Collision Elimination for Random Behavior Nodes in Ad Hoc Wireless Network Using Early Backoff Announcement (EBA)

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Abstract. Due to the detrimental repercussions of hidden terminals, collision avoidance is essential in contention-based media access control systems for multi-hop adhoc networks. Currently, the most common collision-avoidance strategies are four-way sender-initiated schemes. Although many research has been done to assess the performance of these schemes, the most of it has focused on single-hop ad hoc networks or networks with a limited proportion of hidden terminals. This research presents an enhancement to the existing IEEE 802.11 Distributed Coordination Function (DCF) MAC that reduces collisions, medium idle time, and overall network speed. The modification utilizes the existing Early backoff announcement (EBA) mechanism. The frame header in EBA is used by a station to indicate its upcoming backoff time; the backoff value is determined at random. This reduces collisions but no care has been taken to improve the throughput directly. In this paper, an algorithm for selecting the post backoff value based on certain criteria is proposed. The post backoff selection is selected through a round robin scheduling between the number of stations currently being transmitting. This reduces unnecessary wait time for stations that want to transmit back-to-back.

Keywords: Ad hoc networks · Distributed coordination function · Point coordination function · Collision avoidance · Early backoff announcement

1 Introduction

The IEEE 802.11 standard is a commonly used wireless local area network technology. The IEEE 802.11 MAC standard distinguishes between two strategies: the contention-based Distributed Coordination Function (DCF) and the optional polling-based Point Coordination Function (PCF) [1]. DCF is the most extensively utilized MAC approach in IEEE 802.11-compliant products at the time. IEEE 802.11 uses the Carrier Sense Multiple Access (CSMA) approach and other contention-based MAC algorithms. If the medium is considered idle, a station may transmit in CSMA. The goal is to keep any station from broadcasting and interfering with an already broadcast transmission [15].

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The collision prevention mechanism executes random backoff before every frame transmission attempt. Because two or more stations can complete their backoff procedures around the same time, random backoff can reduce the likelihood of collisions, but it cannot completely eliminate them. The primary access strategy of EBA is that the next backoff period bnext is computed and notified to all stations sooner, without negatively impacting any other MAC procedure [16]. The backoff value is determined at random. The MAC frame header is piggybacked with future backoff information. All nearby stations receive the frame containing the EBA data, including the endpoint, depending on the nature of radio transmissions. The DCF requires a station to accept it is in the sleeping state, it should decode all incoming frames and at least the MAC header section. When a station gets an EBA frame, it is notified with the current transmitting station's next frame transmission time, which is saved in the station's Reservation Windows.

In this paper, a priority scheme that enhances the existing EBA mechanism that improves throughput is proposed. The back off value can be selected immediately after the current transmitting slot if other stations do not reserve the slot. If the slot is reserved then the next available slot can be selected. In addition to the above, a set of slots in the reservation window can be reserved. This is to avoid other stations utilizing the same set of slots. This scheme reduces unnecessary wait time for stations that want to transmit back-to-back.

2 Related Work

For IEEE 802.11, the current DCF protocol has been renamed Location Enhanced DCF (LED) by the authors of paper [2]. Other stations sharing the communication channel can better identify interference and analyse blockage using the proposed approach, which incorporates position information in IEEE 802.11 DCF frame exchange sequences. To improve performance, Location Enhanced DCF provides additional communication characteristics, particularly the locations of transmitters and receivers, than the basic 802.11 DCF frames compatible with DCF. Wu et al. introduced a DCF+ scheme in article [3], which is a reliable WLAN transfer protocol. The authors also suggested a Markov chain-based analytical model for calculating the throughput performance of IEEE 802.11 DCF and DCF+.

