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Designing Novel Routing Algorithms for Wireless Mobile Ad-Hoc Networks to Improve Their Enactment

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Abstract: Collections of wireless mobile nodes constitute a Mobile Ad-Hoc Network (MANET), which is a transient network without a fixed infrastructure or centralized management. When they are within the wireless range of one another, nodes in such a network can directly communicate with one another. Communication occurs through intermediary nodes using many hops outside of the wireless range. In a MANET, nodes move randomly and freely, changing the architecture of the network and leading to connection failures between communicating nodes. With such a time-varying network topology, conventional routing methods like shortest path and link-state algorithms are ineffective. Protocols employed in such a setting must be able to deal with changeable topology and quickly identify an effective communication path. The work's goal is to create and refine a fresh routing algorithm for MANET. These modifications were put into the chosen multipath protocols and their effects were studied. Congestion-free and bandwidth-aware AOMDV (CB-AOMDV) uses both CFT and residual bandwidth evaluation to find the optimal route. The available bandwidth is utilized more effectively. Both performance and packet delivery are enhanced by this approach. The congestion on the link and the hosts' remaining energy are both factored into ECAOMDV's pathfinding calculations. As a result, the lifespan of the pipeline is extended and the workload is distributed more fairly throughout the hosts. This protocol has lower power requirements and higher throughput. Increases in packet delivery rates are another benefit of this system. Hosts employing the Energy and Congestion aware AOMDV (ECAOMDV) protocol think about both congestion and energy levels when choosing an active routing. The simulation results demonstrate that the protocol has the potential to lengthen the path and fairly distribute packets across the hosts. Metrics measuring throughput are up. Experiments also showed that this approach increased packet delivery while using less energy than AOMDV.

Keywords*: *MANET, AODV, AOMDV, wireless networks.

1. Introduction

Using a communication network makes information transfer more efficient. Communication networks can be divided into two categories: wired and wireless. Wireless networks use electromagnetic waves, whereas a wired network uses physical wires for communication. Users of wireless networks are not restricted to a certain location and can move about freely without being bound by cables [1]. Its mobility is essential in today's hectic world because it allows users to converse anywhere. Traditional wireless networks require centralized management and are built on a fixed infrastructure. These networks require time and money to install and maintain. Another type of network is one that does not require any existing infrastructure. An ad hoc network is what it is called. They are autonomous and independent of centralized command. Because of this, building up such a network is less expensive than putting up conventional networks [2]. 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 middleman. 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 [3].

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Mobile ad hoc networks are unique due to a variety of intriguing characteristics.

i) Autonomous Nodes: Each node in a MANET is independent and capable of serving as both a host and a router. Every host has the ability to switch, allowing it to route the packet through appropriate paths. Nodes additionally include fundamental processing abilities, enabling them to serve as both sources and destinations in communication [4].

ii) Decentralized operation: MANET does not require a permanently fixed network structure, in contrast to standard wireless networks. Each node works together to cooperatively control communication. The MANET's nodes cooperate with one another and rely on packets to speed up communication. Also, they are involved in security and routing activities.

iii) Single or Multiple-hop Based Forwarding: MANET can use single or multiple-hop routing. Forwarding is a single hop if the nodes are confined inside the communication range. However, additional hops are required to transport the packets among the intermediate nodes if the nodes are outside of the communication range [5].

iv) Dynamic topology: The topology of the network is constantly changing as nodes in MANET are free to migrate in any direction. This causes a quick shift in connectivity among the nodes, which alters the flow of traffic down the path. The outcome is that nodes must dynamically construct and re-establish routes among themselves in response to the network's shifting environment [6].

v) Inconsistent Connection Ability: A wireless medium is subject to noise, signal deterioration, and interference. In this kind of network, the signal-carrying capacity is similarly constrained. Messages may move among diverse networks because communication is accomplished by the joint efforts of the hosts. As a result, there is a discrepancy in the connection capacity that is accessible across the MANET nodes.

vi) Lightweight connectors: Mobile nodes in MANET often have a constrained CPU processing capacity. The size of the RAM is likewise constrained. The battery powers the mobile nodes, which have a limited amount of power storage. So, it is important to optimize the MANET-related devices so that they can do their tasks effectively [7].

