PREDICTION OF VIDEO QUALITY OVER IEEE802.11 WIRELESS NETWORKS UNDER SATURATION CONDITION

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Abstract: In IEEE 802.11 wireless channel, and under the assumption of ideal channel, packets are lost when it exceeds the maximum retry attempt. Such packet losses lead to degradation in the transmitted video quality. This paper provides an analytical approach to estimate the video quality distortion due to the packet losses in IEEE 802.11 wireless networks. The analytical approach is based on the use of two-state Markov chain model combined with the ITU-T Recommendation G.1070 for video quality objective measurements. Our approach provides a relationship between the design parameters of IEEE 802.11 wireless channels and the required video quality.

1 INTRODUCTION

Video transmission over IEEE 802.11 wireless networks has become a popular application in wireless communication. Hence, evaluating the video quality video quality over IEEE 802.11 wireless networks has drawn much attention. Khan et al provides, reference (Khan, 2009), provides quality prediction for various video content types over wireless networks. Methods to estimate the distortion due to packet losses in wireless video communication are provided in references (Babich, 2008), (Bouazizi, 2004) and (Choi, 2005).

In IEEE 802.11 wireless networks, a packet will be discarded when it exceeds the maximum packet retry limit in IEEE 802.11 protocol. This packet loss results in an inherent distortion of video quality, even if the network operates in an ideal physical environment.

Quality of Experience (QoE) has been addressed in ITU-T G.1070. QoE grades the perceptual video quality by mapping subjective quality to peak signal-to-noise ratio (PSNR). The opinion model of ITU-T G.1070, (correlating objective video quality with its subjective video quality), provides a tool to estimate the video quality thus measuring user's specific level satisfaction. The model is able to eventually map the packet loss ratio of the transmission channel to the quality degradation and predict the video quality.

The goal of this paper is to determine a relationship between the design parameters of IEEE 802.11 wireless network and the required video quality. The basic idea of our approach is determine an analytical expression for the packet loss rate using the Markov chain model developed in (Bianchi, 2000). Once this packet loss rate is determined, we make use of the video quality distortion formula in ITU-T G.1070. With this approach, we can calibrate various IEEE 802.11 parameters to control the video quality distortion and thus meet the required level of video quality. The rest of the paper is organized as follows. Section 2 provides the analytical video quality in IEEE 802.11. Section 2.1 is a summary of the opinion model of ITU-T G.1070, while section 2.2 discusses analytical packet drop rate with Markov Chain Model. Section 2.3 provides the numerical analysis results for video quality in IEEE 802.11. Section 3 is the conclusion.

2 ANALYTICAL VIDEO QUALITY IN IEEE 802.11 WIRELESS NETWORKS

2.1 Opinion Model of ITU-T Recommendation G.1070

In ITU-T G.1070, video quality parameters are introduced, such as video delay, T_v [ms], video packet-loss rate, P_{plV}, and jitter. These parameters affect video quality when video is transmitted over

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wireless networks. According to ITU-T J.241, an input value of T_v must be less than hundreds of milliseconds and a jitter less than tenths of milliseconds in order to be tolerated for high quality video streaming services. Video packet-loss rate (P_{plV}) refers to end-to-end video packet-loss rate and should be less than 10 %.

ITU-T G.1070 provides an algorithm that estimates video quality. According to the ITU-T G.1070, objective measurement of video quality, V_q, is calculated by:

$$V_q = 1 + I_{coding} exp\left(-\frac{P_{plV}}{D_{PplV}}\right) \tag{1}$$

where D_{PplV} is degree of video quality robustness due to packet loss; P_{plv} is video packet-loss rate; I_{coding} represents the basic video quality affected by the coding distortion under a combination of video bit rate and video frame rate. I_{coding} is objective measurement of basic video quality accounting for coding distortion.

Every video content has its own video quality robustness D_{PplV}, and its own objective measurement of basic video quality accounting for coding distortion, I_{coding}. These two values are able to be derived by applying the method described in ITU-T G.1070. We only cite some measurement from (You, 2009), and list them in Table 1(To simply discussion, we assume D_{PplV} is constant under different P_{plv} and I_{coding} is constant with different video bit rate and video frame rate). Thus, in this paper, we only focus on how to obtain video packet-loss rate, P_{plv}, using Markov chain analytical model (Bianchi, 2000).

Table 1: Coefficients of I_{coding} and D_{PplV} for a video.

	I_{coding}	D_{PplV}
value	3.655	0.0037

2.2 Analysis Model under Saturation Condition

We use the two-dimensional saturation Markov chain models shown in Figure 1 to analyze the packet dropping rate of IEEE 802.11. In the analysis, we assume that the wireless networks operate in an ideal physical environment, being the same one in Bianchi's model (Bianchi, 2000).

In the discrete-time Markov Chain shown in Figure 1, we define $b_{j,k}$ as the stationary distribution probability of being in state (j, k), where $j \in (0, L)$ is the backoff stage, $k \in (0, w_j - 1)$ is the backoff counter and w_j is the contention window size at backoff stage j.

