International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Optimizing Routing in Nature-Inspired Algorithms to Improve Performance of Mobile Ad-Hoc Network

Dr. Arshey M[1], Ravuri Daniel[2], Deepak Dasaratha Rao[3], Dr. Emerson Raja[4], D Chandrasekhar Rao[5], Aniket Deshpande[6]

Submitted: 20/04/2023 **Revised**: 19/06/2023 **Accepted**: 30/06/2023

Abstract: It is a wireless network made up of mobile nodes that operate independently and use radio waves to communicate. Nodes can communicate with one another without a permanent basic structure by exchanging packers with nearby nodes. When the hosts are in wireless communication range, they exchange packets directly and without the need for a middle man. By sending messages to intermediaries, communication occurs outside of the wireless range. The message is sent to the closest host by the originating node. The host intern passes it on to the host that is the closest to it, allowing for numerous hops between the intermediate nearby nodes to carry out the conversation. In these networks, each node is in charge of deciding which path is the most effective for transferring packets. The best path is picked and the packet is forwarded when a node receives it. Every node of the network has routing capabilities built into it in this fashion. At first, a new protocol called Energy Aware Simple Ant Routing Algorithm (ESARA) was developed in which the node's energy consumption was factored into the cost function. It was discovered that the adjustment boosted the packet delivery ratio and decreased routing overhead. Such an adjustment also helped boost communication throughput. It was observed that ESARA's performance improved even when the number of hosts increased.

Keywords*: *Wireless network, wireless range, MANET, SARA, ESARA.

1. Introduction

The efficiency of the network is dependent on how well the routing protocol performs. The following characteristics are ideal for an efficient MANET routing protocol. The MANET routing protocols should ideally have these qualities in order to function well. i) Distributed control: In MANET, routing is carried out jointly by all nodes because there is no centralized control [1]. The protocols used in MANET should therefore have distributed control for this reason. ii) Loop Free: Packets transmitted along paths with loops will just circle without being eaten by any nodes. This lowers network effectiveness. A perfect protocol would find a direct route from source to destination without any loops. iii) Adjust to the circumstance: The MANET routing protocol should zealously support any changes to the network's structure [2]. They must effectively use resources like bandwidth and power. iv) Secure: The creation of MANET requires the cooperation of all hosts connected to the network. These networks are typically vulnerable to assaults at the network and link layers. Hence, MANET protocols should be resilient to a variety of network threats [3].

1Department of Computer Science and Engineering, SCMS School Of Engineering And Technology, arsheym@scmsgroup.org, 0000-0001-6702-4064
2Department of Computer Science and Engineering, Prasad V. Potluri Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India, danielravuri@gmail.com; 0000-0001-8404-8674
3Research and Development, India, Ddrb2011@gmail.com; 0000-0001-5959-3136
4Faculty of Engineering and Technology, Multimedia University, Malaysia, emerson.raja@mmu.edu.my; 0000-0002-4512-0802
5Department of Information Technology, Veer Surendra Sai University of Technology, Burla, India, dcrao_it@vssut.ac.in; 0000-0001-7414-3360
6Department of Computer Science and Engineering, Mewar University, Gangrar, Rajasthan, India, anik.deshpande@gmail.com; orchid id : 0000-0001-6366-5999

