An enhancement of IEEE 802.11 MAC performance by adaptive adjustment of Contention Window

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***Abstract*— In hidden and exposed wireless scenario collision and poor fairness affect overall IEEE 802.11 MAC performance. This problem has been overcome by binary exponential back-off (BEB) algorithm. Binary exponential backoff algorithm overcomes the collision of packets and achieves better performance only in low traffic load. In this paper we have discussed the limitation of typical backoff algorithm (EBEB [12]) and proposed an adaptive adjustment of contention window method. We have done simulation in ns2.34 in different scenario. Our results indicate significant improvement over EBEB algorithm.**

***Keywords*— backoff algorithm; collision of packets; fairness index; minimum contention window (CWmin); maximum contention window (CWmax); AODV routing protocol**

I. INTRODUCTION

In MANETs, to improve the performance of network special attention is required on IEEE 802.11 medium access control (MAC) protocols [1, 3, 4]. In IEEE 802.11 standard distributed coordination function (DCF) algorithm is an effective functional algorithm that confirms the best MANET compatibility with dynamic topology [2, 5]. By CSMA/CA protocol DCF shares access the wireless medium that follows the basic idea, 'listen before talking'. When a mobile node sense the medium is free then it starts the data transmission otherwise waiting for transmission. For successful reception of packet CSMA/CA protocol uses a positive acknowledgment (ACK) scheme. After a short time interval the receiving node sends the ACK packet to sender node. If case of unsuccessful delivery of ACK packet then sender arranges the retransmission of packets [5-7].

In shared wireless medium collisions of packets resolved by slotted binary exponential backoff (BEB) algorithm in DCF. This backoff algorithm uses the threshold range for contention window (minimum and maximum) to improve the performance of MANET [3]. BEB algorithm works better in low dense region where traffic density is low. As well as, when node density increases in the medium, a node increases the backoff slot number hence the waiting time increase.

In the papers [5-12] authors, has discussed in wireless shared medium number of medium access protocols uses the binary exponential backoff (BEB) algorithm for contention resolution. However, in congested and noisy scenario backoff parameter does not work to avoid collision mechanism. Here such type of scenario increases the collision probability and degrades the channel utilization [10]. In case of low level congestion in the system small backoff window is considered. When level of congestion increases then small backoff value failed to handle the packet loss. In mobile ad hoc network mobile node free to transmit the data packet at any time for this frequent calling of backoff incurs but in this scenario minimum throughput achieved and increases the end to end delay. For practical scenario wireless links are unreliable and noisy so maximum path loss occurs in the channel due to fading and interference causes the bit errors. During the initialization when first transmission attempt occurs, backoff timer takes the minimum contention window (CW_{min}). For every unsuccessful transmission, the contention window (CW) size becomes double until it reaches to maximum backoff window size (CW_{max}). When the CW set to CW_{max} until it is reset, for successful transmission it decreases linearly or multiplicatively or exponentially. An ACK frames are sent by destination when it successfully received [8-13].

Motivation:
Selection of maximum contention window (CW_{max}) and minimum contention window (CW_{min}) degrades the overall performance of network and long time backoff. Proper adjustment of CW_{max} and CW_{min} is required to achieve good results in terms of throughput and minimal packet drop.

Contribution:

1. We are proposing a method for adjustment of CW_{max} and CW_{min} by the help of EBEB [12] algorithm.
2. Simulation is carried out to show the enhancement of EBEB algorithm.

In section II we have described the proposed method. Simulation has been done and discussed in section III. Results and their description are mentioned in section IV. Finally proposed method outcomes concluded in section V.

II. PROPOSED WORK

Dynamic adjustment of contention window in backoff algorithm

In the IEEE 802.11 Wireless Local Area Networks (WLANs), network nodes experiencing collisions on the shared channel need to backoff for a random period of time, that is uniformly selected from the Contention Window (CW). This contention window is dynamically controlled by the Binary Exponential Backoff (BEB) algorithm [2-3, 8]. The BEB scheme, suffers from a fairness problem that shows low throughput under high traffic load. To eliminate this fairness problem an enhanced version of this algorithm that is Enhanced Binary Exponential Backoff Algorithm (EBEB [12]) was introduced. The modifications were made in handling successful transmission using constant counter variables to control Contention Window. The counter variable accounts for several successful attempts. The E-BEB algorithm concept is similar to the IEEE 802.11 BEB algorithm particularly for handling collisions, deferrals and unsuccessful transmission.

