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Dynamically Estimating the Number of WLAN to Improve the Throughput and Fairness

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Abstract: WLANs have become increasingly popular and widely deployed. The MAC protocol is one of the important technologies of the WLANs and affects communication efficiency directly. A distributed MAC protocol has the advantage that infrastructure such as an access point is unnecessary. On the other hand, total throughput decreases heavily increase in network density, which needs to be improved. Previous research works gave proposals with improved throughput but a degraded fairness. In this paper, focusing on MAC protocol, we propose a novel protocol that each node estimates the number of nodes in a network with a short convergence time and no overhead traffic burden added to the network through observing the channel, and nodes dynamically optimize their backoff process to achieve high throughput and satisfactory fairness. Since necessary indexes can be obtained through direct measurement from the channel, our scheme will not involve any added load to networks, which makes our schemes simpler and more effective. Through simulation comparison with recently proposed methods, we show that our scheme can greatly enhance the throughput with good fairness without it signifying whether the network is in saturated or non-saturated state.

Keywords: backoff, traffic adaptability, MAC protocol, DCF, throughput, fairness.

1. Introduction

Wireless local area networks (WLANs) have become increasingly popular and widely deployed. There are two channel access methods, one is DCF (Distributed Coordination Function) and another is an optional centralized PCF (Point Coordination Function). Due to inherent simplicity and flexibility, DCF is preferred in the case of no base station such as vehicle to vehicle communications. Since all the nodes share a common wireless channel with limited bandwidth in WLANs, it is highly desirable that an efficient and fair medium access control (MAC) scheme is employed. However, for the DCF, there is much room for improvement in terms of both efficiency and fairness. Cali et al. pointed out in Ref. [1] that depending on the network configuration, DCF may deliver a much lower throughput compared to the theoretical throughput limit. Meanwhile, as demonstrated in Ref. [2], the fairness as well as throughput of the DCF could significantly deteriorate when the number of nodes increases.

Although many researches have been conducted to improve throughput and fairness, few of them enhanced both of two performance metrics. In DCF, estimating the number of nodes is difficult because each node can reach or leave the network freely. For that reason, many researches have avoided estimating the number of nodes. In Ref. [3], although the number of nodes is estimated, however, it is complicated and it takes time to carry out this procedure. In Refs. [4] and [5], these schemes observe the average idle interval, and adjust the CW (Contention Window) in order to obtain a higher throughput. However these schemes do not estimate the number of nodes and have an issue in that the variation in CW of each node is large, which results in fairness degradation. In Ref. [6], based on Ref. [4], to improve the problem of fairness which is important for real time communication, authors introduced a method to achieve better fairness but this is still not enough. In this paper, focusing on MAC protocol, we propose a novel protocol that each node estimates the number of nodes in a network with short convergence time and no overhead traffic burden added to the network through observing the channel, and nodes dynamically optimize their backoff process to achieve high throughput and satisfactory fairness.

The remainder of this paper is organized as follows. In Section 2, we describe the conventional method and related work. We elaborate on our key idea and the theoretical analysis for improvement in Section 3. Then we present in detail our proposed OBEN (Optimizing Backoff by dynamically Estimating Number of nodes) scheme. Section 4 gives a performance evaluation and discusses the simulation results. Finally, concluding remarks are given in Section 5.

2. Preliminaries

To better understand our scheme, first we briefly introduce the DCF. Then, we discuss the related work.

2.1 Operations of the IEEE 802.11 MAC

The DCF is based on a mechanism called carrier sense multiple access with collision avoidance (CSMA/CA). In DCF, a node

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with a packet to transmit initializes a backoff timer with a random value selected uniformly from the range $[0, CW]$, where CW is the contention window in terms of time slots. After a node senses that the channel is idle for an interval called DIFS (DCF interframe space), it begins to decrease the backoff timer by one for each idle time slot. When the channel becomes busy due to other nodes' transmissions, the node freezes its backoff timer until the channel is sensed idle for DIFS. When the backoff timer reaches zero, the node begins to transmit. If the transmission is successful, the receiver sends back an acknowledgment (ACK) after an interval called SIFS (short interframe space). Then, the transmitter resets its CW to $CW_{\min}$. In the case of collisions, the transmitter fails to receive the ACK from its intended receiver within a specified period with the result that, it doubles its CW until reaching a maximum value CW_{max} after an interval called EIFS (extended interframe space), chooses a new backoff timer, and starts the above process again. When the transmission of a packet fails for a maximum number of times, the packet is dropped.

