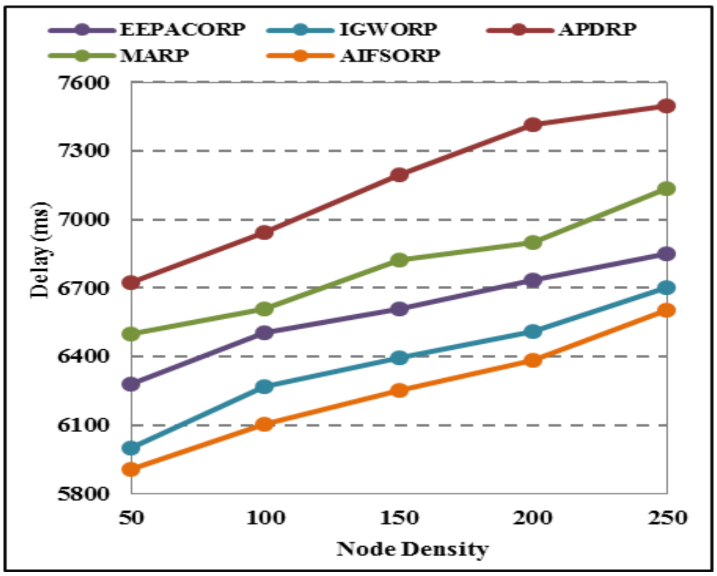

Figure 1 Packet Delay Vs Protocols

Table 2 Result Values of PD Analysis

Nodes	EEPACORP	IGWORP	APDRP	MARP	AIFSORP
50	6278	5999	6721	6498	5904
100	6502	6266	6942	6607	6101
150	6607	6396	7198	6820	6254
200	6732	6511	7413	6899	6385
250	6851	6704	7499	7135	6602

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5.2. Packet Delivery Ratio Analysis

Figure 2 illustrates the packet delivery ratio attained by AIFSORP and current routing protocols. In Figure 2, the X-axis represents the node density, whereas the Y-axis represents the packet delivery ratio, measured in percentage. Figure 2 shows that AIFSORP outperforms existing routing protocols in terms of performance. Swarming mobility and visual range of AIFSORP help it choose the optimum path for transmitting data in the most stable route. This results in repeated route failures and packet delivery problems since current routing techniques choose the route with the shortest distance without assessing the quality. It's also worth noting that with MANET, as node density rises, packet delivery gets minimized. Results from Figure 2 are shown in Table 3, along with their averages.

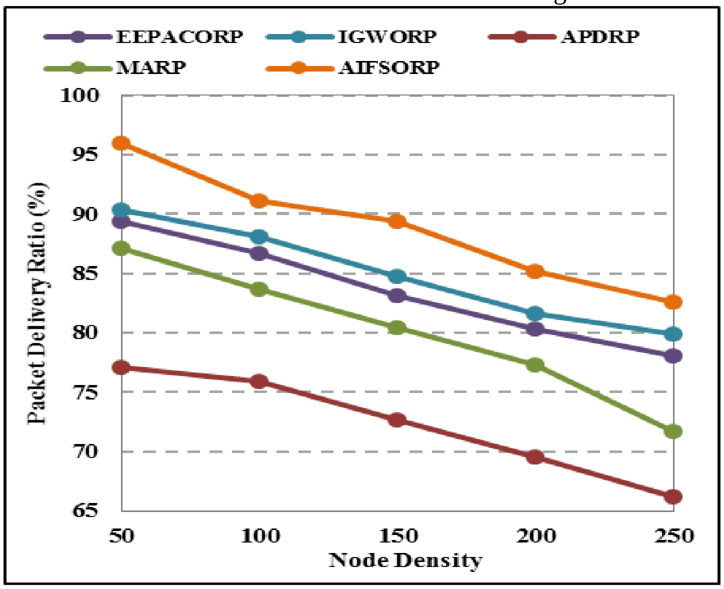

Figure 2 PDR Vs Protocols

Table 3 Result Values of PDR Analysis

Nodes	EEPACORP	IGWORP	APDRP	MARP	AIFSORP
50	89.356	90.326	77.119	87.177	95.949
100	86.684	88.054	75.955	83.697	91.133
150	83.091	84.800	72.701	80.420	89.424
200	80.356	81.659	69.589	77.265	85.239
250	78.083	79.908	66.248	71.732	82.654

5.3. Throughput Analysis

Figure 3 illustrates the throughput attained by AIFSORP and current routing protocols. In Figure 3, the X-axis represents the node density, whereas the Y-axis represents the throughput measured in kbps. Figure 3 shows that AIFSORP outperforms existing routing protocols with varying density of nodes in terms of throughput. AIFSORP uses prey movement and swarming Movement to protect the data transmission path until complete. In prey movement, nodes determine the path within its radio frequency range and share it with neighbors utilizing swarming Movement. To identify the path, existing protocols use the node's prior location, resulting in a lower throughput level because of the limited amount of data that can be sent. Results from Figure 3 are shown in Table 4 and their averages.