Our proposed algorithm is a modification of E-BEB algorithm [12]. We have assumed two separate counters namely C1& C2 are used to encounter both the successful transmission state and unsuccessful transmission state respectively. In case of E-BEB algorithm only the *successful transmission state* was taken into consideration which causes the ambiguity. EBEB algorithm works only for successful transmission but in our proposal we have checked for unsuccessful transmission by applying a condition to check the delivery of data frame. In case of unsuccessful transmission the counter C2 is initialized to counts the no of unsuccessful delivery of data frame. And before adjustment of contention window we have compared the last two values of both counter C1 and C2. In order to get rid of this ambiguity both the cases are taken into account in our proposed method. Figure 1, shows that in flow chart, there are two separate flows for the successful and unsuccessful transmission by the node. The successful transmission is same as that of E-BEB algorithm [12] the difference lies in the case of unsuccessful transmission. Here first the value of unsuccessful counter C2 is compared with the maximum threshold value and then further compared with the value of counter C1. According to the higher value amongst the two the further flow chart is carried out as shown in the figure 1.

TABLE I.

Notations	**Description**
BT_Th	Threshold backoff time
CW	Default Contention window
CW_{min}	Minimum contention window
CW_{max}	Maximum contention window
C_1	Counter for successful attempt
C_2	Counter for unsuccessful attempt
$t_{slot\ time}$	Contention Window slot time
N	Number of slots
C	Number of collisions
W	Wait or backoff states
T	Transmission state

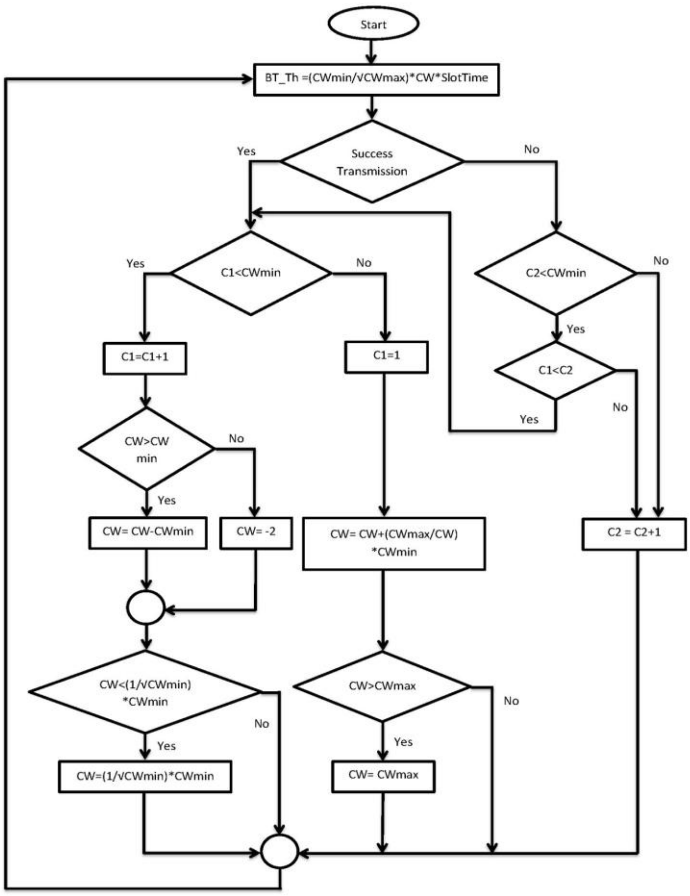

Figure 1 Proposed method flow chart for improvement of EBEB algorithm

III. SIMULATION

We are using network simulator (ns-2.34) [13] for implementation of algorithms in proposed method. IEEE 802.11 WLAN mac.cc, mac.h and timer.cc files are studied for implementation of proposed method. At network layer we have used existing AODV routing protocol for simulation in different scenario [14]. We compared proposed method results with that of existing EBEB method [12].

