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E-BEB Algorithm to Improve Quality of Service on Wireless Ad-Hoc Networks

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Abstract: The Medium Access Control (MAC) protocol is the main element which determines the system throughput in Wireless Local Area Networks (WLANs) IEEE 802.11 standard. The MAC technique of the IEEE 802.11 protocol is called Distributed Coordination Function (DCF). In DCF, stations contend for the use of the channel in distributed manner via the use of the Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) protocol. In the CSMA/CA protocol, each station sets up a Backoff time according to a randomly selected interval from zero to the Contention Window (CW) for an additional deferral time before transmitting. The random Binary Exponential Backoff (BEB) algorithm is used to randomize moments at which stations try to access the wireless medium. However, in the random Backoff mechanism, packet collisions are not entirely eliminated, and the system throughput decreases when the number of stations is large, and there is no fairness between stations. The BEB algorithm has a number of disadvantages; one crucial disadvantage is the problem of fairness. In this paper, we analyze the behavior of the BEB algorithm used in IEEE 802.11 standard. We propose an Enhanced Binary Exponential Backoff (E-BEB) algorithm to improve the fairness of the channel access for BEB algorithm. Our E-BEB algorithm adjusts the way of increase or decrease of the contention window CW based on the number of the frame which is sent successfully. We propose several configurations, and we use NS2 simulator to analyze the network's fairness of the channel access of the E-BEB algorithm. The simulation results show that compared with other algorithms like BEB or Improved BEB (I-BEB), the E-BEB algorithm improves the fairness of the channel access and increases the network's throughput capacity; which is an valuable Quality of Service (QoS) parameter.

Key words: Ad-Hoc, backoff algorithm, CW, DCF, fairness, QoS

INTRODUCTION

In Ad-Hoc Network, the MAC Algorithms have to be efficient enough in order to provide better results. To be compatible with changing challenges topology, the Distributed Coordination Function (DCF) in IEEE 802.11 MAC is a powerful protocol for the best effort service in WLAN. The Ad-Hoc network is a collection of wireless nodes can dynamically self-organize into an arbitrary and temporary topology to form a network without necessarily using any pre-existing infrastructure. The Backoff algorithm is crucial algorithm in Ad-Hoc network for wireless nodes performance. In Backoff algorithm, A node before retransmission, it must defer for Backoff Time (BT) in order to resolve medium collision, also a node which has a small BT slots number has more aggressively of accessing the medium than a node which has a large BT slots number.

The Quality of Service (QoS) for IEEE 802.11 MAC network emerges as a critical issue to meet the development requirements of multimedia applications such as audio and video streaming data services. Therefore, the applications are required to ensure that system bandwidth, packet loss rate and delay are controlled. The improvement of QoS in MAC became considerable interest area (Liqiang and Fan, 2004; Mukherjee *et al*., 2009; Ni *et al*., 2004; Ni and Turletti, 2004). The best effort applications may tolerate large delay and they are sensitive to packet drop rate. It is desirable if the MAC DCF technique supports QoS requirements such as throughput, delay, and packet loss rate for different applications. For that, many algorithms have been proposed on MAC protocols, Backoff algorithm, to meet QoS requirements in Ad-Hoc networks. In addition, many techniques have been proposed on Backoff algorithms. Some researches proposed using a counter to provide managing for accessing nodes in the medium and a counter for knowing the neighbourhood nodes (Dengyin *et al*., 2008). Others proposed to maximize the throughput with constant

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contention window using access probability by Markov Chain for the Backoff window size (Xiangyi *et al*., 2007). Others proposed modifying the CW taking into account the size of the node neighbourhood and state of channel occupation (Berqia *et al*., 2008). Conceptually, others researches also proposed to adapt the "space" occupied by the transmissions of Backoff algorithm (Xue and Vaidya, 2006). In addition, a solution to improve the value of CW to be adjusted reasonably according to the conditions of network load is proposed in (Tiebin and Chang, 2009).
In this study, we propose a new Enhanced Binary Exponential Backoff algorithm called E-BEB. Our proposed algorithm provides better results than other algorithms like the BEB and I-BEB algorithms in terms of the fairness of the channel access and the network's throughput capacity.

MATERIALS AND METHODS

This research was carried out during January 2009 to December 2010 at Faculty of Science and Technology, Algarve University, Portugal.