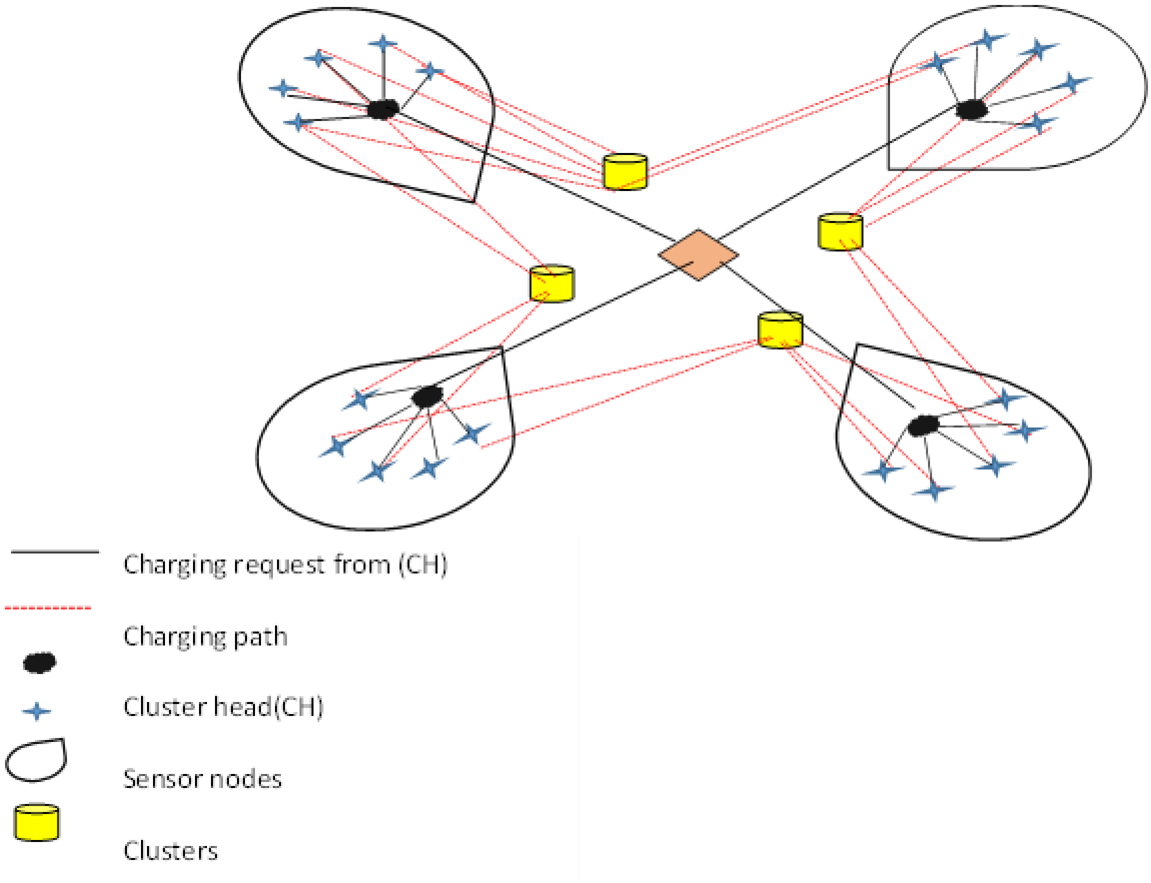

Fig I: A WSN model with multiple mobile chargers.

It can be difficult to route in the changing environment of MANET. Many problems prevent efficient routing operations. These are a few of the concerns that should be addressed when creating MANET routing protocols. MANET communicates over a wireless medium. Due to electromagnetic interference or unfavourable weather, the wireless medium is vulnerable to distortions. Furthermore, erratic are the link's performance and bandwidth availability [4]. These variables all affect the MANET's ability to communicate effectively. Batteries, which cannot maintain electricity for an extended period of time, power hosts in MANET. Because of this, hosts in MANET live shorter lives. They have limited storage and processing power because of their compact size [5]. Nodes in MANET move quickly and abruptly alter the network's structure. Moreover, their erratic mobility will cause links between nearby nodes to fail. Path failure is the result of this. Wireless media is vulnerable to issues like noise, fading, and interference [6]. They have a lower link capacity than wired networks. All of these variables lower the bandwidth that is available while limiting the maximum transmission rate. Using mobile devices carries more danger. They are more vulnerable to physical theft and experience network attacks more frequently. Mobile networks are susceptible to spoofing, eavesdropping, and DOS assaults [7].

The network's anatomy quickly changes as a result of the hosts' erratic movements in MANET. Traditional protocols like shortest-path and link-state protocols become obsolete in such a dynamic setting. Many protocols are developed to deal with this [8]. Four criteria have been used to group these treatments. 1) The method for updating routing information, 2) The utilization of temporal information, 3) The topology utilized for routing, and 4) The kind of resources employed. The classification of protocols is not governed by any strict rules, and the same protocol may fall under more than one heading [9].

