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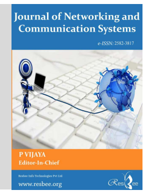


Adaptive Actor Optimization Algorithm for Alternative Path Selection and Resource Optimization Strategies in MANET

Ramgouda B Patil
Department of Computer Science and Engineering
SWVSMs Tatyasaheb Kore Institute oOf Engineering and Technology, Warananagar
ramgoudap@gmail.com

Abstract: Mobility and resource limitations of nodes are critical factors that significantly impact the performance of Mobile Ad Hoc Networks (MANETs). Node mobility affects link stability, while limited node resources lead to network congestion. These inherent challenges necessitate the development of intelligent and adaptive routing mechanisms capable of responding dynamically to environmental changes. These challenges make it difficult to design routing protocols, which effectively support Quality of Service (QoS) in MANETs. In this research, an Adaptive Actor Optimization Algorithm (Adaptive AOA) is proposed for alternative path selection and resource optimization strategies in MANET. Initially, the simulated nodes from MANET are allowed for a multipath routing strategy. This approach ensures enhanced fault tolerance and improves the overall data delivery success under high node mobility scenarios. Here, this routing strategy includes the route discovery phase, route reply process, route maintenance process, alternative path selection, and primary path selection, where Adaptive AOA is utilized for alternative path selection. By hybridizing the adaptive concept with the Actor Optimization Algorithm, the Adaptive AOA achieves a balance between exploration and exploitation in the search space. This Adaptive AOA is formed by the combination of the Adaptive concept and Actor Optimization Algorithm (AOA). Finally, the primary path is selected and the performance of Adaptive AOA is assessed by metrics such as Packet Delivery Rate (PDR), Normalized Routing Overhead (NRO), as well as Throughput, which exhibited superior values of 76.87%, 50.27%, and 0.343Mbps.

Keywords: Quality Of Service, Mobile Ad Hoc Networks, Routing, Adaptive Concept, Actor Optimization Algorithm.

Nomenclature

Abbreviations	Description
MANET	Mobile Ad Hoc Network
QoS	Quality of Service
AOA	Actor Optimization Algorithm
Adaptive AOA	Adaptive Actor Optimization Algorithm
PDR	Packet Delivery Ratio
NRO	Normalized Routing Overhead
RREQ	Route Request
RREP	Route Reply
LASN	Link Abnormal Status Notification
PSP	Path Stability Probability
LBP	Link Stability Probability
PIP	Path Interruption Probability

1. Introduction

The use of wireless mobile devices is growing rapidly in today's internet-driven World. A key component enabling these devices is wireless communication, which often relies on MANETs. MANETs have gained significant research attention due to their appealing infrastructure-less nature. The foundation of MANET development lies in ad hoc technology [1]. An ad hoc network has a group of wireless mobile nodes forming a temporary network without requiring centralized administration or pre-existing infrastructure. In such networks, a mobile node relies on other nodes to forward data packets to the intended destination, because of the limited transmission range of individual nodes. As a result, nodes in a MANET serve dual roles as both hosts and routers, transmitting data packets to other nodes [2]. This dual role not only facilitates end-to-end communication but also introduces dynamic challenges in route maintenance and energy consumption. When these nodes move dynamically, the network is referred to as a MANET. MANETs are self-configuring and self-organizing multi-hop wireless networks, where network topology alters continuously because of node mobility. Nodes are free to move and organize themselves in a decentralized manner. This technology enables the creation of networks anytime and anywhere, supporting user mobility without the need for fixed infrastructure [3].

In MANETs, node mobility and rapid energy depletion present significant challenges in establishing stable and reliable routes for data transmission between source and destination. A stable route in MANET refers to a path that remains intact for a certain duration during data transfer [4]. Energy-efficient routing is a critical concern in MANETs and is essential for ensuring effective communication [5]. It is necessary to identify an efficient and stable path that can support prolonged transmission, especially for applications that require continuous data flow, like video or audio communication. Moreover, unpredictable node behavior due to mobility, battery limitations, and dynamic traffic loads adds layers of complexity to the routing mechanism. MANET consists of mobile nodes that are deployed densely or sparsely in an unstructured manner. The network topology constantly changes due to the random movement of nodes, often resulting in frequent link failures between communicating nodes [6]. Routing involves determining the most suitable path from the source to the destination node based on specific protocols and rules. In MANETs, routing is performed dynamically using a variety of protocols. However, existing models suffer from high time complexity and lack reliability. They also fail to adapt quickly to topological variations, which leads to degraded QoS under high-mobility conditions. Therefore, it is essential to discover optimal and reliable routing paths while efficiently utilizing available resources [7].