TABLE II. Simulation parameters

Parameter	**Value**
Simulation time	10s, 600s
Topology size	2000*1000 m^2
Number of mobile nodes	10
MAC type	MAC 802.11
Radio propagation model	Two ray ground
Range	250m
Size of packet	512 Bytes
Transmitter power	0.281W
Receiver threshold	$7.69113*10^{-8}$ W
Traffic type	CBR
CBR rate	1Mbps
Promiscuous mode	Enable
Hello interval	1000msec
Speed	5-10 m/s

IV. RESULTS AND DISCUSSION

Performance metrics

We have considered three performance matrices to analyze the Network performance that is Throughput, Packet Delivery Ratio and Number of Packet Drops. Results are shown in Figure 2, 3, 4, 5, and 7 that shows significant improvement.

- **Throughput**

Throughput of the network is given by the average number of Bytes received per second.
Throughput = Number of Bytes received/ (Stop Time – Start Time)
Here, Simulation Time = (Stop Time – Start Time)

- **Packet Delivery Ratio (PDR)**

Packet delivery ratio(pdr)/packet delivery function(pdf) : the ratio of the number of delivered data packet to the destination. This illustrates the level of delivered data to the destination.
PDF = ∑ Number of packet receive / ∑ Number of packet send
The greater value of packet delivery ratio means the better performance of the protocol.

- **Packet drop (PD)**

Number of packet drop for successful transmission of packets.

SCENARIO 1
Increasing number of active nodes by changing source and destination pairs

TABLE III. Result 1

Hop Length	EBEB method	Proposed method	% Improvement
1	353.61	412.28	16.59
2	201.6	219.33	8.79
3	103.59	116.61	12.56
4	98.95	109.42	10.58
5	48.83	86.2	76.53
6	56.24	72.31	28.57
7	8.85	41.3	36.66
8	31.71	61.98	95.45
9	18	30.04	66.88

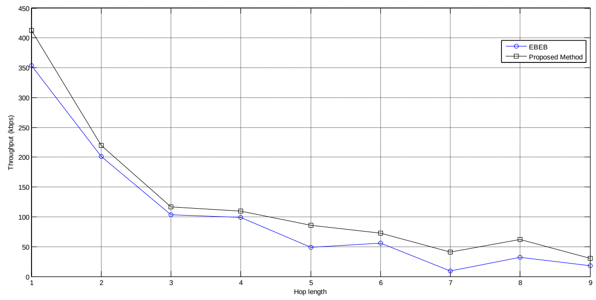

Figure 2, Throughput vs Hop Length

As the hop length increases Throughput decreases because increasing the hop length increases the number of active nodes which have data packets to send that increases the contention on the network increases that causes the decrease of Throughput of network. Proposed method gives better Throughput than EBEB algorithm.

SCENARIO 2
When increasing the network traffic means number of source destination pairs in the network then our performance increases.

TABLE IV. Result 2

Traffic pairs	EBEB	Proposed method	% Improvement
1	41.07	51.88	26.32091551
2	109.91	216.62	97.08852698
3	525.8	545.23	3.695321415
4	1021.88	1032.44	1.033389439
5	1068.55	1135.81	6.294511254

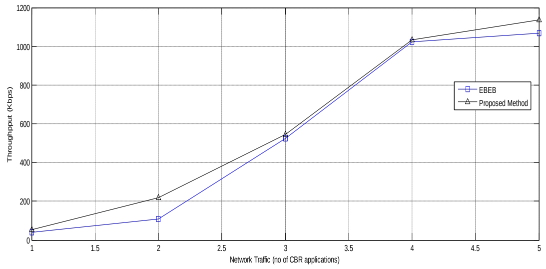

Figure 3, Network traffic vs Throughput

As the number of Active nodes in the network increases Throughput increases because the node generating traffic (number of packets per second) increases causes Throughput of network increases. Proposed method gives better Throughput than EBEB algorithm.

SCENARIO 3

Increasing number of active nodes means changing source and destination pairs on single chain topology.