Using the assumption that there are a finite number of terminals and ideal channel conditions, Giuseppe Bianchi [4] constructed a simple but very reliable mathematical model for predicting 802.11 DCF throughputs. This study focuses on DCF's packet transmission systems' basic and RTS/CTS access techniques. The authors of the paper [5] suggested the design of OSU-MAC, a MAC protocol based on the physical layer features and restrictions of a narrow-band wireless modem test bed currently under development at Ohio State University. Black-burst (BB) contention, a distributed MAC technique that provides QoS real-time access to ad hoc CSMA wireless networks, has been defined and researched by Joao L. Sobrinho et al. [6]. Real-time nodes compete for channel access via energy pulses known as BBs, whose duration are a function of the node's latency until the channel becomes idle in this technique. In carrier sense ad hoc wireless networks, BB contention is a distributed MAC technique for QoS real-time traffic support.

The Fast Collision Resolution (FCR) algorithm, introduced by Younggoo Kwon et al. [7], is an innovative and efficient contention-based MAC protocol for wireless local area networks. This algorithm is built on the following ground-breaking concepts: to reduce the time it takes to resolve collisions, actively redistribute the backoff timers for all active nodes and to reduce the average number of idle slots fixed number of consecutive idle slots are discovered, reduce the backoff timers exponentially quickly. Tamer Nadeem and Ashok Agrawala [8] suggested an upgraded BEB technique that improves IEEE 802.11 by allowing it to distinguish between different sorts of failed transmissions. Chong gang Wang and Weiwen Tang [9] have proposed a 802.11 DCF, a probability-based technique is used to update the contention window. It's based on the fact that following every successful transfer, 802.11 DCF reduces the contention window to its original value, implying that each successful transmission indicates that the system is under low traffic load.

The Exponential Increase Exponential Decrease (EIED) backoff method proposed by Nai-Oak Song et al. [10] is an easy to build backoff algorithm that improves network performance is significantly better than BEB's. For performance comparison, another hackoff approach called Multiple Increase Linear Decrease (MILD) backoff algorithm is investigated. Shaohu Yan et al. [11] presented a new backoff technique for IEEE 802.11 DCF termed the priority backoff algorithm (PBA). The primary idea behind PBA is that while sensing the channel, each station should collect statistical data from the transmissions of other stations and keep a Sent Data Table for the entire network.

In paper [17], the researchers have conducted various studies in order the enhance the performance of IEEE 802.11 MAC layer in MANET. The authors proposed a novel technique to handle throughput issues, packet delivery rate in adhoc environment. The performance comparison was done with several algorithms such as BEB of the IEEE 802.11 DCF and opposite Exponential Backoff (OBEB). The paper offers a novel technique for detecting Denial of Service (DoS) attacks on wireless networks with hidden nodes, which frequently employ the widely used IEEE 802.11 Distributed Coordination Function (DCF) protocols [18]. [19] described how the transmission scheduling approach is used by the node scheduling algorithm. The authors provide a few OBSP strategies for determining the node's status and various levels. To offer resilient streaming in the event of link failures, many pathways are discovered using an efficient genetic algorithm. The server employs dynamic encoding techniques to react to changing network conditions depending on network feedback Handoffs are also predicted ahead of time, and mobile agents containing buffered data are delivered to the anticipated base station [20].

3 Proposed Methodology

In this paper, a priority scheme that enhances the existing EBA mechanism that improves throughput is proposed. The backoff value can be selected immediately after the current transmitting slot if other stations do not reserve the slot. If the slot is reserved, then the next available slot can be selected.

In addition to the above, round robin scheduling could be implemented between the stations currently transmitting. For example, if there is a single station transmitting, then it can reserve the next slot. If there are two stations currently transmitting, then it can reserve the slot after a gap of one slot. It can be expressed, as the selection of the next slot on the reservation window could be the nth slot, where n is the number of stations currently doing the transmission. The number of station currently transmitting could be identified based on the node id. If there is a new node entering into the transmission, then the counter value shall be increased. If the node has completed the transmission then the counter shall be decreased. To fulfill this requirement, each node announces the end of transmission to other stations. This could be added along with the other EBA information. This scheme reduces unnecessary wait time for stations that want to transmit back-to-back. The system architecture of EBA architecture is shown in Fig. 1.

