

Link Availability Estimation for Modified AOMDV Protocol

R. Prabha, N. Ramaraj

Abstract—Routing in adhoc networks is a challenge as nodes are mobile, and links are constantly created and broken. Present on-demand adhoc routing algorithms initiate route discovery after a path breaks, incurring significant cost to detect disconnection and establish a new route. Specifically, when a path is about to be broken, the source is warned of the likelihood of a disconnection. The source then initiates path discovery early, avoiding disconnection totally. A path is considered about to break when link availability decreases. This study modifies Adhoc On-demand Multipath Distance Vector routing (AOMDV) so that route handoff occurs through link availability estimation.

Keywords—Mobile Adhoc Network (MANET), Routing, Adhoc On-demand Multipath Distance Vector routing (AOMDV), Link Availability.

I. INTRODUCTION

AN adhoc network includes wireless nodes, with each node directly communicating with other nodes within transmission range [1]. A Mobile Adhoc Network (MANET) is a self-configuring mobile nodes network connected through wireless links forming an arbitrary topology. Nodes move randomly. Therefore, a network's wireless topology is unpredictable and changes rapidly. Minimal configuration, quick use, and absence of central governing authority make adhoc networks suit emergency situations like natural disasters, military conflicts, and emergency medical situations [2].

Mobile nodes join/leave/change positions inside a network, so topology changes anytime and unpredictably. Another property is absence of a centralized control to manage/assign resources. Additionally, wireless network routing protocols have to cope with exposed and hidden terminal problem [3] or usage of shared medium, which leads to collisions. MANET routing protocols could differ based on application and network architecture.

Routing protocols come under 2 classifications, first Unicast routing protocol and the next Multicast routing protocol [4]. Different routing protocols attempt to solve routing problems in MANET one way or the other. Any one protocol cannot fit all scenarios, different topologies and traffic patterns of MANETs. For example, proactive routing protocols are useful for small scale MANETs which have high mobility, while reactive routing protocols suit large-scale MANETs with moderate/less topology changes. Hybrid

routing protocol are a balance between both.

A reactive protocol, Adhoc On-demand Distance-Vector protocol (AODV) is derived from Dynamic Source Routing (DSR) and Destination Sequenced Distance Vector (DSDV). AODV combines advantages of both protocols [5] as its route discovery process is similar to DSR. When a node wants to send a packet for a specific destination, without having a valid route, it broadcasts a route request packet, specifying destination address. Neighbors without valid route to destination establish a reverse route, rebroadcasting route request packet. The destination on receipt of a route request sends a route reply to source. Route maintenance is by exchanging beacon packets regularly. This protocol is adaptable to highly dynamic topology providing one communication route but its main disadvantage is its huge delay for large networks.

To initiate route discovery, a node creates a Route Request (RREQ) packet containing source and destination node's IP addresses. RREQ contains a broadcast ID, incremented every time, source node initiates a RREQ. Source node's broadcast ID and IP address are a unique identifier for RREQ [6]. The source node broadcasts a packet and awaits a reply. When an intermediate node receives RREQ, it checks whether it is a repeat before using source and broadcast ID's of packet. If packet was seen previously, it is discarded. Otherwise, RREQ packet is processed. To do this, a node sets up a reverse route entry for source node in route table containing ID of neighbor through whom it received RREQ packet.

AOMDV protocol is an AODV extension to compute multiple loop-free and link disjoint paths. Multipath routing provides multiple alternative paths between source and destination, in networks. Its advantage is fault tolerance, bandwidth increase, and security improvement. Looping (infinity loop), overlapping, and optimum disjointed paths or node-disjointed are main issues in these algorithms [7]. Routing entries for every destination has a list of next-hops along with corresponding hop counts. All next hops have similar sequence number which helps to track a route.

AOMDV protocol core ensures that the multiple paths discovered are loop-free and disjoint. In addition, in locating such paths using flood-based route discovery [8]. AOMDV route update rules, applied at nodes locally have a big role in maintaining loop-freedom and disjointness properties. AOMDV relies on routing information available in underlying AODV protocol, thereby limiting overhead incurred in discovering multiple paths. Specifically, it does not use any special control packets. Extra RREPs and RERRs for multipath discovery and maintenance with extra fields in

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routing control packets (i.e., RREQs, RREPs, and RERRs) are the only additional overheads in AOMDV compared to AODV.

