Adaptive Wireless Networks QoS Evaluation Analysis Through Enhanced Parameters Tuning Algorithms

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Abstract: - The enhanced parameters tuning (EPT) algorithm is applied to adjust the parameters of 802.11e, i.e. arbitration inter frame space (AIFS), Contention window minimum (CWmin) and Contention window maximum (CWmax). The EPT tuning algorithm is proposed with the simple and effective adjustment in the priority combinations strategy to achieve the high quality of service (QoS). The internal competition of business analysis methods are determined to detect the channel busy probability. The EPT tunes the conflict probability by the variant setting of AIFS, CWmin and CWmax to approach the performance analysis while the traffic business is retreating into the idle and zero state. Three simulations results in the four businesses of wireless networks applications are applied to present the better adapt parameters regulation machines.

Key-Words: - Wireless Network, 802.11e, EDCA, EPT, QoS, Access Categories

1 Introduction

Several real-time business based on the data transformation services require the higher Quality of Service (QoS) permissions. The main functions in the wireless network platforms not only provide a simple connectivity network but also offer the higher QoS to support the complex and unexpected problems. The traditional IEEE 802.11 standard doesn’t provide the better guarantee of heavy traffic loads to assure the real-time business model. The improvement of accessing mechanisms for the IEEE 802.11e protocol provides several voice and video applications in the WLAN (Wireless Local Area Network) [20]. The appropriate wireless LAN offers a high-speed accessing rate to provide transmitted ability for both non-real-time and real-time dataset. For example, WWW, FTP, HTTP is a non-real-time services data, but videoconference, remote education, remote medical care, Voice are considered as the real-time multimedia applications services.

The agreements of IEEE802.11e standard distinguish the priority of various type’s applications by the evaluation of AIFS, minimum contention window, maximum contention window and internal collision mechanism. It provides the preliminary support for multimedia applications. However, the standard of IEEE802.11e doesn’t guarantee the traffic service to achieve the maximum channel utilization [4]. This study presents the performance analysis of saturated throughput by the three various parameters combinations. Bianchi [2, 3] proposed a Markov chain model to find the solution of the Markov equilibrium probability for packet transmission chain within a generic slot time. The ultimately re-analysis is applied to approach the suitable saturation throughput within a generic time slot. Many researchers devoted themselves to improve these wireless studys in the recent years. The mathematical model of the average replace is proposed by Tay [13], it is used to calculate the probability of the divided packet collisions and solve the maximum collision probability problem of the traffic throughput. Wu et al. applied the modified Bianchi model to give further consideration in the retry limit testing problem [14]. Choi, and others searches [5, 9] described in detail of the IEEE 802.11e EDCA mechanisms to give more performance simulation and methods evaluation in the literature. Xiao and Li [15] proposed the EDCA priority study to obtain the effects of transferring delay conditions when changing the queue buffer size. The paper of the Xiao Yang [17] is developed based on the basis of

Nonlinear united equations (4), (5), (6), (9) and (10) can be solve to obtain the transmission probability of *i*-th class business τ_i and the conflict probability p_{io} at the counter zero state**.**

The throughput and time delay analysis is the main evaluated issues in the QoS evaluation module. The definition of throughput means that it is the average transmit rate in the active data for specific traffic business in every time unit. The considered index of throughput for the related *i*-th business is the idle time, successful time and conflict time. The formulas of the throughput are concluded by the following equations in this article:

$$S_i = \frac{P_{si} T_{E(L)}}{\left[\frac{1}{p_b} - 1\right]\delta + \sum_{i=0}^{N-1} p_{si} T_{s,i} + (p_b - p_s) T_c} \tag{13}$$

Here p_{si} is the total successful probability for the i-th business transferring task. δ denotes the duration time unit. T_c is the largest conflict time. $T_E(L)$ is the transmission duration of valid data. T_{si} is the successful transmission time for the data frames. $T_{c,i}$ is the duration time at the conflict occurrence. p_s is the successful probability of frame transformation. The other parameters are calculated by the following formulas:

$$P_{si} = n\tau_i (1 - P_{io}) = n\tau_i (1 - \tau_b)^{n-1} \prod_{k=0}^{i-1} (1 - \tau_k) \tag{14}$$

$$P_S = \prod_{i=0}^{n-1} P_{si} \tag{15}$$

$$\tau_b = \tau_0 + \tau_1 (1 - \tau_0) + \ldots + \tau_{N-1} \prod_{j=0}^{N-2} (1 - \tau) \tag{16}$$

$$P_b = 1 - (1 - \tau_b)^n \tag{17}$$

$$T_{s,i} = T_H + T_{E(L)} + SIFS + \gamma + T_{ACK} \tag{18}$$

$$T_{c,i} = T_H + T_{E(L^*)} + AIFS[i] + \gamma \tag{19}$$

T_H, $T_{E(L)}$ and T_{ACK} are the required time interval of sending header, validated data and acknowledged procedure, respectively.