3.1 EBA System Architecture

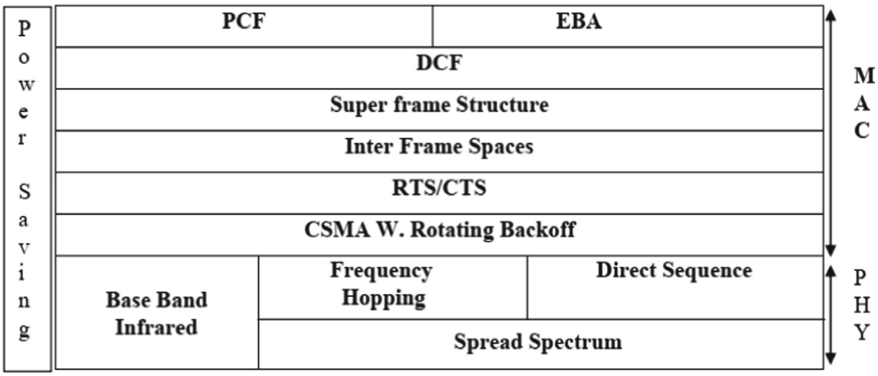

Fig. 1. System architecture of EBA

The Early Backoff Announcement (EBA) is an improvement to the existing 802.11 DCF protocol. The improvement is mostly done at the MAC level. EBA station chooses its next backoff period before broadcasting the frame, not after getting the ACK. This future backoff information, known as the EBA information, is then piggybacked into the MAC frame header. Because radio communications are transmitted, the frame holding the EBA data is broadcasted to all surrounding stations, including the target. Unless a station is in the resting state, DCF requires it to collect all arriving frames and decode at least the MAC header part. When a station receives an EBA frame, it is notified of when the presently broadcasting station will broadcast the next frame and this information is recorded in their Reservation Windows.

3.2 Reservation Window

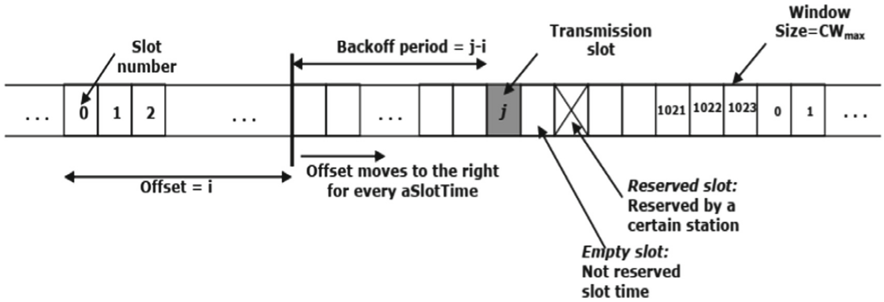

Fig. 2. Reservation window

Figure 2 explains the reservation window scheme. The Reservation window is being used to keep track of the other stations' and its own channel reservations. This window has 1024 slots with numbers ranging from 0 to 1023. The number 1023 represents the maximum size of a contention window. During a backoff procedure, the offset indicates the current slot, which shifts to the right for every aSlotTime. The offset wraps around when it reaches 1023, making the following offset zero.

The Reservation Window keeps three variables per slot: R_{empty}, $R_{reserved}$ and R_{tx}.

R_{empty} represents the initial state in which there is no reservation information on the slot.
$R_{reserved}$ signifies a slot that has been reserved by another station.
R_{tx} signifies the broadcast slot established by the station's own backoff period.
R_{tx}- slot's number = (offset + backoff) mod CWmax.

The receiving station reads the reservation information from the MAC header and marks the slot as $R_{reserved}$ when it receives a frame. If the offset matches the slot with the value R_{tx}, transmission will begin. The channel reservation information is shared by each station with the other stations. This action allows a station to reserve a transmission time as well as notify other stations of its plan to send a frame at the given time, ensuring that other stations do not begin broadcasting a frame at the same time. The system flow for transmitting packet is shown in Fig. 3.

In order to implement the EBA Algorithm, the following notations are employed, where T denotes the current time,

TxQ (Qt1 = m, Qt2 = n): the condition of a station with a TxQ (transmission queue) of m at slot time t1 and n at slot time t2.

