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A Novel Performance Evaluation Model for IEEE 802.11e EDCA

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Abstract. IEEE 802.11e Enhanced Distributed Channel Access (EDCA) is the most popular standard used in WLAN to support QoS for various real-time service flows. Based on DCF, EDCA introduces some new QoS parameters, which are defined by IEEE 802.11e standard. But how to adjust these parameters is still worth investigating. In the paper, we present a novel saturated throughput analysis of the IEEE 802.11e EDCA. This approach involves a novel analytical model that is an extension to previous works by other authors which provide Markov chain analysis to IEEE 802.11e EDCA. The throughput analysis of our model is evaluated by comparison with NS2 simulations and found the model is accurate and suitable for both basic access and request-to-send/clear-to-send (RTS/CTS) access mechanisms.

Keywords: modeling, performance evaluation, IEEE 802.11e EDCA, saturation

1 Introduction

IEEE 802.11 wireless network is used in a wide range of practical applications. Most wireless networks uses IEEE 802.11 protocol. Due to IEEE 802.11 protocol does not provide the support that QoS supports transmission of network multimedia real-time business, in order to satisfy the demands of network development, wireless network protocol is based on DCF protocol providing QoS business support for network business which is on the MAC layer. Due to the reason that IEEE 802.11e is able to support better QoS in WLAN, it has been included as mandatory part in the newest edition of IEEE 802.11 standard. There are two MAC protocals in IEEE 802.11e, one is called Enhanced Distributed Channel Access (EDCA) and the other one is called Hybrid Coordination Function Controlled Channel Access (HCCA). EDCA is designed for distributed networks while HCCA is for centralized networks. EDCA can be compatible with the DCF and is widely adopted to support QoS in WLAN. EDCA adds some new QoS parameters compared with DCF, which are also called EDCA parameters. The IEEE 802.11e standard only defines a suite of default values but how to adjust these EDCA parameters is still not mentioned. How to set up the

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EDCA parameters is the key point of QoS guarantee, which is important for supporting real-time service flows and is worth investigating further.

2 The EDCA Analysis Model

The analysis model established in this paper is mainly manifested in: in allusion to priority distinction channel access features of IEEE 802.11e protocol which supports QoS, the paper presents a new performance analysis model method. Considered in saturation, the model analysis contains EDCA three main aspects: AIFS distinguish mechanism, channel and frame congestion mechanism and different contention window size. Under different transmission load, the number of nodes and network structure, the values of model analysis and simulation values are good agreement in the performance, such as the transmission throughout of each priority access, channel access delay and data loss rate.

For this model, assumptions are: 1. Ideal channel, ignore capture effect. 2. Nodes have the same and fixed number of times of retransmission. The probability of each data frame collision is independent of each other and is a constant. 3. The number of sites is fixed and it does not consider the hidden terminal problem.

2.1 Analyze Backoff Mechanism of EDCA

Using the proposed new three-dimensional discrete-time Markov chain model to analyze backoff mechanism of EDCA, in the Markov chain, a time slot is used to indicate time interval between two consecutive backoff timer start, originally it is a parameter. But, for brevity, in this paper, in IEEE 802.11b standard, it is assumed to be a fixed time interval. S(t) is to represent the backoff stage random process, b(t) is to represent a backoff timer for an access category (AC), and c(t)is to represent the number of remaining slots which need to go through the time of response inter-frame interval after through minimum arbitration inter-frame interval. The three-dimensional Markov process {s(t), b(t), c(t)} constitutes discrete-time three-dimensional process shown in Fig1a, uses the dashed box to express the relationship of Markov subchain shown in Fig1b.

