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FAIRNESS BASED ON BACKOFF ALGORITHMS FOR ENHANCING MANETS PERFORMANCE: A COMPREHENSIVE REVIEW

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Abstract: Recently the paradigm of achieving fairness in MANETs has become a significant issue in networks field. Researchers have been studying methods and proposing algorithms to maintain the best performance of the network as well as achieving fairness in utilizing resources. In MANETs nodes require fairness of accessibility to channel, bandwidth limit, quality of service, etc. many models were proposed in fairness management process to guarantee the allocation and utility fairly between nodes at the same time achieve the best output and performance as well as optimizing the power consumption and network resources. This paper aims at exploring these models and algorithms and focus on the way that fairness is defined, since there is no specific definition for fairness that all researchers agree on. Also this paper compares between the experiments and studies done in this field and evaluate the level they could improve and enhance in MANETs performance in terms of fairness.

Keywords: MANETs; network resources; fairness; performance measurement; simulation.

1. Introduction

The continuous development and emergence of the internet services forced the communication

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sector and networks to grow rapidly in order to meet the emerging demands of users.

Fairness is usually related to resource allocation, in every aspect of our lives. In Networks it is related to nodes that expected to have same amount of Bandwidth and service quality.

Quality of service (QoS) is the main concern of the networks users, to achieve the best quality and user satisfaction, the network consumes much of the available resources, some nodes may not get the same bandwidth or power or even may not get the permission of accessibility to the channels as other nodes.

Here comes the importance of fairness, in which the network can maintain the best performance and best utilizing for the resources as well as distributing the resources fairly among the propagated nodes in the network, backoff algorithms were used to maintain the fairness of the network [1], through the delay time and CW, unfortunately this couldn't be achieved in the traditional backoff algorithms, so many researchers conducted experiments to adjust existing algorithms and focusing on some parameters of backoff to reach fairness [21].

It so hard to predict the requirements (capacity, duration, and bandwidth, etc.) since the distribution and propagation of a node is rapidly changed and not fixed in MANETs [20].

MANETs suffers the denial of service attacks, since it is an infrastructure less nature, also it suffers the flooding attacks too, these attacks can be achieved using the per flow management, which affects the security of the Network. In this case the aggregation must be performed to keep the network secure, which leads to less fairness, again which affect the quality and success delivery of data, the Traditional BEB couldn't solve the problem of fairness since the BEB choses the winner node of the contention and give it the priority over other nodes [21][27].

This all leads to the importance of implementing and achieving fairness process in MANETs.

This paper has surveyed (27) main articles, theses and reports including their references, covering the years from 1999 up to 2017. In which the researchers focused on topics of fairness in networks and MANETs and how to modify backoff algorithms to experiment the effect of backoff in achieving fairness and better throughput of the network.

2. Materials and Methods

Achieving a sustainable environment of MANETs requires mechanisms and procedures for incentives, and applying many algorithms over the processes of the router used in the network.

The awareness of the fairness importance in networks is clear since the beginning of wireless networks appearance.

In early trials in 1999, [2] tried to achieve fairness through introducing new algorithms that adapt any change in the wireless networks, and applicable to all CSMA protocols. The new algorithms namely: connection based and time based, have shown according to the result better fairness index.

[3] Had argued the problem of hidden terminal, when a transmitter send as another transmitter sends simultaneously to the same receiver and the collision happens there. So the researchers proposed a new scheme for the backoff of the distributed foundation MAC, in order to enhance fairness problem and reduce collisions that the hidden terminals cause.

Algorithm 1 Fair share estimation

switch (received packet type) {
case RTS:
  if (destID != localID) $W_{eo} += T_{rts}$
  else {send CTS packet;
    $W_{eo} += (T_{rts} + T_{cts})$}
case CTS:
  if (destID != localID) $W_{eo} += (T_{rts} + T_{cts})$
  else {send DATA packet;
    $W_{ei} += (T_{rts} + T_{cts} + T_{data})$}
case DATA:
  if (destID != localID)
    $W_{eo} += (T_{rts} + T_{cts} + T_{data})$
  else {send ACK packet;
    $W_{ei} += (T_{rts} + T_{cts} + T_{data} + T_{ack})$}
case ACK:
  if (destID != localID)
    $W_{eo} += (T_{rts} + T_{cts} + T_{data} + T_{ack})$
  else {$W_{ei} += (T_{rts} + T_{cts} + T_{data} + T_{ack})$}
}

Whenever sending an RTS packet, $W_{ei} += T_{rts}$

Figure 1: Fair share estimation

The new scheme allows the node to adjust the contention window, according to the estimated calculated fair share algorithm above. The results showed better fairness but it return the throughput has suffered a slight decrease.

In 2001, a new algorithm was introduced by [4], to solve the problem that the traditional BEB suffers when the packet length is not stable. The variability of the packet length can severely affect the fairness of the network. Based on the work of [3] a modification was done to the fair share estimation algorithm to be applicable on the wireless network, and applied to the DFWMAC protocol (the Wireless DFMAC), same results were found in wireless case, the fairness has enhanced but through scarifying some throughput [3][4][20].

In 2005 [5], experimented the ability to achieve fairness in sharing the network bandwidth by proposing a new packet switching and scheduling algorithm. The proposed work depends on cooperation coefficient, in which this coefficient calculated how much a specific node contributes to the network as well consumes from its recourses. The larger the coefficient the larger the bandwidth the node can get accordingly. The cooperation coefficient is calculated according to information of dynamic source routing.

The results showed that the cooperation coefficient has ensured fairness in sharing the network bandwidth, exactly in the cooperative queuing process.

In [6] a new scheme of MAC was proposed which automatically optimizes the backoff of the active nodes. This is done by modifying the contention window to reach the optimal size for the CW in a way that leads to maximize and enhance throughput. At the same time if the channel came into a saturation case or a heavy traffic all active nodes are forced to get same CWs, this insures fairness of the channel capacity [6], [7].

The experiment performed used a new index called “Average Channel Idle Interval”, which is linked to the optimal CW size, during the backoff process.