The MANET has numerous difficulties, much like other network types do.

1) Spectrum Allocation and Purchase: Government regulation authorities control the utilization of all radio spectrums. Adjacent interference is a problem in this range.

2) Media Access: TDMA and FDMA cannot be used in MANETs because they lack global synchronization. Several MAC (Media Access Control) protocols do not work well with MANT's randomly moving nodes since they presume that nodes are immobile [8].

3) Routing: Rapid link breaking caused by node moves at random is one of the main issues in MANET.

4) Energy Efficiency: Routing decisions made by current network protocols seldom ever take energy efficiency into account. They do this because they believe hosts and routers to be static devices that are powered by the mains. MANET nodes, on the other hand, are mobile and run on batteries. The lifespan of mobile hosts is severely constrained [9].

5) Security & Privacy: All of the network's nodes work together to make MANET function. Typically, packets travel via several intermediary nodes before arriving at their final destination. As a result, there is a growing demand for node identification and data protection against unauthorized hostile nodes that could either discard packets or manipulate their contents [10].

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. Previous Related Work

Due to its scarce resources, dynamic morphology, and lack of infrastructure, MANET presents a challenging environment for routing. Routing algorithms must ease connection congestion to improve the network's performance. High packet loss and protracted lags are both effects of congestion. Over the past few years, a number of methods for reducing congestion in wireless networks have been developed [11]. A few scholars developed an interlayer-centred congestion-controlling method that makes use of the congestion window's additive growth and multiplicative fall. This method increases the congestion window by one MSS (Maximum segment size) each time a packet is dropped. The congestion window is multiplicatively reduced upon packet loss. This protocol was able to transport packets more often and with less delay. Others introduced the idea of mobile agent-centred congestion regulation in AODV [12]. The mobile agent updates the routing table and chooses the neighbour with the least burden to act as an intermediary. This method decreases delay and produces a high delivery ratio.

Another group of researchers suggested an active congestion discovery and regulation method for ad hoc networks that calculates the average node queue length and sends a warning message to nearby hosts when the average value is exceeded [13]. When their neighbours receive a notice, they make an effort to choose a less crowded route to the objective. This method promotes trustworthy communication, and simulations demonstrate that DCDR outperforms AODV in terms of performance. A group of workers employed congestion control strategies that used congestion windows and bandwidth approximation. Also, they have offered a full evaluation of their strategies [14].

Ad-hoc On-Demand Multipath Distance Vector Routing is a popular multipath protocol (AOMDV). Its foundation is AODV. AOMDV, however, chooses the path based on the distance. The SPDA protocol uses consistency in the route by counting the number of routes that the host requests and forwards to that which is received at the target, which is an improvement. It ultimately settles on a somewhat or significantly divergent course. This protocol's simulation results demonstrate increased throughput and decreased delay [15]. Another enhancement to AOMDV is MSDM. Between communication nodes, it creates tremendously disjointed, geographically distant paths. By sending packets through spatially distinct channels, it reduces collisions [16]. Compared to AOMDV, this protocol has a smaller overhead. Moreover, there is less delay. In order to maintain a durable connection, CA-AOMDV employs a mean non-vanishing period of the channel while looking for a path and a deterrent handoff [17]. During simulation, the protocol has the ability to reveal improved capabilities. PLS-AOMDV regularly checks the connection's dependability by monitoring the host's movement and power usage. It chooses a very dependable link for communication throughout transmission [18]. Simulation demonstrates that the protocol can extend the life of the network and increase packet delivery.

According to some scientists, hosts in AM-AOMDV switched places with their next-door neighbours and managed to forge a lasting path. Lower delays and higher delivery are shown by the protocol. In a study provided by a few researchers, PPFR-AOMDV, channel behaviour is observed during communication, and signal stability is used to evaluate connection reliability [19-21]. A signal-to-noise ratio is used to perceive the path. This protocol's simulation shows a lower delay with higher throughput. Another method is LBAOMDV, which controls a host's power as well as available bandwidth by taking a variety of paths. The protocol can reduce host failures and increase reliability. The MMRE-AOMDV method, another one put out by a number of authors, preserves a variety of routes to power proficiency and load distribution. Among all hosts along the route, this one has the least amount of power left [22]. Routes are then arranged in decreasing order of power remaining. The communication path is chosen to be at the top. Such a method helps spread the load over the network and offers a longer lifetime.