This is the approach that is most frequently used to categorize routing protocols. It makes a distinction between the protocols based on the method used to get and maintain the route. Protocols falling under this category decide on new paths using information from their previous route and the condition of the links. The routing protocols within this category are further divided into three types based on the route discovery and update times. i) Proactive routing protocols, often known as "table-driven" protocols, keep a list of routing information [10]. They operate by continuously maintaining pathways toward all hosts and routinely discovering paths toward every host in the network. The pre-established paths allow for rapid packet delivery without the need for new path discovery. Regrettably, they send out route revisions on a regular basis to maintain routes. Routing information is typically flooded across the network via proactive protocols, which increases network traffic and decreases the bandwidth that can be used for real data transfer. As a result of node movement, links can break [11].

ii) The reactive routing protocol only looks for a path when it is unquestionably required. A host consults its routing table when it needs to communicate with another host. The previously created path is used if it is still in place. However, a new route is found if there is no previously known route. As a result, route finding only occurs when necessary. They are also referred to as an on-demand routing mechanism for this reason. Request messages are sent out among the neighbours throughout the route discovery phase till they arrive at their destination [12]. An intermediate node checks the routing table when it receives a route request. A route reply packet is returned if there is a viable path. A packet is routed to the following intermediate node if not. iii) Hybrid Routing Protocols combine reactive and proactive routing strategies. It is referred to as a hybrid routing protocol for this reason. Nodes are typically considered to be in a routing zone if they are located in a topographical region or in a pre-established region. With hybrid routing systems, proactive communication occurs within the routing zone while reactive communication occurs across zones [13].

What follows is the outline for the rest of the paper. The related work is briefly described in part 2, and the methodology and the theoretical foundations of the methods used are described in section 3. The simulation results and analysis are presented in section 4. For the chapter’s final section, “key findings” we summarize the most important results.

2. Past Related Work

In a MANET, nodes can take on the roles of a source, destination, or intermediary node. They can send, receive, or forward packets in each of these scenarios. To send and receive packets, power is required. Less powerful hosts will soon lose power, and if these nodes are connected to a route, they will result in route failure. The goal of this work is to reduce energy usage in ant colony routing (ACR). By transferring packets through less congested pathways, the protocol that has been created will also take signal strength into account when switching between alternate paths and lessen the latency [14].

The Ant Colony Optimization approach is based on swarm intelligence, which makes use of foraging ants in nature to choose the best course. A group of academic researchers first suggested using this optimization method. These algorithms are created using two different kinds of ants. They are respective Reverse and Forward ants. Ants moving forward start their journey from the sender node and move toward the destination [15]. At each intermediate node during the traverse, the forward ant gathers crucial information. After they reach their target, forward ants are wiped out and backward ants are created. The backward ant changes the pheromone concentration at each intermediate host while applying the learning from the forward voyage. By transmitting FANT reactively, the ARA protocol overcomes the problem of excessive control overhead in distribution [16]. This protocol cannot significantly reduce the overhead because it assumes that the traffic is balanced. The SARA uses a different strategy. Additionally, it distributes FANTs to nearby nodes while allowing a selected host to redistribute the FANT once more. A controlled neighbour broadcast is what this is. Additionally, the protocol anticipates that there is an imbalance in communication and uses super FANT to balance the pheromone level near the link [17].

A team of researchers has proposed an improved version of the ARA protocol called Ant HocNet. Contrary to the maintenance method, this protocol is different. Here, the sender host sends proactive FANT (PFANT) to its close neighbour on a frequent basis to assess the link quality. PFANTS are distributed more slowly in order to find new routes. HOPNET is a cantered protocol that is another method. Depending on the wireless radius, it divides the surroundings into different parts [18]. While communicating across regions, the proactive approach is used internally and the reactive approach externally. As AODV and ACO combine, MRAA is created. Here, inter-node pathways are created using ACO while AODV is used during a path search operation. The protocol survives while storing and maintaining the standby path, but it shows less delay and overhead. I-ACO employs two techniques to keep the host's pheromone levels high. Transition probability and directional probability are these processes [19]. Although the protocol demands higher control overhead and uses more resources, it reduces delay and improves packet delivery. A reactive region-based protocol called POSANT. Depending on where the source and destination hosts are located, this protocol divides the area around a host into 3 sections. FANT advances through each area as it looks for a way. Due to its inability to preserve host locations, the protocol suffers. Since the objective shifts quickly, it is challenging to distribute regions [20].

According to a group of scientists, MRP protocols operate according to the clustering theory. It establishes many routes between the cluster head and sinks after electing a node with high power as the cluster head. It chooses a communication path based on power and other factors [21]. It has been discovered that the protocol reduces power consumption and keeps the path open for longer. Nevertheless, the protocol does not adequately address pheromone depletion and motion-based connection failures. E- AOMDV builds various pathways between the communication nodes while utilizing hop count and power efficiency [22]. When determining the path, it takes into account the power factors of all the hosts in the path. It is discovered that Protocol offers a longer lifespan than AOMDV. With ACO's positive acknowledgments, ACECR selects the best course of action. The protocol chooses the active path based on distance, mean power, and least power. It extends the life of communication and efficiently uses energy [23].