Adhoc networks routing is a challenge as nodes are mobile and links are regularly created and broken. Current on-demand adhoc routing algorithms initiate route discovery only when a path breaks, incurring great cost in detecting disconnections and establishing new routes. This study modifies AOMDV so that route handoff occurs through link availability estimation. Section II discusses works in literature. Section III deals with methods used for the study. Section IV explains the experimental results and Section V concludes the study.

II. RELATED WORKS

A simple approach to use longer Hello messages to enhance network performance as against using link quality based routing metrics in MANET was proposed by [9] where routing nodes use longer routing messages to filter information from neighboring nodes on low-quality links. For this, routing messages structure of two well-known proactive routing protocols was modified and named DSDV and OLSR, to ensure routing nodes transmitted longer Hello messages. Simulation showed that use of longer Hello message improved packet delivery ratio within acceptable routing message overhead.

A Stable Backbone based MultiPath (SBMRP) routing protocol for MANET was constructed by [10]. Nodes with high residual bandwidth, residual power, link quality, and low mobility nodes were designated candidate nodes. Then multiple paths between source and destination were established through candidate nodes, forming a routing backbone. When a candidate node in path failed, lacking bandwidth, residual energy or link quality, an alternate path was established through another candidate node. Simulation results showed that proposed technique minimized overhead, packet drop, energy, and increased packet delivery rate.

A new routing protocol, called Link Effective Available Time (LEAT) routing was proposed by [11]. The method proposed to find a link available time during an epoch by measuring distances between a mobile link's two nodes instead of using localization information. To reduce link breakage, a new routing link cost was proposed, i.e., product of available time and link availability. Based on new cost, routing was formulated as an optimal routing problem, which need a heuristic algorithm. Simulation demonstrated that LEAT reduced link breakages greatly, while ensuring network performance in delay, hop counts, and throughput compared to current routing algorithms.

A new link cost, i.e., unavailability of a link to reduce link breakages during data services was proposed by [12]. To reduce cost and complexity of implementation, it proposed to use only ranging information in link availability as against complete localization information. Based on new metrics, routing was formulated as an optimal routing problem, which required a heuristic algorithm. Simulation demonstrated that RBLAR improved link connectivity much by reducing link breaks and improved network performance including packet

delivery ratio and throughput, compared to existing routing algorithms.

The effect of mobility and topology changing in MANET was investigated by [13]. Three models: stationary, source and destination movement scenario, and random way-point models were considered to the proposed simulation system performance regarding throughput, number of received packets, and hop distance. From results, AODV protocol showed good performance when source and destination nodes were moving. AODV protocol also provided a flexible and effective routing for indoor environment.

Bamhdi and King [14] presented results on DP-AODV performance based on comparisons with standard protocols like AOMDV, AODV, and DSR. Simulation showed that DP-AODV had better performance than AODV and DSR in all scenarios, but AOMDV performed better in delay than others.

Araghi et al. [15] checked performance metrics like throughput, end to end delay, and packet delivery ratio to find best routing protocol based on enforced network conditions. It was observed that in networks with increased nodes subject to a maximum 20 nodes, DSR and AOMDV had better packet delivery ratio and throughput than AODV while in end to end delay, AOMDV showed reduced delay compared to DSR and AODV.

Yelemou [16] proposed considering link reliability in route choice. Route request process was modified to enable reliable paths as regards Bit Error Rate (BER). The effectiveness of new protocol considered these improvements and was tested under realistic conditions and compared to standard AOMDV and AODV protocols. Results showed that they improved performance of standard AOMDV even in difficult conditions like mobility or Multi-communication.

A new multipath routing protocol for MANETs was proposed by [17] which was a variant of single path AODV routing protocol. The new multipath routing protocol established node-disjoint paths with lowest delays based on interaction of many factors from varied layers. The proposed protocol's performance was investigated and compared to single path AODV and multipath AOMDV protocols through simulation using OPNET. Results showed that the new multipath routing protocol outperformed both protocols regarding average throughput, end to end delay, and packet dropped.

A new fuzzy logic based scheme was proposed to select better paths and increase network survivability by [18]. The approach considered various selection criteria, where some represent network status and others were issued by preventive, reactive and tolerant defense lines. Simulations compared AODV and AOMDV with a modified AOMDV protocol. Results showed the proposed approach's survivability under differing conditions.