A technique that uses the host lifespan and hops throughout the communication was proposed by a small group of workers. For communication, it makes use of routes with higher residual power. It switches to an alternative path when there is an active path failure. Protocol improves energy efficiency, boosts throughput, and decreases delay and loss rates [23]. Another team suggested improving AOMDV to create a new protocol. Here, the power factor and hop count are used to determine the state. The weakest node determines the stability of the path, and weak nodes are avoided during communication. A small group of scientists developed the EE-BWA-AOMDV. The protocol chooses the best route using the least amount of power and remaining bandwidth [24]. The communication path with the most available bandwidth is picked. According to the simulation, it uses the least amount of energy and has fewer packet losses. The protocol has a low packet drop rate and uses less energy. Unfortunately, because the protocol selects a node with lesser power, it uses more energy [25].

3. Purpose of the Work

1. Research the optimization procedure for choosing the fewest possible nodes in route discovery and lowering processing costs.

2. To enhance congestion control, link quality, and available bandwidth in the routing protocol. Moreover, to extend the route's life by taking the nodes' stored energy into account.

4. The Proposed Algorithm:

In a MANET, routing protocols might fall into a number of different classes. During path selection, nearly every protocol works to reduce the total distance travelled (Hop-count). However, the selected route may be overcrowded or have a reduced data transfer rate. Communication efficiency may be drastically reduced if a crowded or slow bandwidth is selected. MANET makes use of battery-operated nodes that can move around. The network's efficiency will also be impacted by the batteries' residual energy. A link failure could occur sooner if a node with a lower residual energy was chosen for communication. A potential intern route-breaker. Hence, congestion, bandwidth, and residual host power must all be taken into account when selecting a data transmission mode with the goal of optimizing network performance.

The stateless category is where the On-Demand Distance-Vector-Routing (AODV) protocol resides. Throughout the routing process, there are two stages: the discovery stage and the maintenance stage. Whereas AODV is derived from Asymmetric On-Demand Distance Vector Routing (AODMV). It generates a large number of routes that are both link-disjoint and free of loops using a reactive approach. By keeping numerous paths, a node can quickly switch between them in the event of a failed link, reducing the time it takes to find an other route. This method will save you the trouble of sending out extra control packets every time you want to find a different route.

A link's congestion is represented by the percentage of the buffer that is currently in use. To calculate the level of congestion along a certain path, one must add the occupied buffer sizes of all nodes in the path and then divide by the total number of hops. This can help determine the most effective method of contact. Active load, which is determined by equation 1, is the metric of choice for this purpose.

$$Active\ load = M_n\left[\frac{1}{N}\sum_{i=1}^{N} buffer\ size(i)\right] \quad (1)$$

The size of the buffer is a dynamic field that is changed at each intermediary node. The Active load for a given path is calculated by dividing the value of the buffer size by the hop count as the reply approaches the source. Below in Figure I is the AOMDV routing table. As shown in Figure II, the routing table structure is modified to account for the current congestion level along the route. The communication path is selected based on the least congested path. Congestion-Controlled Asynchronous Observer-Monitor-Data-Vector (CC-AOMDV).

Table I: Experimental Setup

Parameter	Value
Dimension	1000X1000 sq. m.
Node Count	30-70
Connection Count	25
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

The regimens' efficacy is verified with the help of NS-2.34. The simulation environment settings are presented in table I.

Terminus Address	**Terminus Sequence Numeral**	**Source Address**	**Hop Count**	**Buffer Size**

Fig I: AOMDV routing table.