This work aims at optimum path selection and resource optimization strategy in MANET, wherein the alternative path is selected by the proposed AAOA. Here, the MANET nodes are simulated and then these simulated nodes are allowed for multipath routing. Multipath routing offers improved fault tolerance and load balancing by allowing data packets to travel across different paths simultaneously. Herein, the routing strategies include the route discovery phase, RREP process, route maintenance process, alternative path selection, as well as primary path selection. Moreover, the alternative path is selected by AAOA, which is formed by hybridizing the Adaptive concept and AOA. Lastly, the primary path is selected based on the alternative path.

The main contribution of this work is,

- **Developed AAOA for alternative path selection:** The selection of an alternative path is done using AAOA, which is the hybridized form of both adaptive concepts with AOA. From the alternative path selected, the resource is optimized in MANET.

The remaining sections comprise: Section 2 introduces conventional literature reviews, section 3 comprises the system model of MANET, section 4 introduces the proposed model, section 5 comprises results, and section 6 concludes work.

2. Motivation

The critical resource is the battery power for mobile devices in MANETs. Therefore, energy efficiency and network longevity are the key considerations while designing control strategies. Unpredictable energy depletion can lead to abrupt node failures, affecting overall network connectivity and performance. Developing an energy-efficient routing mechanism, however, requires a holistic approach that considers multiple factors across different network layers, like residual energy, channel conditions, and overall traffic load in selecting the optimal path. Incorporating such cross-layer metrics helps in making informed routing decisions that adapt to real-time variations in network dynamics. Hence, an innovative approach is required to identify the optimal path for extending the network lifetime and ensuring reliable communication.

2.1 Literature Survey

D. R. Keshavrao, *et. al* [8] modeled Alternate Multiple path Routing-Ad hoc On-demand Distance Vector (AMR-AODV) for alternative path selection in MANET. This model reduced the re-discovery and minimized the connection drops. However, this model temporarily increased the network traffic. Despite its improvement in path reliability, the trade-off in increased protocol overhead limited its scalability for large networks. N. Veeraiah and B. T. K., [9] used Bird Swarm Whale Optimization Algorithm (BSWOA) for optimal-secure multi-path routing. This model increased fault tolerance and resilience against node mobility, but this technique had limited Central Processing Unit (CPU) resources, which degraded the performance. Additionally, the computational complexity of hybrid bio-inspired algorithms created latency issues under high mobility conditions. S. Kaddoura, *et. al* [10] presented a Smart and adaptive on-demand Distance Vector (SDODV) for optimal path selection. This method adjusted routing behavior dynamically based on real-time network conditions such as congestion, or energy availability. Nevertheless, this model required more processing power to evaluate factors like link stability. As a result, its application was constrained in energy and computation-sensitive environments. K. Chandravanshi, *et. al* [11] produced

Multipath Multichannel Energy Efficient (MMEE) for multipath selection in MANET. This technique extended network lifetime, especially in battery-powered environments, however, this model was not ideal for lightweight or resource-constrained nodes. Its reliance on multichannel architecture also introduced synchronization issues in scenarios lacking coordinated access mechanisms.

2.2 Challenges

Challenges faced by traditional models are given below,

- In [8], the AMR-AODV model reduced packet loss even in high mobile or unstable environments. However, this model increased protocol complexity and generated implementation errors. Furthermore, its lack of adaptive learning mechanisms restricted its responsiveness to varying traffic conditions.
- BSWOA in [9] isolated or ignored the suspicious nodes, preventing further damage or data leakage based on the optimal path selected. However, this model was complex in maintaining multiple paths, and thus monitoring nodes was unmanageable. Additionally, the overhead in path validation and decision-making reduced routing efficiency under constrained node capacities.
- The higher speed node movement causes frequent link disruptions, severely degrading the performance of QoS. Therefore, it is essential to develop routing protocols for MANETs that dynamically adapt to changing network topologies to maintain QoS. This demands lightweight, scalable optimization strategies that consider real-time variations in node energy, connectivity, and link reliability.

