Influence of Retransmissions on the Estimating Number of Users Associate in a WLAN Using Error Pron-Channel

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Abstract—**Recently, the IEEE 802.11 WLANs are experiencing a vast popularity and widespread deployment particularly with the rapid development in wireless communication technologies. Designing WLANs with traditional steps may allow a specific number of users to utilize from facilities of the networks. The transmission channel condition and number of sharing users are crucial information to be known for the adaptive networks towards achieving better performance. Although numerous of considerable studies investigated estimating number of sharing users in a WLAN utilizes an error-prone channel, influence limited number of retransmissions and type of the accessing transmission channel mechanism on the number of sharing stations are still required more investigation. Therefore, this paper is conducted to analyze these effects. Analytical expressions are presented for studying these effects. The achieved results show that the limited number of retransmissions has a substantial impact on the estimation number of sharing stations using an error-prone channel while type of the access mechanism has ignorable influence on the estimation process.**

Keywords-IEEE 802.11 DCF; WLAN; MAC protocol; Error-prone channel; performance evaluation.

I. INTRODUCTION

In the recent years wireless local area networks (WLANs) have gained popularity due to providing relatively high-bandwidth operation for interconnecting mobile devices and providing access to the internet with its relatively low coast establishment requirements [1]. WLANs operating at the unlicensed ISM frequency bands is one of the available solutions to satisfy the most demands for the next generation communications (subscribe accessible at any time and at anywhere) [2]. Also, it able to comply with fastest growing segments in the communications industry. WLANs have been getting more attractiveness, particularly with producing the new equipments and establishing new standards such as IEEE 802.11n and VoWi-Fi and infrastructure for traditional Wi-Fi expands [2, 3]. The physical media in the WLANs is shared between all stations and has limited connection range compared with its wired counterpart. The MAC protocol defined two functions, namely distributed coordination function (DCF) and the optional point coordination function (PCF). DCF defines two mechanisms to access transmission medium: the two-way (basic) access scheme, which is the default scheme and the request to send/clear to send (RTS/CTS) scheme, also known as four-way handshaking scheme [3, 4]. DCF has superior attractiveness over PCF in many aspects [5]; therefore this paper is conducted to investigate number of users in a WLAN utilizing DCF.

In dynamic and media sharing wireless environment, the capacity enhancements at individual channel may not necessarily benefit, and sometimes even degrade the system performance with multiple users. As we have pointed out in the previous work [6] that to get closer look to the real situation in the WLANs influence of channel condition and the type of mechanism should be taken into the consideration. It has been shown that in multi-user network, throughput can be increased; hence amount of packet delay substantially decreased if a partial knowledge of the channel condition and number of sharing stations are known. The adaptive stations might utilize such information to change the utilized accessing mechanism and some other tunable parameters such as minimum contention window size, data rate, retry limit and length of packets accordingly to the MAC layer as controllable variables. The work in [6] had continued the series of derivations towards providing a completed analytical model. The model has taken into account influence the number of retransmissions, the error level in the utilizing transmission channel, type of the transmission channel mechanism, and the size of the network (number of sharing stations with an access point). While Bianchi and Tinnirllo in Ref. [7] have continued the efforts to estimate number of sharing users utilizing Bianchi's idealistic model, presented in Ref. [8], which based on the assumption that the collision is the only error, packet retransmits are unlimited and a packet is being transmitted continuously until its successful reception. In this paper, the model in Ref. [6] and procedure in Ref. [7] are adopted to formulate the related relations to estimate number of sharing users. Influences of limited number of retransmissions, type of the access channel mechanism and error due to the transmitting channel are considered. The achieved results show that in the error-prone channel the designed maximum number of retransmissions and amount of error in the channel play the key role to estimate the available number of sharing stations, while type of the utilized mechanism has ignorable information on the estimating

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process. The paper is organized as follows: the next section discusses the related formulated relations for two cases in the transmitting channels: ideal and error-prone, then the results are illustrated. The conclusions are presented in the last section.