Terminus	Sequence Numeral	Advertised hop Numeral	Path list	Termination time out

Fig II: CC-AOMDV routing table

In a MANET, the data transfers of its neighbours affect a host's available bandwidth. The complete bandwidth gets shared among its neighbours, which is why this happens. Bandwidth Aware and Congestion Free When choosing a path, the AOMDV (CB-AOMDV) protocol takes into account both the Channel Free Time (CFT) and the available bandwidth.

Channel free time can be used as a proxy for a network's available capacity (CFT). IEEE 802.11 specifies that a channel is considered free if both its transmitting and receiving states are passive and the NAV value is 0. It follows that if the value of the Network Allocation Vector is not 0 and neither the receiving nor the transmitting status is idle, the channel is in use. The MAC layer's usage for a given node is either 1 (busy) or 0 (idle) (idle). Channel Free Time (CFT) can be computed by multiplying the transmission time (Tm) by the sum of the busy times (Tb). If the channel is overloaded for an extended period of time, an alternative route can be selected.

$$CFT = 1 - \frac{\sum T_b}{T_m}, T_b \in T_m \quad (2)$$

Only if the CFT rate is higher than a predetermined threshold will packets be sent. The simulation runs with a threshold of 0.1, though its range is [0,1]. The RREQ and RREP framework is augmented as well, so that it may house the new BWnode feature.

$$RREQ_m = RREQ_{AOMDV} + BW_{node} \quad (3)$$

$$RREP_m = RREP_{AOMDV} + BW_{node} \quad (4)$$

Destination Address	Sequence Numeral	Advertised Hop Count	Next Hop	Last Hop	Hop Count	Path bandwidth	Time out

Fig III: CB-AOMDV routing table

Most Mobile Ad hoc network protocols solely take into account shortest path (hop count) metrics while choosing the active path for communication. Because of their mobility, batteries power the nodes in a MANET. Due to power loss, nodes with lesser residual power are more likely to fail. Moreover, if the node is on the active path, there is a greater possibility of the route failing altogether. Hence, to make the path last longer, it's important to take into account the node's leftover power.

If there are more than F stable paths, all of which cost the same, then the optimal path is the one that results in the lowest sum of costs. It is possible to calculate the optimum route.

$$P_o = min\left(c1(Pj)\right) \qquad Pj€F$$
(5)

Occupied size of the buffer provides the congestion across a link. Sum of occupied buffer along the path provides an estimate of congestion along a path. The congestion level along various paths can be compared by dividing the total congestion along a path by its length (number of hops).

$$Congestion\ level = M_n \left[\frac{1}{N}\sum_{i=1}^{N} buffer\ size(i)\right]$$
(6)

The People Aware of Energy and Traffic When determining the communication's active path, the Ad-hoc On demand Multipath Distance Vector (ECAOMDV) protocol takes into account both residual power and congestion along the route.

Destination Address	Sequence Numeral	Advertised Hop Count	Next Hop	Last Hop	Hop Count	Time out	CL1	Max Cost	Cost

Fig IV: ECAOMDV routing table

RREQ is produced whenever a source has its initial interaction with a destination. Each node adds its own cost and maximum cost to RREQ before sending it out to its neighbours. To propagate RREQ packets, every intermediary node follows the steps below. When RREQ reaches its destination through a path that does not connect two nodes, the destination calculates the maximum cost of that way and sends a response back to the sender. When exchanging information, the source node makes use of the maximum cost and buffer size variables. To initiate communication, the alternative way with the lowest congestion is chosen as the active path. In the event of a link failure during transmission, an RERR packet is generated, and standard maintenance procedures, as in AOMDV, are implemented.

5. Result and Analysis:

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.

$$PDR = \frac{Recieved\ Packet\ Count}{Delivered\ Packet\ Count} \quad (7)$$

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

$$Throughput = \frac{Forwaded\ data}{Transmission\ time} \quad (8)$$

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 III: PDR evaluation of different routing Protocol.