In the analysis of delay, its definition is the total interval between the starting and confirming state while the data is being delivering at the medium-access-control (MAC) layer.

The package deliver and collision probability is determined by the priority of the same station (STA) incident within the time slot. It can obtain the throughput and time delay within different access level. Based on the study of high priority frame delay by Ziegenhain [18], the time delay analysis of the network traffic is presented in the following formulas [8],

$$E(N_i)(E(X)\delta + E(B_i)(P_s T_{s,i} + (1 - P_s) T_{c,i})) + E(X)\delta + T_{s,i} \tag{20}$$

Where X_i denotes as the sending period for the *i*-th level frame in the network channel. The $E(X_i)$ is the average period of X_i. B_i denotes the paused time number within the delivering interval. N_i is the number of retransmission cycle time. *E*(.) is the average function, and B_i denotes the pausing number within the transfer process. N_i is the period number of return cycle. The average of X_i is calculated by

$$E(X_{i)} = \sum_{j=0}^{m} \sum_{k=0}^{W_{i,j}-1} k b_{i,j,k} = \begin{cases} \frac{b_{i,0,0}(W_{i0}^2 (1 - (4p_{io})^{m'+1}(1 - p_{io}) - (1 - 4p_{io})(1 - p_{io}^{m'+1})}{6(1 - p_{it})(1 - 4p_{io})(1 - p_{io})} \\ \quad + \frac{(4^{m'} W_{i0}^2 - 1)(1 - 4p_{io})(p_{io}^{m'+1} - p_{io}^{m+1}))}{6(1 - p_{it})(1 - 4p_{io})(1 - p_{io})}, m \geq m'; \\ \frac{b_{i,0,0}(W_{i0}^2 (1 - (4p_{io})^{m+1}(1 - p_{io}) - (1 - 4p_{io})(1 - p_{io}^{m+1}))}{6(1 - p_{it})(1 - 4p_{io})(1 - p_{io})}, m < m' \end{cases} \tag{21}$$

where

$$E(B_i) = \frac{E(X_i) p_{it}}{1 - p_{it}}, \tag{22}$$

$$E(N_i) = \sum_{j=0}^{m} j\, p_{io}^j (1 - p_{io}) \tag{23}$$

3 Enhanced Parameters Tuning Algorithms

To approach the real-time application service, each type of *ACs* contains its own buffer queue to act as the independent backoff entities and then dynamically regulate three parameters (*CWmin*, *CWmax* and *AIFS*)[4]. Due to the big change of *ACs* number within the variant business in the traffic occupation of the network channel, the adapt parameters tuning algorithm is proposed to reduce the collision probability and achieve the higher QoS even in sending various network topologies. Each internal STA adopts a virtual queue to realize four kinds of ACs before sending the packet data. The STA is assigned to obtain varied *CW's* parameters to simulate its related priority in the competing channel. If two or more queues arrived at the same time, it will possibly generate a collision, which is called a virtual collision. Collusion is always caused the time delay conditions.

The objective of the proposed learning algorithm allows the higher priority of ACs to hold the more opportunities to grab channel's transmission rights. Each category has its own exclusive right of getting data frame within the delivering interval by the appropriate parameters tuning machine. Therefore, each category has its own exclusive right of getting data frame by the randomly generated backoff time parameters, i.e. *CWmin* and *CWmax*. In the EDCA modes, it is listened to the channel conditions before sending the packets to the network. The packages are directly delivered to the network channel if the traffic flow is empty. Otherwise, the process enters the backoff time cycle. The backoff time slots will be randomly chosen within the range of interval [*0*, *CW-1*]. The *CW's* initial default value is *CWmin*, the next *CW's* value is doubled until *CWmax* at every occurrence of a collision. The number of Backoff timer is discounted by 1 time slot while detecting an idle state. Packages engage the channel bandwidth if backoff countering time is equal to 0. The higher priority packets can take the superior sending right if two or more AC backoff timer counts into 0 at the same time. If the channel is detected idle for a period of time that is equal to the arbitration inter frame space (AIFS), the STA transmits to start the backoff time cycle. Otherwise, the network flow is busy in the channel to be continuously monitored the traffic flow until the idle time is equal to the length of *AIFS*. The *AIFS* of *AC* is denotes as *AIFS*[*AC*]. Similarly, *CWmin* and *CWmax* are indicated as *CWmin*[*AC*] and *CWmax*[*AC*] for the discussed *ACs* samples, respectively. In general, different STAs present various admitted time (AT) based on the topology of network type. In some command sense, the shortest backoff time of *ACs* can get the great media accessing right. Chio introduces the regulating number of AIFS (AISFN) to improve the transmission rate [18]. The AIFS is determined by Eq. (24)