2.2 Related Work

Considerable research efforts have been expended on either theoretical analysis or throughput improvement (Refs. [1], [2], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18]). In Ref. [1], Cali et al. derived an optimal CW that can maximize throughput. With the optimal CW, a backoff algorithm is proposed. Also, the method for estimating the number of nodes is proposed, however, this is complicated and it takes time to estimate the number of nodes, which is short of adaptivity to network changes. In Ref. [2], Bianchi used a Markov chain to model the binary exponential backoff procedure. By assuming the collision probability of each node's transmission is constant and independent of the number of retransmissions, he derived the saturated throughput for the DCF. Kim and Hou developed a model-based frame scheduling algorithm to improve the protocol capacity of the 802.11 [18]. In this scheme, each node sets its backoff timer in the same way as in the IEEE 802.11; however, when the backoff timer reaches zero, it waits for an additional amount of time before accessing the medium. Though this scheme improves the efficiency of medium access, the calculation of the additional time is complicated since the number of active nodes must be accurately estimated. In Refs. [8], [9], [10], the works improve throughput and fairness for multirate traffic in the saturated case. However, in Ref. [8], the MAC frame header contains the additional information, and the throughput becomes low in the non-saturated case. These works [9], [10] assume that the system environment is coordinated by an access point (AP). That is, they do not work without AP. In our previous study, a novel MAC protocol OSRAP was proposed [19], which can achieve a low packet delay and higher throughput. However, it needs to select a node as the head, which is not a perfect distributed protocol. In Idle Sense [4] and DOB [5], each node observes the average idle interval between two transmissions, and selects optimal CW according to the average idle interval to obtains high throughtput. However, the works cannot avoid the multiple transmissions from other nodes between two transmissions of a node and fairness is degraded. In AMOCW [6], based on Idle Sense, changes the method of collecting the average idle interval for preventing the multiple transmissions. With throughput like Idle Sense, AMOCW obtains fairness better than Idle Sense but not enough due to using AIMD (Additive Increase Multiplicative Decrease) algorithm. The fairness is another important issue in MAC protocol design [20].

Here, we propose a novel protocol OBEN to improve both throughput and fairness. OBEN estimates the number of active nodes in a simple but effective way instead of the complicated method used before. Compared to the methods in Refs. [4], [5], [6], since each node in OBEN can correctly estimate the number of nodes and keep its CW close to the same optimal value, OBEN can maintain fairness and keep the network operating with less fluctuation.

3. Analysis and the Proposal of Optimizing Backoff by Dynamically Estimating the Number of Nodes

3.1 Motivation

In the IEEE 802.11 MAC, an appropriate CW is the key to providing throughput and fairness. A small CW results in a high collision probability, whereas a large CW results in wasted idle time slots. In Ref. [1], Cali et al. showed that given the number of active nodes, there exists an optimal CW that leads to the theoretical throughput limit and when the number of active nodes changes, so does this optimal CW. Since in practice, the number of active nodes always changes, to let each node attain and keep using the corresponding optimal CW requires the estimation of the number of active nodes. However, previous methods for on line estimation and convergence time for all nodes are complicated since to estimate the exact number of nodes takes a long time. To get around this difficulty, we are thus motivated to find another effective method that leads us to the optimal CW and hence the maximal throughput.

We expect the improvement protocol to have several characteristics such as 1) no added overhead of measurement for understanding network situation 2) being concise and effective; 3) achieving both high throughput and comparatively good fairness. One problem for DCF is that when traffic increases throughput will reach the upper bound and the maximum throughput is lower than PCF, so added overhead of measurement is not expected. In the situation where there is limited computation resource of a mobile node and a changing network, a concise and effective protocol is desirable. For vehicle to vehicle communication, real time data needs to be sent with little delay and each vehicle needs a minimum data rate for urgent data transmission even in a saturation case, so both high throughput and comparatively good fairness are required. We try to get the necessary information for optimizing transmission in a wireless network by listening to the wireless channel, which is simple since the DCF is in fact built on the basis of physical and virtual carrier sensing mechanisms. As shown below, we obtain the necessary indexes to give an improved protocol through listening to the wireless channel.