Time	AOMDV	CC-AOMDV	CB-AOMDV	EC-AOMDV
20	**95.8**	**98.6**	**98.8**	**99.5**
40	**94.7**	**97.4**	**97.9**	**99.2**
60	**95.2**	**96.4**	**97.1**	**98.9**
80	**96.4**	**96.9**	**97.6**	**99.4**
100	**94.3**	**97.8**	**98.2**	**99.7**

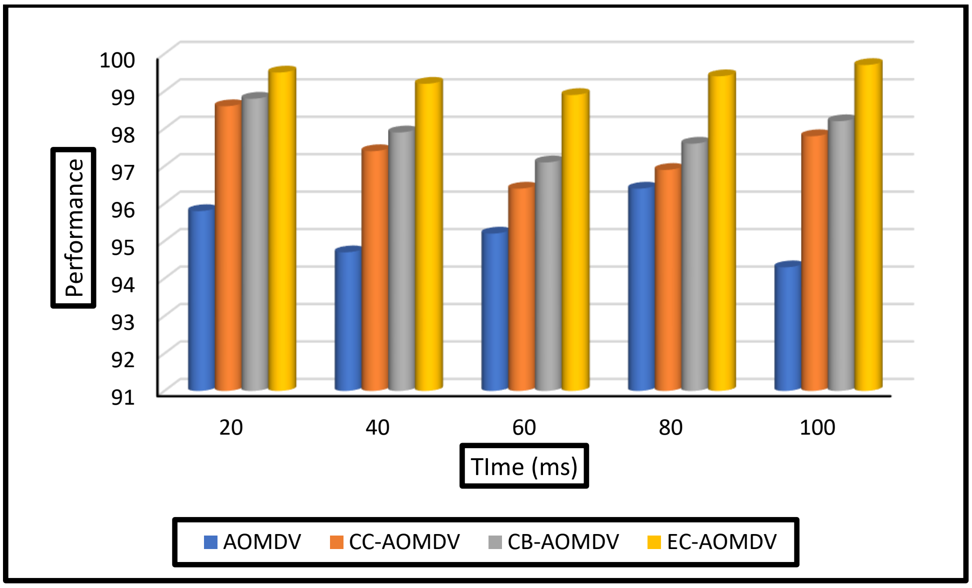

Fig V: PDR evaluation of different routing Protocol.

When the number of connections between the two devices grew, the PDR dropped for both protocols. However, the PDR was larger for CCAOMDV than for AOMDV. The protocol PDF is decreasing as the number of connections increases. CB-AOMDV initially performs worse than AOMDV in terms of packet delivery because, with fewer connections, picking the shortest way may be preferable than picking the longest path with a greater bandwidth. As network congestion increases, however, a higher bandwidth option appears to be the better option. The ECAOMD has an advantage because to the lower congestion level and the reduced likelihood of connection failure.

Table III: Throughput evaluation of different routing Protocol.

Connection Count	AOMDV	CC-AOMDV	CB-AOMDV	EC-AOMDV
5	**105**	**103**	**112**	**125**
15	**169**	**171**	**176**	**183**
25	**218**	**204**	**225**	**237**
35	**227**	**231**	**257**	**261**
45	**248**	**258**	**269**	**275**

