ACHIEVING ENHANCED THROUGHPUT IN MOBILE ADHOC NETWORK USING COLLISION AWARE MAC PROTOCOL

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ABSTRACT

Since wireless medium is high demand resource the design of an efficient medium access protocol is important for Mobile Adhoc Networks. As MAC is the base layer in the protocol stack a performance gain in this layer will have significant improvement in the overall performance of the network. Since the current IEEE 802.11 MAC standard is not adaptive to the network scenario its performance is poor in terms of throughput, fairness and delay. Although several alternatives to the existing standard is proposed many of them are not satisfactorily address the key issues of keeping the simplicity of the protocol and avoiding the overhead on the nodes on duty in emergency situations where usually adhoc networks are applied. In this paper we propose an adaptive, collision aware MAC protocol for wireless adhoc networks, termed the Collision Based Contention (CBC) protocol, in which depends on the current collision level on the shared medium contending nodes dynamically decides its Backoff value to avoid a blind random waiting before access to the medium. The CBC scheme outperforms the BEB scheme employed in the IEEE 802.11 MAC standard and other competing proposals.

KEYWORDS

Adhoc Networks, MAC, CBC, MILD, MIMD, AETF, Contention Window, Throughput, Fairness, Delay

1. INTRODUCTION

Mobile Ad hoc Network (MANET) is a kind of self coordinating wireless network of autonomous mobile nodes. In such a network, each node plays the role of a host as well as a router, forwarding packets for other nodes in the network, that may not be within the direct reach of wireless transmission range of each other[5]. The unique features of MANETs grant them a high degree of flexibility and survivability[6]. Therefore Adhoc network is ideally suited for potential crisis management services applications in civil and military environments, such as responses to hurricane, earthquake, tsunami, terrorism and battlefield conditions where the entire communication infrastructure is destroyed and restoring communication quickly is crucial[23]. By using ad-hoc network, communication could be set up very fast and start rescue operation

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immediately. As the large scale disasters very frequently happens in these days it is important to have an efficient and durable disaster emergency communication systems like Mobile Adhoc networks. In these networks, the medium access control (MAC) protocols that are used to share common channel resources among wireless nodes are responsible for coordinating the access from active nodes. Since MAC is running in the base layer in the TCP/IP protocol stack the design of an efficient and high performance underlying MAC protocol is significant for the overall performance of the adhoc network.

Aiming at the model of adhoc networks, IEEE802.11 developed a Wireless LAN(WLAN) channel access protocol—Distributed Coordination Function (DCF)[8][9][11] by making an expansion of the conventional carrier sense mechanism—CSMA/CA [6][7]. To deal with the hidden terminal problem and exposed terminal problem, DCF can be implemented with Request To Send/Clear To Send (RTS/CTS) [12][18] or using the technique mentioned in[13]. As per the Distributed Coordination Function(DCF) scheme, a station first senses the medium to determine whether any transmission is going on or not. If it finds the medium to be idle for more than DIFS, station proceeds with its transmission. However, if the medium is found busy, transmission is deferred till current ongoing transmission terminates. Then station selects random interval called the backoff interval from an allowed range of values and use this value to initialize the backoff timer. In the IEEE 802.11 DCF scheme, the CW is dynamically controlled by the Binary Exponential Backoff (BEB)scheme[16][18][24]. In the BEB algorithm, the contention window is doubled every time a node experiences a packet collision, i.e., when the CTS packet or the ACK reply are not received before a timeout occurs. If a node is successful in its packet transmission, the contention window is reset to the minimum value. In order to avoid the contention window from growing too large or shrinking too small, two bounds on CW are defined: the maximum contention window (CWmax) and the minimum contention window (CWmin).

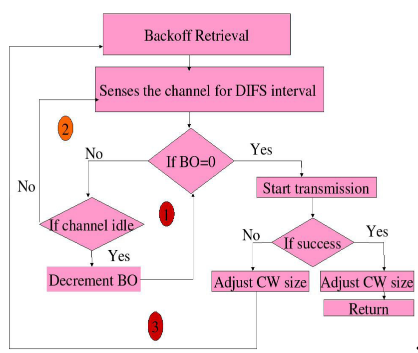

Fig. 1 . Generic Backoff scheme

As the BEB scheme is too greedy to reset to the minimum value of the contention window immediately after a success in transmission so that the node can access the shared medium again very shortly, this scheme cannot prevent collisions in big extend. Besides, the BEB scheme lacks the fairness in sharing the channel among the active nodes. Therefore some nodes can achieve significantly larger throughput than others. The fairness problem occurs due to the fact that the scheme resets the contention window of a successful sender to the minimum value after a single success, while other nodes continue to maintain larger contention windows, thus reducing their chances of seizing the channel and resulting in channel domination by the successful nodes[4][10][21].