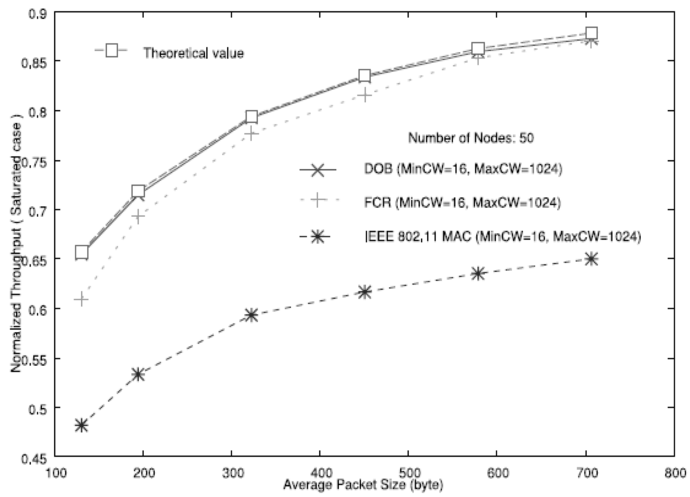

Figure 2: Simulation results of throughput with 50 nodes.

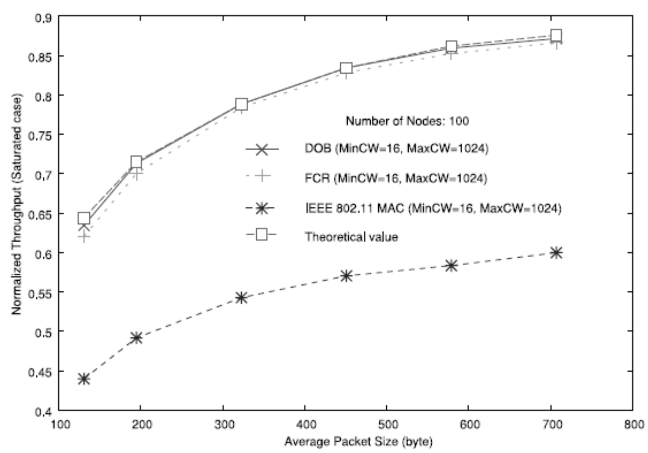

Figure 3: Simulation results of throughput with 100 nodes.

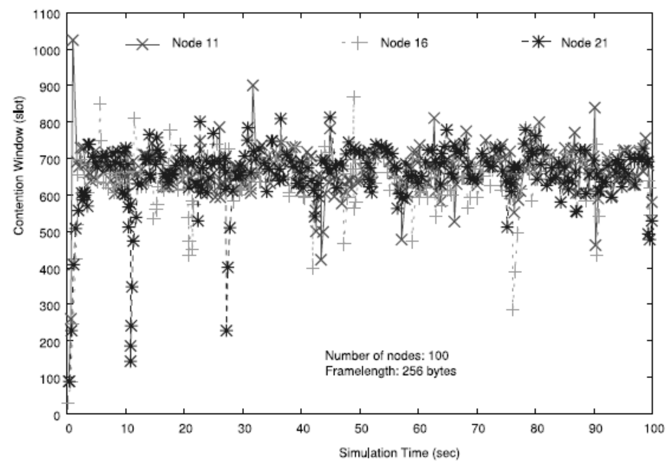

Figure 4: Changes of CW in simulation with 100 nodes.

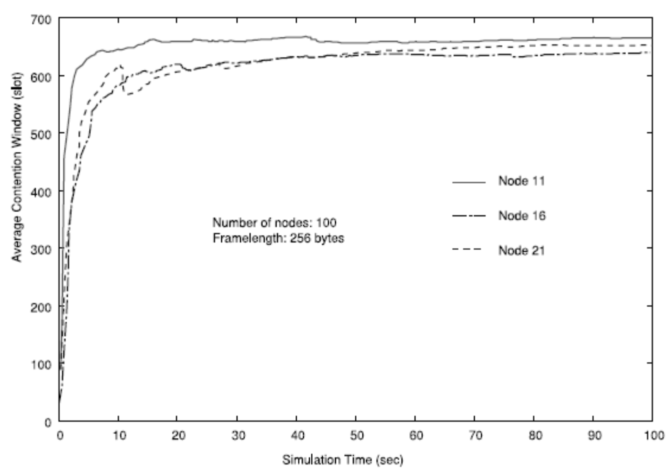

Figure 5: Average CW in simulation with 100 nodes.

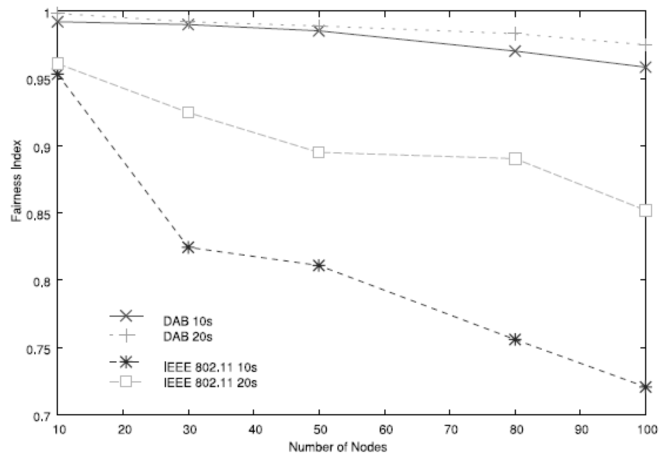

Figure 6: Fairness index.

The average idle interval shows the density of the network and the optimal CW. It doesn't need the estimation of the nodes number which make it a simple scheme and increase its reliability in the dynamic environment of networks where the traffic changes frequently. As the results showed that the throughput has increased and fairness is maintained since each node can adjusts the backoff according to the idle channel interval to reach the optimal CW.

To resolve the problem of flooding attacks and enhancing the QoS, in 2006 [8] had proposed a quantitative metric to measure the experienced fairness in the network during a flooding attacks, and studied the effect of flow aggregation in such case. The experiment conducted introduced a scheme of 3 levels of flow aggregation, the results showed the impact that flooding attacks have on fairness, and proved that the proposed flow aggregation, is effective in such cases of flooding attacks in maintaining the fairness approached by the network nodes, and higher resistance to exhaustion attacks.

A modified logarithmic backoff algorithm was presented by [9], where the results showed better opportunities on accessing the network channels, which implies better fairness.