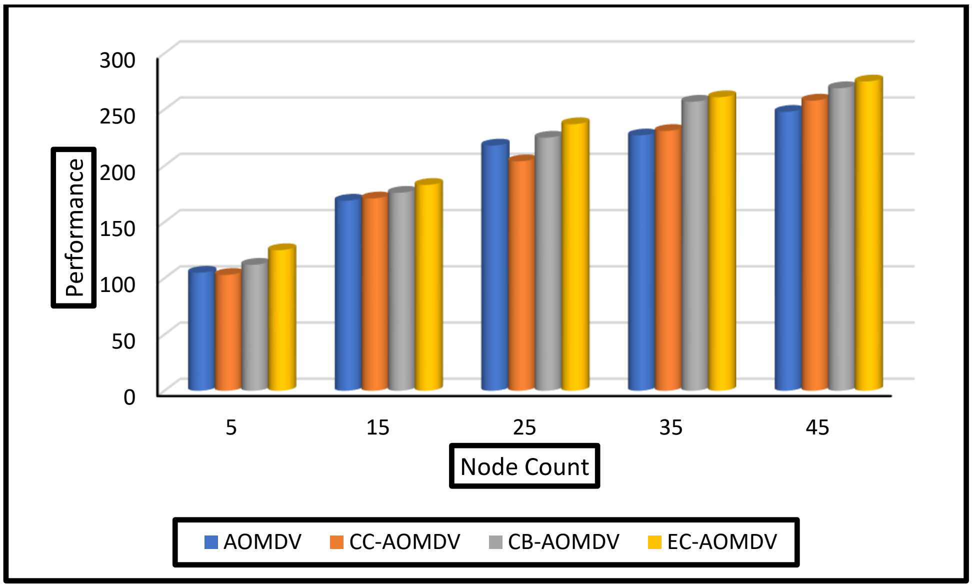

Fig VI: Throughput evaluation of different routing Protocol.

It was shown that delays in both protocols tend to increase as network traffic grows. In contrast to AOMDV, however, CC-AOMDV has a noticeably shorter latency.

Table III: End to End Delay evaluation of different routing Protocol.

Time	AOMDV	CC-AOMDV	CB-AOMDV	EC-AOMDV
20	**0.69**	**0.63**	**0.57**	**0.45**
40	**0.75**	**0.69**	**0.61**	**0.59**
60	**0.79**	**0.76**	**0.72**	**0.62**
80	**0.83**	**0.75**	**0.73**	**0.69**
100	**0.88**	**0.81**	**0.79**	**0.71**

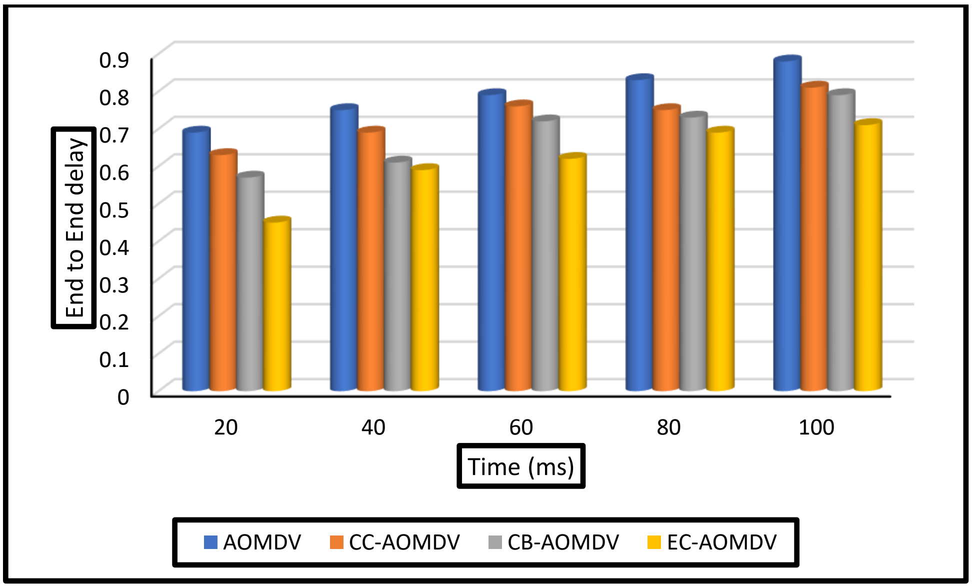

Fig VI: End to End Delay evaluation of different routing Protocol.

A greater throughput was seen with CB-AOMDV compared to AOMDV. Throughput can be improved by reducing packet delivery latency and increasing the packet delivery ratio. This means that ECAOMDV's throughput has been growing over time. The proposed procedures select a path depending on the host's remaining battery life and the level of congestion along that path. Throughput increased, while network stress decreased, according to the trial. The protocol improves network performance by accounting for the remaining power of all hosts to provide a longer lifetime to the route.