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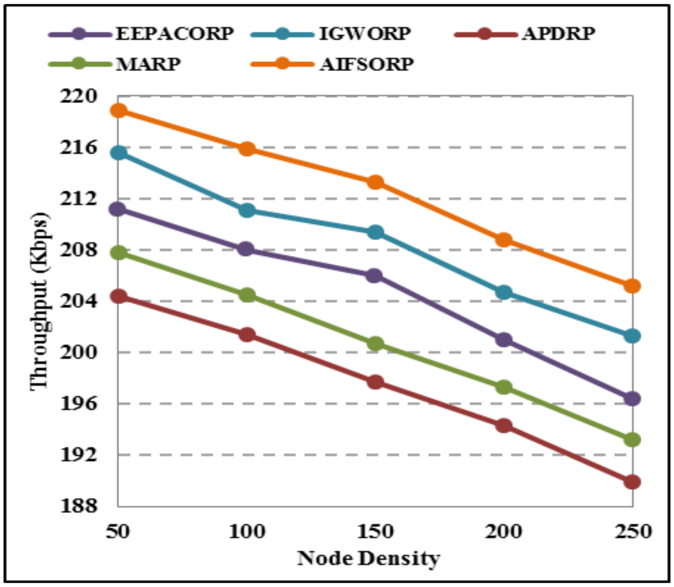

Figure 3 Throughput Vs Protocols

Table 4 Result Values of Throughput Analysis

Nodes	EEPACORP	IGWORP	APDRP	MARP	AIFSORP
50	211.180	215.617	204.372	207.804	218.869
100	208.031	211.068	201.395	204.478	215.903
150	205.945	209.410	197.697	200.695	213.263
200	201.027	204.708	194.332	197.264	208.837
250	196.421	201.306	189.876	193.191	205.212

5.4. Energy Consumption Analysis

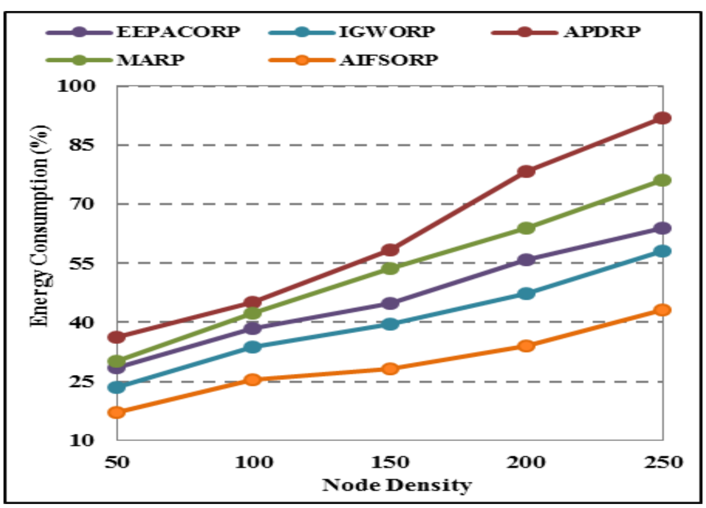

Figure 4 Energy Consumption Vs Protocols

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Table 5 Result Values of EC Analysis

Nodes	EEPACORP	IGWORP	APDRP	MARP	AIFSORP
50	28.395	23.451	36.175	30.262	17.263
100	38.336	33.672	45.014	42.381	25.576
150	44.725	39.504	58.442	53.686	28.278
200	55.971	47.390	78.427	63.935	34.169
250	64.039	57.980	91.789	76.119	43.057

6. CONCLUSION

Mobile Ad-hoc networks (MANETs) are made up of several mobile wireless nodes that may move around and join or depart at any moment. This work proposes the Ambient Intelligence Fish Swarm Optimization Routing Protocol (AIFSORP) to discover the most efficient route and reduce delay faced and energy spent. AIFSORP has been developed to mimic its swarming strategies to emulate the fishes natural characteristics. When a node discovers a feasible path to its destination, it immediately alerts its neighbors. Nodes can share data with other nodes only when a route matches a predetermined threshold condition. Optimization is a critical component of AIFSORP's approach to figuring out the most direct path to a given destination. NS3 simulations evaluate AIFSORP's performance to that of other routing protocols. AIFSORP consumed 29.669% of energy during the simulation, whereas APDRP and MARP consumed 61.969% and 53.277%. AIFSORP's future direction may be determined by testing with various bio-inspired strategies to minimize energy consumption even more.

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