Multihop wireless networks are necessary for systems such as vehicle to vehicle communications. The DCF is preferred since it can work without AP. In multihop wireless networks, the throughput becomes low because of hidden terminal problems and a multi-channel is an effective method in that a group of nodes communicates with a single frequency channel. In this paper, we assume that the nodes of network communicate with each other using a certain frequency channel in one hop area, while leaving the task of how to arrange frequency channel to each group as the next work. Here, we try to give an effective protocol with high throughput and good fairness for one hop area.

In the following, we derive the relationship between average idle interval and throughput through analysis. For the purpose of simplicity, we assume the frame length is constant and give the simulation results with different packet sizes.

3.2 Analytical Study

In the IEEE 802.11 MAC, an appropriate CW is the key to providing throughput and fairness. In Ref. [1], the DCF is analyzed based on the assumption that, in each time slot, each node contends for the medium with the same probability p subject to $p = 1/(E[B] + 1)$, where $E[B]$ is the average backoff timer and equals $(E[CW] - 1)/2$. Since our OBEN would enable all the nodes to settle on a quasi-stable CW shortly after the network is put into operation, for simplicity we assume that all the nodes use the same and fixed CW. Consequently, we have

$$p = \frac{2}{CW + 1} \tag{1}$$

as all the expectation signs E can be removed. Channel events can be thought of as three types of events, successful transmission, collision, and idle. Suppose every node is an active one, i.e., always having packets to transmit. For every packet transmission, the initial backoff timer is uniformly selected from $[0, CW]$. For each virtual backoff time slot, it may be idle, or busy due to a successful transmission, or busy due to collision. Accordingly, we denote by P_{idl}, P_s, and P_{col} the probabilities of the three types of events, respectively. Thus, we can express the above probabilities as

$$\begin{aligned} P_{idl} &= (1 - p)^n \\ P_s &= np(1 - p)^{n-1} \\ P_{col} &= 1 - P_{idl} - P_s \end{aligned} \tag{2}$$

where n is the number of active nodes. Thus, the throughput is expressed as

$$\rho = \frac{TP_S}{t_{slt}P_{idl} + T_{col}P_{col} + T_{tx}P_s} \tag{3}$$

where T is the transmission time of one packet, t_{slt} is slot time, T_{tx} is the successful transmission duration and T_{col} is the collision duration. Our aim is to maximize throughput shown in Eq. (3). To this end, we need to obtain the optimal CW according to the network condition such as the number of nodes. In the following, we give the method for estimating the number of nodes on line by three parameters P_{idl}, P_s and P_{col} which can be obtained directly by listening to the channel for a certain interval. Then, using obtained P_{idl}, P_s and P_{col}, we give the method for maximizing the throughput dynamically. Calculating the number of nodes directly by Eq. (2) is inefficient and unrealistic. Here, we use a simple and effective method which is suitable for real time estimating. From Eq. (2), we have $P_{idl}/p_s = (1 - p)/(np)$, then $p = P_s/(nP_{idl} + P_s)$. Substitute p in $P_{idl} = (1 - p)^n$, it becomes as following,

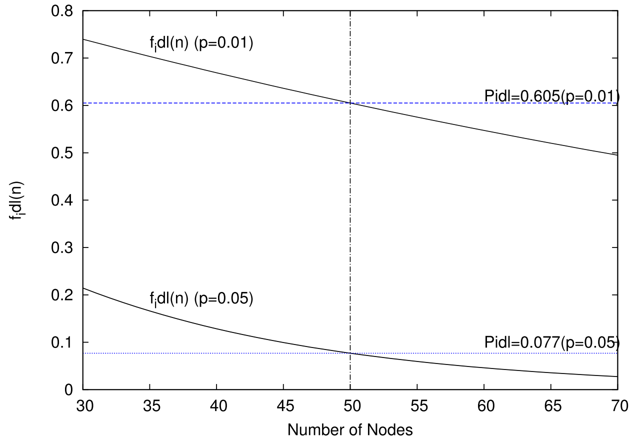

Fig. 1 Monotone function $f_{idl}(n)$ when the real value of n is 50.

