CC-ADOV: An Effective Multiple Paths Congestion Control AODV

Yefa Mai, Fernando Molina Rodriguez and Dr. Nan Wang
Department of Electrical and Computer Engineering
Calfornia State University, Fresno
Fresno, USA
maiyf1991119, fermolina, nwang @mail.fresnostate.edu

Abstract—MANETs are characterized by wireless mobile nodes in a network that supports the functionality of self-configurable and independently movable nodes. These nodes in turn can be shape as hosts or clients to construct dynamic networks for package delivery from its source to their respective destinations via dynamic routing path. Regarding the network performance, routers perform a critical role of delivering the data to the appropriate destinations. Engineers have been implementing various routing algorithms to improve wireless network performance. Ad hoc On-Demand Distance Vector (AODV) routing is one of the famous routing algorithms. Tremendous amounts of research on this protocol have been done to improve the performance. In this paper, a new control scheme, named congestion control AODV (CC-AODV), is proposed to manage the described routing condition. With this table entry, the package delivery rates are significantly increased while the package drop rate is decreased, however its implementation causes package overhead. This paper uses NS3 (network simulator 3) for simulation.

Keywords—MANET, NS3, AODV, congestion control

I. INTRODUCTION

Mobile Ad hoc Network (MANET) has introduced a promising solution as it provides an efficient wireless communication for the future of mobile nodes communication, thus it dominates the routing research topic since the mid-1990s. MANETs allow the random movement of nodes in every direction at all times, as a result, the information of their interconnective relations requires to be updated accordingly. Researchers' biggest challenge in MANET design is how to ensure each node interconnection with its neighbors and how to successfully deliver packages to its appropriate destinations in a setting of dynamic traffic.

MANETs are generally used in scenarios such as disaster areas, war zones and transportation sites. In most cases, the infrastructure is not fixed while the communication happens. Cars, soldiers, ships, buses, airplanes and model wireless devices, can represent MANETs as shown in Fig 1. At the same time, nodes can be moved out of range at any time, thus, the network needs to be reconfigure. There are several MANET types, including VANETs (vehicular ad hoc networks), SPANs (smart phone ad hoc networks), iMANETs (Internet based mobile ad hoc networks), and military or tactical MANETs [1].

MANET nodes serve as routers to deliver data from their source to their corresponding destination. As a result of the nature of MANET design, the network accomplishes better performance by accommodating the routers tightly together. Nevertheless, for the case of vast spaces it is essential to implement robust algorithms to obtain satisfactory network connection results.

In the TCP/IP architecture, the host-to-host transport layer is being used for the implementation of the routing protocol, which in turn plays a critical role in the design of the algorithm. Researchers have been focusing on the routing algorithm for MANET routing protocol design for the last several years. Ad hoc On-Demand Distance Vector (AODV) routing is one of the most famous MANET reactive routing protocol [2-4]. Thus, researchers have extensively modified this protocol in order to improve its performance.

This paper will compare the AODV and the proposed Congestion Control AODV (CC-AODV) using the NS3 wireless communication simulator. The paper is organized into following sections. Section II discusses two of the existing reactive routing protocols and section III presents the proposed CC-AODV protocol mechanism. The simulation setup will be discussed in section IV and the corresponding simulation results and justification will be presented in section V. Section VI concludes the paper.

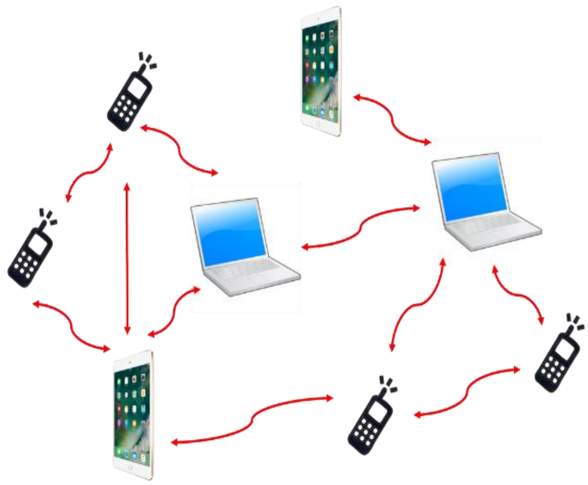

Fig. 1. Example of MANET (mobile ad-hoc network)