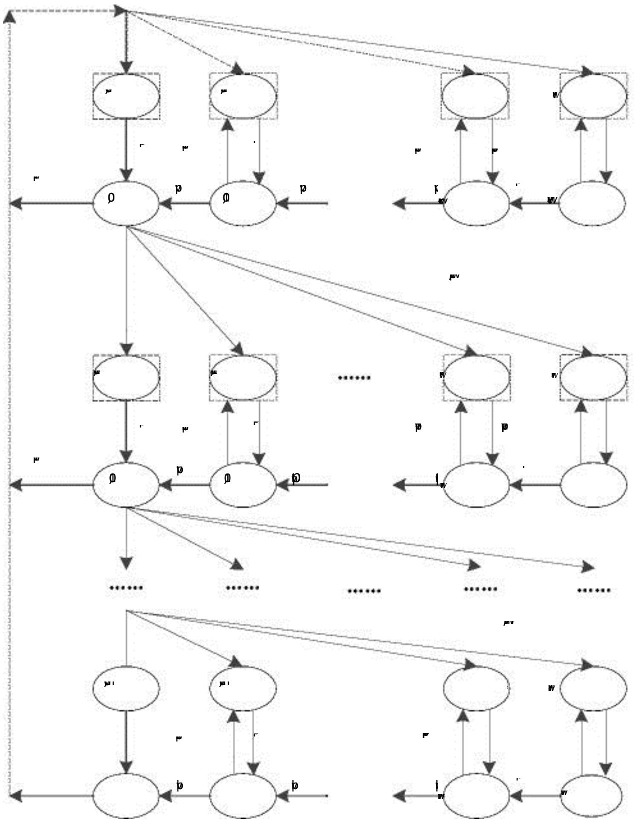

Fig1a. Three-dimensional Markov chain AC backoff process model

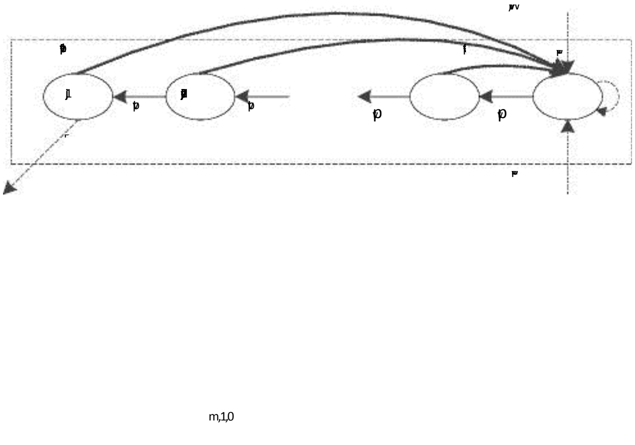

Fig1b. Relationship of Markov subchain

As shown in Fig, P_v expresses the probability that a node transmits a data frame occurring collision because of channel competition. P_{bv} expresses the probability that after access categories go through the inter-frame interval, the channel is still in idle state in a time slot. P_{tv} expresses the probability that during the inter-frame interval which after access categories go through the minimum inter-frame interval. D_v expresses the difference of time slot number in the time of minimum inter-frame interval and inter-frame interval. d_v=$AIFSN_v$-$AIFSN_{min}$·m expresses retransmission limit. The analysis model reflects the state transition relation shown as follows:

W_{iv} expresses the contention window of non-successful transmission i times. W_{iv} can be expressed as:

(2)

Which, W_{0v} and $2^{m}W_{0v}$ respectively expresses ACv corresponding to CW_{min} and CW_{max}.

The probability relation of state transition equation (1a) to (1h) are expressed successively as follows: A. Whenever through an idle time slot, the backoff timer minus one. B. While scouting the channel in a busy state, the backoff process will be in a frozen state. C. The backoff timer will be recalled after passing inter-frame interval. D. If the channel is scouted in a idle state in a time slot, the remaining time-slot number which is in the inter-frame gap time will minus one. E. When the channel is scouted in a busy state in the inter-frame gap time, access category have to pass an inter-frame gap time again. F. The node is in a suspended state when the backoff timer reduces to zero, then wait for the corresponding inter slot to perform transmission. If the data frame transmitted in the channel has error, the node contention window value will be updated and then enter the next backoff process immediately. G. After a successful transmission, CW is set to CW_{min}. H. The number of retransmission reaches to the highest times limit, the CW value is set to CW_{min}.

