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COMPARATIVE STUDY OF DIFFERENT BACKOFF ALGORITHMS IN IEEE 802.11 DCF MAC PROTOCOL

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***Abstract*—The IEEE 802.11 Medium access control layer is responsible for a structured channel access scheme. The medium access control (MAC) protocol is the main element that determines the system performance in wireless local area networks. Distributed coordination function (DCF) is the fundamental MAC technique of the IEEE 802.11 based WLAN standard. In IEEE 802.11 WLAN, network nodes experiencing collisions on the shared channel need to backoff for a random period of time, which is uniformly selected from the Contention Window (CW). This contention window is dynamically controlled by the Backoff algorithm. Backoff algorithm has to take an important and crucial decision to correctly predict the precious waiting time for the station before accessing the medium. Hence deigning an effective and efficient Backoff algorithm is required for Wireless Networks. This paper discusses, simulates and analyzes the various Backoff Algorithms and compares the results obtained using NS2 simulator.**

***Index Terms*— DCF, Backoff algorithms, Contention Window, BEB, Modified BEB, DIDD.**

I. INTRODUCTION

In recent years, wireless local area network (WLAN) technology has been widely used due to startling developments of mobile technology. The IEEE 802.11 standard provides both Medium Access Control (MAC) layer and the physical (PHY) layer specification for WLAN. IEEE 802.11 MAC has defined two medium access coordination functions including the contention-based Distributed Coordination Function (DCF) and the contention-free based Point Coordination Function (PCF) [1]. Every IEEE 802.11 station should be supported by the DCF mode. Unlike DCF, the implementation of PCF is optional according to the standard. In this paper, we limit our investigation to the DCF and corresponding enhanced schemes.

Coordination and scheduling of transmissions among competing stations are taken care by MAC layer that has to ensure the maximum channel utilization and fairness among the users with minimum of interference [2]. There are three basic access methods that have been defined for IEEE 802.11 WLAN: the mandatory basic method (2-way handshake DATA ACK), the optional four way handshake (RTS-CTS- DATA-ACK) method and finally a contention free polling method. For all these access methods, it is required to have some mechanisms that control waiting time of stations before accessing the medium.

Backoff (BO) is a scheme commonly used to assign appropriate waiting time in order to resolve the contention problems among different stations willing to transmit at the same time. The BO algorithm must be executed in three cases:

(i) Whenever the station senses the busy medium before the first transmission of a packet (ii) After each retransmission and (iii) after a successful transmission. When a station goes into a BO state, it waits an additional random number of time slots. The random number must be greater than 0 and smaller than maximum Contention Window (CW), i.e. [0, CWmax]. During this period, the station is continuously sensing the medium to check whether it remains free or another transmission begins.

Every IEEE 802.11 station should implement DCF mode, which is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. Before transmitting packets, the wireless node must detect the state of the wireless channel first. When the wireless channel is in the idle state, the wireless node will start the transmission. On the contrary, when the wireless channel is in a busy state, the wireless node will select a waiting time at random from the contention window, and then continue detecting the state of the wireless channel. When the state of the wireless channel is sensed idle, then the node will carry on the waiting time and decrease progressively. When decreasing progressively to zero, the wireless node can start the transmission. When two or more wireless nodes decrease to zero at the same time, the transmission packets of wireless nodes will collide.

Accordingly, in order to reduce the collision rate, IEEE 802.11 adopts the BEB (Binary Exponential Backoff) algorithm. In the BEB algorithm, the wireless node selects a backoff time to count backwards at random from the competition window. When the time of counting backwards is zero, the wireless node will start the transmission. If the transmission is successful, the contention window will be set to a minimum value (CWmin). If collision happens, the contention window will be doubled. The shortcoming of the BEB algorithm is that the collision rate will increase because of the rapidly reset to minimum value of the contention window. In recent years, plenty of proposals have been carried out with the aim of increasing stability, network performance and other aspects.

This paper analyzes the behavior of various BO algorithms, simulates them using NS2 and compares the performance. The rest of the paper is organized as follows.

Section II gives literature survey about comparative study of BEB, Modified BEB, DIDD Backoff algorithms. Performance Evaluation Parameters are described in Section III. Section IV gives simulation methodology. Finally the section IV and V gives simulation results and concludes the paper.