3. System model for MANET

In MANET, the gateways act as interfaces among neighboring nodes of the network for increasing connectivity and coverage [12]. Energy-aware routing mechanism comprises multiple phases, like optimization framework, path discovery, and optimal path establishment. This layered routing approach enhances decision-making granularity and ensures energy is conserved across each phase of transmission. Here, the graph structure of MANET is indicated by $\mathrm{X}(a,b)$, wherein $a=\{a_1,a_2,...,a_c,....,a_d\}$, and b indicates the link set. Also, d specifies overall node numbers and $1\le c\le d$. The mobile nodes of $b=\{b_1,b_2,...,b_e\}$ connecting among a_f and a_μ, such as that $1\le f\le \mu\le d$. Firstly, the path in the network selected such as the optimum path used in transferring data to the destination from the source is selected. Herein, the best-secured path is chosen based on multi-objective scenarios, such as distance, delay, energy, and link maintenance. This multi-criteria decision-making approach ensures robustness and enhances the QoS under varying operational conditions. For securely transmitting information and reducing data loss in the mobile network, secure routing is highly recommended for the transmission of data without a conjunction in the path. The nodes a_μ and a_f are selected as destination and source and the links existing in mobile networks utilize various multi-objective factors for packet transmission. Such a design allows the system to support fault tolerance and efficient bandwidth utilization while avoiding routes prone to discrimination. Fig. 1 specifies MANET's system model.

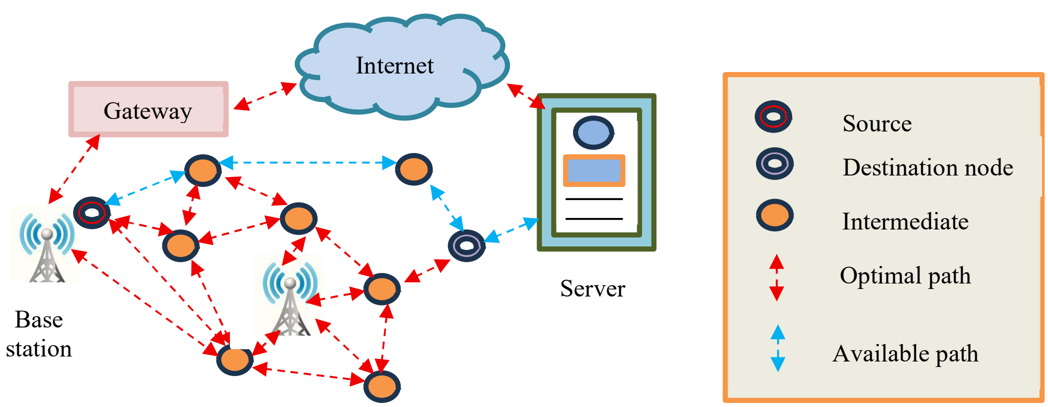


Fig. 1. *MANET's system model*

4. Developed Adaptive AOA for alternative path selection and resource optimization strategies in MANET

MANET is inherently dynamic and faces significant challenges related to energy efficiency and security. Among these challenges, energy optimization remains one of the most critical and difficult issues, often addressed through the use of routing protocols. Due to the decentralized and infrastructure-less nature of MANETs, conventional routing mechanisms are insufficient to adapt swiftly to changing topologies and energy constraints. In response, this research proposes an AAOA for selecting alternative paths and optimizing resource strategies in MANET. The routing strategies [13] encompass the route discovery phase, RREP process, route maintenance process, primary path selection, and alternative path selection. This multi-phase approach ensures that the path selection is not only optimized for energy but also maintains robustness in the face of node mobility and link fluctuations. The alternative path is determined using AAOA, a hybrid approach that combines the Adaptive concept with AOA [14]. By integrating adaptability into the AOA, the model dynamically adjusts its search behavior to balance exploration and exploitation. The primary path is then selected based on the identified alternative path. Fig. 2 shows a block diagram of AAOA for the selection of alternative path and resource optimization strategies in MANET.