II. RELATED WORK

In MANETs, routing protocols are classified into three types: reactive routing protocols, pro-active routing protocols and hybrid routing protocols. This paper will primarily concentrate on reactive routing protocols. These type of routing protocols are on-demand routing protocols which initiate a route discovery process only when the source wants to communicate with the destination. Likewise, when there is no communication, the nodes will not maintain the updated routing information. Inside the network, the source floods the entire network with route request (RREQ) to find a path to the desire destination, such as the Dynamic Source Routing (DSR) and the AODV routing as they will be discussed shortly.

A. Dynamic Source Routing (DSR)

In DSR, the routing information is send by the source node and stored in the route cache of each node. The source node checks the route cache for a valid destination route whenever any data is to be send to a destination node. When the source node realizes that there is no valid route, it starts the route discovery process by broadcasting route request (RREQ) packets. If a node that has a valid route to its destination receives this RREQ packets, a route from its source to its destination will be established [3-6].

B. Ad-hoc On demand Distance Vector Routing (AODV)

In AODV, the route is requested only when the source node wants to send data to the desired destination node. Hence, the source node starts to send RREQ to its neighboring nodes initiating communication as shown in Fig 2.

When an intermediate node received the RREQ packets, the routing table adds the routing information. If the table already has the entry, then the routers compare the sequence number and hop count with the existing information in the table. If the condition passes, the table will update the routing information in the table. The routing table has fixed entries, <destination IP address, destination sequence number, valid destination sequence number flag, network interface, hop count, next hop, list of precursors, live time>. With these entries, the node determines whether it is the destination node or not. Moreover, the node can check whether it received the same RREQ packets with the same ID previously. As a result, if a node receives the same ID packets, then it determines whether it requires an update to the table or not. There are two main conditions that the node checks: if the sequence number is greater than the existing routing table entry and if the hop counter is less than the previous hop count, consequently the table entry will be updated by the RREP that transports the information.

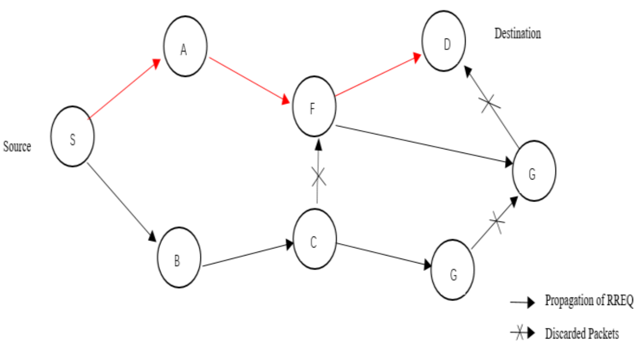

Fig. 2. Propagation of RREQ Packets

Once a destination node receives a RREQ packet, it generates the routing reply packets (RREP). This packet unicasts back to its represented source node and updates the intermediate node routing table. Thus, AODV establishes the routing path.

Once a link has failed or the connection is lost, a router error (RRER) packet is generated and sent to the source node, which in turn requests to establish the new routing path. When the source node receives the RRER packets, it starts the flooding broadcast of RREQ packets to reinitiate the route again, allowing AODV to maintain the routing path. Though sometimes intermediate nodes are too busy to transmit data packages, yet those nodes are used since they are on the shortest path of communication. Nonetheless, when using this approach other nodes that are available are not fully utilized even if they might have low traffic, leading to a lack of bandwidth utilization. As a result, the performance is degraded as the delays in delivering packets increase as well as the number of packets delivered is reduced. To overcome this challenge, the congestion control CC-ADOV is proposed.