$$AIFS = SIFS + AIFSN[AC] * aSlotTime \qquad (24)$$

The *AIFS* can be dynamically adjusted based on the AT value to reduce the collision probability.

The network transmission model of Xiao [19-20] doesn't consider the impact of internal scheduling scheme. Thus, its disadvantage is not giving the detailed EDCA function of the 802.11e. In the EDCA mode of Fig.2, each category has its own exclusive right of getting data frame in the interval time with the adjustable time parameters, i.e. *CWmin* and *CWmax*. In this case, *CW's* initial value is setting as *CWmin*, and the next *CW's* value is increased one unit until arriving the *CWmax* when it meets the collision.

An appropriate parameter tuning machine acts an important role for approaching the great WLAN global system performance. In general, the smaller *AIFSN* value gets higher probability to obtain the transmission rights.

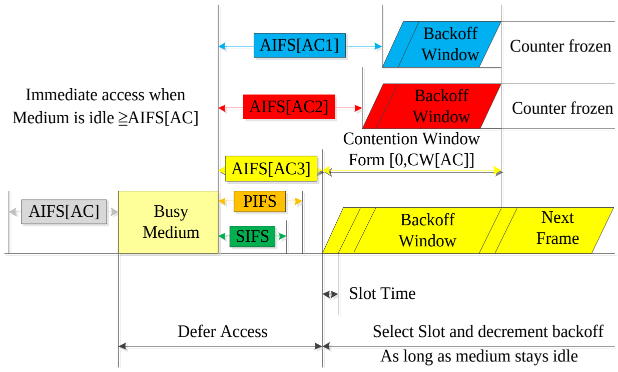

Fig. 2. IEEE802.11e EDCA operations

The concept of the enhanced parameters tuning (EPT) algorithm is proposed to randomly generate some intervals of time window (TW) with the following formula:

$$BackoffTime = Random(CW_{min}[ACi], CW_{max}[ACi]) * aSlotTime \qquad (25)$$

Where $CW[ACi]$ is the adjustable contention window size, *aSlotTime* denotes as the time slot size and $Random(CW_{min}[ACi], CW_{max}[ACi]) * aSlotTime$ are the range of minimal and maximal time window size in the random generation. If the package transmission fails, the size of TW is required to be modified to avoid the recurrent probability of collision. The *CW's* parameters are proposed to be regulated based on the variant *AC* channel of occupancy rate. A suitable parameter adjustment of *CW* and the appropriate $CW[ACi]_{min}$ and $CW[ACi]_{max}$ selections are proposed to ensure the high-priority priority of business flow, which can improve the efficiency of accessing to the network channels.

The concept of sustainable factor (Per-sistence Factor, PF) is applied in this cross-layer regulation algorithm. The regulation of available window size is related to the variant of Traffic Categories (TC) value. Based on the priority regulating mechanism, the small $PF[TC]$ and $CW[ACi]$ values contain the high accessing priority. In a word, the smaller regulation algorithm index results the higher priority in accessing the network channel. The new *CW* is updated by the respective output value of $PF[TC]$ function in the following equation:

$$CW_{new} = (CW_{old} + 1) * PF[TC] - 1 \tag{26}$$

When the CW values of traffic business is countering down 0 at the same network channel, the probability of traffic collision is happen. The scheme of transmission opportunity (TXOP) is proposed in the article to avoid this problem. The queue holds the higher level TXOP can achieve the better priority to send and receive the data package. The TXOP scheduler of each queue is adjusted by the specific priority theory to allocate and tune the token right in several applications [1, 8].