Although several alternatives to the existing standard is proposed many of them are not satisfactorily address the key issues of keeping the simplicity of the protocol and avoiding the overhead on the nodes on duty in emergency situations where usually adhoc networks are applied. Besides as mentioned in [16][22] most of the proposals addresses one or two features and neglect others.

The outline of the paper is as follows. Section 2 reviews some related works proposed by other authors . In Section 3 we describe about Collision Based Contention (CBC) protocol to improve the performance of the Adhoc networks. In Section 4 we simulate our proposed scheme and compare its performance with existing IEEE802.11 Binary Exponential Backoff algorithm. Section 5 concludes this paper.

2. A REVIEW ON RELATED WORKS

IEEE802.11 MAC protocol uses a simple method to deal with the contention in the wireless medium. According to this each node doubles its contention window, CW, up to the maximum contention window (CWmax) after a collision occurs and resets its CW to the minimum value (CWmin) after a single successful transmission irrespective of the number of active nodes within the range of that node or number of previous consecutive collision encountered by that node. This can be represented as follows

CW = min(2:CW;CWmax) ; upon a collision
CW = CWmin ; upon a success

Where CWmax and CWmin is the maximum value, minimum value of CW respectively. CWmax and CWmin are defined to avoid the contention window from growing too large and shrinking too small. The values of the CWmin and CWmax are predetermined based on the expected range of the number of active nodes and the traffic load of the network[18]. This scheme is known as Binary Exponential Backoff (BEB). A node which has a low backoff value contends more aggressively for the medium than a node which has a high backoff time, and has a higher probability of accessing the medium. Backoff window size affects the throughput in IEEE 802.11 MAC protocol[4][14][15].The BEB algorithm essentially favours the last transmitter to aggressively contend for the channel again since it has a low backoff the next time around and thus leads to unfairness, particularly when the offered load is high and low throughput when network size is large [10]. Besides this its sharp fall to the minimum CW immediately after a single success causes for the high collision in the channel and hence poor throughput.

To address the fairness problem in the BEB scheme, the Multiplicative Increase and Linear Decrease (MILD) algorithm was introduced in the MACAW scheme. In the MILD scheme, a collided node increases its CW by multiplying it by 1.5. A successful node decreases its CW by one unit, where a unit is defined as the transmission time of the RTS packet. The MACAW protocol assumes that a successful node has a CW value that is related to the contention level of the local area. The current CW is included in each transmitted packet and a contention window copy mechanism is implemented at each overhearing node to copy the CW of the overheard successful transmission into its local CW.

Besides increasing the header size of the RTS packets, the MILD scheme may also suffer from the migration of the CW value into areas with different contention levels that do not match the CW values When the number of active nodes changes sharply from high to low, MILD cannot adjust its CW fast enough because of the linear decrease mechanism. For example, when we set values 16 and 1024 for minimum and maximum value of contention window , it takes a maximum of 1008 successful transmissions for MILD to reach CWmin. As a refined version of MILD later Multiplicative Increase and Multiplicative Decrease (MIMD) scheme is proposed. In MIMD whenever a packet transmitted from a node is involved in a collision, the contention window size for the node is increased by backoff factor 2 and the contention window for the node is decreased by factor 2 if the node transmits a packet successfully. The MIMD is really a special case of Exponential Increase and Exponential Decrease Backoff Algorithm (EIED) in which whenever a packet transmitted from a node is involved in a collision, the contention window size for the node is increased by backoff factor rI and the contention window for the node is decreased by factor rD if the node transmits a packet successfully[1]. Both MIMD and EIED have a main drawback- CW becomes too large after some failures in the packet transmission, because of its exponential increase irrespective of the window size. Similarly it will come down too fast to the minimum level with some successful transmission, because of its exponential decrease. MIMD or EIED is not following the conservative approach of MILD. Therefore throughput loss occurs especially in heavy loaded network as number of collisions is high.