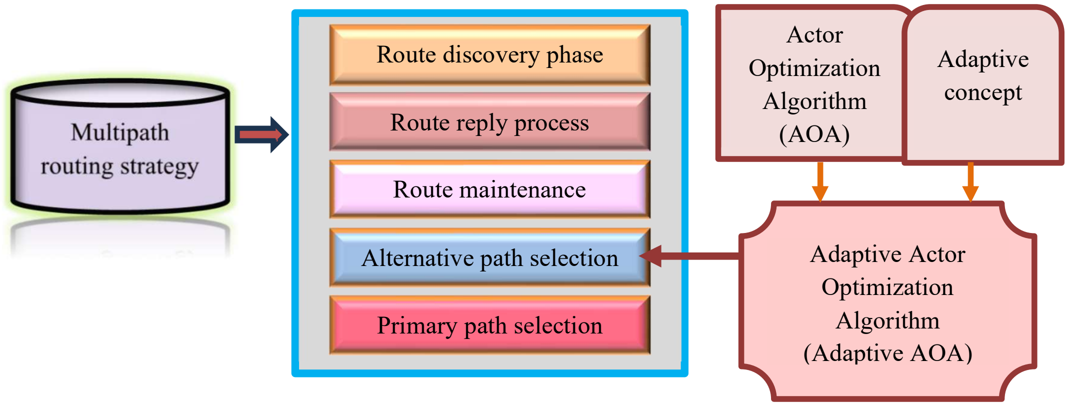


Fig. 2. *Block diagram of AAOA for alternative path selection and resource optimization strategies in MANET*

4.1 Route Discovery Process

The important task of routing protocol is to discover every routing path with adequate communication resources [13]. This phase forms the foundation for establishing connectivity between the source and destination nodes in a dynamic and decentralized environment. In this phase, an alternative path selection algorithm is utilized at the destination node, that obtains the desired path based on related resource information provided by the intermediate node. Initially, at the beginning of this route discovery, the RREQ packet is generated at the source node. While compared with the RREQ format, new fields for storing energy, queue length, and bandwidth are added. These augmented fields ensure that the routing process accounts for cross-layer parameters critical to QoS provisioning. While RREQ is received by the intermediate node, the routing protocol needs an update on energy, queue length, and bandwidth, and the next new RREQ is broadcasted. Each intermediate node appends its local resource metrics, allowing the destination node to evaluate cumulative path costs accurately. The destination node immediately starts the timer after receiving the first RREQ. The alternative path selection algorithm extracts RREQ information after the timer ends to find the cost function of the path.

4.2 RREP Process

In this phase, the stable probability of the path is calculated by each intermediate node through which the RREP packet travels through ending at the source node. This stability probability is derived based on parameters such as signal strength, residual energy, and node mobility history. After obtaining the stable probability of the path by the source node, the primary path selection algorithm arranges every alternative path in descending order in accordance with the stable probability of the path to select the first path as a data transmission path [13]. This method ensures that the selected route has the highest likelihood of sustaining reliable communication throughout the session duration.

4.3 Route Maintenance Process

For reducing retransmission and transmission loss caused by link interruption, the topology alteration monitoring and feedback mechanism is embedded in routing maintenance [13]. This proactive monitoring enhances network robustness by enabling timely rerouting decisions in response to link degradation. In this system, each node along the path monitors the probability of link stability with its next-hop node. If probability drops below a certain threshold, the node sends a LASN packet back to the source node. LASN packet includes the ID of the node involved in an unstable link. When an intermediate node receives RREQ, RREP, or LASN packets, it triggers the routing update rule to refresh its routing table. Upon receiving an RREQ, the intermediate node adds route entry to the reverse routing table and rebroadcasts the RREQ. When an RREP is received, the node adds an entry to the forward routing table and utilizes the reverse route to forward RREP. If a LASN is received, the intermediate node removes the route entry associated with the unstable link and uses the reverse route to continue forwarding the LASN. This reactive repair mechanism limits the scope of route disruptions and maintains high network availability with minimal delay overhead.

4.4 Alternative Path Selection Algorithm

After receiving the first RREQ, the destination node immediately starts the timer. After the timer ends, RREQ information is extracted using an alternative path selection algorithm. This delay allows the node to collect multiple RREQs arriving via different paths, ensuring a wider variety of route options. This is utilized for calculating the cost function of the path and this information is used as conditional parameters in case of alternative path selection [13]. The algorithm evaluates each candidate path using a multi-criteria cost function involving energy, bandwidth, and queue length to determine the most suitable alternative.