II. LITERATURE SURVEY

Backoff is a mechanism used to avoid collisions in mobile ad hoc networks when more than one node tries to access the channel. Collision is avoided in which only one of the nodes is granted access to the channel, while other contending nodes are suspended into a backoff state for some period (BO), before trying to access the channel after a transmission failure [3]. This concept is used in Backoff Algorithms.

A. Binary Exponential Backoff (BEB)

In the IEEE 802.11 standard MAC protocol, the Binary Exponential Backoff (BEB) is used. IEEE 802.11 DCF uses CSMA/CA as the access method [4]. In the mechanism of DCF, the carrier sense activity persists in listening to the channel before transmitting: If the channel is found to be idle for a time interval greater than the Distributed Inter-Frame Space (DIFS) period, the station transmits directly; otherwise the station alters its transmission time until the ongoing transmission terminates. When the channel becomes idle again for a DIFS [5], the station enters the collision avoidance phase by selecting a random interval of time slots called backoff interval that is used to initialize a backoff timer. If detected the wireless channel to be busy, the node is frozen and backoff counter is paused. When the wireless channel is transferred to an idle condition and passed the DIFS time, the node continues the unfinished backoff countdown. Until counting backward to zero, the node may access the channel and begin to transmit packets.

If the channel is found to be idle and not being used by any other node, the node is granted access to start transmitting. Otherwise, the node waits for an inter-frame space and the backoff mechanism is invoked. A random backoff time will be chosen in the range [0, CW-1]. A uniform random distribution is used here, where CW is the current contention window size.

If the medium is determined to be busy during backoff, then the backoff timer is suspended. This means that backoff period is counted in term of idle time slots. Whenever the medium is determined to be idle for longer than an inter-frame space, backoff is resumed. When backoff is finished with a BO value of zero, a transfer should take place. If the node succeeded to send a packet and receive an acknowledgment for it, then the CW for this node is reset to the minimum, which is equal to 31 in the case of BEB. If the transfer fails, the node goes into another backoff period. When going for another backoff period again, the contention window size is exponentially increased with a maximum of 1023.

BEB has a number of disadvantages. One major disadvantage the BEB scheme suffers from a fairness problem; 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 CWmin, 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.

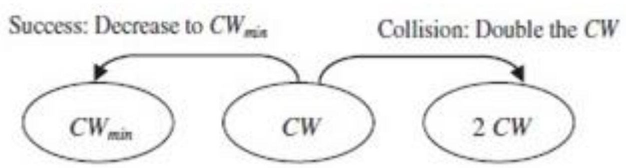

Fig.1.Binary Exponential Backoff Scheme

•In case of Collision
CW (new) = 2*CW (1)

•In case of Successful Transmission
CW = CWmin (2)

B. Modified BEB

As indicated earlier, BEB algorithm stated in (1) and (2) might introduce long transmission delays without any significant benefit in respect of contention resolution due to node mobility [6]. In fact, contending mobiles are likely to move to a different location during a large waiting time for retransmission after a packet collision and might get involved into another independent collision process elsewhere. Thus, the large growth rate in waiting time might not be appropriate in a mobile scenario as in a MANET.

In particular, the backoff time is increased exponentially, but with a reduced base value (less than 2) after each unsuccessful transmission until a prescribed maximum value (CWmax) is reached. Whenever a node transmits a packet successfully, its backoff time is reduced to a specified minimum value (CWmin). The base value equal to 1.8 offers better performance as compared to other possible base values. The modified backoff algorithm can therefore be expressed as,

- In case of Collision
  CW = min [1.8*CW, CWmax] (3)

- In case of Successful Transmission
  CW = CWmin (4)

C. Double Increment Double Decrement (DIDD)

The DIDD Backoff algorithm utilizes a 'smooth' decrease of the CW after a successful packet transmission. More specifically, if a packet collides, DIDD operates exactly as BEB and doubles the CW in order to reduce the probability of a packet collision [7]. However, in the case of a successful packet transmission, DIDD halves the CW (BEB reduces it to CWmin) to avoid potential packet collisions. Another characteristic of the DIDD scheme is that packets that reach their maximum number of retransmission attempts are not discarded as under BEB

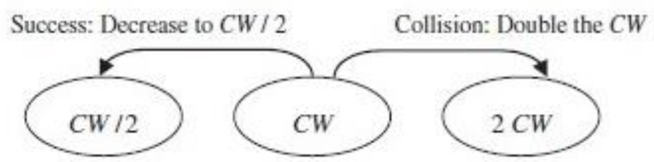

Fig.2. DIDD Scheme

The DIDD backoff algorithm can therefore be expressed as,

•In case of Collision

CW (new) = 2 * CW (5)

•In case of Successful Transmission

CW = CW / 2 (6)

III. PERFORMANCE EVALUATION PARAMETERS

To analyze behavior of the network following parameters have been evaluated,

Throughput: Throughput is measure of number of packets successfully delivered in a network [8]. It is measured in terms of packets/second. Equation (7) shows how to calculate the throughput.