$$P_{idl} = \left(1 - \frac{P_s}{nP_{idl} + P_s}\right)^n . \tag{4}$$

Let $f_{idl}(n) = \left(1 - \frac{P_s}{nP_{idl}+P_s}\right)^n$, where P_{idl}, P_s and P_{col} are known parameters and n is the unknown parameter that needs to be estimated. Then when $f_{idl}(n_0) = P_{idl}$, n_0 is the needed value. We find that $f_{idl}(n)$ is the monotone function. We take the derivative of f_{idl} with respect to n, and let $\frac{\mathrm{d}f}{\mathrm{d}n} = [\ln\left(1 - \frac{P_s}{nP_{idl}+P_s}\right) + \frac{P_s}{nP_{idl}+P_s}]\left(1 - \frac{P_s}{nP_{idl}+P_s}\right)^n$. It can be found that the second term is always plus. Let $x = \frac{P_s}{nP_{idl}+P_s}$, then $0 \leq x \leq 1$.Then, the first term of $\frac{\mathrm{d}f}{\mathrm{d}n}$ becomes $\ln(1 - x) + x$ which changes from 0 to $-\infty$ when x changes from 0 to 1. So, it can be understood that $\frac{\mathrm{d}f}{\mathrm{d}n}$ is not plus.

We can estimate the number of nodes by the simple calculation method, without solving a complicated equation. As shown in **Fig. 1**, the monotone function $f_{idl}(n)$ always decreases as the number of nodes is increasing. Since P_{idl} is a known value, $f_{idl}(n)$ should be adjusted in agreement with P_{idl}. When P_{idl} is equal to $f_{idl}(n)$, n is the number of nodes deployed in real network.

The above characteristic is favorable for estimating the number of nodes n which can be calculated by the following dichotomy. Supposing n is in a range $[0, n_{\max}]$, initially let $n_{try1} = n_{\max}/2$ and substitute it into $f_{idl}(n)$. Then compare $f_{idl}(n_{try1})$ with P_{idl}. If $f_{idl}(n_{try1}) > P_{idl}$, we should set $n_{try2} = [n_{try1} + n_{\max}]/2$. Otherwise, we should set $n_{try2} = [n_{try1} + 0]/2$ for the following calculation. Obviously, this method is simple and effective. For example, when $n_{\max} = 100$, we just need to calculate four times to estimate n in the worst case with maximum error 3. In the following, we present the condition of high throughput. And then, we give the method of how to dynamically tune CW to enhance throughput and fairness. The average idle slot interval is denoted by L_{idl}, it can be expressed as

$$L_{idl} = \frac{P_{idl}}{1 - P_{idl}}. \tag{5}$$

With Eqs. (1), (2) and (5), this equation can be further written as

$$L_{idl} = \frac{1}{(1 + 2/(CW - 1))^n - 1}$$

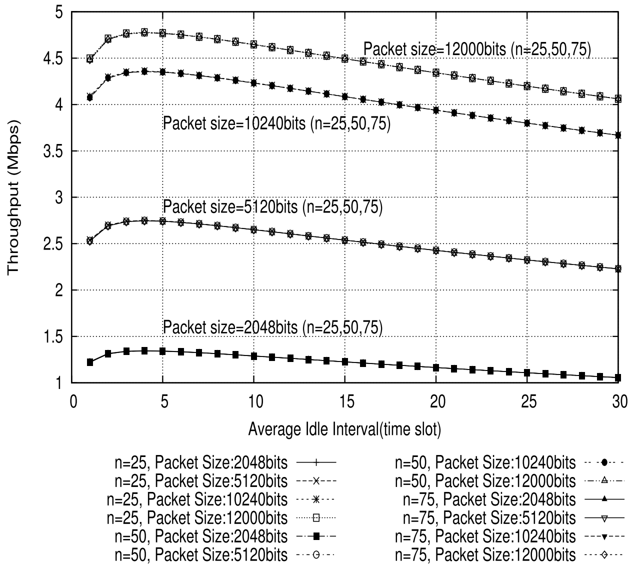

Fig. 2 Throughput with average idle slot interval.