4.4.1 Solution Encoding

Solution encoding plays a crucial role in optimization algorithms by defining potential solutions within search space, effectively bridging the gap between problem formulation and computational optimization. Each encoded solution represents a distinct path from the source to the destination and indicates an ordered list of node indices traversed by the packet. Fig. 3 indicates solution encoding.

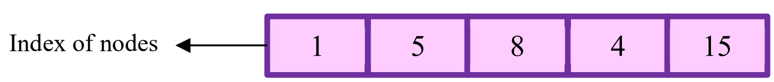


Fig. 3. *Solution encoding*

4.4.2 Fitness Function

The fitness function measures the quality or effectiveness of the candidate solution, which is formulated below,

$$Fi_{(\max)} = \frac{R_{(\max)} + B_{(\max)} + (1 - C_{(\min)})}{3} \tag{1}$$

where, $R_{(\max)}$ is maximum energy, $B_{(\max)}$ is maximum bandwidth, and $C_{(\min)}$ is minimum bandwidth.

4.4.3 Conditional parameters for alternative path selection

The conditional parameters guide the choice of alternative solution paths, wherein the parameters include energy, bandwidth, and queue length [13].

i) Energy: The energy factor is considered for achieving high energy efficiency while choosing alternative paths. Here, average and minimal residual energy is calculated as follows,

$$R_{avg} = \frac{1}{S}\sum_{k=1}^{S} R_k \tag{2}$$

$$R_{\min} = \min_{1 \le k \le S} R_k \tag{3}$$

where, R_k is the residual energy of node, and S is the count of hops in RREQ.

ii) Bandwidth: It is necessary to find the channel's idle and busy states to find channel utilization and thus average and minimal bandwidth is calculated based on the below formula.

$$B_{avg} = \frac{1}{S}\sum_{k=1}^{S} B_k \tag{4}$$

$$B_{\min} = \min_{1 \le k \le S} B_k \tag{5}$$

Herein, B_k is available bandwidth.

iii) Queue length: Queue length indicates the number of packets, or data units waiting in queue. The calculation of minimal and average queue length is calculated by the below formula.

$$C_{avg} = \frac{1}{S}\sum_{k=1}^{S} C_k \tag{6}$$

$$C_{\min} = \min_{1\le k\le S} C_k \tag{7}$$

where, C_k is available queue length.

4.4.3 Optimization for path selection using AAOA

The path selection is done by AAOA, which is formed by the hybridization of the Adaptive concept and AOA [14]. This hybrid model enhances the algorithm's ability to respond dynamically to the fluctuating conditions of MANET environments. AOA is a population-enabled algorithm for achieving appropriate solutions based on search power. Each AOA member is a candidate solution specifying the decision variables of the problem. In the context of MANET, each member represents a potential routing path characterized by parameters such as node sequence, residual energy, link bandwidth, and hop count. The adaptive concept refers to an idea, mechanism, or system that adjusts or evolves in response to alterations in its environment or context. This allows the algorithm to fine-tune its exploration and exploitation behavior over time, optimizing convergence towards more stable and energy-efficient paths. The algorithmic steps are given below,

Step 1-Initialization: The initial AOA position of each AOA member is given in matrix form.

$$M = \begin{bmatrix} M_1 \\ \vdots \\ M_t \\ \vdots \\ M_A \end{bmatrix}_{A\times j} = \begin{bmatrix} m_{1,1} & \cdots & m_{1,l} & \cdots & m_{1,j} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ m_{t,1} & \cdots & m_{t,l} & \cdots & m_{t,j} \\ \vdots & \therefore & \vdots & \therefore & \vdots \\ m_{A,1} & \cdots & m_{A,l} & \cdots & m_{A,j} \end{bmatrix}_{A\times j} \tag{8}$$

$$m_{t,l} = (BL)_l + n.\left[(BU)_l - (BL)_l\right] \tag{9}$$

where, M is AOA population matrix, M_t is t^{th} painting student, $m_{t,l}$ is d^{th} dimension in search space, A is the count of painting students, j is the count of decision variables, n is a random variable in range $[0,1]$, BL is a lower bound variable, and BU is an upper bound variable.