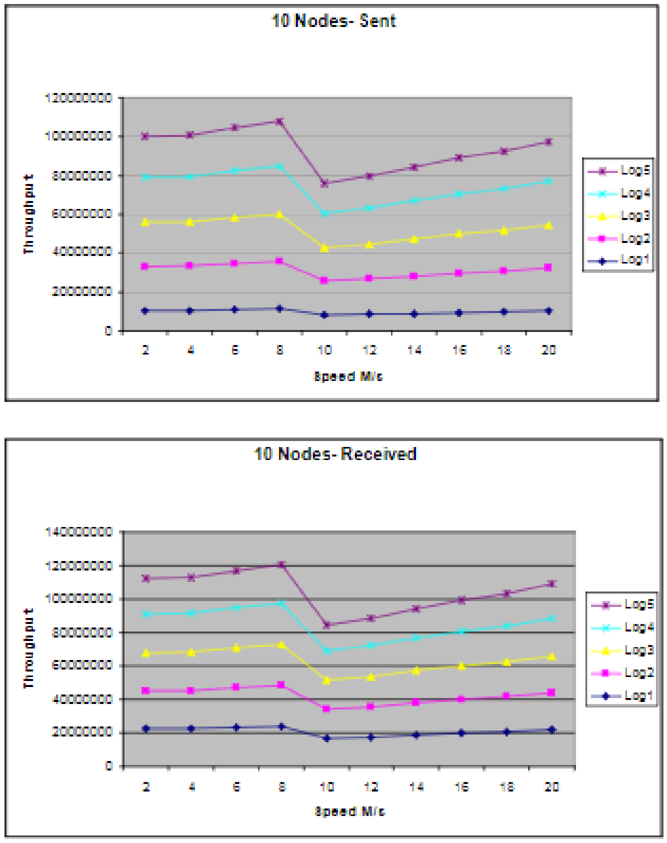

Figure 7: Sent and received data for a network of 10 nodes

Nodes near the gateway that links the Ad—hoc network to the internet to exchange packets through, consumes more bandwidth than other nodes inside the network, to solve this problem and the problem of the internal overhead caused by having the source and destination inside the network, [10] proposed a new tree structure that shall be existed at the gateway to maintain faire use of bandwidth. Also an algorithm for rerouting to enhance the process of internal traffic and minimize overhead within the same network.

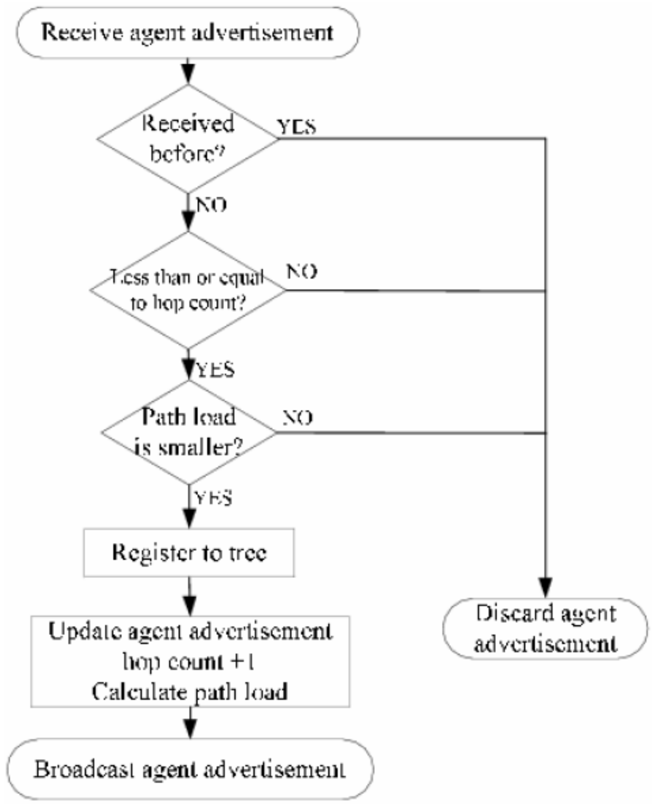

Figure 8: Tree construction algorithm.

The following figures shows the performance evaluation for the proposed algorithm and scheme when number of nodes =100.

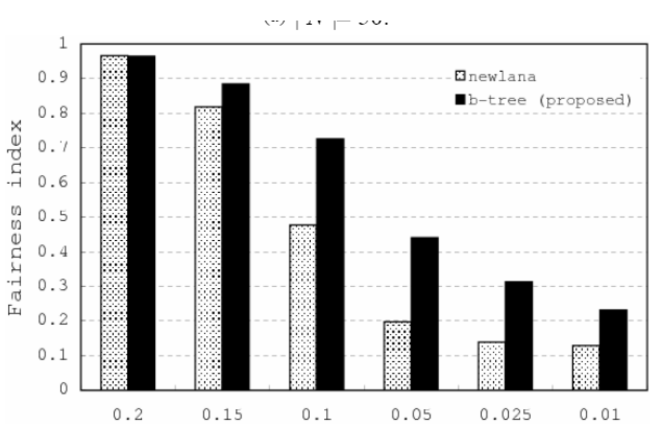

Figure 9: Fairness of per-flow throughput.

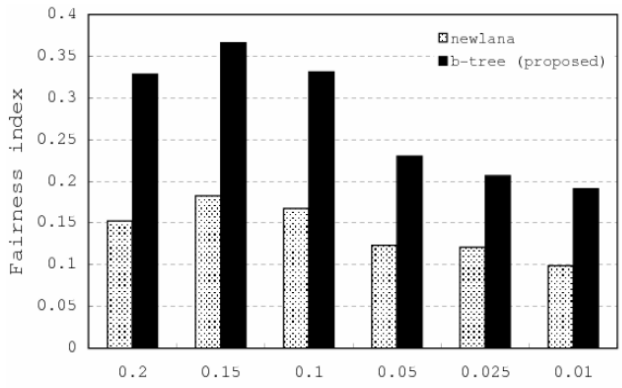

Figure 10: Fairness of power consumption.

The results in the figures showed that the proposed tree, and rerouting algorithm, had enhanced the fairness of the network remarkably, as well as the algorithm achieved balance in high traffic or moderate one cases.

In [11], researchers had argued that the backoff algorithm (Exponential) become significantly unfair towards the nodes that located in the middle area of a network. Since those nodes suffers more collisions and failure due to the density in the middle of the network compared to the nodes that have few neighbors, which makes the delay of the backoff larger and less throughput comparing to those on the network borders. A modification was made to backoff algorithm and the Impatient backoff (IBA) was proposed.

The proposed Backoff algorithm, decreases the delay when a collision happen, and the failure. The algorithm reset the average backoff delays if they become too small, so the nodes maintain stability.