II. THE ANALYTICAL MODEL

A. Ideal channel

Let the number of associate stations with an AP is *n*. When a transmitted packet from a station encounters a collision with at least one of the $n-1$ remaining stations in a time slot the probability of unsuccessful receiving (called conditional collision probability) is given as:

$$p = 1-(1-\tau)^{n-1} \tag{1}$$

It depends on the probability of a station to transmit a packet in a randomly chosen slot time as:

$$\tau = \frac{1-p^{m+1}}{(1-p)} . Q_{0,0} \tag{2}$$

where :

$$Q_{0,0} = \begin{cases} \dfrac{2(1-2p).(1-p)}{W(1-(2p)^{m+1}.(1-p)+(1-2p).(1-p^{m+1}))} & m \le m' \\ \dfrac{2(1-2p).(1-p)}{W(1-(2p)^{m'+1}).(1-p)+(1-2p).(1-p^{m+1})+W.2^{m'}p^{m'+1}.(1-2p).(1-p^{m-m'})} & m > m' \end{cases}$$

τ does not depend on the type of the mechanism adapted by a station: two-way or four-way handshaking. Instead, it depends on the designed maximum number of the backoff stages, *m,* and condition of the transmitting channel via the probability of collision [9, 10]. When a station transmits and the remaining $n-1$ stations defer their transmissions, the packet would be arriving successfully with probability p_s . So, assuming absent error in the channel (ideal case) we can express the number of estimated stations, based on model in Ref. [6] as:

$$n(p,m') = \begin{cases} 1+\dfrac{\log(1-p)}{\log\left[1-\dfrac{1-p^{m+1}}{1-p}\cdot\dfrac{2(1-2p)(1-p)}{W(1-(2p))^{m+1}\cdot(1-p)+(1-2p)(1-p^{m+1})}\right]} & m \le m' \\ 1+\dfrac{\log(1-p)}{\log\left[1-\dfrac{1-p^{m+1}}{1-p}\cdot\dfrac{2(1-2p)(1-p)}{W(1-(2p))^{m'+1}\cdot(1-p)+(1-2p)(1-p^{m+1})+k}\right]} & m > m' \end{cases} \tag{3}$$

where, $k = w.2^{m'}.p^{m'+1}.(1-2p)(1-p^{m-m'})$ and m' is the retry limit.

B. Error-prone channel

Influence of error in the transmitting channel may be included through considering the parameter p_c as introduced in Ref. [9] and investigated in Ref. [6]: In the case of adopting two-way access mechanism:

$$p_c = 1-(1-BER)^L \tag{4-a}$$

where $L = PHY_h + MAC_h + P + ACK$.

In the case of using four-way handshaking:

$$P_c = 1-(1-BER)^{RTS} * (1-BER)^{CTS} * (1-BER)^{P} * (1-BER)^{ACK} \tag{4-b}$$

so, rewriting the above relations the number of users can be obtained as:

$$n(p,m') = \begin{cases} 1+\dfrac{\log\left[\dfrac{(1-p)}{(1-p_c)}\right]}{\log\left[1-\dfrac{1-p^{m+1}}{1-p}\cdot\dfrac{2(1-2p)(1-p)}{W(1-(2p))^{m+1}\cdot(1-p)+(1-2p)(1-p^{m+1})}\right]} & m \le m' \\ 1+\dfrac{\log\left[\dfrac{(1-p)}{(1-p_c)}\right]}{\log\left[1-\dfrac{1-p^{m+1}}{1-p}\cdot\dfrac{2(1-2p)(1-p)}{W(1-(2p))^{m'+1}\cdot(1-p)+(1-2p)(1-p^{m+1})+k}\right]} & m > m' \end{cases} \tag{5}$$

in this case, the probability that each packet collides after launched into the channel, the conditional collision probability, is:

$$p = 1-(1-\tau)^{n-1}(1-p_c) \tag{6}$$

which is proportional to amount of error in the channel via p_c .