Step 2-Simulating movements and dialogues of a given role or exploration phase: Selecting the right actor to play a role is important in filmmaking. The extensive alterations in the behavior of actors change the position of AOA members in solving optimization issues. Based on the actor's effort in choosing a role, the new position update is given as,

$$G_t = M_t + n.(M_{best} - M_t) \tag{10}$$

$$M_t^{P1} = M_t + n.(G_t - D.M_t), t = 1,2,...,A \tag{11}$$

wherein, G_t is given a role as t^{th} AOA member, M_{best} is the best member location, M_t^{P1} is the new position of t^{th} the actor by the first phase of AOA, and D is a random number from $\{1,2\}$. Here, n is made adaptive and this is expressed in the below formula.

$$n = \left[1.5\times\frac{(Y - y + 1)}{Y}\right]\frac{(BU - LB)}{y} \tag{12}$$

wherein, Y is a maximal number of iterations, and y is iteration counter.

Step 3-Practice or Exploitation phase: After understanding roles, the actor tries to bring behaviors and movements closer to the role by practice. These changes in movements also generate position changes in AOA members. Thus, this alteration in practice sessions of AOA members is given below,

$$M_t^{P2} = M_t + \left(1 - 2.\sin\left(\frac{n.\pi}{2}\right)\right).\frac{(BU - BL)}{y} \tag{13}$$

where, M_t^{P2} is the new position of AOA member in the second phase.

Step 4-Reevaluating fitness: Fitness value is re-evaluated for achieving optimal solution using Eq. (1).

Step 5-Termination: This procedure is stopped after obtaining the best solution to find the alternative path selection.

4.5 Primary Path Selection

The primary path selection algorithm chooses the most stable path among various alternative paths for transmitting data [13]. This selection is crucial in MANETs, where frequent link breaks and topology changes can severely degrade data delivery performance. For maintaining PSP, the source node obtains the stability probability of each link-generating path. LBP is found by the intermediate node through the signal strength of the received RREP and the PSP field is updated and lastly transferred to the source node. This mechanism ensures that the path selection accounts not only for static metrics like energy and hop count but also for dynamic metrics such as real-time link reliability. Thus, LBP and PSP are estimated as below,

i) LBP: The prediction of identifying the break of links in MANET is difficult. But relative stability of the link is estimated by comparison of recent and current signal strengths. A greater variance between successive signal strength measurements indicates an unstable link, which is penalized in the stability score. The probability of the distribution function of distance among dual nodes obeys normal distribution. In the Random Waypoint Mobility Model (RWMM), the probability density function of distance exceeding transmission range among dual nodes is given below,

$$LBP_{(h,H)} \approx 1 - e^{-\frac{h}{H}}, 0 \le h \le H \tag{14}$$

where, h, H are dual nodes. This simplified LBP expression easily estimates PSP.

ii) PSP: From the destination node after receiving RREP, extraction of PSP value is extracted. Lastly, the PIP value of the path is calculated at the source node to select a stable path among various alternative paths and this is calculated as below,

$$PSP_g = \Pi_{i=1}^{l}(1 - LBP_i) \tag{15}$$

$$PIP_g = 1 - PSP_g \tag{16}$$

Thus, the list of paths is updated while the source node receives RREP. After gaining PSP value from RREP, the primary path is selected by the primary path selection algorithm with minimal PIP value for data transmission.

5. Results and Discussion

The results of AAOA for the selection of alternative paths and optimization of resource strategies in MANET are given in this section.

5.1 Experimental Setup

AAOA is experimented with in the Python tool.

5.2 Performance Measures

Performance measures included are PDR, throughput, as well as NRO.

5.2.1 PDR

The ratio of the count of packets received by the target to the count of packets sent actually by the source is PDR [13] [15]. This is expressed by the below formula,

$$P_{dr} = \frac{\sum_{u=0}^{p} T}{\sum_{v=0}^{w} F} \tag{17}$$

where, T is received packet counts, and F is the count of packets sent.

5.2.2 Throughput

This is the count of bits received by destination note at simulation time and this is formulated [13] [15] as below,

$$T_{put} = \frac{\sum_{u=0}^{p} T_b}{S_d} \tag{18}$$

Here, T_b is overall bytes received by every node, and S_d is simulation duration.

5.2.3 NRO

This is the ratio of routing control packet to count of packets received by the destination node, which is expressed [13] [15] as below,

$$N_{ro} = \frac{C_p}{D_p} * 100\% \tag{19}$$

wherein, C_p is the total count of control packets, and D_p is the total data packets.