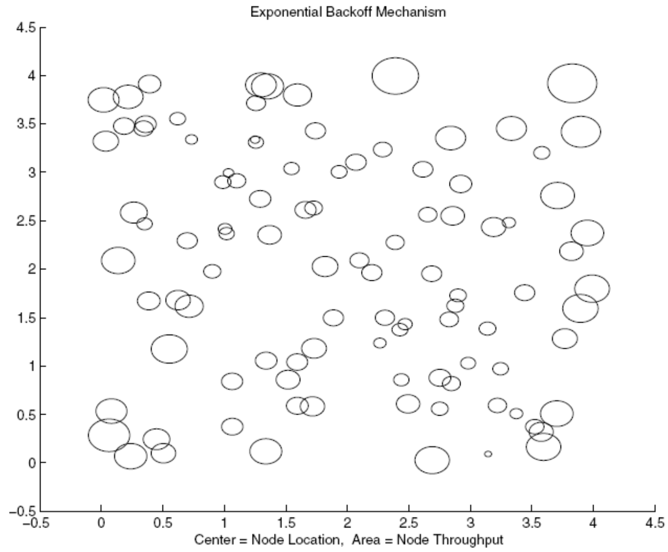

Figure 11: Node throughput in a random topology, Exponential Backoff.

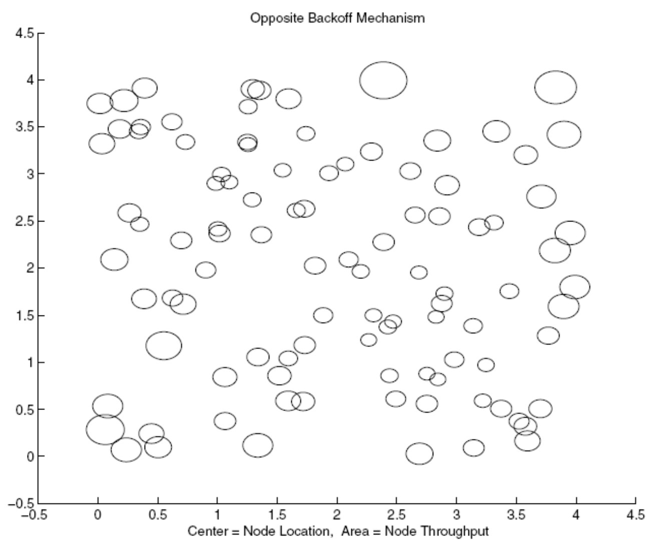

Figure 12: Node throughput in a random topology, Impatient Backoff

The traditional protocols of MANETs uses backoff algorithms to reduce congestions and collisions. The main purpose is to make the node less aggressive in the collision, so the new backoff algorithm as showed in the results allow the nodes to decrease the delay when a collision happens. The results proved that the new algorithm maintained higher fairness index.

Later in 2009, [12] came up with a new scheme which they named PEP (proportional fairness backoff algorithm), which introduce a new scheme that allows the close nodes to the sink area to get more opportunities to reach the proportional fairness.

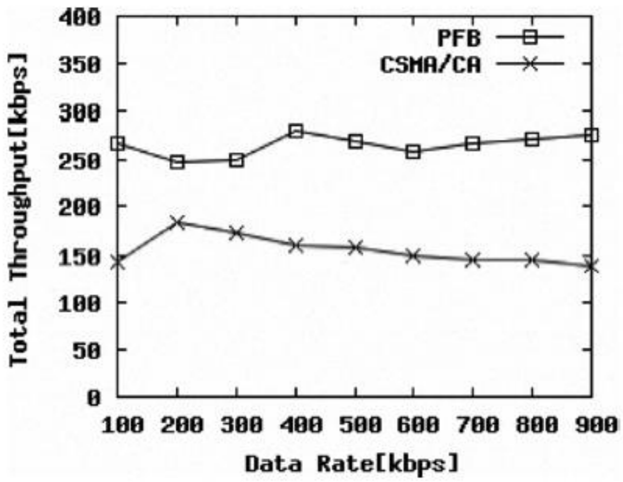

Figure 13: Throughput Comparison with Varying Data Rate

The figure shows that the rates of Data 100kbps, 200kbps, and 800kbps represent light, medium, and overload traffic scenarios respectively.

Results of this study showed that the new method outperformed the throughput of IEEE 802.11, CSMAlCA.

Contention window based fairness backoff algorithm was proposed by [13], as a modification on the binary backoff to enhance the unfairness of the opportunities a node can have after contention in 802.11 protocol.