BEB algorithm: Binary Exponential Backoff (BEB) algorithm is widely used in distributed MAC protocol. The IEEE 802.11 MAC and DCF procedure (RTS-CTS-Data-ACK frames) use to manage multiple access nodes. In BEB algorithm, the CW doubles at each time of collision in order to give further space between successive transmissions and thus absorbing the growing contending flows. In addition, CW sets to CWmin at each successful or unsuccessful transmission. The Backoff slot time is used to define the shortest and distributed inter frame spaces and to update the Backoff interval in the shared medium access. In fact, this time make delays for accessing the medium in order to provide transparent and avoid a collision, whenever any node finds the medium busy, it gets a random value within a contention window for Backoff time (Xue and Vaidya, 2006; Tiebin and Chang, 2009; Kun and Sun, 2009; Malli *et al*., 2005).

In BEB algorithm, the node starts counting down its Backoff time only when the medium becomes free. If the medium has been found free for an interval of time longer than Distributed Coordination Function Inter Frame Spacing (DIFS) time (Tiebin and Chang, 2009), the node transmits the packet immediately. Otherwise, it chooses a random Backoff time (random waiting time) to avoid collision. The Backoff time is different from one node to another or may they have the same amount of slot time within contention window. After the expiration of the Backoff time, the nodes start sensing the medium. As long as the node senses the channel is busy, it loses its turn and selects another Backoff time for next cycle. The nodes select their Backoff time from the random interval between 0 to the CW size. The Backoff time calculated using the following formula:

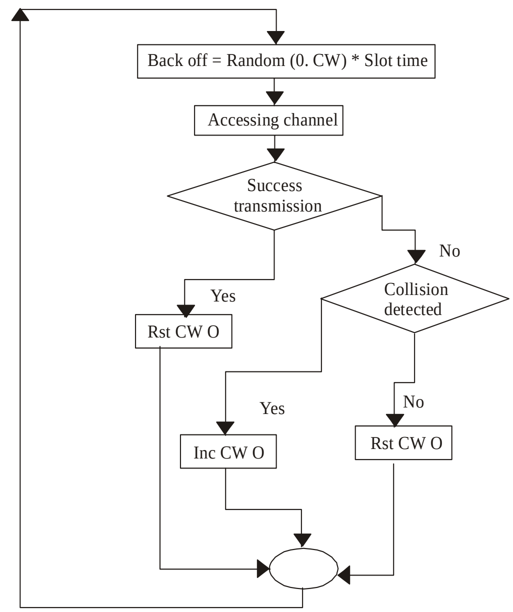

Fig. 1: Flowchart of the BEB algorithm

$$\text{Backoff Time} = \text{Random } [0, CW] * \text{SlotTime} \quad (1)$$

If a node transmission fails because of a collision or deferring, the node doubles its CW size exponentially. The new CW size recalculated using the following formula:

$$CW\ new = \min(2*CW\ old,\ CW\ max) \quad (2)$$

The node resets its CW *CWmin* initial size after every successful or unsuccessful transmission using the following formula:

$$CW = CW\ min \quad (3)$$

The flowchart of the BEB algorithm is shown in Fig. 1.

In general, the node in the BEB algorithm starts selecting its random Backoff time using formula (1). When the node detects a collision of its packet, it doubles its CW value using formula (2). When the transmitter node detects a successful transmission of its packet; it resets its Backoff time to CWmin using formula (3). In BEB, the last transmitter is unfairly contend the channel again as it has a low Backoff time the next time cycle and thus leads to unfairness, especially when the offered load is high. For that and based on these analyses, we propose the Enhanced Backoff algorithm based on the fairness equality for Ad-Hoc networks to build a robust and fair enough wireless medium access protocol.