Th = ———————————— (7)

End to End Delay: Delay or latency could be defined as the time taken by the packets to reach from source to destination. The main sources of delay can be categorized into: propagation delay, source processing delay, network delay and destination processing delay. Here we have calculated end to end delay which is a measure of elapsed time taken during modulation of the signal and the time taken by the packets to reach from source to destination. End to end delay could be measured as the difference of Packet arrival and packet start time. Equation (8) shows the calculation of average end to end delay

Delay = (8)

Packet Delivery Ratio (PDR): Packet delivery ratio signifies the total number of packets successfully delivered to the destination. Equation (9) shows how to calculate PDR (Packet Delivery Ratio)

PDR = ———————— (9)

IV. SIMULATION METHODOLOGY

For the purpose of implementation and simulation an open source discrete event Network Simulator NS2 is used. NS2 is an open-source event-driven simulator designed specifically for research in wireless networks. To investigate network performance, researchers can simply use an easy-to use scripting language to configure a network and observe results generated by NS2 [9], [10]. Undoubtedly, NS2 has become the most widely used open source network simulator.

Table I and II gives the brief details of the simulation specifications used in this paper].

TABLE I
SIMULATION PARAMETERS USED IN THE NETWORK

Parameters	**Value**
Simulator	NS2
Type of channel	Wireless channel
Propagation Model	Two Ray Ground
MAC Protocol	802.11
Interface Queue type	Drop tail Queue
Antenna type	Omni directional
Traffic source	TCP
Routing protocol	AODV
Max. Simulation time	150 sec
Number of Nodes	10, 20, 50, 100, 150

TABLE II
THE MAIN PARAMETERS

Parameters	**Value**
CWMin	31
CWMax	1023
Slot Time	20 µs
SIFS	10 µs
Data Rate	1 Mb

V.SIMULATION RESULTS

Table III and IV gives the simulation results for variation in Throughput and End to End Delay with varying number of nodes and Table V and VI gives the simulation results for variation in PDR and Energy Consumption with varying number of nodes for BEB, Modified BEB and DIDD

A. Throughput varying with number of nodes

TABLE III
SIMULATION RESULT

Throughput in Kbps with varying Number of Nodes					
Number of Nodes	**10**	**20**	**50**	**100**	**150**
BEB	296.18	271.39	227.73	227.31	240.90
Modified BEB	534.26	561.21	680.26	433.59	339.09
DIDD	680.80	629.81	680.27	537.05	680.60

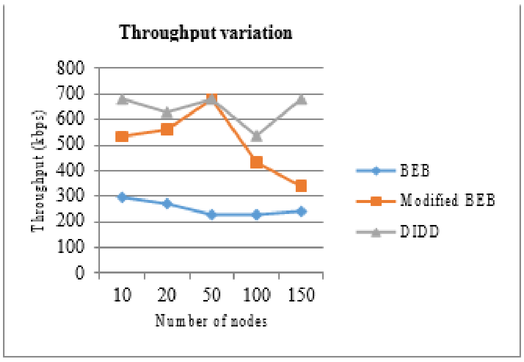

Fig.3. Graphical Analysis of Throughput variation for BEB, Modified BEB, DIDD Backoff algorithms

B. End to End Delay

TABLE IV
SIMULATION RESULT

End to End Delay in ms with varying Number of Nodes					
Number of Nodes	**10**	**20**	**50**	**100**	**150**
BEB	144.511	122.112	185.449	184.46	47.900
Modified BEB	94.834	84.426	66.084	68.147	121.69
DIDD	62.649	76.796	62.242	92.019	55.734