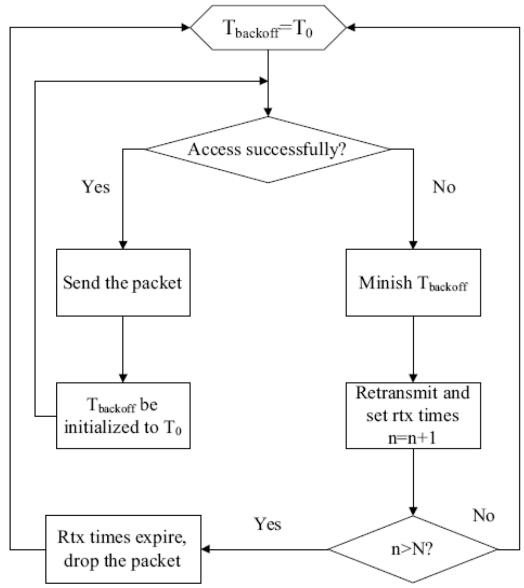

Figure 14: Algorithm for authority nodes

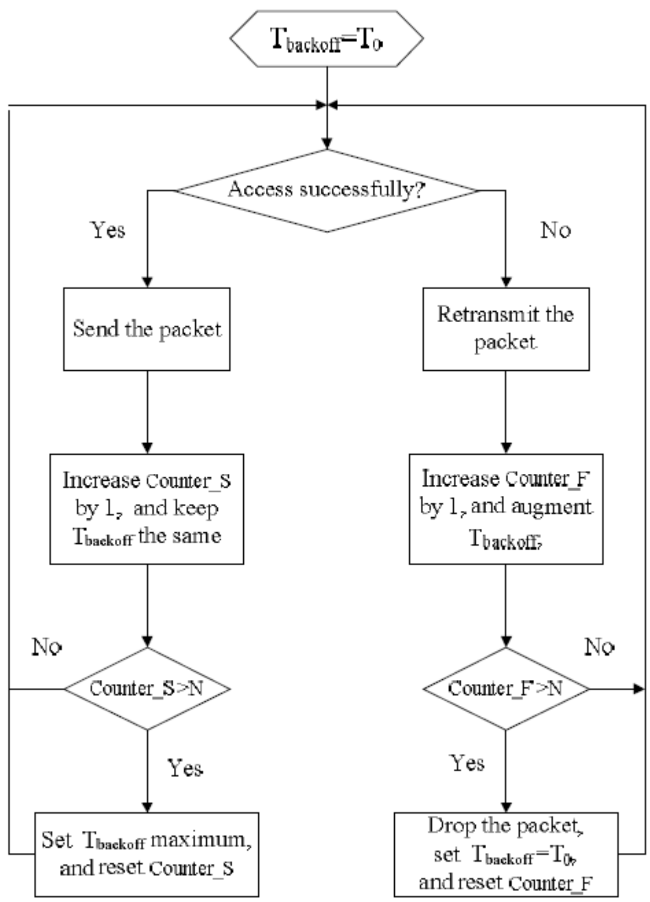

Figure 15: Algorithm for ordinary nodes

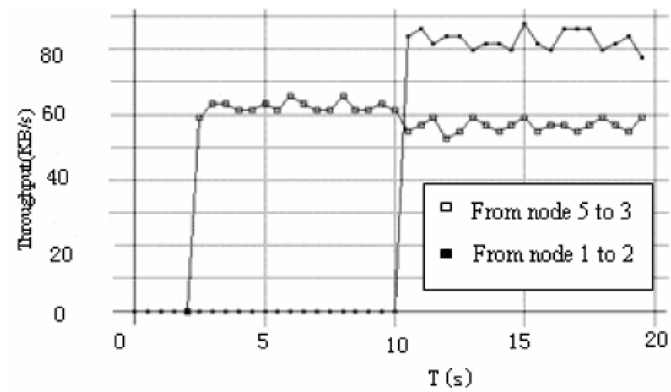

Figure 16: Transmission performance of ordinary nodes using

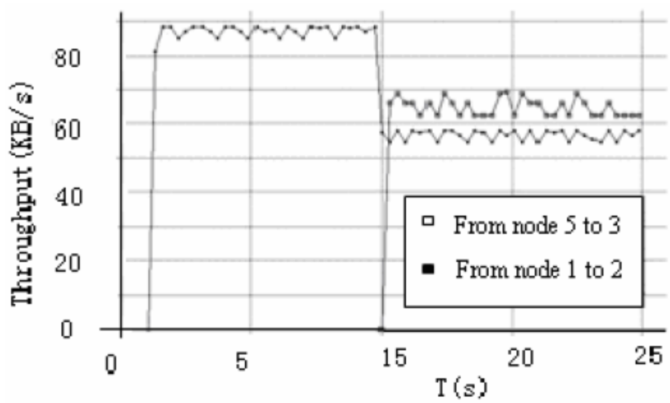

Figure 17: Transmission performance of leader nodes using

The results showed that this proposed algorithm could improve the fairness of accessing the channel of the network. This algorithm outperformed the enhancing algorithm suggested in [2][3][4], in enhancing the low system and decrease the overhead of communication.

In 2009, [14] introduced a new algorithm based on modifying the traditional backkoff algorithm, and was named the adaptive efficiency fairness tradeoff (AEFT). The new scheme increase the CW during the high traffic density, as well as using an adaptive window algorithm to decrease the backoff delay when the channel is inactive due to fair scheduling process. The fair schedule uses the Max-Successive transmission and collision limit to reach fairness.

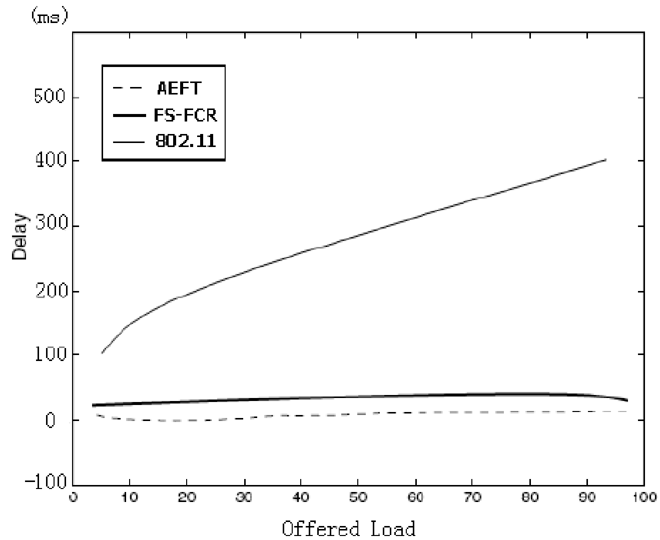

Figure 18: Time Delay with different loads

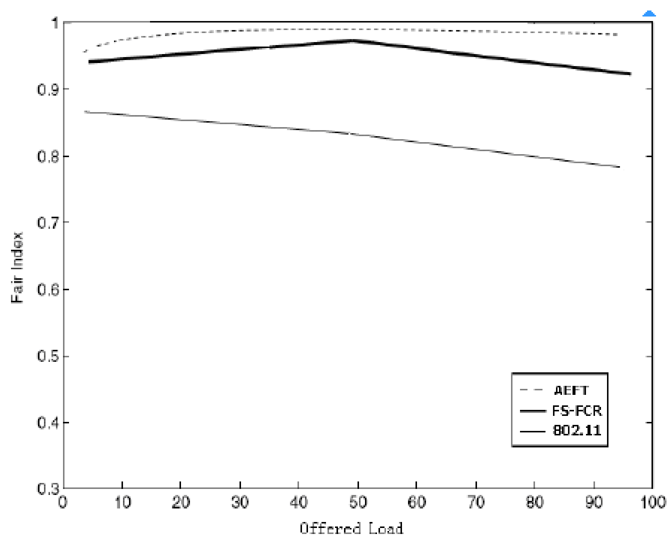

Figure 19: Fairness Performance

The results showed high throughput, and high fairness index too, also a tradeoff between fairness and network efficiency.

The effect of funneling on fairness was studies by [15], a scheme based on proportional fairness backoff was proposed for mitigating the funneling effect. The new algorithm named smac-based proportional fairness backoff (SPFB), has proven to achieve better fairness in energy consumption, moreover it outperforms the traditional MAC and SMAC in throughput.

[16] Made a comparison, between the TAOVD and TEA-AOVD protocol, in establishing a fair node process. The problem arise since the MANETs don't have tangible infrastructure, so the lack of centralization makes them targeted by networks attacks and sometimes for misbehavior by the nodes of the network [17][18]. The results showed that such protocols (Trust routing protocols) especially the two studied namely TAODV, TEA-AODV, deal with nodes unfairly, also they can cause a misbehaved node to take many opportunities than others.

Another algorithm was proposed by [19] to enhance the short term fairness in 802.11 protocol, regardless the CW size, named the Inverse binary exponential backoff scheme (iBEB), the algorithm proved enhancement in the throughput and a reduction in collision[28].