I-BEB algorithm: I-BEB algorithm concept is the same as BEB algorithm especially in collision, deferring, and

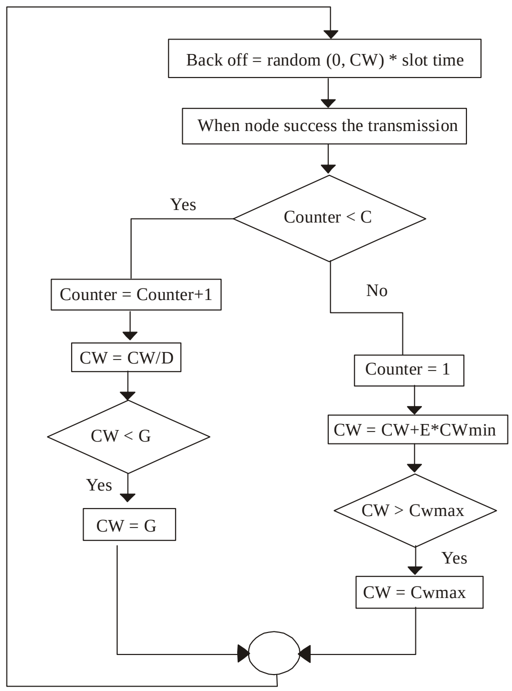

Fig. 2: The flowchart of I-BEB algorithm.

unsuccessfully transmission, the modifications were made in successful transmission using some constant variables to control CW, as C = 12, D = 4, E = 8, and G = 0.125*CWMin (Kun and Sun, 2009). Figure 2 illustrate I-BEB algorithm flowchart.

E-BEB algorithm: In the Backoff algorithm, as it was shown in Fig. 1, the random time is called Backoff Time (BT), which is crucial for WLAN performance. Conceptually, a node before retransmission, it must select BT value in order to resolve medium collision. Therefore, BT value randomly taken from formula 1, so that a node that has a small BT slots number has more aggressively of accessing the medium than a node that has a large BT slots number. When the nodes are in communication, some possibility that the nodes have less throughput as in the case of standard Backoff algorithm. This is because the nodes choose the new CW taking into account the last activities.

E-BEB Algorithm offers some relationship between Backoff Time Threshold (BT_Th) and CW size. When we have many nodes using the medium, we require small value of BT_Th relative to current CW size to reduce collisions. On the other hand, when we have few nodes

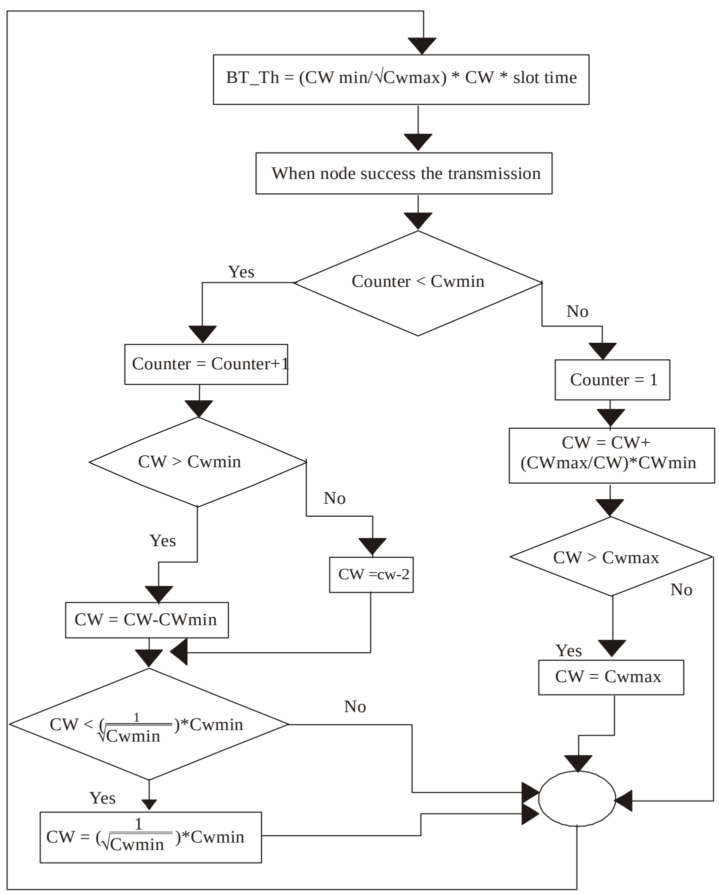

Fig. 3: The flowchart of E-BEB algorithm

using the medium, we require high value of BT_Th relative to current CW size to fast collision resolution (Younggoo *et al*., 2003).