TABLE V. Result 3

Hop Length	EBEB	Proposed method	% Improvement
1	95.74	98.7	3.09
2	93.44	96.79	3.58
3	91.67	95.18	3.82
4	88.84	92.02	3.57
5	79.22	90.48	14.21
6	82.98	85.47	3.00
7	63.64	82.28	29.28
8	79.31	89.87	13.31
9	71.73	81.16	13.14

As the Hop Length between source and destination increases Packet Delivery Ratio decreases because the distance between source and destination increases which increases the number of Active nodes which have Data Packet to send increases the contention in the network therefore Delivery of Packet get decreases. Proposed method gives better PDR than EBEB algorithm.

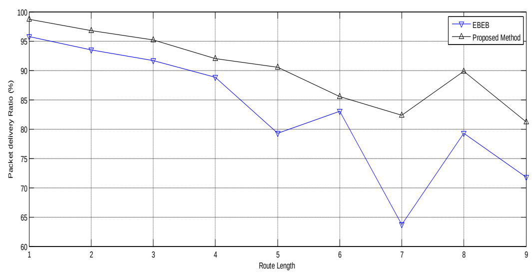

Figure 4, PDR vs Hop length

SCENARIO 4

In hidden node scenario we have observed number of packet drops for 10 second simulation time.

TABLE VI. Result 4

Hop Length	EBEB	Proposed method	% Improvement
1	32	36	12.5
2	26	33	26.92
3	19	21	10.52
4	22	27	22.72
5	20	23	15
6	26	28	7.69
7	14	20	42.85
8	16	18	12.5
9	13	15	15.38

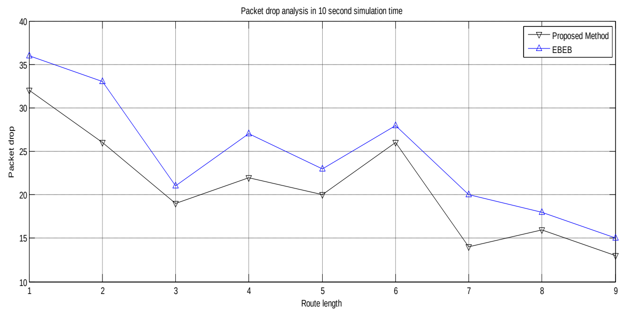

Figure 5, Packet drops vs Route Length

As the route length increases the number of Packet drops decreases as the distance between the source and destination increases therefore there are more number of nodes get involved to deliver a single Data Packet. Proposed method has less number of Packet Drop than EBEB algorithm.

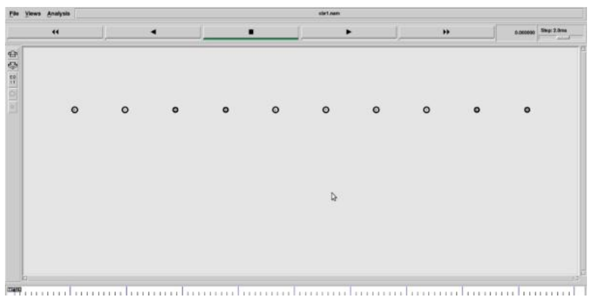

Figure 6, Simulation snapshot of 10 node chain topology

SCENARIO 5

In this scenario we observed the per hop throughput of chain topology for 10 second simulation.

TABLE VII. Result 5

Node ID	EBEB	Proposed method	% Improvement
0	22.59	33.42	47.94
1	19.61	30.43	55.17
2	19.56	30.38	55.31
3	19.52	30.28	55.12
4	19.48	30.18	54.92
5	19.44	30.15	55.09
6	18.2	30.11	65.43
7	18.13	30.07	65.85
8	18	30.04	66.88

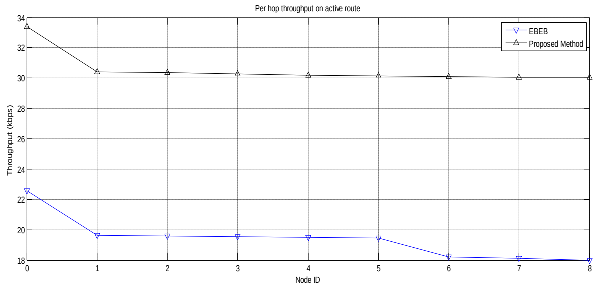

Figure 7, Per-hop throughput vs Node ID (Hop)

Per Hop Throughput increases in case of proposed method about 50% more than EBEB Algorithm.