$$= \frac{1}{n\frac{2}{CW-1}+\ldots+\binom{n}{i}\left(\frac{2}{CW-1}\right)^{n-i}+\ldots+\left(\frac{2}{CW-1}\right)^{n}}. \quad (6)$$

We can simplify Eq. (6) as

$$L_{idl} = \frac{CW-1}{2n}. \quad (7)$$

We can obtain Eq. (7) when CW is large enough. As a matter of fact, this is the case when the network traffic load is heavy. In this case, to effectively avoid collisions, the optimal CW is large enough for the approximation $L_{idl} = (CW-1)/(2n)$ in our OBEN, which is also verified through simulations.

With Eqs. (3) and (7), thinking IEEE 802.11b, we can express the throughput as a function of Lidl with SIFS = 10 s, DIFS = 28 s, ACK = 304 bits and time slot = 9 s, as shown in **Fig. 2**. From the figure, first, we find that every curve follows the same pattern; namely, as the average idle slot interval L_{idl} increases, the throughput first rises quickly, and then decreases relatively slowly after reaching its peak. Second, although the optimal value of L_{idl} that maximizes throughput is different in cases of different frame lengths, it varies in a very small range, which hereafter is called the optimal range of L_{idl} corresponding to different frame lengths. Finally, this optimal value is almost independent of the number of active nodes. Therefore, L_{idl} is a suitable measure that indicates the network throughput. If nodes can estimate the number of nodes correctly, they can set the optimal CW by L_{idl} and n to achieve high throughput.

In Fig. 2, it can be observed that L_{idl} is almost a linear function of CW when CW is larger than a certain value. Specifically, in the optimal range of L_{idl}, say $Lidl = [4, 6]$. From the above Eq. (7), according to the number of nodes, each node can set the optimal CW that $CW = 2nL_{idl} + 1$. Since we are interested in tuning the network to obtain maximal throughput, given the linear relationship, we can achieve this goal by adjusting the size of CW. In other words, each node can estimate the number of nodes and adjust its backoff window accordingly so that the throughput of the network is maximized.

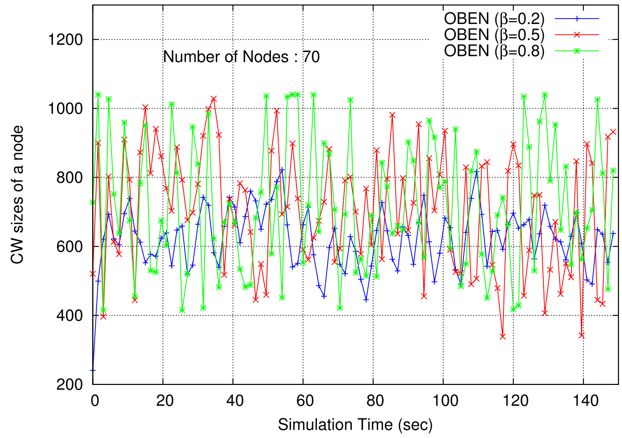

Fig. 3 CW sizes with simulation time when the β is changed.

3.3 OBEN Scheme

As mentioned above, we can obtain the optimal CW by Eq. (7) by using the estimated number of active nodes. Hence, each node can adjust its CW dynamiclly and tune the network to deliver high throughput. To obtain the P_{idl}, P_s and P_{col}, we can count the number of idle slots (C_{idl}), collisions (C_{col}) and successful transmissions (C_s) individually. To avoid occasional cases, C_{idl}, C_{col} and C_s are expected to be measured in resetting the counters before a transmission. The P_{idl}, P_s and P_{col} can be calculated as

$$P_{idl} = \frac{C_{idl}}{C_{idl}+C_s+C_{col}}$$
$$P_s = \frac{C_s}{C_{idl}+C_s+C_{col}}$$
$$P_{col} = \frac{C_{col}}{C_{idl}+C_s+C_{col}} \quad (8)$$

Since different MAC protocols have different definitions of time interval such as DIFS, SIFS, C_{idl} may need to be adjusted. A node calculates the CW before packet transmissions. After new CW (newCW) is obtained, the CW can be updated as

$$CW = \beta \cdot CW + (1-\beta) \cdot newCW \quad (9)$$

where β is a smoothing factor with the range of [0,1]. **Figure 3** shows the sizes of CW of a node with simulation time when the β is changed. The higher β leads to stability but maybe reduces adaptivity to network changes such as traffic and active nodes. In OBEN, the sizes of CW are largely varied by little changes in the probabilities of idle, successful transmission and collision, which results in degraded throughput and fairness. For minimizing the variation of CW and adjusting the changes in the number of nodes, we set $\beta = 0.8$ in simulation results in the next section. In the following, we give the tuning algorithm.