III. PROPOSE CC-AODV MECHANISM

The proposed CC-ADOV aims to lower the performance degradation caused by the packets congestion while the data is delivered using AODV. Furthermore, CC-AODV determines a path for the data by using the congestion counter label. This is achieved by checking how stressed the current node is in a table, and once the RREP package is generated and transmitted through the nodes, the congestion counter adds one to the counter. [7-11]

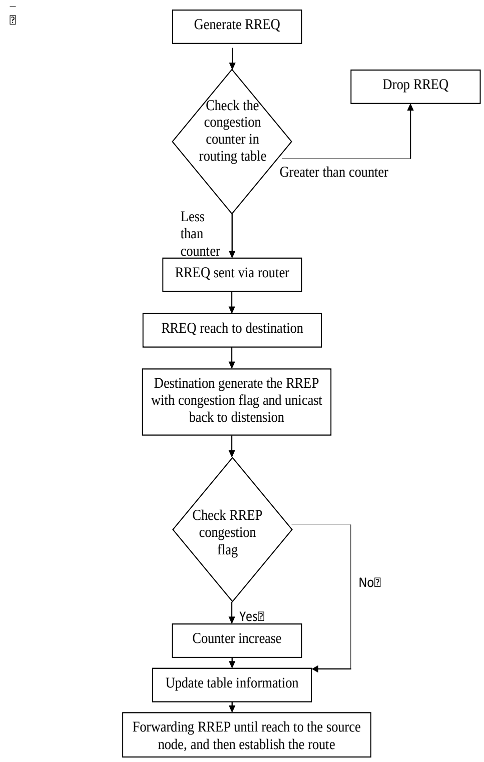

Fig .3. Process of CC-AODV flow chart

The process of CC-AODV flow chart explains how to establish the route in Fig 3. First, the source node performs a flooding broadcast RREQ package in the entire network. When RREQ package arrives to the intermediate node, the router checks the congestion counter whether it is less than a certain predetermined value. If the comparison yields less than the counter, the routing table updates and forwarding to next router; otherwise, the router drops the RREQ package. Once the RREQ arrives to the corresponding destination, the RREP is generated by the router. In CC-AODV, the congestion flag is added to the RREP header. There are two cases of which a RREP is generated corresponding to a RREQ. One is from the source node to establish the route and the other is from the neighbor nodes to maintain the route. When the destination node receives the RREQ from the source node, it generates the RREQ with the congestion flag set to true. While the RREP unicast back to the corresponding source node, passing by the intermediate node, the router checks the congestion flag. If it is true, the counter increases; otherwise, the counter keeps the same. Then, the router updates the routing information.

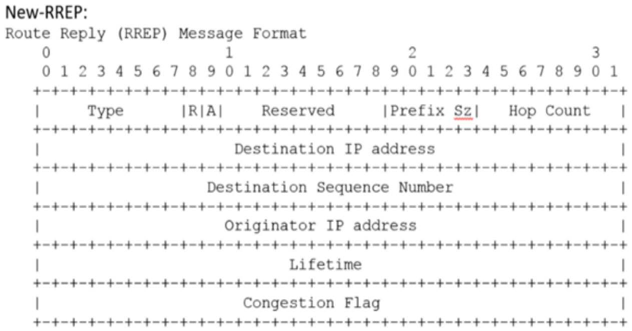

Fig. 4. New-RREP Packets

In order to implement this method using NS3, it is necessary to abide the following rules. A 32-bits congestion control flag needs to be added to the RREP header as shown on Fig 4. In addition, the routing table needs to add the following congestion control entries.

A. Initial congestion counter

Once the table is initialized, the congestion counter is generated and initialized to 0.

B. Increment the congestion counter

Once the node receives the RREP package, the router checks the congestion flag, if the flag is true, then the counter is incremented by 1, otherwise the counter does not change.

C. Decrement of the congestion counter

- There is one entry in the table called life time. When the life time expires, the counter subtracts 1.
- When a node sends the RRER package back to the source node, the intermediate path between the source node and the destination node is broken from this node. Thus, the counter with this node is subtracted by 1.

D. Reset the congestion counter

When the node is removed from the network, the congestion counter resets to 0.

IV. SIMULATION

To verify that the proposed CC-AODV performs better when compared to the existing reactive protocols AODV and DSR, simulations have been carried out using the Network Simulator 3 (NS3) which was made for wireless networks and works on Linux Ubuntu environment.

Table I shows the parameters that have been used to setup the simulation environment.