TxQidle, busy station: a station that was idle previously and is now busy (newly transmitting station).

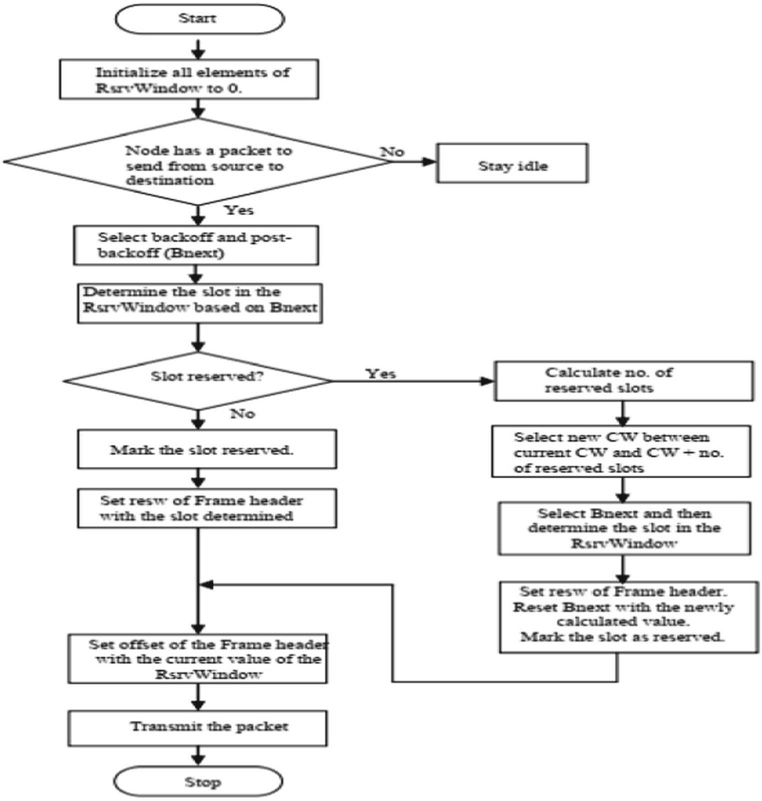

Fig. 3. System flow for transmitting packet

TxQbusy, idle station: indicates a station that was formerly busy but is now idle (a station that will perform post backoff procedure).

TxQbusy, busy station: indicates a station that was broadcasting previously and is presently transmitting (station making successive broadcasts).

TxQidle, idle station: a station that is idle.

One of the two Backoff selection strategies can be used in the Early Backoff Announcement (EBA).

EBA – I

EBA – I is a straightforward MAC with slight modifications to the IEEE 802.11 DCF. It is compatible with earlier DCF versions. In the same WLAN, EBA – I and DCF stations can coexist peacefully. Figure 4 depicts the system flow for accepting packets.

EBA – II

EBA – II is a refined version of EBA – I with increased throughput over EBA – I and DCF. It is EBA – I backward compatible.