Researchers have proposed POSANT, which uses positional data and ant colony optimization to shorten the time needed to determine the path. Additionally, fewer control messages are sent. The protocol assumes that hosts are aware of their surroundings, including their immediate surroundings. As recommended by another group, EMP-DSR selects the active route based on connection stability and FANT duration [24]. It employs a regional repair method. DSR, which selects the close-by nodes to reroute lost paths. Sadly, the protocol necessitates more resources and increases overhead. As a result, efficiency suffers. In addition, there are issues with increased congestion and incorrect management of lost connections as a result of host failure [25].

3. The Objective of the Work

1. To optimize routes using nature-inspired algorithms that take signal strength, traffic, and host power into account.

2. Use simulation to evaluate and contrast the performance of the improved algorithms with those of the baseline methods.

4. The Projected Work:

In a MANET, any node can act as a source, a sink, or an intermediate node. Each of these scenarios allows for packet transmission, reception, and forwarding. To transmit and receive packets, energy is required. Those hosts with weaker batteries will run out of juice sooner, which can bring down the entire route if those nodes are integral to it. In this section, we will discuss how to reduce Ant Colony Routing's power usage (ACR). To further reduce delays, the newly designed protocol will take signal intensities into account while choosing between available channels.

The network is modelled in the Simple Ant Routing Algorithm (SARA) as a weighted graph with V vertices and E edges. The notation for this is G = (V, E). Adj[u] is an adjacency list that every node uses to keep track of its neighbours. This directory is constantly updated through neighbouring nodes exchanging HELLO messages. The routing table stores information such as the final destination, the next hop, and the total number of hops. In SARA, only one neighbour is allowed to forward the FANT, thanks to the application of control neighbour broadcast. If the ant stops at a node along the way that has a convincing path to the final destination, or is itself the final destination, a BANT will be produced. The BANT makes its way back to the node that sent it. As a control or data message travels along a network, the pheromone level at each node increases by. Then, after a time lag of, its value is reduced. Nevertheless, transmission does not account for the node's remaining power. Whenever a node sends or receives a packet, it loses energy. Consequently, a longer lifespan for a node means that it can keep the route going for longer. In this method, the route's steadiness can be strengthened.

The residual power of the host is based on the energy's evolution from the beginning to the present. Here's how it's compared:

$$E_c = E_i - E_{co} \tag{1}$$

The node uses power when sending packets Et, receiving packets Er, and eavesdropping on packets Eo. Thus, the amount of energy used is equivalent to (2). In most cases, Eo is irrelevant and is not given any thought during proceedings.

$$E_{co} = E_t + E_r + E_o \tag{2}$$

Table 1: Simulation background for protocols comparison.

Parameter	Value
Dimension	1000X1000 sq. m.
Node Count	10-90
Connection Count	5-60
Source Type	CBR
Packet size	512 Bytes
Buffer Size	50 packets

MAC layer	802.11b
Simulation Model	Random way point
Propagation radio model	2 ray ground
Maximum speed	20 m/s
Pause Time	20s
Interval time to send	2 packets/s
Simulation time	100 sec
Transmission power	0.7 packets/joule
Reception power	0.3 packets/joule

It appears that SARA and ESARA's routing workload increases when more nodes are added to the network. When there are fewer nodes in ESARA, the routing workload increases. This is because ESARA may fail to detect nodes with higher energy and a greater need for control packets during transmission if they are in a sparse environment. ESARA, on the other hand, chooses reliable nodes that send out minimal control packets as the number of nodes in the network grows.

5. Result and Discussion:

Throughput and packet delivery rate (PDR) for different nodes in the presence and absence of outliers are analysed and compared with the current method. Since the maximum number of nodes are taking part in the activities of the network, it is determined that the throughput improves with an increase in the number of nodes. The suggested network scenario has throughput within the threshold limits while there are no outliers, and throughput below the lower worthy threshold limit when there are outliers.