TABLE I. PARAMETER SETUP FOR SIMULATION

Parameter	Value
Operating System	Ubuntu 14.04
Simulator	NS3(ns-3.26)
Channel Type	Wireless Channel
Number of Nodes	10, 30, 50
Number of Sink Nodes	5, 15, 25
Node Min Movement Speed (m/s)	4
Node Max Movement Speed (m/s)	10
Data Type	UDP
Simulation Time	30
MAC protocol	802.11
Wi-Fi Transmits Frequency	2.4 GHz
Data Packet Size (bytes)	512
Data Packet Size	512
Simulation Area	500*500
Radio Propagation Model	Two Ray Ground
Routing Protocols	C-AODV, AODV
Initial Nodes Power(J)	50
Each Received Consumption Power (J)	0.0174

Simulations have been carried out using a different number of nodes in a network to symbolize different practical applications of wireless network. For example, 10 nodes symbolize a small network that can be used in an agricultural setup. 30 nodes symbolize a medium size network that can be used in an industrial setup and a large 50 nodes network that can be used in an army base.

V. SIMULATION RESULTS AND JUSTIFICATION

CC-AODV has been compared with two other reactive protocols AODV and DSR based on four different performance metrics presented as follows [12-13] :

- Packet Loss: total loss packets during the delivering.
- Packet Delivery Ratio: ratio of the number of packets successfully delivered to the corresponding destination.
- End-to-End Delay: time to deliver a packet from souce to destination.
- Throughput: ratio between amount of received packets and the duration of simulation time.
- Power consumption: the power comsumption due to sink nodes receving packets.

A. Simulaion Result

Table II and Fig 5 show the Packet loss of the values for the routing protocols over 10, 30, and 50 nodes.

TABLE II. PACKET LOSS WITH 10, 30, AND 50 NODES

Number of Nodes	AODV	C-AODV
10 nodes	539	544
30 nodes	1016	938
50 nodes	1291	1238

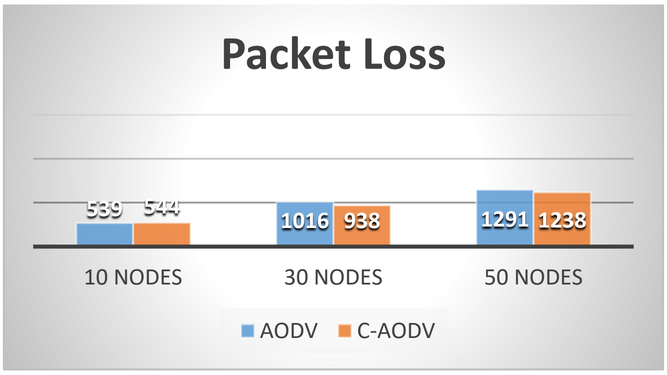

Fig. 3. Total Packet Loss

In this simulation, the time to life (TTL) threshold value is fixed, thus, more densities network will decrease the performance. Table III and Fig 6 show PRD of 10, 30, and 50 nodes.

TABLE III. PACKET DELIVERY RATIO WITH 10, 30, AND 50 NODES

Number of Nodes	AODV	C-AODV
10 nodes	76.80%	76.34%
30 nodes	33.77%	42.98%
50 nodes	7.32%	7.89%

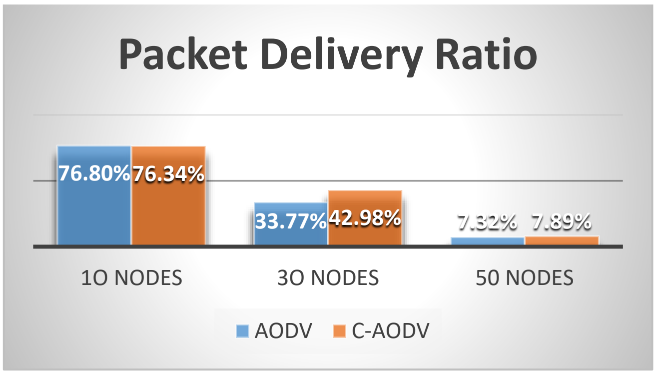

Fig. 4. Packet Delivery Ratio

Table IV and Fig 7 show ETED for 10, 30 and 50 nodes.