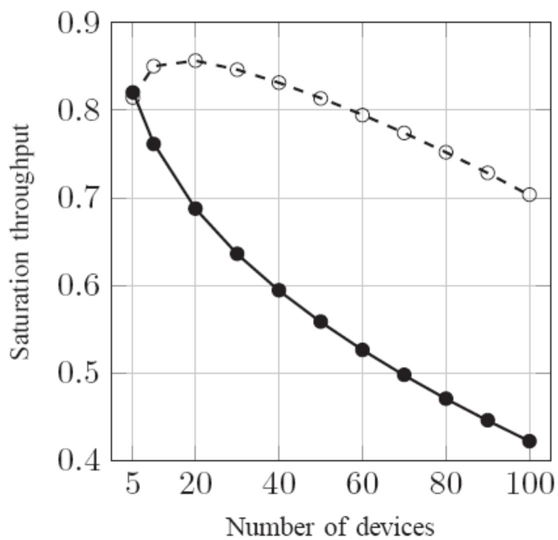

Figure 20: Saturation throughput

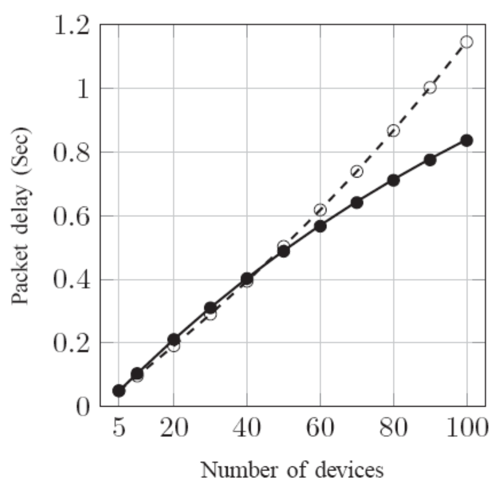

Figure 21: Average packet delay

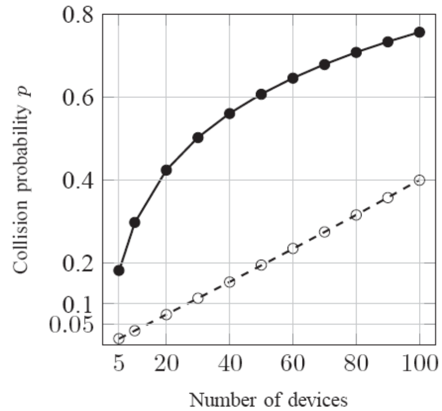

Figure 22: Collision probability p

DCF (analysis); iBEB (analysis);
DCF, basic access (simulation); iBEB, basic access (simulation);

The best of this algorithm is that it doesn't require any estimation of the network status, it simply allows nodes to get their backoff time randomly, then if a collision happens the node minimize its CW to enhance its opportunity to channel accessibility, thus increasing the fairness.

EXAMPLES OF FAIRNESS ISSUES IN WIRELESS NETWORKS.

Layers		Fairness issues	
		Resource allocation	Performance/utility measurements
Application		Resources (e.g., Internet bandwidth) should be shared fairly among different applications. For example, the on-line video application for two users in a LAN should share the bandwidth fairly.	The applications on one wireless device or different devices should have fair utility in wireless environment. For instance, two devices running online video application should provide fair continuous real-time playing and quality of videos.
Transport		Flow control at transport layer, multiplexing ports, and data buffering.	Quality of Service (QoS) among different end terminals such as congestion control, reliability, end-to-end communication and data loss rate.
Network		Routing path choices, route discovery, message forwarding, and flow control at network layer.	Load balancing for wireless routers and security.
Data link	LLC	Flow control on LLC, Error detections, and multiplexing among different upper layer protocols.	Bit error rates (BER) and packet delay.
	MAC	Multiple channel accessing such as collision avoidance using TDMA or CSMA/CA, data packet queuing and scheduling on physical layer, channel sharing among different wireless technologies, such as Bluetooth, WiFi and zigbee, and flow control on MAC layer.	Environment interference among nodes, and transmission power control.
PHY		Transmission power assignment on antennas and battery energy allocation.	Lifetime, energy consumption, and other performance measures.

To solve the problem of DSDV and AODV protocol mentioned earlier, some modifications were made to these protocols by [22], the Ant colony optimization is used, and results were compared to the traditional version of these protocols.

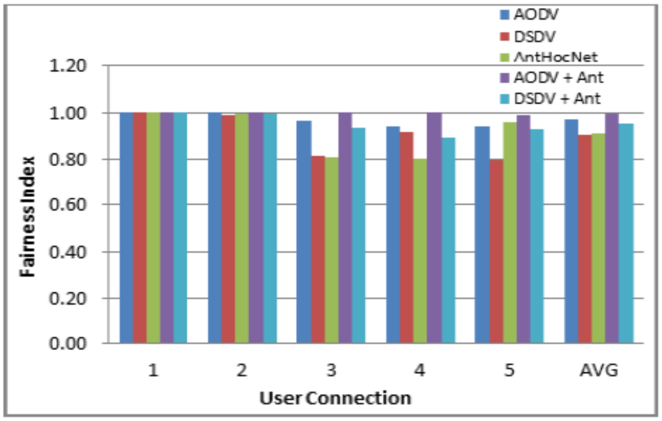

Figure 23: Fairness Index all routing protocols

TABLE 1: SUMMARY OF COMPARISON RESULT

Routing Protocols	Throughput	Delay Time	OR	Index Fairness
AODV	High	High	High	0.97
DSDV	Low	Low	Low	0.90
AntHocNet	Low	High	High	0.91
AODV+Ant	Morse High	High	High	1.00
DSDV+Ant	High	Low	Low	0.95

The results showed an enhancement in throughput for AODV 6.36%-13.2%, and for DSDV .68%-5.47%.

Recently in 2016, [23] proposed a new backoff algorithm for 802.11 MANETs; to help in achieving higer throughput and approach fairness through adjusting the CW size. The proposed algorithm is named Maximum Throughput and fairness aware backoff (MTFB).

The results showed that the new algorithm outperformed the traditional one.