5.1. PDR (Packet delivery ratio): PDR is the ratio of packets received to packets sent. The primary success of wireless networks is the transmission of packets. As far as PDR is concerned, this delivery ratio is a success.

$$PDR = \frac{Recieved\ Packet\ Count}{Delivered\ Packet\ Count} \tag{7}$$

5.2. Throughput: The throughput is the rate at which data packets are successfully relayed from the sending node to the receiving node.

$$Throughput = \frac{Forwaded\ data}{Transmission\ time} \tag{8}$$

5.2. End-to-end delay: Reducing Reduced power consumption and increased reliability are two benefits of end-to-end (E2E) delay. Hence, less time spent waiting improves both efficacy and dependability. E2E delay measures how long it takes for a packet to go from one node to another. Time spent on tasks such as data processing, transmission, and reception are all factored into the end-to-end delay.

$$End\ to\ end\ Delay = Time\ for\ (Data\ transmission + Data\ processing + Data\ delivery\ ) \quad (9)$$

All these evaluation parameters are calculated for above mentioned routing protocols and compared the effectiveness of proposed routing protocols with existing ones.

Table II: Evaluation of proposed method with existing model based on different parameters.

Node Count	**Throughput (Kbps)**		**End to End Delay (ms)**		**PDR (%)**		**Energy Consumed (J)**	
	SARA	**ESARA**	**SARA**	**ESARA**	**SARA**	**ESARA**	**SARA**	**ESARA**
10	190.02	189.15	236.42	236.12	99.24	99.35	7.89	7.63
30	226	226.14	245.48	244.57	98.89	99.16	15.27	14.82
50	249.12	250.54	220.43	218.67	99.48	99.57	24.43	24.03
70	260.28	264.18	237.28	236.49	99.67	99.75	34.58	34.16
90	252.41	253.83	215.83	213.56	99.73	99.87	43.52	42.19

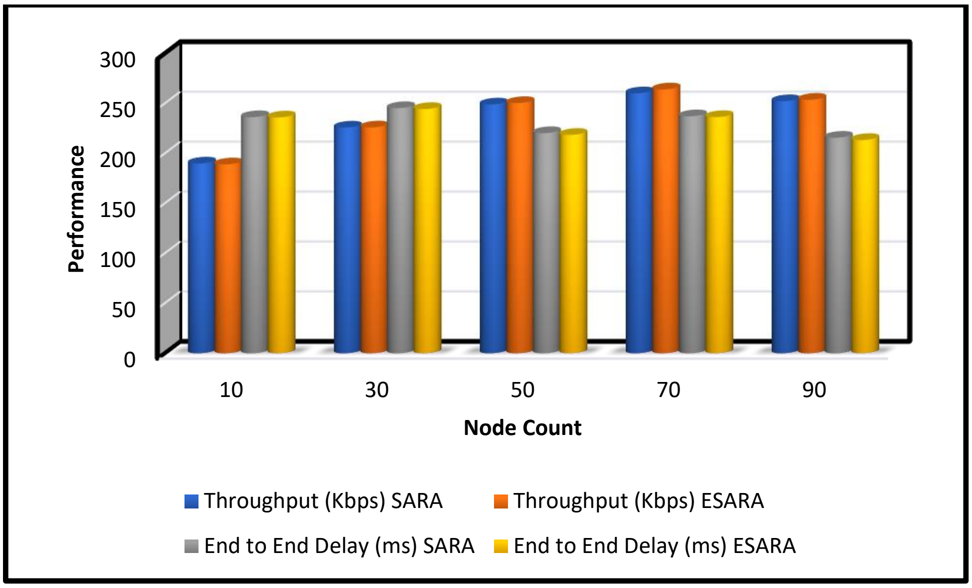

Fig II: Throughput and End-to-End delay enactment Comparison of the proposed method.