Almanaseer and Ould-khaoua[17] proposed a logarithmic backoff algorithm but they were neglecting the negative effect of the algorithm on transmission delay and number of routing packets as mentioned in [3].

Another remarkable proposal is Adaptive efficiency fairness tradeoffs (AETF) backoff in which with the help of two counters, ns (number of success) and nf (number of failure), and two threshold values ns_Th (threshold for number of consecutive success) and nf_Th (threshold for number of consecutive failure) tries to control the domination of some nodes over the shared channel as well as the starvation of some without getting channel access for a long period of time[11]. Backoff threshold is calculated with the following self regulated expression

$$\sqrt{(CWmax - CWmin)/CWmax} * CW * aSlotTime$$

It is needless to say that this expression and two counters make the algorithm too complex and considerable overhead on the nodes which is quite unsuitable for a system like adhoc network which is applied in mission critical areas and besides that usually MANET devices are battery driven and over head on the device severely affect the battery life. Several other proposal are appeared in recent years

3. COLLISION BASED CONTENTION PROTOCOL

According to our proposed Collision Based Contention Protocol unlike in the case of BEB and other above mentioned schemes contention window of the sender nodes increase or decrease adaptively in a non uniform rates taking in to account the current scenario of the shared medium and collisions encountered by the nodes. Usually contention window size is incremented on a collision on transmission. Similarly, contention window size is decremented on a success(absence of collision). Therefore we have a legitimate conclusion that contention window can be used as the implicit pointer that reflects the frequency of collision encountered by the nodes without having additional counters unlike in the case of AETF. In this scheme we have one set of values say I1, I2, I3 etc (Incrementing factors) and another set of values say D1, D2, D3 etc(Decrementing factors) by which we increment and decrement CW adaptively depends on the number of previous consecutive collisions experienced by the nodes. We divide the collision to the various level say 1, 2, 3 etc. Number of levels may vary depends on the size of the network.

As the size of the network increases number of levels also can be increased. When there is a collision on the first level we considerably increment the CW. If there is again collisions in higher layers we drop the factor for increment. Case is same on a success in transmission. Here when there is a success in transmission on the first level we considerably decrement the CW. But on a success in the higher levels we drop the factor for decrement. This can be summarized as follows.

Upon a failure under collision level i:
CWnew = CWcurrent increment by Ii
CWcurrent = CWnew

(Where i = 1, 2, 3… and I1>I2>I3…)

Upon a Success under collision level i:
CWnew = CWcurrent decrement by Di
CWcurrent = CWnew
(Where i = 1, 2, 3… and D1>D2>D3…)

To understand the legitimacy of our proposed scheme it is important to understand the puzzled relationships between the throughput, collision and backoff time. To increase the throughput we have to reduce idle period. This can be done by reducing the backoff time. But reduction in backoff time causes for the increase in collision because nodes would get a premature access to the shared channel and result in collision with packets from other nodes[20]. This increase in the collision will reduce the throughput!

This relationships keep us in puzzled state, because, to get higher throughput either we have to decrease the CW size (to reduce the backoff time) or we have to minimize the collisions. But if we decrease the CW size to get higher throughput, it will increase the chance for more collisions and in effect less throughput! Similarly if we try to minimize the collisions to get higher throughput by keeping larger CW, it also result in low throughput since idle time increases. Therefore we should try to decrease the CW size without creating much collisions in the network. We effectively achieve this goal in CBC scheme.

Unlike BEB and other proposed schemes, in CBC on a a collision on initial stage (level 1) we increment contention window by a larger factor(I1) because initially window size will be very small. But if there is a again collisions in higher levels, we reduce the scale for increment since already CW has become large because of the increment in previous levels by larger scale. In this way we always get an optimum sized window to mitigate the chances for the future collisions. Similarly when we have a success for transmission on the higher collision levels , instead of shoot down to minimum CW, we slightly reduce the size of the window, because even if we have an occasional success it does not mean that network load is light or number of active nodes is less. So conservative approach is that we reduce the size of window in a small factor. When the window size becomes smaller and smaller (it means number of successful transmission is large) we increment the factor for reduction of CW to avoid unnecessary delay in transmission due to large sized contention window.