In the proposed E-BEB algorithm, a relationship between BT_Th value and CW value was built-up. E-BEB algorithm starts computing the BT_Th threshold using formula 4, taking into account a CW value for all nodes.

$$BT\_Th=(CW\ min/\sqrt{CW\ max})*CW*Slot\ Time \quad (4)$$

The flowchart of the E-BEB algorithm is shown in Fig. 3. As shown in Fig. 3, E-BEB algorithm has setup special counter as the maximum successful transmission for each node. When a successful transmission occurs, the node starts checking its own counter. The idea of our algorithm is to adjust CW taking into account the BT_Th value of the node. In addition, we take into account the counter successful transmission numbers by the node in order to guarantee a fair access to the communication support to all nodes in competition. The proposed E-BEB algorithm has improved the I-BEB algorithm used by (Kun and Sun, 2009) especially when the node has successes the transmission and also propose new formula better than formula that used by (Malli *et al*., 2005). It increases the contention window (CW) when the medium is busy while reduce CW to zero when successful transmission in order to have a higher throughput and to facilitate a node to access the medium by fast decrease the Backoff time when the medium is free. This fairness notion can be quantified by a fairness index (FI) using the following formula:

$$\text{Fairness Index (FI)} = \frac{(\sum_{i=1}^{n} Xi)^2}{n_* \sum_{i=1}^{n} (Xi)^2} \quad (5)$$

where n is the number of the same priority flows and Xi is the throughput of flow i. Therefore, $FI \leq 1$ and it is equal to 1 if all Xi are equal, which corresponds to the highest degree of fairness between the different nodes.

RESULTS AND DISCUSSION

The performance of E-BEB algorithm compared with the standard IEEE 802.11 BEB and Improved Backoff (I-BEB) algorithms were compared using NS-2.34 simulation software. The standard simulation parameters are shown in Table 1 unless otherwise stated. We simulate two scenarios: single-hop scenario with 8 nodes and multi-hop scenario with 10 nodes to show how the fairness achieved in E-BEB algorithm.

The value of Fairness Index (FI) metric calculated as the ratio of the minimum number of packets sent by any individual node to the maximum number of packets sent by any individual node. This FI metric demonstrates how fairly the channel shared among all active nodes in the presence of E-BEB algorithm. For a perfectly fairness, FI metric should be one, and the lower of the FI value expresses unfairness in the channel sharing between the nodes in the network (Tiebin and Chang, 2009).

Table1: Simulation parameters

Parameter	Value
Slot time	20 µs
ACK	20 bytes
RTS	25 bytes
CTS	20 bytes
Packet size	1000 bytes
DIFS	40 µs
SIFS	10 µs
Cwmin	31
Cwmax	1023
Bandwidth	2 Mbits/s
Transport protocol	UDP

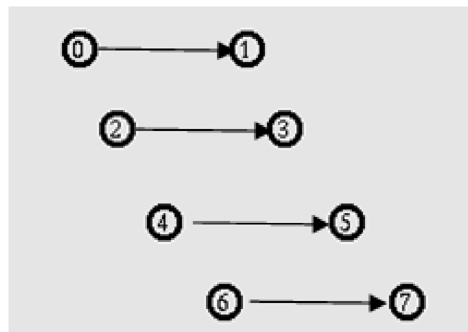

Fig. 4: The scenario1 of 8 nodes

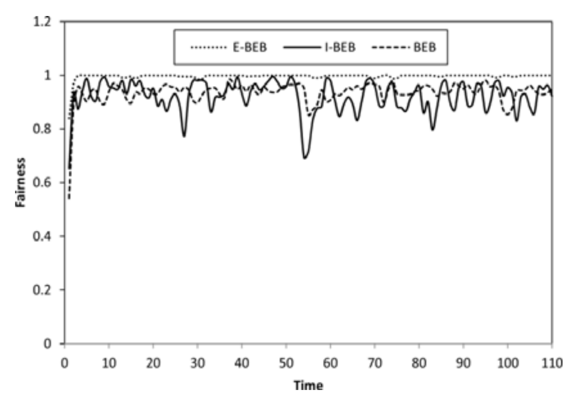

Fig. 5: The fairness index for E-BEB, I-BEB, and BEB algorithms-scenario 1

Table 2: The FI metric average for E-BEB, I-BEB, and BEB algorithms - scenario 1

Scenario 1	FI average for 3 algorithms, all traffics
BEB	0.93
I-BEB	0.92
E-BEB	0.98