A scheme which considered energy conservation, shortest path, and load balancing was proposed by [19] where both shortest path and energy conservation were considered with proposed energy based AOMDV routing (E-AOMDV). An energy factor was defined as product of energy factors of all nodes on different paths as selection criteria. Energy factor

informed status of energy, and then evaluated AOMDV and E-AOMDV performance. The life of proposed E-AOMDV was limited but improved routing compared to AOMDV without including energy factor. Performance of the proposed scheme was better in limited lifetime and performance metrics showed better results in the new scheme.

A Network Coding-based AOMDV (NC-AOMDV) routing algorithm in MANET was proposed by [20] to increase data transmission reliability or ensure load balancing. In simulation, NC-AOMDV routing protocol was compared to AOMDV routing protocol, regarding packet delivery ratio, packet overhead, and average end-to-end delay during packet transmission. Simulation results showed that NC-AOMDV routing protocol ensured accurate and efficient estimate and evaluated route stability in dynamic MANETs.

A new algorithm named Delay Remaining Energy for AOMDV (DRE-AOMDV) routing protocol was proposed by [21] which was a solution to find maximal nodal remaining energy of every route in selecting a path regarding end-to-end constraint. The authors concentrated on route failures caused by lack of energy. Simulation's result showed significant network performance improvement in terms of energy consumption, network life, and packet delivery.

A new channel adaptive routing protocol which extended AOMDV routing protocol to accommodate channel fading was proposed by [22]. The proposed Channel-Aware AOMDV (CA-AOMDV) used channel average nonfading duration as routing metric to select stable links for path discovery applying a preemptive handoff strategy to maintain reliable connections exploiting channel state information. Using same information, paths were reused when available, instead of being discarded. The authors provided new theoretical results for downtime and lifetime of live-die-live multiple path system, and also detailed theoretical expressions for common network performance measures, ensuing useful insights into differences in performance between CA-AOMDV and AOMDV. Simulation and theoretical results showed that CA-AOMDV improved network performance over AOMDV.

III. METHODOLOGY

AOMDV is modified, so that route handoff occurs, using link availability estimation in this work. When a path is about to be broken, the source is warned about the proposed disconnection. The source then initiates path discovery, avoiding total disconnection. A path is about to break when link availability decreases. The new AOMDV performed better than other protocols. Link availability estimation is computed for modified AOMDV.

Data packet transmissions over unreliable wireless connections lead to huge packet losses. Here, it is best to use CA-AOMDV. AOMDV is an extension of AODV routing protocol. The difference between AOMDV and AODV is that AOMDV ensures many paths between source and destination nodes. All paths are mutually link-disjoint and loop free. Routing table entries for AOMDV protocol are modified to

maintain multiple paths and multiple entries in routing tables [23].

Advertised hop-count replaces hop-count and advertised hop-count replaces are liable from current node to destination node. Next-hop IP address is replaced by next-hop nodes and hop-counts of destination paths from that node as:

< destination IP address,
destination sequence number,
advertized hop – count,
route list : $\left\{ \begin{array}{l} (\text{next hop IP 1, hop – count 1}), \\ (\text{next hop IP 2, hop – count 2}), \dots \end{array} \right\}$,
entry expiration time >

The proposed AOMDV protocol routing table includes

< destination IP address,
destination sequence number,
advertized hop – count,
route list : $\{(\text{next hop IP 1, hop – count 1}),$
 $(\text{next hop IP 2, hop – count 2}) \dots\}$,
entry expiration time,
handoff dormant time >

A. Link Availability Estimation

Assumptions for the proposed estimation algorithm is made as,

- Mobility epoch² lengths are exponentially distributed by using mean λ^{-1} , i.e.,

$$E(x) \triangleq P\{\text{Epoch length} \leq x\} = 1 - e^{-\lambda x} \quad (1)$$

- Node mobility is uncorrelated.

Given a prediction T_p on continuously available time for active link between two nodes at time t_0 , availability of this link, $L(T_p)$, is defined as in (2):

$$L(T_p) \triangleq P\{T_o \text{ last to } t_0 + T_p \mid \text{Available at } t_0\} \quad (2)$$

which indicates probability that link will be continuously available from time t_0 to $t_0 + T_p$.