In the CBC scheme CW size does not go down to the minimum value after a single success. So successful node and other node will have almost equal chance for seizing the channel. Therefore this algorithm alleviate fairness issue among the nodes. At the same time since it is not decremented linearly it will not have to wait for several successful transmission to reach at the minimum CW as in the MILD. Therefore if we have a sufficient number of success, then we can come to the minimum CW and thereby avoid unwanted delay and channel idle period. In the case of MIMD, CW increment and decrement exponentially irrespective of the current network load. This will result in a too large and too small CW after a minimum number of success and failure in transmission respectively. In this case most of the time CW size will be more than enough or less than enough. In most of the cases this algorithm will not justify the behaviour of actual computer networks. Since CBC scheme infer the collision rate and network load from the current CW and number of consecutive success and failure from the collision levels (which is represented in terms of CW) there is no need of separate counters and complex calculation of backoff threshold unlike in the case of AETF.

3.1 Selection of parameters used in algorithm

Because of the peculiarity of our scheme (high increment on initial collision level) we can initially set a very small value for CWmin. Since adhoc networks is usually applied in the rescue operations and other emergency situations as mentioned in the first section, nodes in adhoc networks are becoming active in large volume simultaneously rather than consecutively. Therefore we have made a reasonable assumption that if there is a collision initially in the network there is a high chance for subsequent collisions due to more number of active nodes. From this assumption we made relatively high value for initial increment and later reduce factor for increment.(even if there is no bulk number of active nodes in the network against the assumption we made, it wont create any problem in our algorithm, because we decrement CW in big scale to compensate initial larger increment). Same logic is applied for decrementing CW when a success in transmission comes. Taking into account the major network parameters like throughput, fairness, delay and collisions and depends on total number of collision levels selection of Ii has been made reasonably. For example for a network with three collision levels selection of incrementing factors have been made in a way that in which increment by I1 is done until one eighth of the CWmax, Increment by I2 is done until one half of the CWmax and increment by I3 is done until CW max. Similarly selection of Di has been made in a way in which decrement by D1 bring down the contention window to CWmin and decrement by D2 bring down to one eighth of the CWmax and decrement by D3 bring down to half of the CWmax .

4. PERFORMANCE EVALUATION AND RESULTS

4.1 Simulation Environment

We have used network simulator ns-2.33 for evaluating the performance of our proposed backoff algorithm. ns-2 is a powerful network simulator. ns-2 is extensively used by the networking research community. It provides substantial support for simulation of TCP, routing, multicast protocols over wired and wireless (local and satellite) networks, etc[25][26]. The simulator suite also includes a graphical visualiser called network animator (nam) to assist the users get more insights about their simulation by visualising packet trace data. We have used AWK, a text processing utility to extract desired information from ns trace file and XGRAPH to plot the graphs. We have used Linux Operating System to run our simulation code. We have considered the different networking scenario with varying number of nodes to evaluate the performance. Each pair of node consists of a transmitter and a receiver. We have taken DIFS = 50µs, SIFS = 10µs and slot time = 20µs. Packet interval is five milliseconds. The performance is evaluated by adding new nodes in the network as time varies or expedited arrival of several nodes simultaneously. Sufficient time is given for running the simulation in order to get chances for every node to participate in the network activity of transmission or reception.

Table 1Simulation Parameters

Parameter	Value
Phy	wireless
Packet size	1500
Queue length	500
SIFS	10µs
DIFS	50µs
ProType	Free Space
Antenna type	Omni directional
CWmin	15 or 31
CWmax	1023
Simulation time	30 s
Number of nodes	50 or 100

4.2 Throughput

We have calculated overall throughput in the network. For this purpose we have counted the received packet at every node at every second. We have performed a comparison of throughput getting from our algorithm with standard binary exponential backoff algorithm(BEB) in the heavily loaded network with 100 nodes and lightly loaded network with merely 50 nodes as shown in the Figure 2 to Figure 5. We have tested performance with two different values for CWmin (ie 15 and 31). From the Figure 2 to Figure 5 it is very clear that our algorithm performs better than the binary exponential backoff algorithm in each case.