1. A node, say Node A, begins listening to a channel and counts events of idle slot, successful transmission and collision individually.

2. When Node A needs backoff and the number of packet transmissions reaches a certain number, it calculates the optimal CW as a new CW and resets CW according to Eq. (9).

3. It resets counting events of idle slot, successful transmission and collision.

The certain number of packet transmissions needs to be set appropriately. When the number is small, CW changes rapidly with network changes. In contrast, if the number is large, the network can have higher stability but is short of adaptivity. In the following simulation, we set a certain number as 2. Ideally, each node should have the same CW when the network enters into a steady state in saturated case; in reality, each node sets its CW around the optimal value. Using this method, high throughput and good fairness are achieved, which can be found in the following simulations.

4. Performance Evaluation

In this section, we focus on evaluating the performance of our OBEN through simulations, which are carried out on OPNET Modeler [21]. For comparison purposes, we also present the simulation results for the IEEE 802.11b DCF. In all the simulations, we consider the MAC scheme, where RTS/CTS mechanism is used. Generally, OBEN works for all IEEE 802.11 family. Though many improved IEEE 802.11 MAC protocols have been proposed, the evaluation condition and environment are different. Here, we compare our proposed OBEN with AMOCW proposed in Ref. [6] which achieved the best results and Idle Sense [4]. In view of the fact that the performance of IEEE 802.11 standard is well known, in this paper, we also use IEEE 802.11b as the standard reference. The related parameters of IEEE 802.11b are shown in **Table 1** and the OBEN-specific parameters in **Table 2**. The L_{idl} is 5 for obtaining high throughput as shown in Fig. 2.

We assume that network nodes are distributed at random in a round area with a 200 meter radius and that all nodes are in the communication range. Without a specific application, we assume that each node generates traffic according to a Poisson process with the same arrival rate. Since we focus on throughput in the saturated case, the throughputs with different arrival distributions are slightly different in the border around the non-saturated and saturated case but the effects of an arrival distribution are extremely small. In the fully non-saturated case and saturated case, the throughputs are almost similar. Each node selects another node at random as a receiver. The arrival rate is kept increasing until the network is saturated. As shown below, OBEN exhibits a better performance.

4.1 Throughput

Firstly, we give the throughput of four schemes, i.e., OBEN, AMOCW, Idle Sense and DCF of IEEE 802.11b under different offered loads and packetsizes. **Figure 4** shows the throughput results with a different number of nodes. The packet size is the size of payload data at MAC layer and does not include MAC overhead, which is one reason that the simulation results are lower than the theoretical values. The throughput is the total data traffic successfully received.

The throughput of IEEE 802.11 DCF decreases with the number of nodes increasing. When the number of nodes changes from 10 to 100, the throughput of IEEE 802.11 DCF falls from 3.68 Mbps to 3.12 Mbps, about 18% down. On the contrary, our proposal OBEN, Idle Sense and AMOCW have almost no changes. The throughput of OBEN is almost same as that of Idle Sense and AMOCW, that the three lines of OBEN, Idle Sense and AMOCW overlap each other in the figure. The detail can be found in the **Table 3** with throughput data. While achieving as high throughput as AMOCW, OBEN has a better fairness, which will be shown in the next section.

4.2 Variation of CW and Fairness

Many researches deal with the fairness of networks [22]. For different applications, there are different requests. Here, we omit the detail and just evaluate this item in way of an intuitive awareness. IEEE 802.11 applies an exponentiation backoff algorithm which can disperse retransmission timing among collision nodes. However, some nodes may defer time too long so that they cannot transmit for a long interval, which results in poor fairness as occurred in AMOCW and Idle Sense. We can evaluate the fairness of OBEN with AMOCW through the observation of CW variation in the saturation case. **Figure 5** shows the instantaneous value of CW of a node in simulation. At the beginning, 20 active nodes compete for the channel. After 50 seconds, 40 nodes

Table 1 Network configuration.