The calculation of $L(T_p)$ is divided into 2 parts: link availability when velocities of two nodes are unchanged between t_0 and $t_0 + T_p$, $L_1(T_p)$, and one for the other cases, $L_2(T_p)$. That is,

$$L(T_p) = L_1(T_p) + L_2(T_p) \quad (3)$$

Denote $\Phi < T_p$ as a random variable for time interval between t_0 and $t_0 + T_p$ during which either of two nodes or

both change movements. $P\{\phi \leq \Phi < T_p\}$ indicates probability of nodes to keep their movements unchanged between t_0 and $t_0 + T_p$ while either of them or both change after $t_0 + \phi$.

$L_2(\phi)$ is further introduced to estimate link availability corresponding to ϕ as in (4) [24]:

$$L_2(\phi) = \frac{\phi + (T_p - \phi)pe^{-2\lambda(T_p - \phi)}}{T_p} + \epsilon \quad (4)$$

where p is probability for two nodes to move closer after changing movements and $\epsilon \geq 0$ is an adjustment to link availability calculated by first part on the right of (4). Both are supposed to be independent of ϕ . Equation (4) tries to estimate link availability by calculating total time (T_t) that a link is available continuously between t_0 and $t_0 + T_p$ if movement changes happen as discussed below. After first movement change happens at $t_0 + \phi$, link between related nodes can be continuously available if the change makes two nodes move close to each other with probability p . The link is anticipated to be continuously available from $t_0 + \phi$ to $t_0 + T_p$ if two nodes keep movements unchanged during this period with probability $e^{-2\lambda(T_p - \phi)}$. So, T_t can be calculated by (5):

$$T_t = \phi + (T_p - \phi)pe^{-2\lambda(T_p - \phi)} + \dots \quad (5)$$

The accurate T_t is achieved by repeating above calculation considering second possible changes in movements during remaining period. However, doing so complicates the calculation. Instead, it is best to assume that averaged contribution of this part (i.e., ' \dots ') to overall link availability is relatively smaller than sum of $L_1(T_p)$ and $\frac{\phi + (T_p - \phi)pe^{-2\lambda(T_p - \phi)}}{T_p}$. For simplicity's sake, ϵ is introduced to estimate link availability contributed by this part.

IV. RESULTS AND DISCUSSION

Experiments were conducted with 60 nodes and each node's transmission power is 0.005 watt. Experimental results are stated below. Table I and Fig. 1 show results of packet delivery ratio in nodes' different pause times.

TABLE I
PACKET DELIVERY RATIO

Node pause time in second	AOMDV	Proposed AOMDV
100	0.9191	0.9643
75	0.8442	0.9509
50	0.7852	0.8741
25	0.7597	0.8617
0	0.7195	0.7139

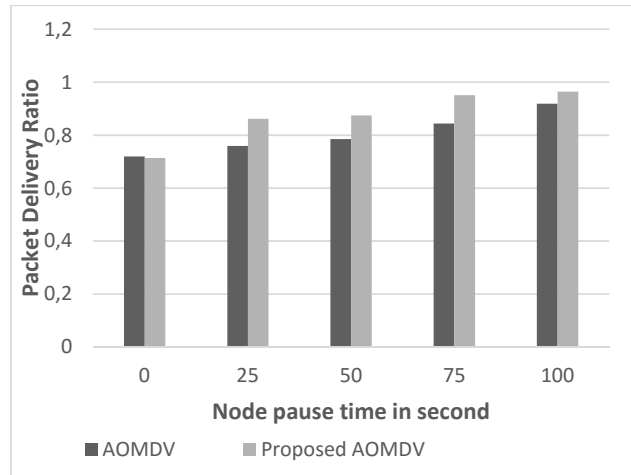


Fig. 1 Packet delivery ratio

The proposed AOMDV improves the packet delivery ratio by 13.43% when compared to AOMDV for pause time of 25 seconds and by 12.64% for pause time of 75 seconds. Table II and Fig. 2 show the results of end to end delay.