To calculate the throughput we have taken the total number of received packets in the network. This information will be available in the agent trace file. Multiplying this number with packet size we get the total number of bits received. To get the overall throughput we divide this value with the time duration upto which we were sending the packet

$$Overall\ \ Throughput = \frac{\sum_{i=1}^{T} N_{pr}}{T} * S$$

where Npr is the total number of packets received in each second, S is the packet size and T is the total time in second upto which we have sent the packets

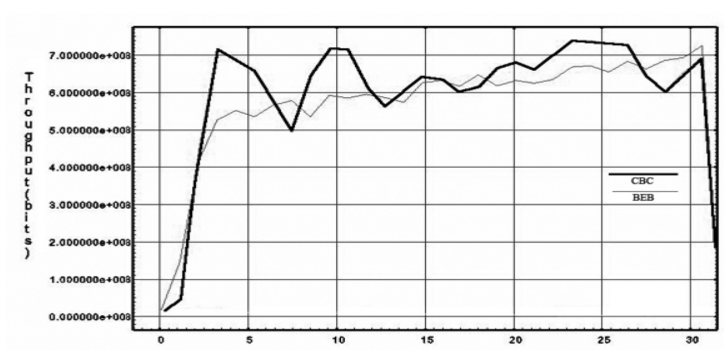

Figure 2 Throughput Comparison of BEB and CBC with 50 nodes and CWmin=15

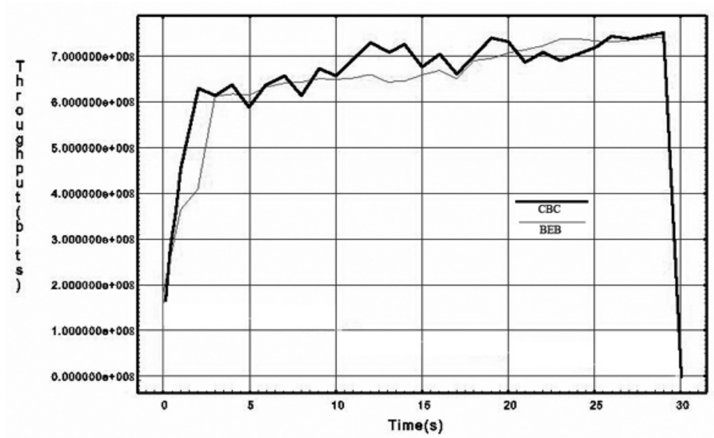

Figure 3 Throughput Comparison of BEB and CBC with 50 nodes and CWmin=31

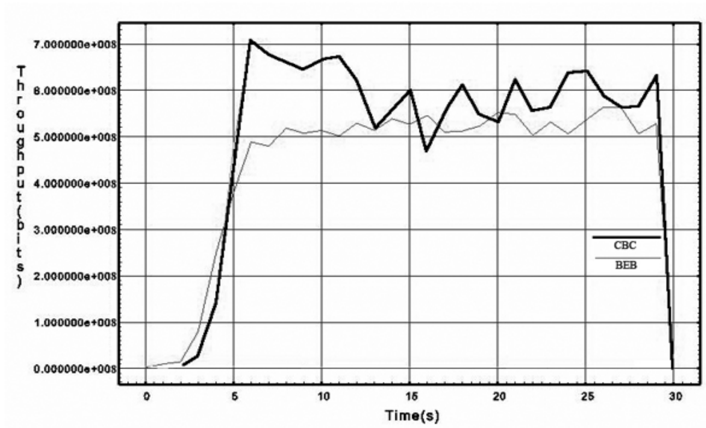

Figure 4 Throughput Comparison of BEB and CBC with 100 nodes and CWmin=15

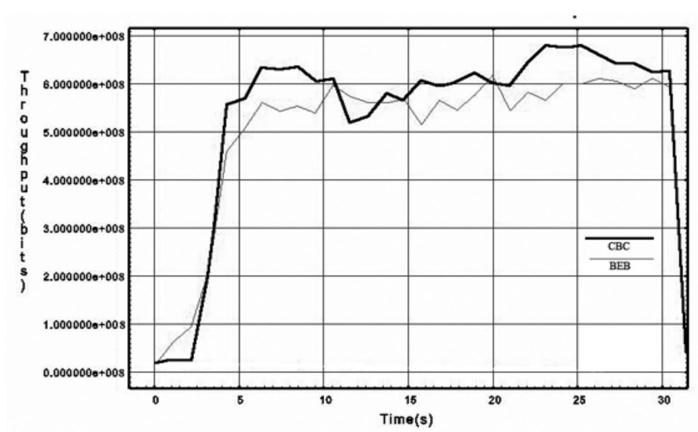

Figure 5 Throughput Comparison of BEB and CBC with 100 nodes and CWmin=31

4.3 Collision

Besides the throughput we have calculated the number of packet collisions in the network. Unlike IEE802.11 BEB scheme we have designed our scheme to reduce the contention window size without a compromise on collision. We have no greed to reset the CW to the minimum value immediately after a success on transmission irrespective of the the node's previous collision history. Instead decision on reducing factor is taken based on the node's previously experienced collisions. If a node is within the high collision domain reduction factor is less and reduction factor is more within a low collision domain. In addition to this, a larger increment on CW on a collision at the initial stage helps to reduce the probability for the subsequent collisions on the same node. Even though the direct benefit of our scheme is the reduction in the collision (hence increase in the throughput) indirectly it provides the better fairness among the contending nodes in the channel. Following graph is the comparison of collision in CBC and BEB scheme.

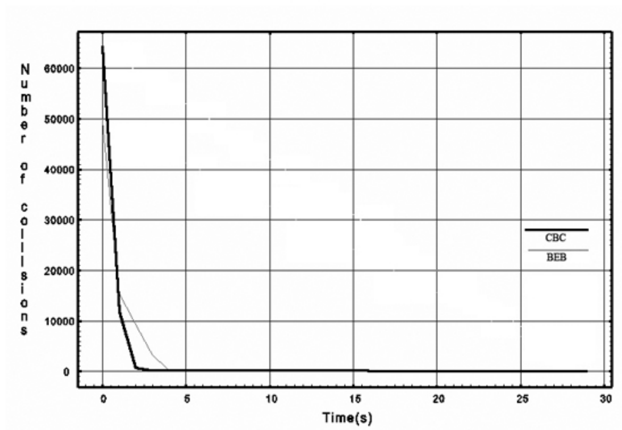

Figure 6 Comparison of Collision in BEB and CBC

4.4 Delay