5.3 Comparative Techniques

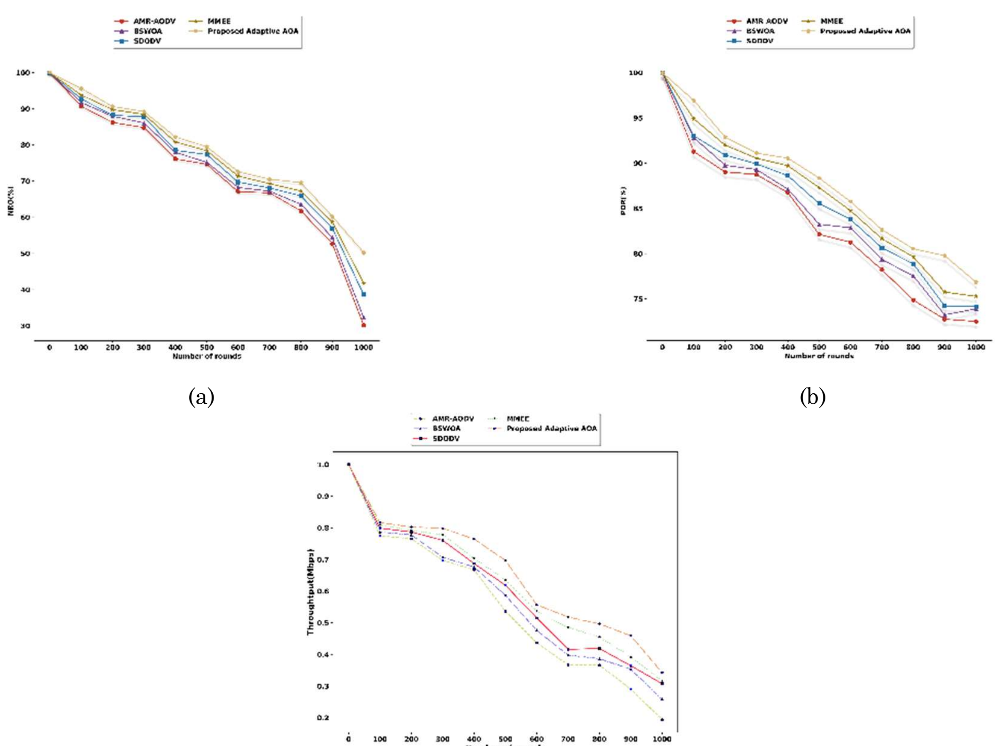
The Proposed AAOA is compared with various methods, like AMR-AODV [8], BSWOA [9], SDODV [10], and MMEE [11].

5.4 Comparative Analysis

The assessment is done by considering the number of nodes as 50 and 100.

5.4.1 For number of nodes=50

Fig. 4 shows a comparative discussion of AAOA concerning the number of nodes=50. Fig. 4 a) is NRO based comparative analysis. When the number of rounds=100, the AAOA achieved an NRO of 95.68%, whereas other models attained 90.76%, 91.76%, 92.77%, and 93.87%. Fig. 4 b) shows a PDR-based comparative analysis. While the number of rounds= 100, then PDR for AAOA is 96.93%, whereas 91.29%, 92.83%, 93.03%, and 94.9% are PDR values attained by other techniques. Fig. 4 c) exhibits throughput-based comparative assessment. While 100 is the number of rounds, then throughput for AAOA is 0.816Mbps, whereas other techniques gained throughput of 0.194Mbps, 0.258Mbps, 0.307Mbps, and 0.316Mbps.



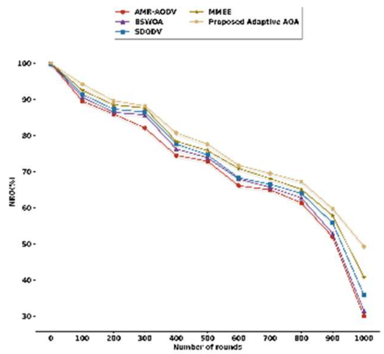
(a) (b)

(c)