TABLE II
END TO END DELAY

Node pause time in second	AOMDV	Proposed AOMDV
100	0.265	0.0207
75	0.3318	0.5107
50	0.3076	0.2815
25	0.4711	0.4035
0	0.9245	0.8712

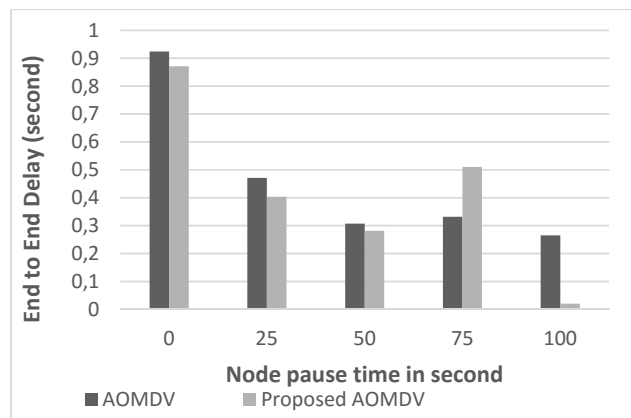


Fig. 2 End to End delay

The proposed AOMDV decreased end to end delay by 14.35% when compared to AOMDV for pause time of 25 seconds and by 92.19% for pause time of 100 seconds. Table III and Fig. 3 show the results of routing control overhead.

TABLE III
ROUTING CONTROL OVERHEAD

Node pause time in second	AOMDV	Proposed AOMDV
100	16	17
75	17	28
50	20	29
25	23	35
0	30	35

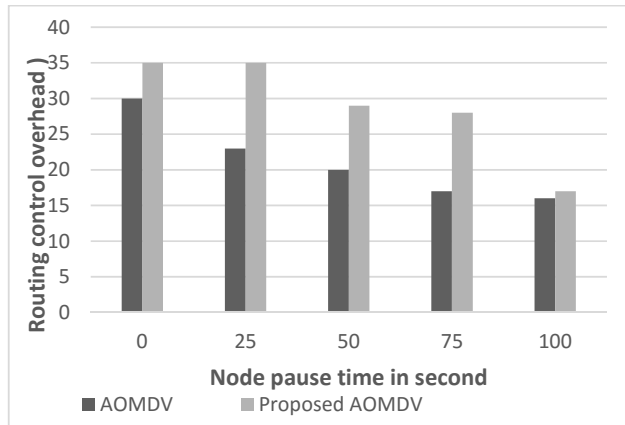


Fig. 3 Routing control overhead

The proposed AOMDV increased routing controlled overhead by 52.17% when compared to AOMDV for pause time of 25 seconds and by 64.71% for pause time of 75 seconds.

V.CONCLUSION

MANET is a dynamic wireless networks that is formed without pre-existing infrastructure where each node acts as a router. Every routing algorithm's goal is to direct traffic from source to destination, maximizing network performance while reducing costs. In MANETs, routes are multihop due to limited propagation range, frequent topology changes as each network host moves randomly. Hence, routing is an integral part of adhoc communications and aims to find and maintain routes between nodes in a dynamic topology with unidirectional links with minimum resources. The proposed AOMDV improves the packet delivery ratio by 13.43% when compared to AOMDV for pause time of 25 seconds and by 12.64% for pause time of 75 seconds.