Besides the throughput and collision we have calculated the delay in the network when we apply CBC and BEB . Figure 7 shows the delay experienced by different packets in a network with CBC and BEB in MAC layer. The graph shows that CBC brings down the packet delay considerably in the network. Unlike in the case of [3] our algorithm performs well in lightly

loaded network as well as heavily loaded network. Taking the average of the delay for every packet transmitted we get the average delay in the network. Average packet delay is defined as the time duration from the time the packet is at the head of the MAC queue ready to be transmitted until the packet delivery is confirmed by an ACK[19]

Delay for one packet = Tps –Tpr , where Tps is the sending time of a packet and Tpr is the receiving time of that packet.

$$Average\ Delay = \frac{\sum_{i=1}^{N} T_{ps} - T_{pr}}{N}$$

where N is the total number of packets

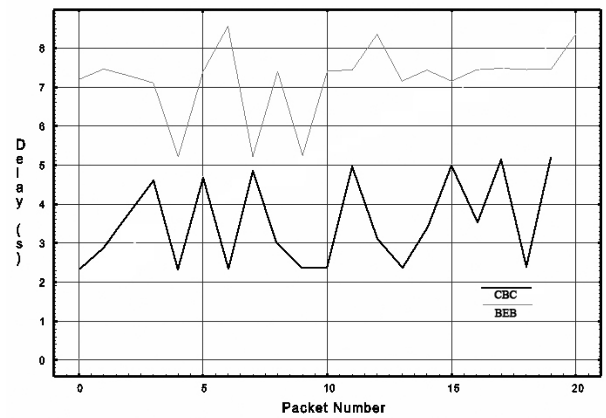

Figure 7 Comparison of Delay in BEB and CBC

5. CONCLUSION

In this paper, we proposed a new MAC scheme for mobile adhoc network called Collision Based Contention Protocol (CBC). We have analyzed the BEB and some other new proposals in this paper. We have pointed out the major drawbacks of the different alternatives to BEB which made them unsuitable for Adhoc network. Performance of CBC scheme is evaluated using the ns-2.33 network simulator. The simulation results show that CBC outperforms the BEB . Our proposed method present an approach, in which depends on the current collision level on the shared medium contending nodes dynamically decides its Backoff value to avoid a blind random waiting before access to the medium. CBC scheme prevent CW from growing too large on collision and from shrinking too small on a success in transmission, hence prevent unnecessary delay for transmission and throughput degradation. Besides, unlike in the case of BEB, here CW size does not become the minimum value after a single success. So successful node and the other nodes will have almost equal chance for seizing the channel. Therefore this algorithm reduces the fairness issue. At the same time it does not have the "more than enough and less than enough" problem of MIMD

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