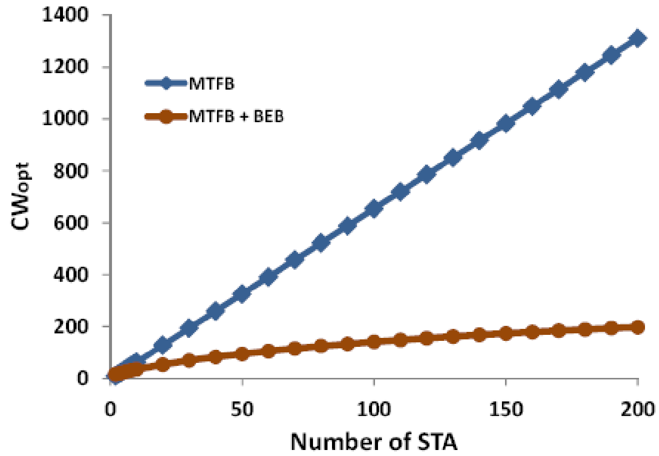

Figure 24: MTFB CW size for single and co-existence scenarios

Regarding performance evaluation, the results shown in the following figures:

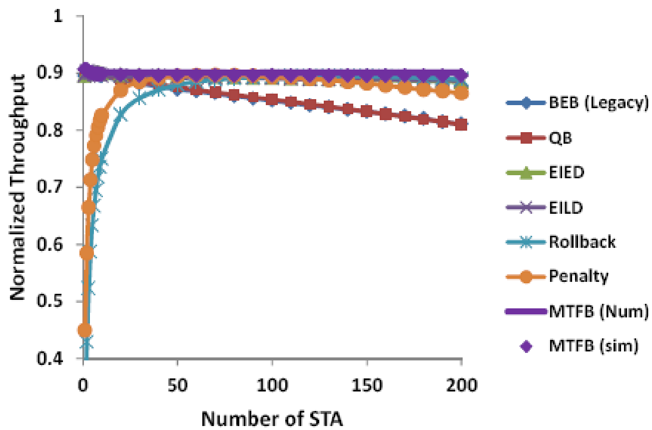

Figure 25: Normalized throughput comparison

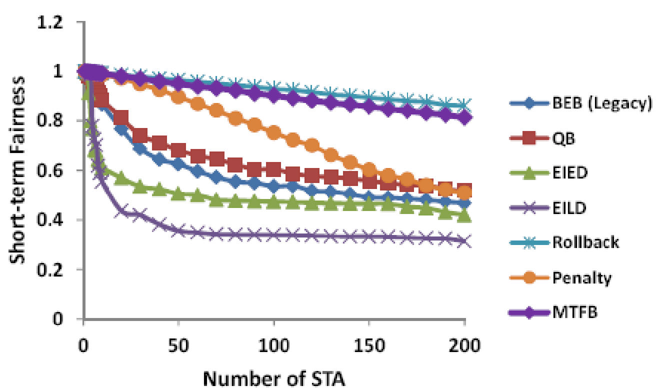

Figure 26: Short-term fairness comparison

The algorithm helps to select the optimal CW adaptively. It proved high throughput and higher short-term fairness with lower complexity, since it doesn't need the multiple stages and levels of backoff [23][24].

The Fair MAC Protocol (FMAC), was proposed based on IEEE 802.11, to enhance fairness in [25]. Since the nodes that are slower than others overrun channel utilities for a long time, this affects the throughput of the networks.

The proposed protocol uses the periods of backoff delay to choose the optimal CW time and enhance the utilizing of power consumption in the network be decreasing the number of collisions.

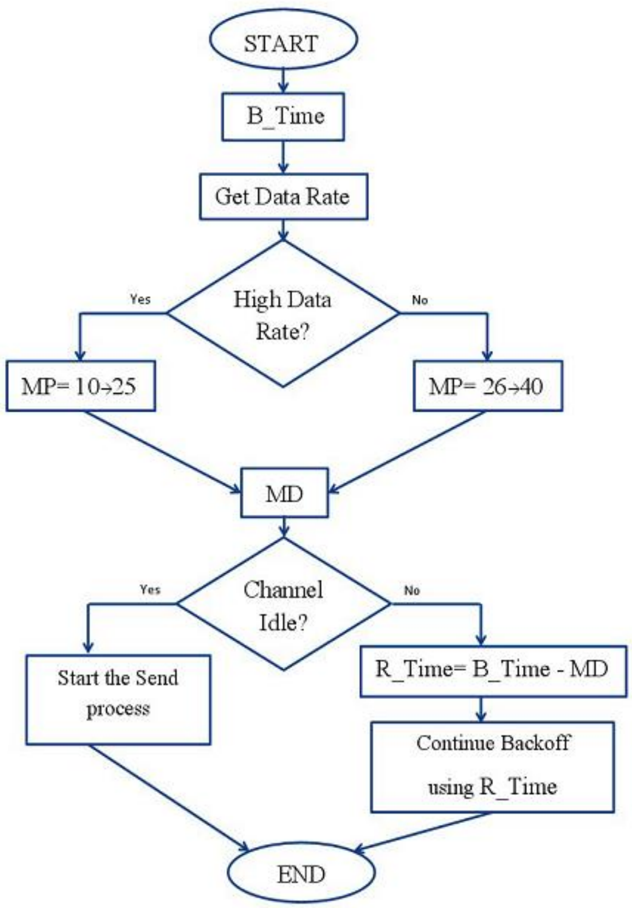

Figure 27: Flow chart of the main stages of FMAC.

The results of comparison between the traditional 802.11 and the proposed FMAC are showed in the following figures regarding the fairness:

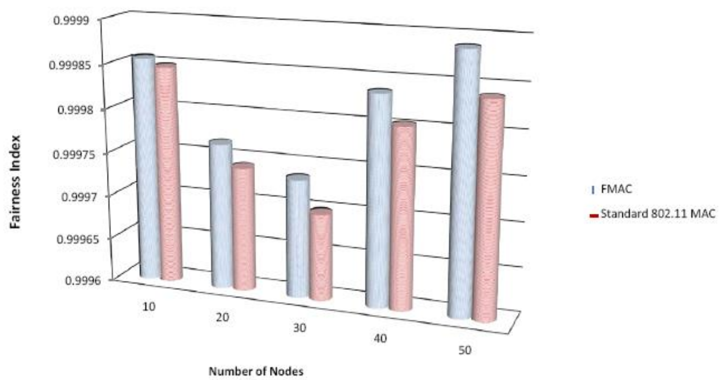

Figure 28: Comparison of Jain's fairness index of FMAC and standard MAC

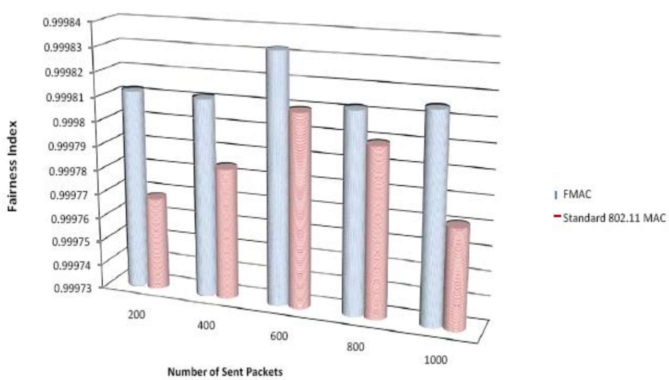

Figure 29: Comparison of Jain's fairness index of FMAC and standard MAC

The experiment showed that transmission is faster through applying FMAC, and the power consumption has decreased. And the fairness has increased. Thus, the throughput has been enhanced and increased.