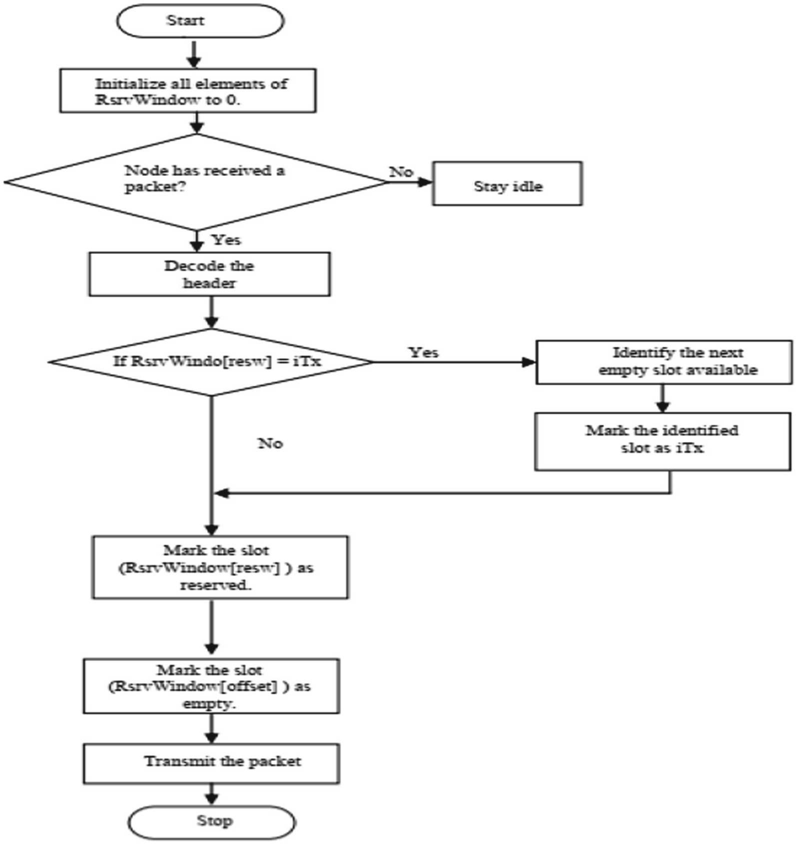

Fig. 4. Receiving a packet

3.3 EBA Backoff Mechanism

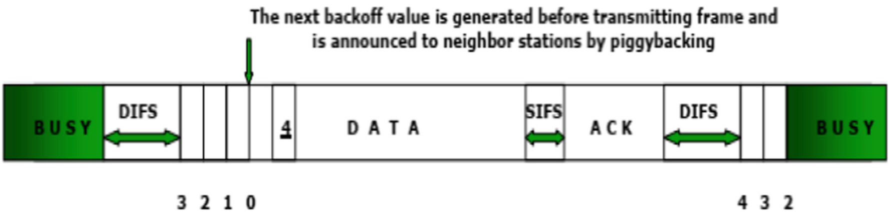

Fig. 5. Basic operation of EBA

The basic operation of EBA is pictorially presented in Fig. 5. The method of picking the next backoff value in EBA – I is nearly identical to the IEEE 802.11 DCF backoff selection mechanism. In this case, the backoff value bnext for a non-reserved slot is chosen at random from the range [0, CW]. For each unsuccessful transmission, the CW value is doubled. The distinction is that the station uses its own Reservation Window (Rempty slot), which is an empty slot, to select only non-reserved backoff periods.

After choosing the (offset + bnext)th slot in the Reservation Window, the station inserts the next backoff period bnext into the transmitted frame header (EBA FIELD) and sets the (offset + bnext)th slot in the Reservation Window to Rtx.

It's likely that the 0 through CW slots will be full if there are more stations than the CW number. In this situation, a backoff value is picked at random from the non-reserved slots in the range [CW, CW + CWreserved], where CWreserved is the number of Reservation Windows reserved slots.

3.4 Additional Collision Prevention Options

Because other stations do not broadcast during the time slot, a station that booked the channel via EBA can send its frame during the specified time without causing a collision. As a consequence, the reserving station obtains a frame to transmit during the reserved time slot, signalling that it is a TxQbusy,busy station. In contrast, the reserving station, i.e. a TxQbusy, idle station, may not include a frame for the reservation. In this case, the access mechanism is identical to that of DCF. TxQbusy, idle stations have no frames to broadcast in the allocated slot while having a reserved channel through EBA. As a result, the channel will be inactive throughout the slot.

Additionally, since TxQbusy, idle stations do not offer any reservation information to their neighbours for their next transmission, they will be unable to reserve the following channel access period. Consider what happens when this station, which corresponds to TxQidle, busy station, tries to transmit a new frame after such an idling interval. Other stations are uninformed of the station's backoff value because it did not reserve the channel for its scheduled transmission, letting them to pick a backoff value that will result in a collision with this station. The following additional algorithms can be used to reduce the likelihood of a collision in such situations.