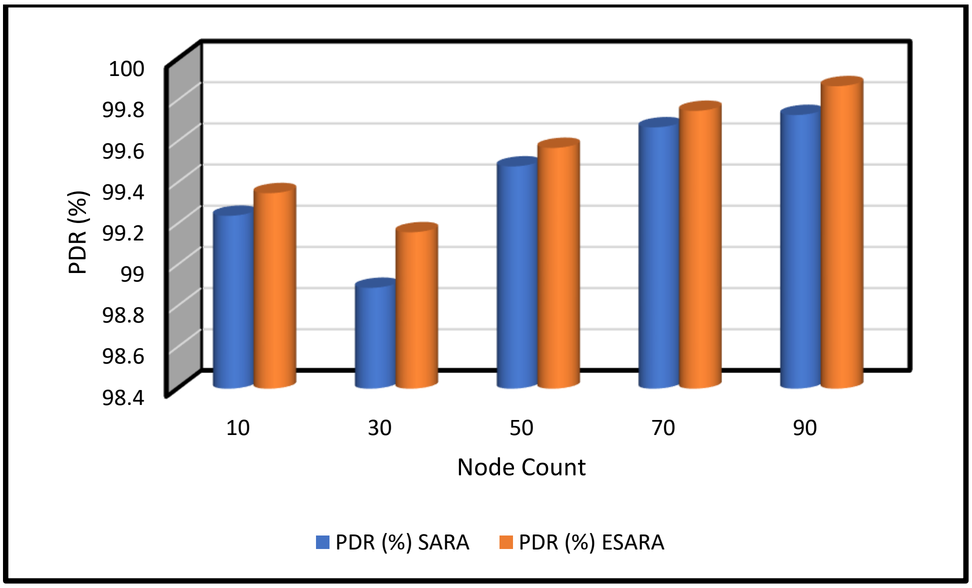

Fig III: PDR (%) enactment Comparison of the proposed method.

When choosing a path, ESARA ignores congestion. This causes longer latencies in data transmission. When hosts increase, experimental results suggest that latency decreases. In contrast, ESARA's simulation delay is very imperceptible. Table II and Figure II demonstrate that ESARA has a shorter latency than SARA.

It was found that ESARA increases the quantity of packets transferred as more nodes are introduced into the ecosystem. This is because ESARA is able to find a more reliable path and send more packets when there is a large increase in the number of hosts sending data. Figure III displays the outcome of the simulation. If there are enough nodes, ESARA's throughput is much higher. As seen in diagram II, network throughput improves as more nodes are added. The average amount of energy used by ESARA is shown in diagram IV.

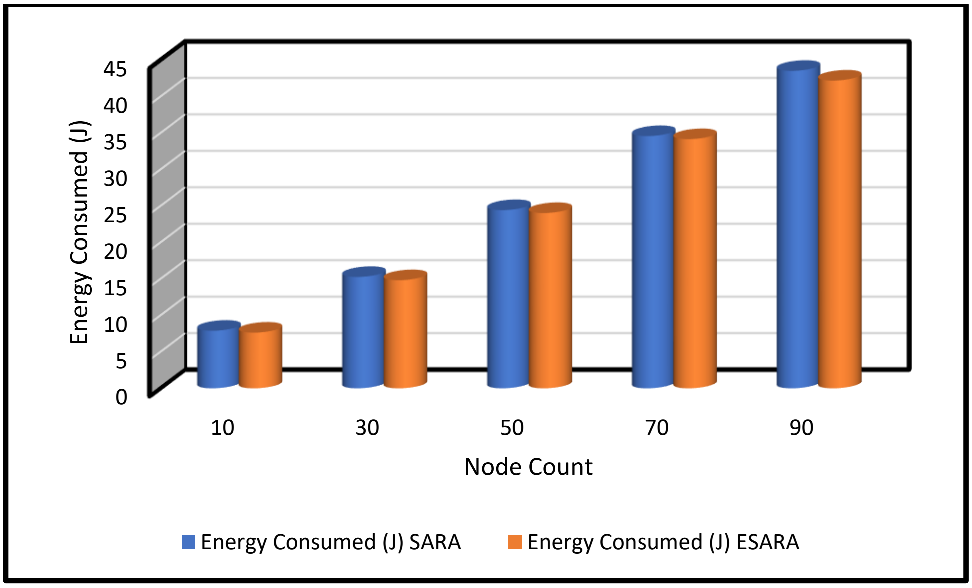

Fig IV: Energy Consumed enactment Comparison of the proposed method.

The findings indicate that ESARA uses less energy than its predecessor. When ESARA disperses the data packets over the network, it steers clear of the nodes with the lowest residual energies. As a result, the network nodes' residual energies drop across the board. The results indicated that the proposed protocol had better PDR even when the network was fairly crowded. Throughput predominated when the routing overhead was minimised. Simulation results demonstrate that while SARA performed well for low-to-medium node counts, ESARA outperformed it for higher-to-extreme node counts.

6. Conclusion:

The lack of a single authority figure is what sets MANET apart. The route is decided at each node independently. The network's hosts collaborate to facilitate communication. By mimicking their foraging behaviour, ant colonies use the Ant Colony Optimization (ACO) approach to lay down a superior path between the origin and destination hosts. Ant agents are used in these protocols to aid the intermediary node in its path selection process. Here, all of the intermediate nodes work together to facilitate communication. As a result, the MANET is a perfect fit for the ant colony optimisation method. An optimal route can be attained with the use of ACO by considering factors like available bandwidth, congestion, and available residual energy.