TABLE IV. END-TO-END DELAY WITH 10, 30, AND 50 NODES

Number of Nodes	AODV	C-AODV
10 nodes	0.6117	0.6117
30 nodes	4.4471	4.9428
50 nodes	11.1233	13.9471

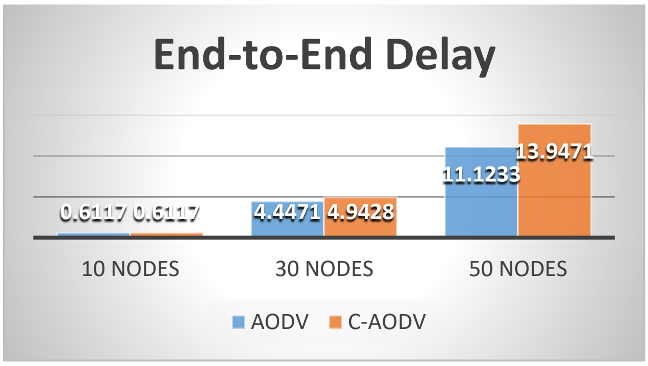

Fig. 5. End-to-End Delay

Table V and Fig 8 show throughput value for 10, 30, and 50 nodes.

TABLE V. THROUGHPUT WITH 10, 30, AND 50 NODES.

Number of Nodes	AODV	C-AODV
10 nodes	36980	45360
30 nodes	43764	46116
50 nodes	43672	49080

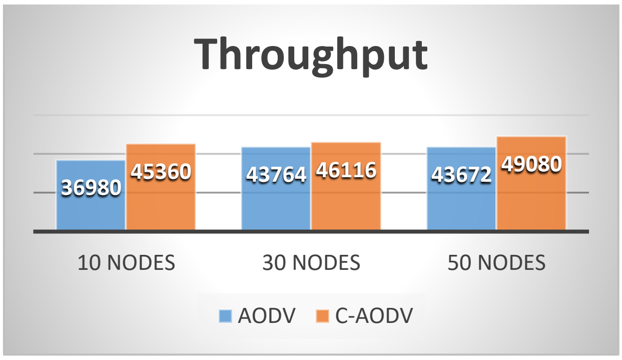

Fig. 6. Throughput

Table VI and Fig. 9 show throughput value for 10, 30, and 50 nodes.

TABLE VI. POWER CONSUMPTION WITH 10, 30, AND 50 NODES

Number of Nodes	AODV	C-AODV
10 nodes	9.17362	9.18601
30 nodes	6.53536	5.97681
50 nodes	6.60854	6.53709

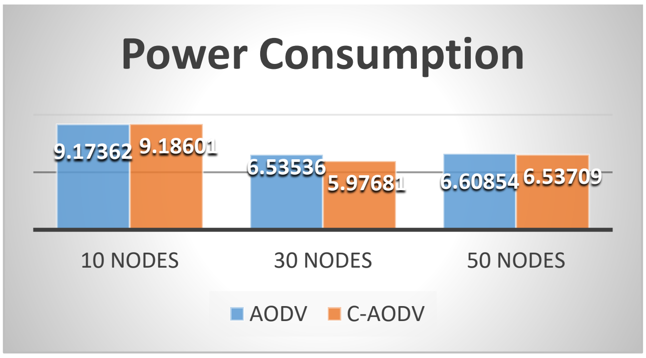

Fig. 7. Power Consumption

B. Result Justification

All five tables and graphs display the comparison between AODV and CC-AODV.

- From Table II and Fig 5, it can be seen that the CC-AODV has less packet loss when the internal nodes increase because routers have more options to route.
- Table III and Fig 6 both portray that the CC-AODV achieves higher packet deliver ratio. In this simulation, the ratio decreased when the nodes increase because TTL affects the performance considerably. When the wireless network densities are increased, the threshold value of TTL decides whether the routing path can be established or not. However, CC-AODV has better performance when the network has more density.
- Both Table IV and Fig 7 demonstrate that CC-AODV has slightly higher End-to-End performance than the AODV, the result is achieved by rerouting the path of the data if the router is on a busy state.
- Table V and Fig 8 depict that the proposed CC-AODV has higher throughput than the AODV. In CC-AODV, the internal nodes can be utilized much efficiently than AODV because the counter helps to reroute the path if the internal node is busy. This can increase the network channel utilization.
- As seen in Table VI and Fig 9, the power consumption is not improved by the CC-AODV. However, in the case of 30 nodes, power consumption of the CC-AODV is significantly smaller than AODV. In 10 and 50 nodes setup, the two almost consume the same power.