III. PERFORMANCE ANALYSIS

The expressions presented in the previous section are used to analyze influence of retransmission on the estimating number of the sharing users in a WLAN. The results are presented for the maximum number of the backoff stages, *m*, is 5 as it is considered in Ref. [7] for comparison purpose, the size of the contention window, W, is 32, PHY is 128 bits, MAC is 272 bits, packet payload is 8184 bits. The two access channel mechanisms in DCF considered. Since the stations can measure p efficiently [7] it is a suitable tool to estimate number of stations. Fig. 1 shows variation of estimated numbers of users with the conditional collision probability for two values of retry limits, 3 and 6, with considering only the collision is the source of transmission failing. As probability of collision and allowed number of retransmissions get higher values the estimated number of shared users goes higher. This is due to increasing number of collisions as number of users getting higher which yield that number of reaching packets to the destination is low, therefore, with increasing number of retransmissions the chance for the transmitted packets reach successfully is increased. However, designers should consider type of applications in perspective of packet delay. For instance, packet delay in real time applications must not exceed 30 ms, which indicate that number of retry limit should not be more than 5 [11-13]. Otherwise, many transmitted packets are delayed and then dropped. This has two consequences. The first, stations would suffer from high losses due to increasing number of dropped packets, which probably affect QoS and total performance of the system. The second, relying on the probability of collisions and number of retransmissions in the estimating number of sharing users would be unreliable, particularly when the number of retry limit exceeds the maximum number of the backoff stages, as illustrated in the results shown in Fig. 2. Figure 2-a, and b illustrate variation of estimated number of users with retry limit in a WLAN uses error-prone channel. Three different levels of conditional collision probability, 0.7, 0.8, and 1, are considered. The results with using two-way accessing mechanism are listed in Fig. 2-a, and that with using four-way accessing mechanism are illustrated in Fig. 2-b. The difference between the two results is ignorable. This is due to estimating collision probability is a weak function to the utilized mechanism, see Eqs. 4 and 6. Results in figure 2 show that the number of stations is insensitive to retry limit as it exceed the designed maximum number of backoff. This is due to probability of conditional collision is ignorable when the network exceeds the maximum number of backoff stage [6]. Fig. 3-a, and b show that for a WLAN's channel with three different states, specifically ideal, BER = 10^{-4} and 10^{-5}. Figure 3 –a and –b illustrate influence of the conditional collision probability on the estimated number of users for the two mechanisms, two-way, Fig. (3-a) and four-way handshaking, Fig. (3-b). The difference between the two cases can be ignored. As the estimated conditional collision probability increases the number of the estimated stations getting higher. However, number of retry limit and amount of error in the channel play the key role on the obtained results. For instance, for collision probability 0.7 and BER = 10^{-4} number of estimated users is 18 when $m' = 3$, but number of users about 30 as m' increased to 5. On the other hand, if the used channel has less error, BER = 10^{-5}, number of estimated users goes to 64 when $m' = 3$ and around 100 when $m' = 5$. this is reasonable due to possibility of high number of users be increased as the used channel is less error and give more chance to be transmitted (increase number of retransmissions).

IV. Conclusions

The paper has presented influence number of retransmissions on the estimating number of sharing stations in a WLAN. The estimation based on using our previous model to formulate the required relations. Beside influence number of retransmissions, the estimation has taken into consideration influence of the error level in the utilizing transmission channel, type of the transmission channel mechanism, and the size of the network. The results show that when the number of retransmissions exceeds the maximum number of backoff stages the number of sharing stations insensitive to the retransmissions. Type of the utilized mechanism has no significant influence on the estimating number of sharing stations. Probability of conditional collision has a crucial role in the number of retransmissions and then number of sharing stations. And, level of BER has a considerable impact on the number of stations.