6. Conclusion:

This research paper offered a number of methods for bettering routing quality. Several methods, such as taking congestion and available bandwidth into account and assessing the received signal intensity, are added to improve the quality of the routing protocol. Choosing hosts with larger resources also increased the route's efficiency. The lifespan of a route is increased when its nodes have larger residual energies. The selected multipath protocols had these enhancements implemented, and their results were analysed. CFT and residual bandwidth evaluation are used together in Congestion Free and Bandwidth aware AOMDV (CB-AOMDV) to determine the best path. It is a more efficient user of available network bandwidth. This protocol improves performance and packet delivery. When forging a path, ECAOMDV takes into account both the link's congestion and the hosts' remaining energy. It distributes the workload evenly across the hosts and increases the lifespan of the pipeline. The protocol has better throughput and less power consumption. This protocol not only improves packet delivery rates but also increases them. When deciding on an active path, hosts using the Energy and Congestion aware AOMDV (ECAOMDV) protocol take into account both the level of congestion and their remaining energy. The simulation results show that the protocol may extend the path and evenly distribute packets among the hosts. Throughput metrics have increased. Compared to AOMDV, experiments also demonstrated that this protocol reduced energy consumption and improved packet delivery.

References

[1] V. Thilagavath and K. Duraiswamy, "Cross Layer based Congestion Control Technique for Reliable and Energy Aware Routing in MANET," International Journal of Computer Applications,vol. 36, no. 12, December 2011.

[2] Vishnu Kumar Sharma and Sarita Singh Bhad, "Mobile Agent Based Congestion Control Using Aodv Routing Protocol Technique for Mobile Ad-Hoc Network," International Journal of Wireless & Mobile Networks (IJWMN), vol. 4, no. 3, April 2012.

[3] T. Senthilkumaran and V. Sankaranarayan, "Dynamic congestion detection and control routing in ad hoc networks," Journal of King Saud University –Computer and Information Sciences, vol. 25, p. 25–34, 2013.

[4] Alhamali Masoud Alfrgani Ali, Raghav Yadav and Hari Mohan Singh, "Congestion Control Technique for Wireless Networks," IOSR Journal of Computer Engineering (IOSR-JCE), vol. 16, no. 2, Ver. II, pp. 31-33, Mar-Apr. 2014.

[5] Anju and Sugandha Singh, "Modified AODV for Congestion Control in MANET," International Journal of Computer Science and Mobile Computing, vol. 4, no. 6, pp. 984-1001, June-2015.

[6] V. Sharma and A. Vij, “Broadcasting methods in mobile ad-hoc networks,” in 2017 International Conference on Computing, Communication and Automation (ICCCA), pp. 582–587, Greater Noida, India, May 2017.

[7] J. Sharma, V. Bhatia, and G. Kaur, “A review on broadcasting strategy for mobile ad-hoc wireless network,” International Journal of Advanced Computer Engineering, vol. 7, no. 8, pp. 692–699, 2018.

[8] K. Shanmugam, K. Subburathinam, and A. V. Palanisamy, “A dynamic probabilistic based broadcasting scheme for MANETs,” Scientific World Journal, vol. 2016, article 1832026, pp. 1–8, 2016.

[9] K. A. Darabkh, M. S. A. Judeh, H. Bany, and S. Althunibat, “Mobility aware and dual phase AODV protocol with adaptive hello messages over vehicular ad hoc networks,” AEU - International Journal of Electronics and Communications, vol. 94, pp. 277–292, 2018

[10] W. A. Jabbar, M. Ismail, and R. Nordin, “Energy and mobility conscious multipath routing scheme for route stability and load balancing in MANETs,” Simulation Modelling Practice and Theory, vol. 77, pp. 245–271, 2017.

[11] W. A. Jabbar, M. Ismail, R. Nordin, and R. M. Ramli, “EMA-MPR: energy and mobility-aware multi-point relay selection mechanism for multipath OLSRv2,” in 2017 IEEE 13th Malaysia International Conference on Communications (MICC), pp. 1–6, Johor Bahru, Malaysia, November 2017.

[12] W. A. Jabbar, W. K. Saad, and M. Ismail, “MEQSA-OLSRv2: a multicriteria-based hybrid multipath protocol for energy-efficient and QoS-aware data routing in MANET-WSN convergence scenarios of IoT,” IEEE Access, vol. 6, pp. 76546–76572, 2018.