In 2017, [26] has used the history of network collisions number, to propose a new adaptive MAC for CW size, to solve the backoff delay that the network suffers in heavy load and dense situations, the CW is automatically modified, to lower the power consumption and increase the throughput.

Begin

$CW = CW_{min}$

If (collision occurs), **then**

If $(0 < i <= TH_1)$

$$CW = \left[CW_{min} * \prod_{n=0}^{i-1} \left(1 + \frac{TH_1 - n}{TH_1}\right) \right]$$

Else if $(TH_1 < i <= TH_2)$

$CW = \mathrm{Min}(CW * 2, CW_{max})$

Else

$CW = CW_{min}$

End

Else if (transmission is successful), **then**

If (last transmission is successful)

$CW = \mathrm{Max}([CW / 2], CW_{min})$

Else

$CW = CW$

End

End

End

Figure 30: Proposed back-off algorithm.

The experiment was applied on both topologies of Mesh and linear networks. The results in both cases showed higher throughput and lower energy usage, as well as achieving better fairness. The following figures are chosen for Mesh and linear networks though the traffic load is lighter in linear topology.

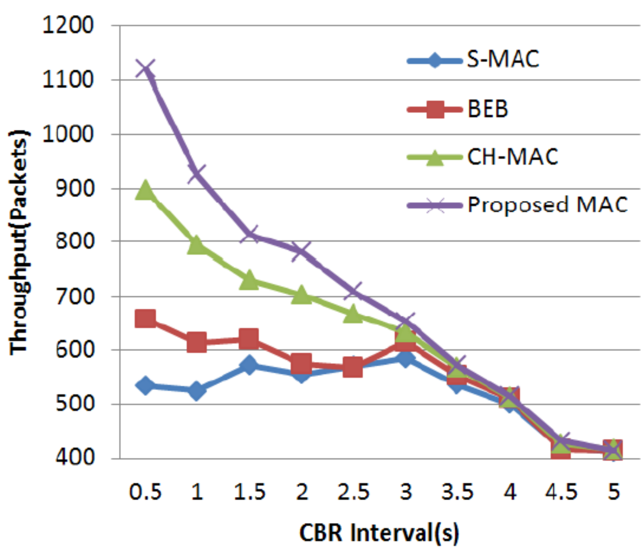

Figure 31: Throughput comparison in mesh topology.

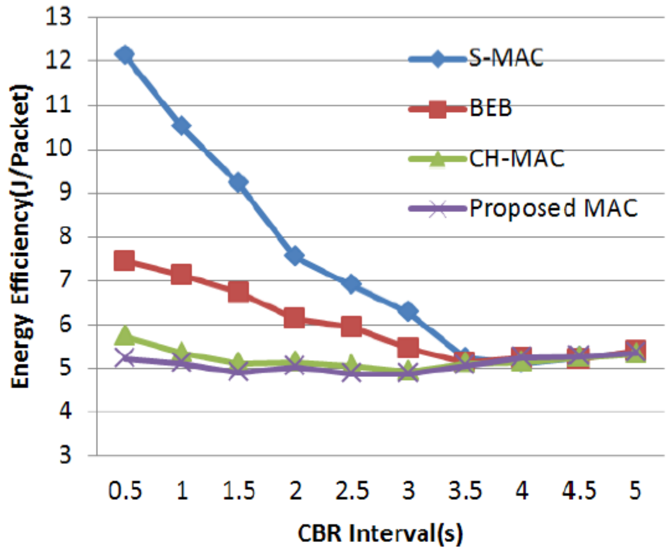

Figure 32: Energy comparison in mesh topology

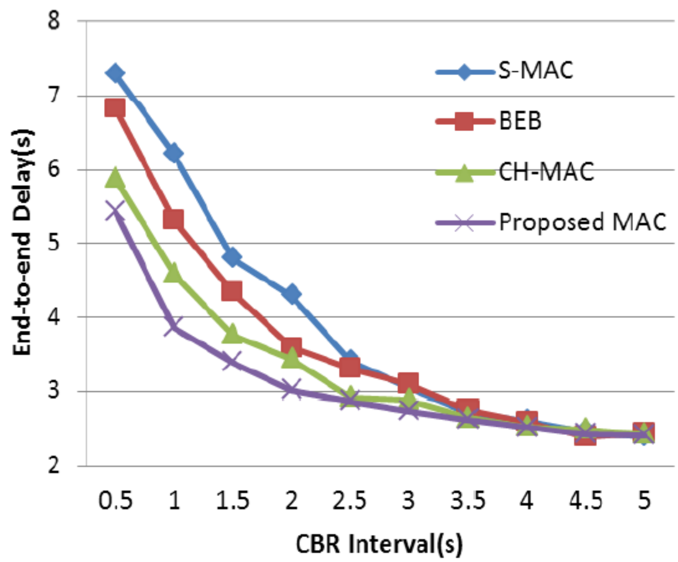

Figure 33: End-to-end delay comparison in linear topology

Many research papers has focused on proposing back algorithms, to enhance fairness and performance of the network, backoff is considered as one of the mail algorithms that can be modified and used to mitigate the delays and collisions during transmissions, main studies that targeted the fairness directly are detailed above, and many other algorithms like [28][29][30][31], can be modified to enhance the performance through fairness in networks [32].

3. Conclusion

Most of the studies surveyed in this paper, have searched the fairness issue in network and how to enhance it, mainly concentrating on these parameters: Contention window (Min and Max values), backoff delay time, packet size, Area of network, speed, density (Traffic load), transmit energy.

Most of the experiments showed an enhancement in fairness achieved, through adjusting backoff algorithms and contention windows, in terms of reducing collisions and resulting in high throughput. Considering the network conditions and settings of the studies parameters. This implies that fairness affects the quality of service which makes it is a significant factor that should be studied well to enhance the performance of the wireless network, increasing the efficiency and decreasing the collisions and delays.

4. Recommendations

More research should be conducted in the field of fairness algorithms and more parameters should be taken into considerations.

Conflict of Interests

The authors declare that there is no conflict of interests.

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