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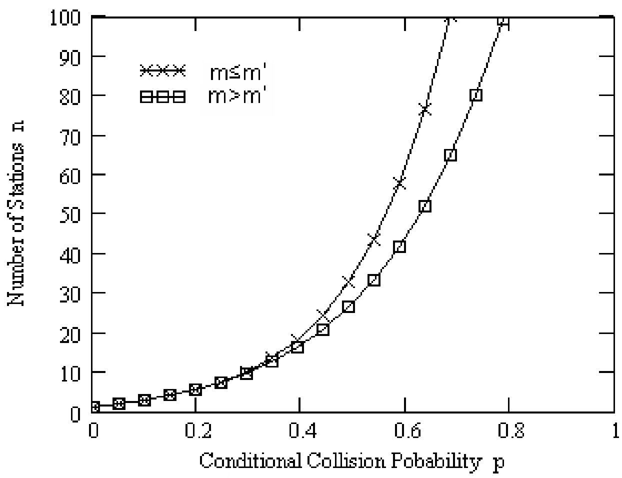
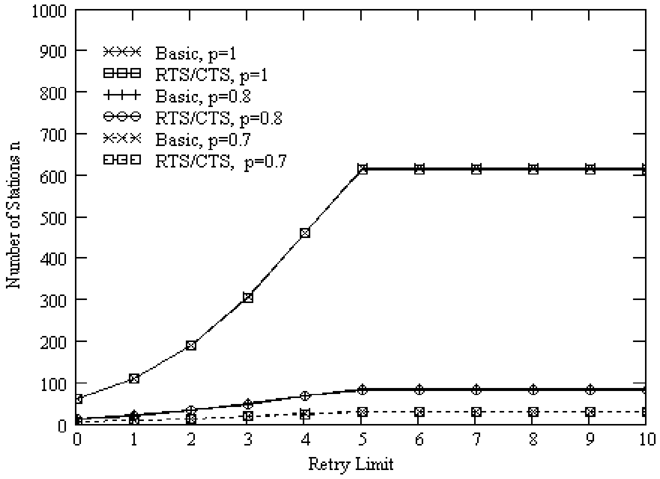
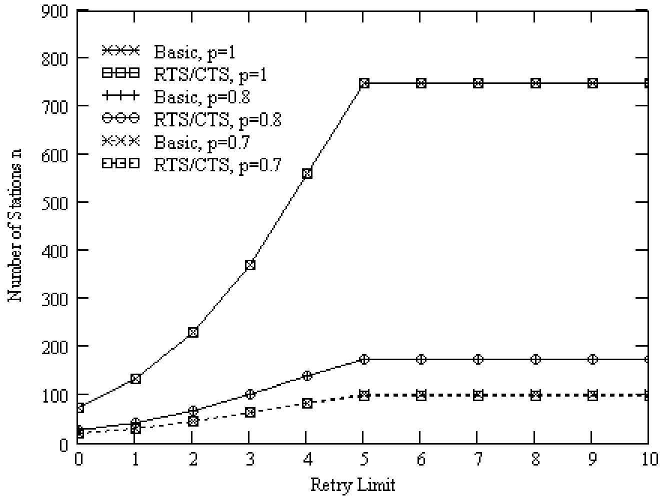


Figure 1: Conditional collision probability versus number of stations (ideal channel).

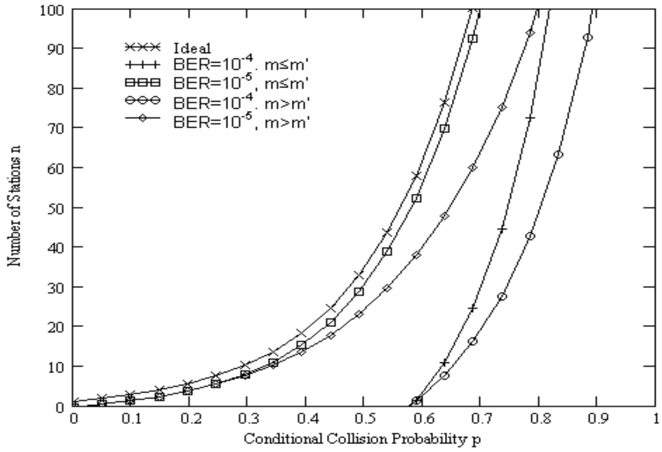


(a)

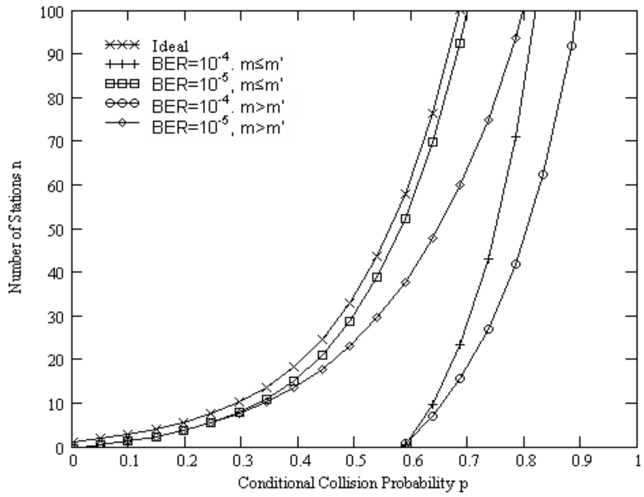


(b)

Figure 2: Number of sharing stations as a function to retry limit. BER = 10^{-4} (a), BER = 10^{-5} (b).



(a)



(b)

Figure 3: Conditional collision probability versus number of stations . (a) two-way mechanism, (b) RTS/CTS mechanism.