In this study, we explore some potential ways in which the ACO protocol's implementation could be enhanced. In the first phase, we balanced the energy by picking the nodes with the highest residual energy. Measurements of queue length are made later on to evaluate connection congestion. The adjustment was shown to increase throughput and decrease latency. The energy needed for talking was lowered as a side effect of this procedure. The Simple Ant Routing Protocol is one such protocol that has seen enhancements. At first, a new protocol called Energy Aware Simple Ant Routing Algorithm (ESARA) was developed in which the node's energy consumption was factored into the cost function. It was discovered that the adjustment boosted the packet delivery ratio and decreased routing overhead. Such an adjustment also helped boost communication throughput. It was observed that ESARA's performance improved even when the number of hosts increased.

References

[1] R. H. Jhaveri, N. M. Patel, D. C. Jinwala, J. H. Ortiz, and A. P. de la Cruz, “A Composite Trust Model for Secure Routing in Mobile Ad-Hoc Networks,” Ad Hoc Networks, vol. 2, pp. 19-45, 2017.

[2] G. Singal, V.Laxmi, M. S. Gaur, S. Todi, V. Rao, M. Tripathi, and R.Kushwaha, “Multi-Constraints Link Stable Multicast Routing Protocol in Manets,” Ad Hoc Networks, vol. 63, pp. 115-128, 2017.

[3] Y. M. Khamayseh, S. A. Aljawarneh, and A. E. Asaad, “Ensuring Survivability Against Black Hole Attacks in MANETS for Preserving Energy Efficiency, Sustainable Computing,” Informatics and Systems, vol. 18, pp. 90-100, 2018.

[4] P. S. Rajendra Prasad, “Efficient Performance Analysis of Energy Aware on Demand Routing Protocol in Mobile Ad-Hoc Network,” Engineering Reports, vol. 2, no. 3, pp. 1-14, 2019.

[5] N. M. Quy, N. T. Ban, and V. K. Quy, “An Adaptive on-Demand Routing Protocol with Qos Support for Urban-Manets,” IAENG International Journal of Computer Science, vol. 49, no. 1, pp. 1-8, 2022

[6] M. Abu Zant, and A.Yasin, “Avoiding and Isolating Flooding Attack by Enhancing AODV MANET Protocol AIF_AODV,” Security and Communication Networks, vol. 2019, pp. 1-13, 2019.