3.5 Non-reserved Transmission of TxQidle, Busy Stations

Consider the following scenario: station X has been idle for some time and now has to broadcast a new frame, so it sets its backoff counter to a value, and station X is a TxQidle,busy station. After one slot time TxQbusy, busy station A starts transmitting and reserves its next channel access time by setting its next backoff value to the same as station X's. Station X has now seen that station A is attempting to broadcast at the same time as it. Because it is difficult to persuade station A to change its backoff value, we believe station X is accountable for averting the anticipated accident.

Station X converts its existing Rtx-slot to Rreserved-slot and selects another Rempty-slot for its new backoff period as a result. Station X does not choose at random; instead, it advances the Rtx-slot to the left until it finds a Rempty-slot and switches it to the Rtx-slot. If a Rempty-slot does not exist on the left side, it selects the Rempty-slot on the right side that is closest to the original Rtx-slot.

3.6 Newly Arriving Station

Consider the following scenario: a new station joins the WLAN. The Reservation Window for this new station provides no reservation information for its new neighbors. In this case, the station calculates a backoff value and initiates the backoff operation. Consider the case when station Y enters the network and chooses a backoff value for its transmission. Station Y begins transmission after this backoff value and reserves the following channel access period by declaring its next backoff value. However, station B has already reserved this backoff amount. This occurs because station Y was unaware that station B had previously reserved the slot time.

Station B determines that after obtaining the EBA information, station Y intends to transmit at the same time. Station B surrenders the reservation to Station Y by withdrawing its own reservation and selecting the next vacant neighbour slot on the left side as a new backoff value to avoid a collision. In this way, the risk of a collision caused by a newly arrived station can be avoided.

4 Implementation and Results

The proposed model is implemented in Parsec programming language. Glomosim simulator environment is used to implement and evaluate the performance of the proposed protocol over the existing 802.11 DCF. The following parameters is used for the simulation.

Parameters	Values
OS	Fedora 13
Simulator	GloMoSim
Application	Telnet
No. of nodes	49,64
Mobility model	Random way point

4.1 Performance Evaluation

Output for 49 Nodes

The output generated using Glomosim simulator is presented in a Table 1. Table 1 is organized as: First two columns represent EBA and its collision details at the corresponding nodes. Next two columns represent the output generated for the existing 802.11 DCF protocol.

Figure 6 represents the performance comparison of existing 802.11 DCF protocol with the EBA protocol for 49 nodes configuration. The X-axis denotes the nodes and the Y-axis denotes the corresponding collisions occurring at each node. As evident from Fig. 6, the number of collisions occurring at each node using EBA is comparatively less than the legacy DCF protocol.

Table 1. Output for 49 nodes configuration.

EBA		DCF		EBA		DCF	
Node	**Collisions**	**Node**	**Collisions**	**Node**	**Collisions**	**Node**	**Collisions**
Node 0	44	Node 0	183	Node 25	33	Node 25	102
Node 1	165	Node 1	276	Node 26	0	Node 26	11
Node 2	205	Node 2	292	Node 27	30	Node 27	67
Node 3	28	Node 3	107	Node 28	0	Node 28	15
Node 4	24	Node 4	77	Node 29	1	Node 29	5
Node 5	1	Node 5	45	Node 30	109	Node 30	206
Node 6	2	Node 6	25	Node 31	0	Node 31	0
Node 7	1	Node 7	45	Node 32	49	Node 32	81
Node 8	40	Node 8	107	Node 33	90	Node 33	197
Node 9	41	Node 9	118	Node 34	65	Node 34	99
Node 10	76	Node 10	156	Node 35	7	Node 35	49
Node 11	1	Node 11	14	Node 36	0	Node 36	11
Node 12	7	Node 12	40	Node 37	0	Node 37	0
Node 13	0	Node 13	11	Node 38	159	Node 38	263
Node 14	18	Node 14	157	Node 39	7	Node 39	54
Node 15	35	Node 15	161	Node 40	0	Node 40	1
Node 16	2	Node 16	21	Node 41	177	Node 41	332
Node 17	1	Node 17	23	Node 42	74	Node 42	256
Node 18	1	Node 18	13	Node 43	93	Node 43	170
Node 19	8	Node 19	27	Node 44	1	Node 44	15
Node 20	135	Node 20	321	Node 45	40	Node 45	105
Node 21	32	Node 21	62	Node 46	4	Node 46	33
Node 22	3	Node 22	32	Node 47	1	Node 47	13
Node 23	29	Node 23	68	Node 48	49	Node 48	162
Node 24	213	Node 24	345				