Scenario (1) Single hop: Scenario 1, as shown in Fig. 4, has 8 nodes that share one channel at the same time. In order to make sure that any node only communicates with

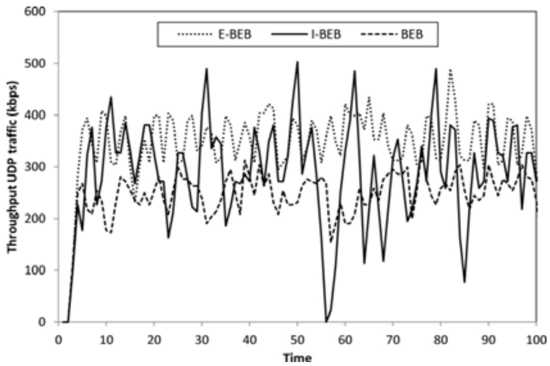

Fig. 6: Traffic throughput between node 0 to 1 for E-BEB, I-BEB, and BEB algorithms- scenario 1.

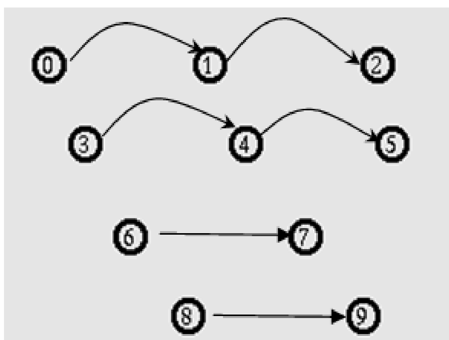

Fig. 7: The scenario2 for 10 nodes

its neighbouring node; all nodes are single-hop type. The distance between nodes is 50 m (in 802.11 the nominal communication radius is 250 m). To simplify the scenario, we assume that all nodes are static. At 1.0s simulation time, nodes (0, 2, 4 and 6) start simultaneously sending data to its neighbouring nodes (1, 3, 5 and 7) respectively. To facilitate the comparison, we first depict the result using three algorithms, BEB algorithm, I-BEB algorithm, and the proposed E-BEB algorithm.

As we can see from Fig. 5 that the proposed algorithm has a higher fairness values according to the formula (5), Table 2 shows the E-BEB algorithm has a higher average values of FI metric than the I-BEB and BEB algorithms. FI demonstrates how fairly the channel is shared among all active nodes. Therefore, FI indicates that the proposed E-BEB algorithm meets the fairness requirements perfectly than the I-BEB and BEB algorithms for scenario 1.

Figure 6 shows the throughput comparison between BEB, I-BEB and E-BEB algorithms. The Figure shows the minimum traffic from node 0 to node 1 that has the lowest throughput occupied the medium. This experiment indicates that the E-BEB algorithm has the best throughput than both BEB and I-BEB algorithms.

Scenario (2) multi-hop: Scenario 2, as shown in Fig. 7, has 10 nodes with both multi-hop and single-hop together

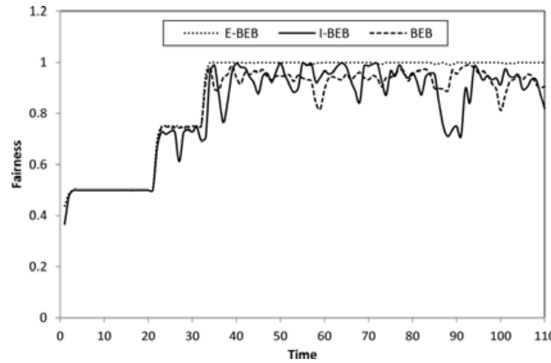

Fig. 8: The fairness index for E-BEB, I-BEB, and BEB algorithms - scenario 2

Table 3: The FI metric average for E-BEB, I-BEB, and BEB algorithms - scenario 2

Scenario 2	FI Average for 3 algorithms, all traffics
BEB	0.936
I-BEB	0.920
E-BEB	0.998

to share one channel at the same time. This scenario made to evaluate and test the fairness and QoS requirements of all algorithms in the different access priority in channel for both multi-hops and single-hop. The multi-hop nodes are: node 0 to node 2 via node 1 and node 3 to node 5 via node 4. The single-hop nodes are: node 6 to node 7 and node 8 to node 9. The distance between the nodes is 50 m.