V. CONCLUSION

In this paper, we proposed a new approach for improving the performance of EBEB algorithm for IEEE 802.11 MAC protocol. The proposed method helps to achieve better results for throughput, packet delivery ratio (PDR), and packet drop and stability in high traffic. The nodes with smaller CW values have a greater chance of accessing the medium among competitors. We adjusted the CW size on the basis of C2 counter which is used to monitor the unsuccessful attempt and before transmission it compared to C1 counter. On the basis of C2 counter value it rapidly decreases the backoff timer (BT) when the channel is free. The advantages offered by the proposed algorithm are shown in different scenarios that satisfy the MAC layer requirements.

References

[1] Bensaou, B., Y. Wang, and C.C. Ko. Fair medium access in 802.11 based wireless ad-hoc networks. in Proceedings of the 1st ACM international symposium on Mobile ad hoc networking & computing. 2000: IEEE Press.

[2] Deng, J., P.K. Varshney, and Z.J. Haas, A new backoff algorithm for the IEEE 802.11 distributed coordination function. 2004.

[3] Rama Krishna, C., S. Chakrabarti, and D. Datta. A Modified Backoff Algorithm for IEEE 802.11 DCF-based MAC protocol in a Mobile Ad hoc Network. in TENCON 2004. 2004 IEEE Region 10 Conference. 2004: IEEE.

[4] Kwak, B.-J., N.-O. Song, and M. Miller, Performance analysis of exponential backoff. Networking, IEEE/ACM Transactions on, 2005. 13(2): p. 343-355.

[5] Xia, Q. and M. Hamdi. Contention window adjustment for IEEE 802.11 WLANs: a control-theoretic approach. in Communications, 2006. ICC'06. IEEE International Conference on. 2006: IEEE.

[6] Bih-Hwang, L. and L. Hui-Cheng, Analysis of adaptive control method in IEEE 802.11 and IEEE 802.11 e wireless LANs. IEICE transactions on communications, 2008. 91(3): p. 862-870.

[7] Guang, L., C.M. Assi, and A. Benslimane, Enhancing IEEE 802.11 random backoff in selfish environments. Vehicular Technology, IEEE Transactions on, 2008. 57(3): p. 1806-1822.

[8] Manaseer, S. and M. Masadeh. Pessimistic backoff for mobile ad hoc networks. in Al-Zaytoonah University, the International Conference on Information Technology (ICIT'09), Jordan. 2009.

[9] Deng, D.-J., H.-C. Chao, and H.-H. Chen. Slow Start Backoff Algorithm for Ad-Hoc Wireless Networks. in Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE. 2010: IEEE.

[10] Laddomada, M., et al., On the throughput performance of multirate IEEE 802.11 networks with variable-loaded stations: analysis, modeling, and a novel proportional fairness criterion. Wireless Communications, IEEE Transactions on, 2010. 9(5): p. 1594-1607.

[11] Zhu, Y.-H., X.-Z. Tian, and J. Zheng. Performance analysis of the binary exponential backoff algorithm for ieee 802.11 based mobile ad hoc networks. in Communications (ICC), 2011 IEEE International Conference on. 2011: IEEE.

[12] Al-Hubaishi, M., et al., Enhanced binary exponential backoff algorithm for fair channel access in the IEEE 802.11 medium access control protocol. International Journal of Communication Systems, 2014. 27(12): p. 4166-4184.

[13] McCanne, Steven, Sally Floyd, Kevin Fall, and Kannan Varadhan. "Network simulator ns-2." (1997): 1059-1068.

[14] Perkins, Charles, Elizabeth Belding-Royer, and Samir Das. "RFC 3561-ad hoc on-demand distance vector (AODV) routing." *Internet RFCs* (2003): 1-38.