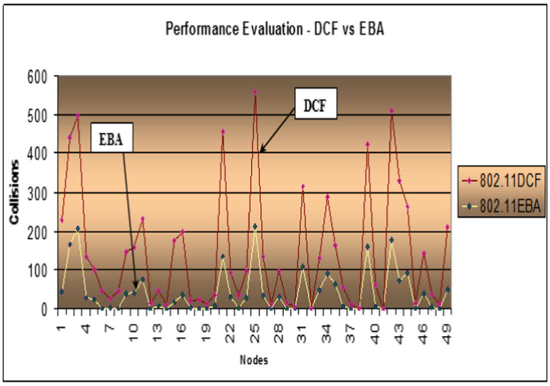

Fig. 6. Performance comparison of DCF vs EBA for 4 nodes

Output for 64 Nodes

The output generated using Glomosim simulator is presented in Table 2. Here the number of nodes is configured to be 64. Table 2. is organized as: First two columns represent EBA and its collision details at the corresponding nodes. Next two columns represent the output generated for the existing 802.11 DCF protocol.

Table 2. Output for 64 nodes configuration.

EBA		DCF		EBA		DCF	
Node	Collisions	Node	Collisions	Node	Collisions	Node	Collisions
Node 0	71	Node 0	277	Node 32	20	Node 32	33
Node 1	186	Node 1	292	Node 33	134	Node 33	300
Node 2	274	Node 2	354	Node 34	106	Node 34	218
Node 3	107	Node 3	293	Node 35	174	Node 35	273
Node 4	73	Node 4	152	Node 36	3	Node 36	9
Node 5	12	Node 5	82	Node 37	0	Node 37	0
Node 6	179	Node 6	235	Node 38	186	Node 38	309
Node 7	12	Node 7	78	Node 39	144	Node 39	287
Node 8	44	Node 8	121	Node 40	5	Node 40	34
Node 9	43	Node 9	150	Node 41	188	Node 41	329
Node 10	61	Node 10	184	Node 42	160	Node 42	316
Node 11	1	Node 11	19	Node 43	337	Node 43	576
Node 12	241	Node 12	389	Node 44	8	Node 44	33
Node 13	34	Node 13	89	Node 45	44	Node 45	110
Node 14	101	Node 14	277	Node 46	9	Node 46	45
Node 15	350	Node 15	591	Node 47	4	Node 47	34
Node 16	4	Node 16	24	Node 48	369	Node 48	544
Node 17	200	Node 17	375	Node 49	13	Node 49	37
Node 18	75	Node 18	155	Node 50	94	Node 50	208
Node 19	111	Node 19	195	Node 51	193	Node 51	291
Node 20	251	Node 20	449	Node 52	162	Node 52	349
Node 21	11	Node 21	13	Node 53	117	Node 53	273
Node 22	87	Node 22	196	Node 54	201	Node 54	347
Node 23	68	Node 23	104	Node 55	4	Node 55	32
Node 24	239	Node 24	395	Node 56	222	Node 56	400
Node 25	214	Node 25	418	Node 57	109	Node 57	282
Node 26	35	Node 26	69	Node 58	4	Node 58	26
Node 27	39	Node 27	60	Node 59	6	Node 59	41
Node 28	2	Node 28	30	Node 60	136	Node 60	316
Node 29	11	Node 29	89	Node 61	116	Node 61	262
Node 30	190	Node 30	397	Node 62	140	Node 62	306
Node 31	2	Node 31	9	Node 63	89	Node 63	230