At 1.0 s simulation time, node 0 and node 3 starts simultaneously to send data to its neighboring nodes 2 and 5 via node 1 and 4 respectively. At 20 s simulation time, node 6 starts send data to node 7. At 30 s simulation time, node 8 starts transmission to node 9, the simulation parameters keep unchanged as it was in Table 1.

As shown in Fig. 8, the proposed E-BEB algorithm has a higher fairness value, which is near to one, according to the formula (5). The average values of FI metric represented in Table 3, FI metric demonstrates how fairly the medium is shared among all active nodes. Therefore, it indicates that the proposed E-BEB algorithm meets the fairness requirements perfectly than the I-BEB and BEB algorithms for scenario 2.

CONCLUSION

In this study, we proposed a new Enhanced Binary Exponential Backoff algorithm; E-BEB. Our proposed algorithm provides better results than other algorithms like the BEB and I-BEB algorithms in terms of QoS requirements of all traffics in channel. The E-BEB has a higher fairness index, a high throughput as well as more stability between all traffics in Ad-Hoc networks. The nodes that have a smaller CW value have more chance to access the medium relative to their competitors. When the channel is busy, E-BEB increases the CW and when the channel is free, E-BEB decreases fast the Back off time.

The simulation results obtained using NS-2 has shown the enhancement added by the E-BEB algorithm among different scenarios which satisfies a QoS-based applications needs.

In our future works, we aims to extend our E-BEB algorithm to meet mobility challenges in MANET in terms of QoS requirements and a cross-layer approach between MAC, routing, and transport layers.

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REFERENCES

Berqia, A., B. Angoma, N. Mikou and Y. Dehbi, 2008. Fairness and QoS in Ad-Hoc Networks. IEEE Vehicular Technology Conference, VTC Spring 2008, pp: 16-20.

Dengyin, Z., B. Zhang and D. Lu, 2008. Contention Window Based Fairness Backoff algorithm in Ad Hoc Networks. Proceeding of 2008 International Conference on Neural Networks and Signal, pp: 210-214.

Kun, W. and C. Sun, 2009. An Improved Backoff Algorithm of Ad Hoc Networks. International Conference on Computational Intelligence and Software Engineering, CISE, pp: 1-4.

Liqiang, Z. and C. Fan, 2004. Enhancement of QOS differentiation over IEEE 802.11 WLAN. IEEE Commun. Lett., 8(8): 494-496.

Malli, M., Q. Ni, T. Turletti and C. Barakat, 2005. Adaptive fair Channel Allocation for QOS Enhancement in IEEE 802.11 Wireless LANs. IEEE Int. Conf. Commun., 6: 3470-3475.

Mukherjee, S.X., H. Peng and Q. Gao, 2009. QOS Performances of IEEE 802.11 EDCA and DCF: A Testbed Approach. Wireless Communications, 5th International Conference on Networking and Mobile Computing. WICOM '09, pp: 1-5.

Ni, Q., L. Romdhani and T. Turletti, 2004. A Survey of QOS Enhancements for IEEE 802.11 Wireless LAN. Wireless Commun. Mobile Comput., 4(5): 547-566.

Ni, Q. and T. Turletti, 2004. QOS Support for IEEE 802.11 WLAN. Nova Science Publishers, New York, USA.

Tiebin, T. and C. Chang, 2009. A New Backoff Algorithm for IEEE 802.11 Distributed Coordination Function. Sixth International Conference on Fuzzy Systems and Knowledge Discovery, FSKD '09, 3: 455-459.

Xiangyi, Z., L. Wang, L. Zhao and H. Zhang, 2007. Using a Constant Contention Window to maximize The Throughput of IEEE 802.11 WLANs. IET Conference on Wireless, Mobile and Sensor Networks (CCWMSN07), pp: 174-177.

Xue, Y. and N. Vaidya, 2006. Spatial Backoff Contention Resolution for Wireless Networks. 2nd IEEE Workshop on Wireless Mesh Networks, WiMesh, pp: 13-22.

Younggoo, K., Y. Fang and H. Latchman, 2003. A Novel MAC Protocol with Fast Collision Resolution for Wireless LANs. Twenty-Second Annual Joint Conferences of the IEEE Computer and Communications, INFOCOM, IEEE Soc., 2: 853-862.