This paper presents a mathematical probability procedure by the Markov model chain analyses to simulate the package travelling behaviours. The study proposed a cross-layer based enhanced parameters tuning (ECP) algorithm by tuning three parameters of *CWmin*, *CWmax* and AIFS to achieve the appropriate performance models. The objective of ECP algorithm determines to adjust the parameters sizes in stabilizing the network channel load of the traffic business. Traffic flows of the business load are evaluated from all the access points (AP) in the disposing topology of the wireless network. An appropriate $CW[ACi]$ size can be selected by the ECP and then the information of $CW[ACi]$ is broadcasted into the internal points in the network channel. The competitive length of the packages by the mean of $CW[ACi]$ can be adapted to fairly balance the flow utilization in the heavy wireless network channel. The proposed algorithm monitors the network throughput by the evaluation of load change from the dynamic routing environments. Due to the increasing probability of network collision problem, the initial length of delivering queue is not directly resetting as *CWmin* after the frame is successfully completed in the package transmitted cycle. The queue length is gradually decreased by the steps of $CW[ACi]/3$.

The ECP algorithm with the on-line regulation machine of $CW[ACi]$ to determine the variance of network flow. Their learning steps are described as follows:

1st) Set each initial queue length of the related i-th CW[ACi] as $CW_{\min}[ACi]$.

2nd) Increase the CW[ACi] value when detecting the collision in network channel until the maximal value ($CW_{\max}[ACi]$), the new $CW[ACi]$ is modified by the following formula:

$$CW_{new}[ACi] = \min(CW_{\max}[ACi], (CW[ACi]+1)*2-1 \tag{27}$$

3rd) Regulate the next $CW[ACi]$ with the linear reducing scaling factor (0.5) by the following formula when the traffic flow is successfully transmitted,

$$CW_{new}[ACi] = \max(CW_{\min}[ACi], 0.5*(CW[ACi]+1)) \tag{28}$$

In the concept of learning algorithm, the adopted random early detection (RED) scheme presents to make a great congestion control method to efficiently avoid the condition of queue collision. The optimal queue managed algorithm is by

$$qlen(AC[i]) = (1-Wi)qlen(AC[i]-1) + Wi*Qt(n) \tag{29}$$

Where $qlen(AC[i])$ and $qlen(AC[i])-1$ are average queue length. The Wi is denoted as the average weight factor. $Qt(n)$ is the current amount of queue size. The flow probability of the best data sending type calculates as follows:

$$\Pr ob_{AC[i]}\_Best = \begin{cases} 0; & qlen(AC[i]) < Threshold_{low} \\ 1; & qlen(AC[i]) > Threshold_{high} \\ \dfrac{qlen(AC[i]) - Threshold_{\_low}}{Threshold_{high} - Threshold_{low}} Threshold_{p}; & \\ \quad \text{where } Threshold_{low} \le qlen(AC[i]) \le Threshold_{high} & \end{cases} \tag{30}$$

where $Threshold_{low}$ and $Threshold_{high}$ are been assigned as the threshold for the minimal and maximal sizes of queue length. The $Threshold_{p}$ is the possible extensive probability of falling down action. Based on the previous probability of the obtained value, the new probability for the next sending media of $AC[3]$ is mapped by the next formula,

$$\Pr ob_{AC[3]}\_New = \Pr ob\_TYPE * \frac{qlen(AC[3]) - Threshold\_low}{Threshold\_high - Threshold\_low} \tag{31}$$

In this case, the $AC[3]$ type data set is directly acquired the token right to be sent to.

4 Simulations Results

All the performance analysis and network simulation of the proposed implementation is based on the network assumption. The network channel is setting at the ideal environment and also keeping in the saturated state, i.e. no hidden nodes, no third-party interception of ideal channel conditions, without reference to the channel bit error rate, signal attenuation and other factors. The general characteristics are suitable for the IEEE 802 standard. Any agreement body of the IEEE 802.11 ensures the deployment in the MAC and PHY layers. Parameter settings are shown in Table 1.