Parameter	Value
$MinCW$	31
$MaxCW$	1,023
SIFS	10 μsec
DIFS	50 μsec
Slot time	20 μsec
Bit rate	11 Mbps

Table 2 Backoff parameters.

Parameter	Value
L_{idl}	5
β	0.8
Maximum number of nodes	100

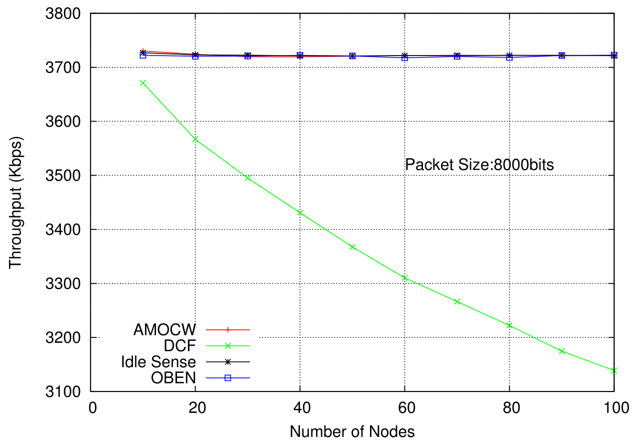

Fig. 4 Throughput with node numbers.

Table 3 Throughput (Kbps) with node numbers.

N	AMOCW	DCF	Idle Sense	OBEN
10	3,730	3,671	3,727	3,722
20	3,724	3,567	3,723	3,721
30	3,720	3,495	3,723	3,721
40	3,719	3,431	3,721	3,722
50	3,721	3,368	3,721	3,721
60	3,722	3,310	3,722	3,718
70	3,721	3,266	3,722	3,720
80	3,723	3,222	3,722	3,718
90	3,721	3,175	3,722	3,722
100	3,722	3,139	3,721	3,723

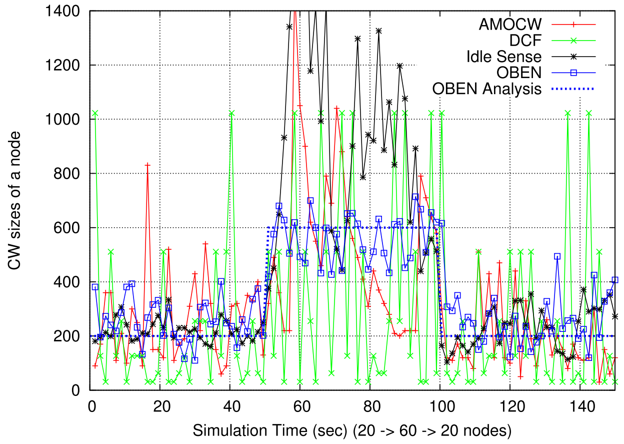

Fig. 5 *CW* sizes of a node with simulation time.

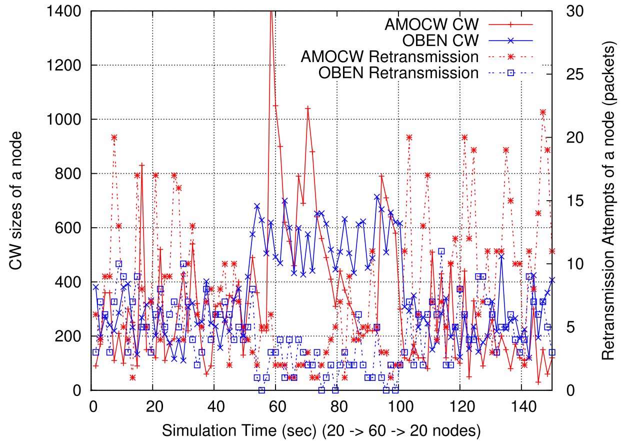

Fig. 6 *CW* sizes and retransmission attempts of a node with simulation time.

start competing for the channel. Then, the 40 nodes leave after 100 seconds. From Fig. 5, OBEN is coincided with the analysis results and has good scalability in runtime. In contrast, *CW*s of AMOCW, Idle Sense and DCF vary intensely when the number of nodes increases quickly, which means a big change of the transmission interval in view of the time dimension and this results in poor fairness and high jitter. **Figure 6** shows the instantaneous value of *CW* and the retransmission attempts of a node. OBEN has a small variation of *CW* and the number of retransmission attemps because OBEN always obtains *CW* around the optimal value. In contrast, in AMOCW, the variation of *CW* is large, which causes many retransmission attempts and decreases fairness as described below.