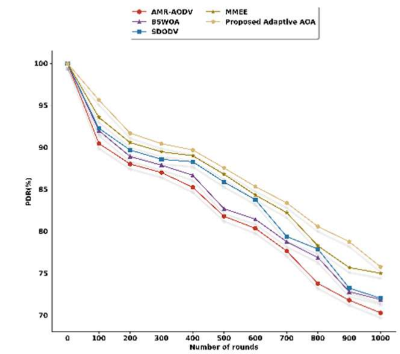
Fig. 4. *Comparison with number of nodes=50, a) NRO, b) PDR, c) Throughput*

5.4.1 For Number of Nodes=100

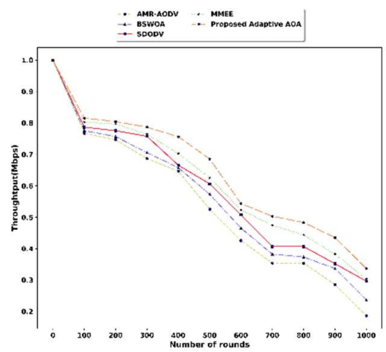
Fig. 5 shows the comparative discussion of AAOA for the number of nodes=100. Fig. 5 a) is NRO based comparative analysis. When the number of rounds=1000, the AAOA achieved an NRO of 49.31%, whereas other models attained 30.01%, 31.48%, 35.87%, and 40.77%. Fig. 5 b) shows a PDR-based comparative analysis. While the number of rounds= 1000, then PDR for AAOA is 75.76%, whereas 70.29%, 71.88%, 72.02%, and 75% are PDR values attained by other techniques. Fig. 5 c) exhibits throughput-based comparative assessment. While 1000 is the number of rounds, then throughput for AAOA is 0.337Mbps, whereas other techniques gained throughput of 00187Mbps, 0.237Mbps, 0.297Mbps, and 0.303Mbps.



(a)



(b)



(c)

Fig. 6. *Comparison with number of nodes=100, a) NRO, b) PDR, c) Throughput*

5.6 Comparative Discussion

Table 1 shows the comparison of AAOA with other techniques, like AMR-AODV, BSWOA, SDODV, and MMEE. Here, maximum values of NRO, PDR, and throughput of 50.27%, 76.87%, and 0.343Mbps are attained by AAOA when number of nodes is 50. Moreover, for the number of nodes=100, the NRO, PDR, and throughput values are 49.31%, 75.76%, and 0.337Mbps. Thus, this enables better reliability and fault tolerance with a reduction in the risk of complete disconnection. Also, this helps in handling larger networks by adapting more efficiently to frequent topology changes.

Table 1. *Comparative discussion*

Variations	Metrics/ Methods	AMR-AODV	BSWOA	SDODV	MMEE	Proposed AAOA
Number of nodes=50	*NRO (%)*	30.12	32.25	38.62	41.78	**50.27**
	PDR (%)	72.52	73.91	74.15	75.29	**76.87**
	Throughput (Mbps)	0.194	0.258	0.307	0.316	**0.343**
Number of nodes=100	*NRO (%)*	30.01	31.48	35.87	40.77	49.31
	PDR (%)	70.29	71.88	72.02	75.00	75.76
	Throughput (Mbps)	0.187	0.237	0.297	0.303	0.337

6. Conclusion

The constantly changing topology of MANET presents significant challenges in path selection and recovery mechanisms, which are crucial for enabling requesting nodes to determine the most suitable path for downloading a specific file and to efficiently recover from path failures when they occur. These challenges are exacerbated in high-mobility environments where route stability and energy availability fluctuate rapidly. Initially, the simulated MANET nodes employ a multipath routing strategy that consists of several key phases, like route discovery, RREP, route maintenance, selection of alternative path, and selection of primary path. For selecting alternative paths, an AAOA is proposed as the optimization technique. This AAOA is a hybrid model that integrates the adaptive concept with traditional AOA to enhance decision-making. Its adaptive behavior allows the routing process to dynamically respond to topological variations and fluctuating node conditions, leading to more resilient communication. Ultimately, the best primary path is chosen based on this optimization, and the effectiveness of the proposed AAOA is evaluated using performance metrics such as PDR, NRO, and Throughput. The results demonstrate improved values as PDR of 76.87%, NRO of 50.27%, and Throughput of 0.343 Mbps. These outcomes reflect not only improved efficiency but also the algorithm's robustness and scalability in handling dynamic network conditions. In the future, the optimal path will be selected in accordance with some other hybrid optimization algorithms with appropriate routing strategies.

Compliance With Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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