REFERENCES

- [1] Wang, Y. C., & Tseng, Y. C. (2006). Attacks and defenses of routing mechanisms in ad hoc and sensor networks. *Security in Sensor Networks*, 4-23.
- [2] Divecha, B., Abraham, A., Grosan, C., & Sanyal, S. (2007). Impact of Node Mobility on MANET Routing Protocols. *Journal of Digital Information Management*, 5(1).
- [3] Becker, P. (2007). Qos routing protocols for mobile ad-hoc networks-a survey. *Technische Universität Kaiserslautern, Fachbereich Informatik*.
- [4] Lakshmi, M. V., & Venkatachalam, S. (2012). Comparative analysis of QoS routing protocols in MANETS: Unicast & Multicast. *International Journal of Emerging Technology and Advanced Engineering*, 2(4), 242-250.
- [5] Biradar, S. R., Sarkar, S. K., Rajanna, K. M., & Puttamadappa, C. (2010). Analysis QoS Parameters for MANETS Routing Protocols. *International Journal on Computer Science & Engineering*, 2(3).
- [6] Jawhar, I., & Wu, J. (2005). Quality of service routing in mobile ad hoc networks. In *Resource Management in Wireless Networking* (pp. 365-400). Springer US.
- [7] Wadhwa, D. S., & Panag, E. T. S. (2005). Performance comparison of single and multipath routing protocols in adhoc networks. *International Journal of Comp. Tech. Appl*, 2(5), 1486-1496.
- [8] Marina, M. K., & Das, S. R. (2006). Ad hoc on-demand multipath distance vector routing. *Wireless Communications and Mobile Computing*, 6(7), 969-988.
- [9] Kang, D., & Bahk, S. (2013, October). Use of longer routing messages to filter out low-quality link information in MANET. In *ICT Convergence (ICTC), 2013 International Conference on* (pp. 151-152). IEEE.
- [10] Mallapur, S. V., & Patil, S. R. (2013, March). Stable Backbone Based Multipath Routing Protocol for Mobile Ad-Hoc Networks. In *Circuits, Power and Computing Technologies (ICCPCT), 2013 International Conference on* (pp. 1105-1110). IEEE.
- [11] Yu, M., Liu, W., & Xing, T. (2011, April). Link availability modeling for routing algorithms to reduce the link break time in MANETs. In *Networking, Sensing and Control (ICNSC), 2011 IEEE International Conference on* (pp. 115-120). IEEE.
- [12] Yu, M., & Bao, J. (2010, April). A Ranging-Based Link Availability Routing Algorithm for MANETS. In *Wireless Communications and Networking Conference (WCNC), 2010 IEEE* (pp. 1-6). IEEE.
- [13] Ikeda, M., Kulla, E., Hiyama, M., Barolli, L., & Takizawa, M. (2010, November). Analysis of manet routing protocols for indoor environment. In *Broadband, Wireless Computing, Communication and Applications (BWCCA), 2010 International Conference on* (pp. 9-16). IEEE.
- [14] Bamhdi, A. M., & King, P. J. (2013, June). Performance evaluation of Dynamic-Power AODV, AOMDV, AODV and DSR protocols in MANETS. In *Smart Communications in Network Technologies (SaCoNeT), 2013 International Conference on* (Vol. 1, pp. 1-5). IEEE.
- [15] Araghi, T. K., Zamani, M., & Mnaf, A. B. (2013, September). Performance Analysis in Reactive Routing Protocols in Wireless Mobile Ad Hoc Networks Using DSR, AODV and AOMDV. In *Informatics and Creative Multimedia (ICICM), 2013 International Conference on* (pp. 81-84). IEEE.
- [16] Yelemou, T. (2013, March). New approach to improve the robustness of AOMDV protocol. In *Systems, Signals & Devices (SSD), 2013 10th International Multi-Conference on* (pp. 1-6). IEEE.
- [17] Obaidat, M., Ali, M. A., Obaidat, M. S., Obeidat, S., & Shahwan, I. (2011, September). A novel multipath routing protocol for MANETS. In *Wireless Communications, Networking and Mobile Computing (WiCOM), 2011 7th International Conference on* (pp. 1-6). IEEE.
- [18] Lima, M. N., da Silva, H. W., Dos Santos, A., & Pujolle, G. (2008, April). Survival multipath routing for MANETS. In *Network Operations and Management Symposium, 2008. NOMS 2008. IEEE* (pp. 425-432). IEEE.
- [19] Sharma, B., Chugh, S., & Jain, V. (2014, April). Energy Efficient Load Balancing Approach to Improve AOMDV Routing in MANET. In *Communication Systems and Network Technologies (CSNT), 2014 Fourth International Conference on* (pp. 187-192). IEEE.
- [20] Yang, F., Ling, S., Xu, H., & Sun, B. (2012, March). Network coding-based AOMDV routing in MANET. In *Information Science and Technology (ICIST), 2012 International Conference on* (pp. 337-340). IEEE.
- [21] Tekaya, M., Tabbane, N., & Tabbane, S. (2011, September). Delay Remaining Energy for AOMDV Protocol (DRE-AOMDV). In *Wireless Communications, Networking and Mobile Computing (WiCOM), 2011 7th International Conference on* (pp. 1-5). IEEE.
- [22] Chen, X., Jones, H. M., & Jayalath, D. (2011). Channel-aware routing in MANETS with route handoff. *Mobile Computing, IEEE Transactions on*, 10(1), 108-121.
- [23] Jadhav, A. P., Takale, S. B., & Lokhande, S. D. Implementation of CA-AOMDV Protocol using ANN.
- [24] Jiang, S., He, D., & Rao, J. (2001). A prediction-based link availability estimation for mobile ad hoc networks. In *INFOCOM 2001. Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE* (Vol. 3, pp. 1745-1752). IEEE.

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