Table1: MAC/PHY parameters

Parameters	Values	Parameters	Values
PHY_{header}/byte	24	ACK/*byte*	14
MAC_{header}/byte	34	CWmin	32
Slot_time/µs	20	CWmax	1024
SIFS/µs	10	Short Retry Limit	7
DIFS/µs	50	Long Retry Limit	4
RTS/byte	20	Packet size/byte	1500
CTS/byte	14		

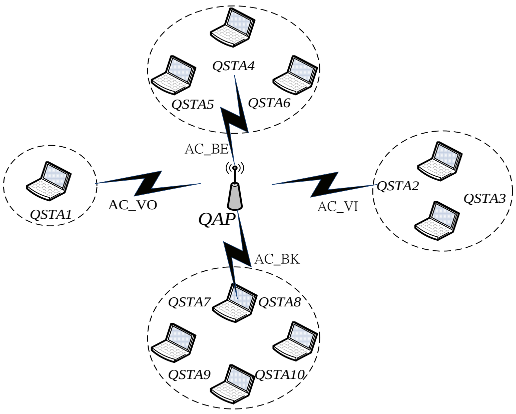

Fig. 3. Simulation environments.

In our simulated environments of Fig. 3, a QAP with 10 wireless stations are present in the Fig.2. Detail experiments settings are described in the others searches [7, 10, 12]. Total 10 stations support four business streams, AC_VO * 1, AC_VI * 2, AC_BE * 3 and AC_BK * 4, in this experiment. Ten transferred scenes, no.1 to no.10, are continuously delivering in the duration of 300 seconds.

In case one study, all parameters are setting by the default standard of 802.11e. Three illustrated examples are proposed to demonstrate the variance of traffic flow by various parameters settings of AIFS, *CWmin* and *CWmax*. Detail parameters settings are described in Table2.

Table2: Parameters settings for AIFS, CWmin and CWmax in various parameters setting Case.

Example	Paramenter	AC_BK	AC_BE	AC_VI	AC_VO
No.1	AIFS	7	3	2	2
	CWmin	31	31	15	7
	CWmax	1023	1023	31	15
No.2	AIFS	8	6	4	2
	CWmin	31	31	31	31
	CWmax	1023	1023	1023	1023
No.3	AIFS	2	2	2	2
	CWmin	31	31	15	7
	CWmax	1023	1023	31	15

The parameters selections of this case are the IEEE 802.11 standard. Fig.4a. shows the simulated throughputs rate of the AC_VO, AC_VI, AC_BE and AC_BK in this example 1. It presents that the AC_VO is the highest-priority service point to obtain the large throughputs. The AC_BK contains the lowest throughputs in this case. The throughput response for this selected parameters model is gradually decreased with respect to the increasing station number. The system saturation of total throughputs is approaching to 80% when the station is 10. Fig.4b. shows the simulated accessing delay in the same case 1. The result presents that the higher priority service point determine the lower accessing delay. This experiment proves that the proposed simulation model conform the condition of IEEE 802.11 standard.

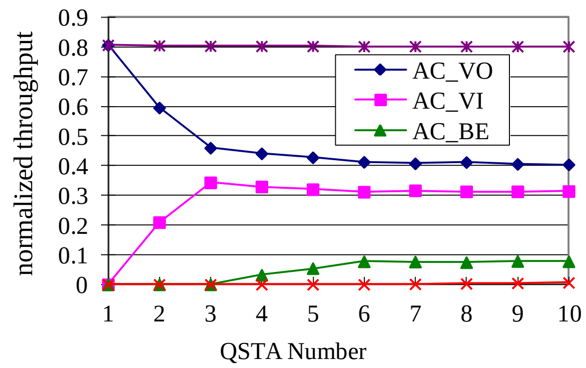

Fig. 4a. Throughputs vis. station number in example 1.

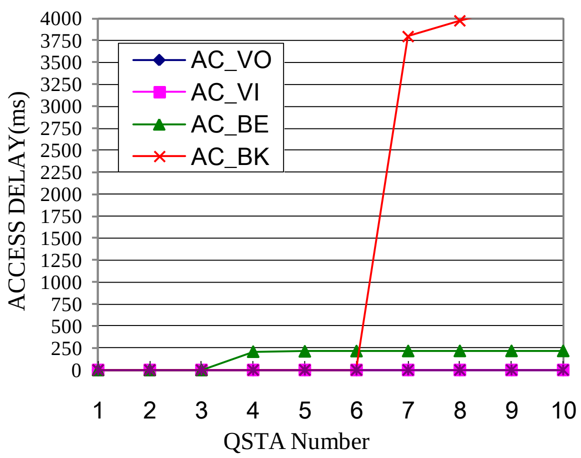

Fig. 4b. Access time delay vis. station number in example 1.

In the results of example 2, New parameters settings of AIFS, *CWmin* and *CWmax* illustrate that we select the same *CWmin* and *CWmax* parameters values and compare the effect of various AIFS values. The new *CW* values is adjusted the AC_VI