VI. CONCLUSION

An improved AODV routing algorithm, named CC-AODV is proposed in this paper. Simulations have been carried out and results are compared between the AODV and the proposed CC-AODV based on five different parameters. From the simulation results, CC-AODV has higher end-to-end delay than the AODV when the network has more nodes. On the other hand, throughput, packet loss and packet deliver ratio of CC-AODV outperforms the AODV. It is shown that the congestion counter can help reduce the network "busy" nodes by enhancing the network throughput. Finally, although the congestion counter in the routing table increases the overhead, it creates better performance as shown on the simulation results. To summarize, the congestion counter implementation in the routing table will be a keystone to achieve multiple routing paths while increasing the wireless performance. The future implementation of CC-AODV will be improved by optimizing the predefined counter threshold module.

REFERENCES

[1] Mobile Ad Hoc Network, WIKIPEDIA, https://en.wikipedia.org/wiki/Mobile_ad_hoc_network

[2] Perkins, C., & Royer, E. (1999). Ad-hoc on-demand distance vector routing. Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA '99. Second IEEE Workshop on, 90-100.

[3] Yefa Mai, Yuxia Bai, Nan Wang. "Performance Comparison and Evaluation of the Routing Protocols for MANETs Using NS3", Journal of Electrical Engineering 5 (2017) 187-195 doi: 10.17265/2328-2223/2017.04.003

[4] Yoshimachi, M., & Manabe, Y. (2016). "A New AODV Route Discovery Protocol to Achieve Fair Routing for Mobile Ad Hoc Networks", 6th International Conference on Information Communication and Management . Retrieved from http://www.ns.kogakuin.ac.jp/~wwa1056/pdf/YoshimachiMANET2.pdf

[5] Udayakumar, P., and Ambhaikar, A. 2009. "Experimenatal Comparison of AODV and DSR Protocols." International J. of Eng. Research & Indu. Appls. 2 (III).

[6] Rahman, M. A., Anwar, F., Naeem, J. and Abedin, M. S. M. 2010. "A Simulation Based Performance Comparison of Routing Protocol on Mobile Ad-hoc Network (Proactive, Reactive and Hybrid)." International Conference on Computer and Communication Engineering, 11-13.

[7] Bhatia, B. (2015). "Performance analysis of AODV based congestion control protocols in MANET". Futuristic Trends on Computational Analysis and Knowledge Management (ABLAZE), 2015 International Conference on, 453-458.

[8] Ramesh, B. (2008). "CA-AODV: Congestion Adaptive AODV Routing Protocol for Streaming Video in Mobile Ad Hoc Networks". *Int'l J. of Communications, Network and System Sciences, 01*(04), 322-328.

[9] Mohammad Meftah Alrayes, Sanjay Kumar Biswash, Neeraj Tyagi, Rajeev Tripathi, Arun Kumar Misra, & Sanjeev Jain. (2013). "An Enhancement of AODV with Multi-Radio in Hybrid Wireless Mesh Network". *ISRN Electronics, 2013*, 1-13.

[10] Phate, N., Saxena, M., & Rizvi, M. (2014). "Minimizing congestion and improved QoS of AODV using clustering in mobile ad hoc network". *Recent Advances and Innovations in Engineering (ICRAIE)*, 2014, 1-5.

[11] Xia, L., Liu, Z., Chang, Y., & Sun, P. (2009). "An Improved AODV Routing Protocol Based on the Congestion Control and Routing Repair Mechanism". Communications and Mobile Computing, 2009. CMC '09. WRI International Conference on, 2, 259-262.

[12] Jorg, D. O. 2003. "Performance Comparison of MANET Routing Protocols in Different Network Sizes." University of Berne, Switzerland.

[13] Harrismare, "Packet Delivery Ratio, Packet Loss, End to End Delay", Retrieved from http://harrismare.net/2011/07/14/packet-delivery-ratiopacket-lost-end-to-end-delay/, last accessed on May 10, 2014.