[7] Z. A. Zardari, J. He, M. S.Pathan, S. Qureshi, M. I. Hussain, F.Razaque, and N.Zhu, "Detection and Prevention of Jellyfish Attacks Using KNN Algorithm and Trusted Routing Scheme in Manet," International Journal of Network Security, vol. 23, no. 1, pp. 77-87, 2021.
[8] A. Al Sharah, T. Oyedare, and S. Shetty, "Detecting and Mitigating Smart Insider Jamming Attacks in Manets Using Reputation-Based Coalition Game," Journal of Computer Networks and Communications, vol. 2016, pp. 1-14, 2016.
[9] K. Manojkumar, S. Devi, "Jamming Attack in Wireless Sensor Networks using Ant Colony Algorithm," SSRG International Journal of Computer Science and Engineering, vol. 8, no. 2, pp. 6-9, 2021.
[10] M.Supriya, Dr.T.Adilakshmi, "Secure Routing using ISMO for Wireless Sensor Networks," SSRG International Journal of Computer Science and Engineering, vol. 8, no. 12, pp. 14-20, 2021.
[11] S Yasaswini, G.M.Naik, P G K Sirisha, "Efficient Loss Recovery in Ad Hoc Networks," SSRG International Journal of Computer Science and Engineering, vol. 4, no. 1, pp. 1-7, 2017.
[12] Nelesh Sharma, Dr. NirupamaTiwari, "Implementation of Multipath AODV for Enhanced Performance in Wireless Ad hoc Network," SSRG International Journal of Computer Science and Engineering, vol. 6, no. 9, pp. 15-19, 2019.
[13] Alameri, I. A., & Komarkova, J. (2020, June). A multiparameter comparative study of manet routing protocols. In 2020 15th Iberian Conference on Information Systems and Technologies (CISTI) (pp. 1-6). IEEE. doi.org/10.23919/CISTI49556.2020.9141119
[14] Alameri, I., Hubálovský, Š., & Komarkova, J. (2021, June). Evaluation of impact of mobility, network size and time on performance of adaptive routing protocols. In 2021 International Conference on Information and Digital Technologies (IDT) (pp. 245-253). IEEE. doi.org/10.1109/IDT52577.2021.9497568
[15] Alkahtani, S. M., & Alturki, F. (2021). Performance Evaluation of Different Mobile Ad-hoc Network Routing Protocols in Difficult Situations. Performance Evaluation, 12(1). doi.org/10.14569/IJACSA.2021.0120119
[16] Mani Bushan Dsouza, Manjaiah D.H., "Improving the QoS of multipath routing in MANET by considering reliable node and stable link", In: Karuppusamy P., Perikos I., Shi F., Nguyen T.N. (eds) Sustainable Communication Networks and Application. Lecture Notes on Data Engineering and Communications Technologies,2021 vol 55. Springer, Singapore. https://doi.org/10.1007/978-981-15-8677-4_43
[17] Mani Bushan Dsouza, Manjaiah D.H., "Signal Strength Based Routing Using Simple Ant Routing Algorithm", In: Gunjan, V.K., Suganthan, P.N., Haase, J., Kumar, A (eds) Cybernetics, Cognition and Machine Learning Applications, Proceedings of ICCCMLA 2020, Springer, pp. 535-546, 2021,https://doi.org/10.1007/978-981-33- 6691-6_38
[18] J. Dhanapal, S. Narayanan and G. Asha, "Efficient load sharing using multipath channel. Awareness routing in mobile ad hoc networks," Indian Journal of Science andTechnology, vol.
[19] 8, no. 15, 2015.
[20] S. A. Alghamdi, "Load balancing ad hoc on-demand multipath distance vector (LBAOMDV) routing protocol," EURASIP Journal on Wireless Communications and Networking, pp. 1-11, 2015.
[21] Correia, A., Moura, R., & Fonseca, M. (2020). Assessing the location of search and rescue stations on the Portuguese coast. In Developments and Advances in Defense and Security (pp. 321-331). Springer, Singapore. doi.org/10.1007/978-981-13-9155-2_26
[22] Hassan, M. H., & Muniyandi, R. C. (2017). An improved hybrid technique for energy and delay routing in mobile ad-hoc networks. International Journal of Applied Engineering Research, 12(1), 134-139.
[23] Hassan, M. H., Mostafa, S. A., Budiyono, A., Mustapha, A., & Gunasekaran, S. S. (2018). A hybrid algorithm for improving the quality of service in MANET. International Journal on Advanced Science, Engineering and Information Technology, 8(4), 1218-1225. doi.org/10.18517/ijaseit.8.4.5004
[24] Hassan, M. H., Mostafa, S. A., Mohammed, M. A., Ibrahim, D. A., Khalaf, B. A., & Al-Khaleefa, A. S. (2019). Integrating African Buffalo optimization algorithm in AODV routing protocol for improving the QoS of MANET. Journal of Southwest Jiaotong University, 54(3). doi.org/10.35741/issn.0258-2724.54.3.13
[25] Pattnaik, P. K., Panda, B. K., & Sain, M. (2021). Design of novel mobility and obstacle-aware algorithm for optimal MANET routing. IEEE Access, 9, 110648-110657. doi.org/10.1109/ACCESS.2021.3101850
[26] Rao, S. V. R. K., Devi, M. S., Kishore, A. R., & Kumar, P. (2018). Wireless sensor network based industrial automation using internet of things (IoT). International Journal of Advanced Trends in Computer Science and Engineering, 7(6), 82-86. doi.org/10.30534/ijatcse/2018/01762018
[27]

[28] Mr. Rahul Sharma. (2015). Recognition of Anthracnose Injuries on Apple Surfaces using YOLOV 3-Dense. International Journal of New Practices in Management and Engineering, 4(02), 08 - 14. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/36

[29] Rambabu, B. ., Vikranth, B. ., Anupkanth, S. ., Samya, B. ., & Satyanarayana, N. . (2023). Spread Spectrum based QoS aware Energy Efficient Clustering Algorithm for Wireless Sensor Networks . International Journal on Recent and Innovation Trends in Computing and Communication, 11(1), 154–160. https://doi.org/10.17762/ijritcc.v11i1.6085