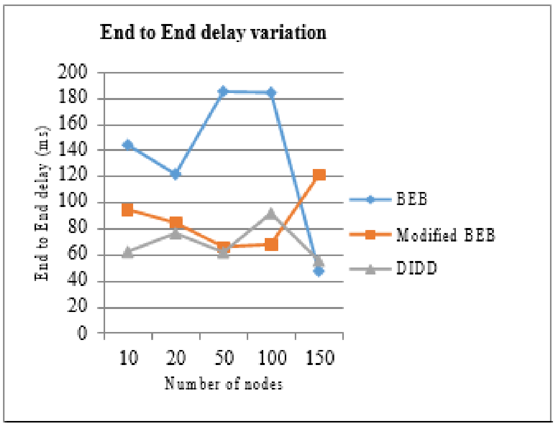

Fig.4. Graphical Analysis of End to End Delay variation for BEB, Modified BEB, DIDD Backoff algorithms

C. Packet delivery Ratio (PDR)

TABLE V
SIMULATION RESULT

PDR in % with varying Number of Nodes					
Number of Nodes	**10**	**20**	**50**	**100**	**150**
BEB	99.589	99.449	99.743	99.719	99.443
Modified BEB	99.819	99.678	99.914	99.589	99.667
DIDD	99.914	99.842	99.914	99.795	99.914

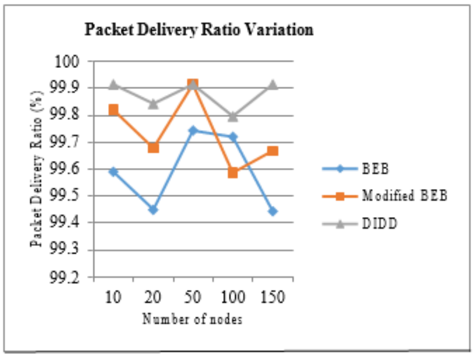

Fig.5. Graphical Analysis of PDR variation for BEB, Modified BEB, DIDD Backoff algorithms.

D. Total Energy Consumption

TABLE VI
SIMULATION RESULT

Total Energy Consumption in J with varying Number of Nodes					
Number of Nodes	**10**	**20**	**50**	**100**	**150**
BEB	163	145	160	08	39
Modified BEB	171	171	171	154	56
DIDD	171	171	171	171	171

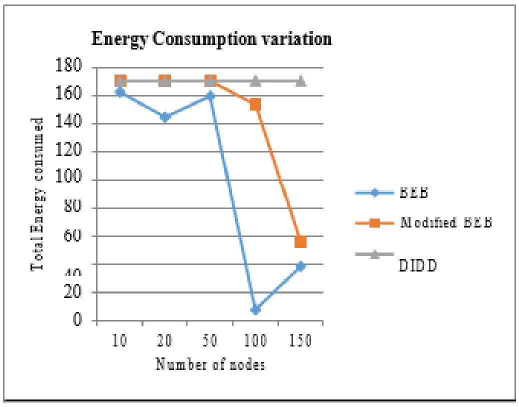

Fig.6. Graphical Analysis of Total Energy variation for BEB, Modified BEB, DIDD Backoff algorithms

CONCLUSION

In this paper, Standard algorithm of IEEE 802.11 DCF that is Binary Exponential Backoff algorithm, Modified BEB and DIDD Backoff algorithm were compared and the impact of BO Algorithms on the IEEE802.11 WLAN were analyzed. Simulations with NS2 show that Throughput, End-to-end delay, Energy Consumption and PDR changes based on the BO algorithms. When BO algorithm chooses larger CW size to reduce the collision probability, delay is increased which is not suitable for delay sensitive networks. On the other hand, when BO algorithm selects smaller CW, the collision probability is increased thereby reducing the throughput. Hence there will be always tradeoffs between CW size and the performance. Hence designing a BO algorithm to enhance the network performance remains a very crucial research area in the future.

As compared to BEB and Modified BEB backoff algorithm, improved Throughput and PDR are obtained when DIDD algorithm is used. Also, the End to end Delay is reduced using DIDD backoff algorithm.

TABLE VII
PERFORMANCE COMPARISON OF BACKOFF ALGORITHMS

Performance Analysis of BEB, Modified BEB, DIDD			
Parameters	**Backoff Algorithms**		
Ranking Based on Performances	**1**	**2**	**3**
Throughput(Kbps)	DIDD	Modified BEB	BEB
PDR	DIDD	Modified BEB	BEB
End-to-End Delay (ms)	DIDD	Modified BEB	BEB
Energy Consumption(J)	BEB	Modified BEB	DIDD

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