[13] W. A. Jabbar, “Mobility-based performance comparison of MBQA-OLSRv2 and MBMA-OLSRv2 routing protocols,” in 2019 23rd International Computer Science and Engineering Conference (ICSEC), pp. 281–286, Phuket, Thailand, October-November 2019.

A. Swidan, H. B. Abdelghany, and R. Saifan, “Mobility and direction aware ad-hoc on demand distance vector routing protocol,” Procedia Computer Science, vol. 94, pp. 49–56, 2016.

[14] T. K. Vu and S. Kwon, “On-demand routing algorithm with mobility prediction in the mobile ad-hoc networks,” Tech. Rep., Sch. Electr. Eng. Univ. Ulsan, 2016.

[15] T. D. Nguyen, J. Y. Khan, and D. T. Ngo, “A distributed energy-harvesting-aware routing algorithm for heterogeneous IoT networks,” IEEE Transactions on Green Communications and Networking, vol. 24, no. 14, pp. 1–10, 2018.

[16] M. Khan, M. F. Majeed, M. F. Majeed, and J. Lloret, “The impact of mobility speed over varying radio propagation models using routing protocol in MANET,” in Advanced Intelligent Systems for Sustainable Development (AI2SD’2019). AI2SD 2019. Lecture Notes in Networks and Systems, vol 92, M. Ezziyyani, Ed., pp. 277–288, Springer, Cham, 2019.

[17] D. Bhatia and D. P. Sharma, “A comparative analysis of proactive , reactive and hybrid routing protocols over open source network simulator in mobile ad hoc network,” International Journal of Applied Engineering Research, vol. 11, no. 6, pp. 3885–3896, 2016.

A. Adlakha and V. Arora, “Performance evaluation of AODV and DSR routing protocols under constrained situation,” International Journal of Advanced Research in Computer and Communication Engineering, vol. 4, no. 7, pp. 189–191, 2015.

[18] U. Rashid, O. Waqar, and A. K. Kiani, “Mobility and energy aware routing algorithm for mobile ad-hoc networks,” in 2017 International Conference on Electrical Engineering (ICEE), pp. 1–5, Lahore, Pakistan, March 2017.

[19] Mani Bushan Dsouza, Manjaiah D.H., “Congestion Free and Bandwidth Aware Mulitpath Protocol for MANET”, First International Conference on Advances in Information Technology, July 2019 [published on IEEE xplore https://doi.org/10.1109/ICAIT47043.2019.8987274]

[20] Mani Bushan Dsouza, Manjaiah D.H., “Congestion Aware Reverse AODV Routing Protocol for MANET”, International Journal of Scientific Research in Network Security and Communication Feb 2020

[21] M. B. Dsouza and M. D.H., "Energy Aware Simple Ant Routing Algorithm for MANET," 2020 5th International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, IEEE Xplore 2020, pp. 381-385, doi: 10.1109/ICCES48766.2020.9137947.

[22] Mostafa, S. A., Mustapha, A., Shamala, P., Obaid, O. I., & Khalaf, B. A. (2020). Social networking mobile apps framework for organizing and facilitating charitable and voluntary activities in Malaysia. Bulletin of Electrical Engineering and Informatics, 9(2), 827-833. doi.org/10.11591/eei.v9i2.2075

[23] Mostafa, S. A., Tang, A. Y., Hassan, M. H., Jubair, M. A., & Khaleefah, S. H. (2018, August). A multi-agent ad hoc on-demand distance vector for

improving the quality of service in MANETs. In 2018 International Symposium on Agent, Multi-Agent Systems and Robotics (ISAMSR) (pp. 1-7). IEEE. doi.org/10.1109/ISAMSR.2018.8540554

[24] Prof. Nikhil Surkar. (2015). Design and Analysis of Optimized Fin-FETs. International Journal of New Practices in Management and Engineering, 4(04), 01 - 06. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/39

[25] Swathi, V. N. V. L. S. ., Kumar, G. S. ., & Vathsala, A. V. . (2023). Cloud Service Selection System Approach based on QoS Model: A Systematic Review. International Journal on Recent and Innovation Trends in Computing and Communication, 11(2), 05–13. https://doi.org/10.17762/ijritcc.v11i2.6104