To evaluate the fairness of OBEN, we adopt the following Fairness Index (FI) [22] that is commonly accepted:

$$FI = \frac{(\sum_{i=1} T_i/\phi_i)^2}{n \sum_{i=1} (T_i/\phi_i)^2} \quad (10)$$

where T_i is throughput of flow i, ϕ_i is the weight of flow i (normalized throughput requested by each node). Here, we assume all nodes have the same weight in simulation. According to Eq. (10), $FI \leq 1$, where the equation holds only when all T_i/ϕ_i are equal. Normally, a higher FI means a better fairness.

Figure 7 shows the results with a different number of nodes from 10 to 100, in which the results of OBEN, AMOCW, Idle Sense and IEEE 802.11 DCF are put together for comparison.

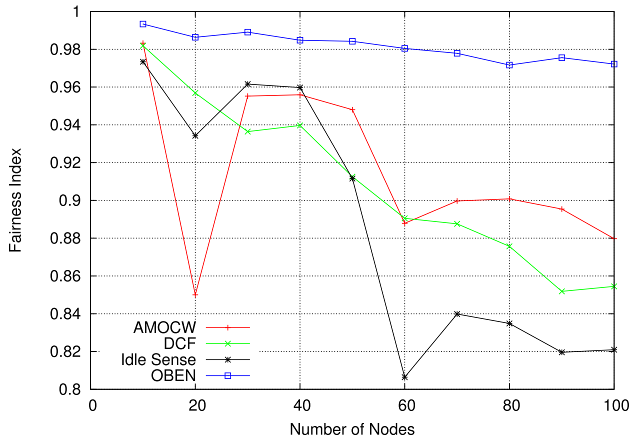

Fig. 7 Fairness Index.

From the figure, we can see that our proposal OBEN has the best fairness among the four protocols. In particular, when the number of nodes increases, the fairness of OBEN has no obvious changes. On the other hand, Idle Sense degrades fairness heavily and becomes lower than DCF from 50 nodes, which results from each node of Idle Sense not knowing the correct *CW* to which it should set and it just increases or decreases *CW* according to the common channel situation indicated by the average idle interval. Thus, a lack of balance occurs among nodes in the network. The same tendency also can be found for AMOCW except that the fairness is improved. For Idle Sense and AMOCW, the fairness changes periodically, which is thought to be the result of AIMD algorithm used in Idle Sense and AMOCW. From the figure, we can see that the fairness of OBEN is dramatically enhanced.

5. Conclusion

In OBEN, nodes just need to confirm if the media is busy or idle to obtain the number of idle slots, successful transmissions and collisions through listening to a wireless channel without added overhead. And then using a simple and effective method, OBEN estimates the number of nodes to set an optimal *CW*. Meanwhile, though all the nodes may not have the same *CW*, occasionally, each node can adjust its *CW* rapidly and keeps close to the optimal value, which means they will fairly share the common wireless channel. This leads to good fairness.

Through both analysis and simulation, our scheme has the following advantages. First, the method of estimating the number of active nodes of a channel is simple and effective for each node to grasp the network traffic situation and average idle length is insensitive to the change in packet length or the number of active nodes. Each node can adjust its backoff process simply, avoiding complex calculations. Second, compared with the Idle Sense and AMOCW, OBEN achieves better fairness with almost the same throughput. As a future work, we need to verify by the actual environment and evaluate the validity of OBEN and extend OBEN to multihop wireless networks by multiple frequency channels.

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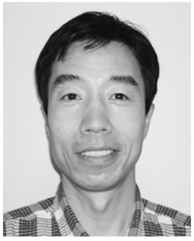

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