The probability $b_{i,j,k}$ of the Markov chain state{i, j, k} satisfies the following relation:

$$1 = \sum_{i=0}\sum_{j=0} b_{i,j,0} + \sum_{i=0}\sum_{j=0}\sum_{k=1} b_{i,j,k} \tag{3}$$

which, $i \in [0,m], j \in [0, W_{iv} - 1], k \in [0, d_v]$

Calculating the three-dimensional Markov chain state equation can get the initial state of $b_{0,0,0}$,

(4)

when AIFS of access category is at a minimum, d_v can be consider equal to zero, therefore, the above expression can be written as:

(5)

In view of the saturation condition, namely that the transmission queue is nonempty. The probability that access category ACv transmits successfully in a time slot randomly selected can be expressed as:

(6)

2.2 The Relevant Parameter of EDCA

Relative to IEEE 802.11, IEEE 802.11e protocol is in order to improve the QoS that supports multimedia business.

The protocol stipulates that access category audio (AC3), video (AC2), best effort (AC1) and background (AC0) by the priority from low to high and they also have corresponding queue. When the media channel is being idle, the time that different queues need to wait for depends on AIFS, queue which has high priority has smaller contention window value and also has smaller created resignation process time, so the probability of that high priority business competes to get the channel is higher. The relationship expression between AIFS time value and the parameter AIFSNi is $AIFS_i=SIFS+AIFSN_i \cdot T_e$, which the unit time slot is T_e.

Assuming that the probability of access category ACi successful transmission is p_i. If each access category ACi has the same number of nodes n_i, that when a node is successfully competing to get the channel and transmitting unmistakably within the appointed time, it belongs to successful transmission. The probability p_{si} of ACi successful transmission reaches a conclusion by analysing the literature [1]:

$$(7)$$

$_j$ □

$_j$□

If we want to know all the probability of AC successful transmission, first of all, we can know the probability p_s of AC successful transmission in a appointed time

$_0$

slot,

(8)

In the process of wireless LAN transmission, if the transmission channel is busy in a time slot, the probability is the same as the probability that at least one node transmits data packets in the channel, the expression of the probability p_B is:

$s \quad i \quad H$

$P_c \quad H \quad$ m

(9)

When the channel is busy, the node scouts that at least one node is transmitting data packets in the media channel; assuming the probability is p_{Bi}, and we can consider that the probability p_{Ci} of the data frame collision is equal to p_{Bi}, and the relevant probability formula[1] is:

$$T = \min[AIFS] + T + T + SIFS + ACK + 2 8$$

(10)

2.3 Analysis of Throughput

The throughput of access category AC*i* is equal to the data packet size of the access category successful transmission in the unit competition time. according to the analysis of the literature[1], we can get the throughput of the average per node S_i, it can be expressed as:

$_{Si}$ □ （11）

which, the duration of the competition $_{TCS}$ can be expressed as:

（12）

Which, T_e is the unit time slot, δ is transmission delay, T_s is on behalf of the time of successful transmission, T_c is on behalf of the time of collision. According to the derivation of the literature[1], under the basic transmission access visit mode, the relationship between T_s and T_c is:

（13）

（14）

Which, T_H is the total transmission time of PHY header and MAC header in the data header file. $_{AIFSmin}$ is the minimum arbitration inter-frame interval value in the all AC access category. The minimum value of extended inter-frame interval *EIFS* is $EIFS_{min}$. $AIFS_{min}{}^{\text{and}}{}_{EIFSmin}$ can be expressed as:

（15）

（16）

Under the RTS/CTS transmission access visit mode, the relation of T_s and T_c is:

（17）

（18）

Then according to the above several expressions to calculate the probability of successful transmission and calculate the corresponding throughput of AC.

3 Conclusion

In this paper, we present a novel saturated throughput analysis of the IEEE 802.11e EDCA. This approach involves a novel analytical model that is an extension to previous works by other authors which provide Markov chain analysis to IEEE 802.11e EDCA. The throughput analysis of our model is evaluated by comparision with NS2 simulations and found the model is accurate and suitable for both basic access and request-to-send/clear-to-send (RTS/CTS) access mechanisms.

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