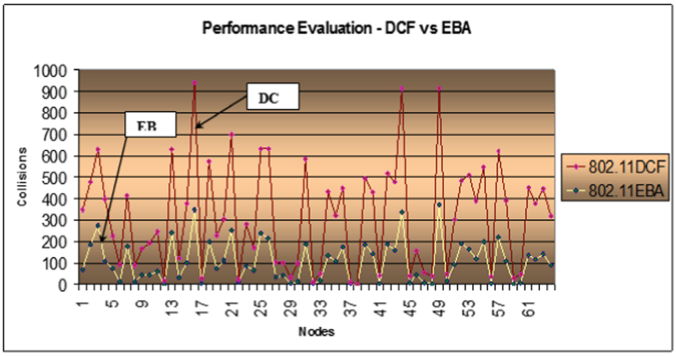

Fig.7. Performance comparison of DCF vs EBA for 64 nodes

Figure 7 represents the performance comparison of existing 802.11 DCF protocol with the EBA protocol for 64 nodes configuration. The X-axis denotes the nodes and the Y-axis denotes the corresponding collisions occurring at each node. As evident from Fig. 7, the number of collisions occurring at each node using EBA is comparatively less than the legacy DCF protocol. Also with the number of contending stations increasing the collision factor gets greatly reduced.

Figure 8 and Fig. 9 shows the overhead and delivery ratio of DCF and EBA for 64 nodes.

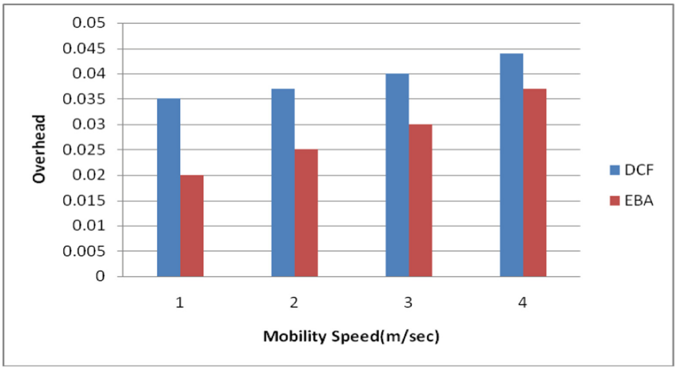

Fig. 8. Overhead of DCF vs EBA for 64 nodes

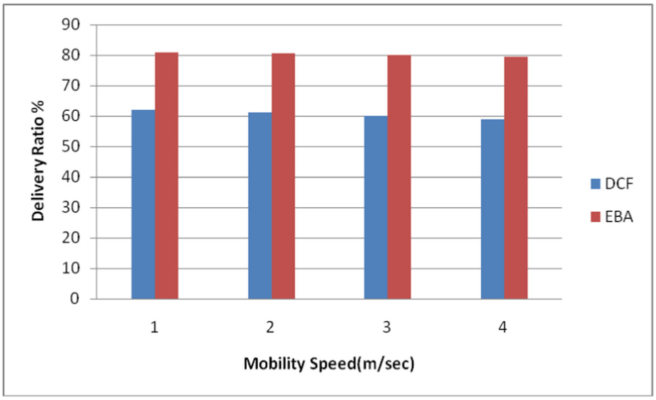

Fig. 9. Delivery Ratio of DCF vs EBA for 64 nodes

5 Conclusion and Future Work

The proposed work is an enhancement to the existing IEEE 802.11 DCF protocol. This scheme is compatible with existing DCF and EBA [1] protocols. The priority scheme enhances the existing EBA mechanism to reduce collisions and improve throughput. The backoff value selection used in this model improves channel usage by allowing stations to transmit back-to-back without any wait time due to post backoff. It provides better performance improvement over the legacy DCF. Some techniques, in addition to random selection, might be used for backoff selection as a future development to the EBA. Scheduling algorithms such as round robin can be used to provide scheduling by reserving channel access time in FIFO order. Instead of a random number, the backoff value might be decided straight after the final reserved slot, saving time at the station that transmits frames back-to-back.

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