Define m as maximum backoff stage when contention windows will double. By the Markov Chain regularities, a normalization requirement, $1 = \sum_{j=0}^{L} \sum_{k=0}^{w_j-1} b_{j,k} + \sum_{k=0}^{w_0-1} b_{0,k,e}$, and $w_j = \begin{cases} 2^j w_0 & j \le m \\ 2^m w_0 & m < j \le L \end{cases}$, we obtain

$$\frac{1}{b_{0,0}} = \frac{1-2p^{L+1}}{2(1-p)} - \frac{p-p^{L+1}}{2(1-p)(1-p)} + \frac{w_0}{2(1-p)}\left[1 + \frac{2p-(2p)^{m+1}}{(1-2p)} + \frac{2^m(p^{m+1}-p^{L+1})}{1-p}\right] \tag{2}$$

where p is a probability that a node senses the channel busy in a random slot. We denote τ the transmission probability that a node attempts to transmit a packet in a randomly chosen slot time. Knowing that any transmission occurs when the backoff time counter equals to zero, we will have Equation (3).

$$\tau = \sum_{j=0}^{L} b_{j,0} = \frac{1-p^{L+1}}{1-p} \times b_{0,0} \tag{3}$$

Substituting equation (2) into equation (3) furthermore, we obtain equation (4) for the node's transmission probability τ.

$$\tau = \frac{1-p^{L+1}}{(1-p)\left\{\frac{1-2p^{L+1}}{2(1-p)} - \frac{p-p^{L+1}}{2(1-p)(1-p)} + \frac{w_0}{2(1-p)}\left[1 + \frac{2p-(2p)^{m+1}}{(1-2p)} + \frac{2^m(p^{m+1}-p^{L+1})}{1-p}\right]\right\}} \tag{4}$$

Equations (4) are called the IEEE 802.11 node property formula since it represents a binary exponential backoff scheme to access to the medium. It determines the node's transmission probability in terms of the channel busy probability as well as the network configuration parameters (L, m, w_0). The set of variables of $\{p, \tau\}$ in equation (4) will be regarded as the attributes of a transmission of an IEEE 802.11-based station with arbitrary traffic arrival rate. Noticing that every node i will have its own $\{p, \tau\}$, we now attach the node's serial number to $\{p, \tau\}$ and formulae (4) become equation (5), where i=1,2,… N; and N is number of nodes in the network.

$$\tau_i = \frac{1-{p_i}^{L+1}}{(1-p_i)\left\{\frac{1-2{p_i}^{L+1}}{2(1-p_i)} - \frac{p_i-{p_i}^{L+1}}{2(1-p_i)(1-p_i)} + \frac{w_0}{2(1-p_i)}\left[1 + \frac{2p_i-(2p_i)^{m+1}}{(1-2p_i)} + \frac{2^m({p_i}^{m+1}-{p_i}^{L+1})}{1-p_i}\right]\right\}} \tag{5}$$

τ_i =If the packet has not been successfully transmitted after packet retry limit L times attempting, the packet is dropped. Hence, the packet dropping probability can be estimated as: $p_{drop} = p^{L+1}$ (collision $L + 1$ times before dropping). If the traffic is video, (and assuming IP and TCP/UDP does not increase packet loss rate) then the video packet-loss rate is obtained by

$$P_{plv} = p^{L+1} \tag{6}$$

Probability, p_i in equation (5), that a node senses the channel busy in a random slot, depends on the transmission status of its neighbors nodes and varies from one node to the other. If given a network topology, we can obtain the other equation for every node i's p_i . Then using numerical solutions, we are able to solve equation (5), and ultimately obtain every node's objective measurement of video quality, V_q by equation (1).

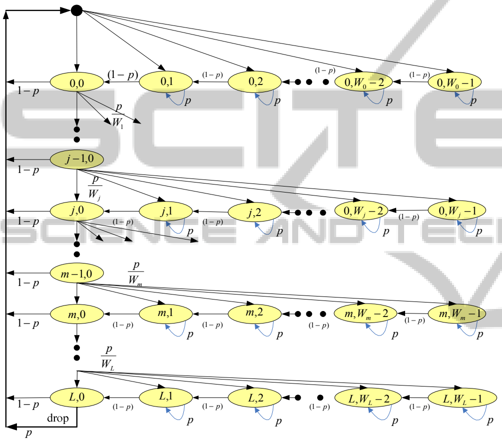

Figure 1: Markov Chain model for saturation.

For example, we discuss video quality in a single hop wireless network under saturation condition. Assuming a wireless network has N nodes; all nodes are in a single hot coverage area. Hence we obtain

$$p = 1 - (1 - \tau)^{N-1} \tag{7}$$

We can solve equations (5) and (7) numerically. The parameters L, m, w_0, N will determine, then affect V_q. If parameters L, m, w_0, N change, then V_q will change; we will compare V_q with IEEE 802.11a/b/g in our numerical calculations (Table 2). IEEE 802.11a and IEEE 802.11g should have the same results.

Table 2: System default parameters /configuration.

	802.11a	802.11b	802.11g
CWmin	15	31	15
CWmax	1023	1023	1023
L	6	5	6
M	6	5	6

2.3 Numerical Results of Video Quality, V_q

In order to understand what are the optimal setting parameters for IEEE 802.11 network to achieve certain video quality, we change the packet retry limit, L, minimum contending windows, w_0, and the number of nodes, N. We also let $m = L$. We notice that the packet retry limit L has more effect on the video quality than the minimum contending windows, w_0, as seen in figure 2. When $L = 5$, V_q changes more moderately with the increase in the number of nodes in the network. On the other hand, when $L = 2$, V_q decline rapidly with the increase in the number of nodes; only with network size of $N = 2$, $V_q > 4$ can be achieved.

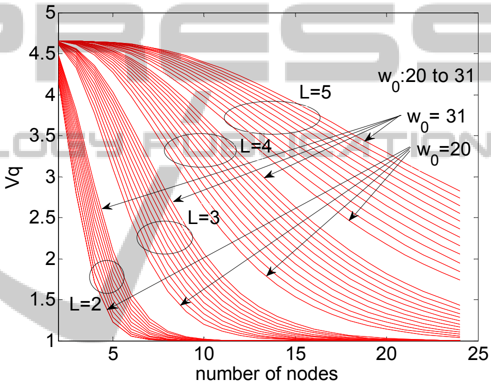

Figure 2: IEEE 802.11 setting parameters to achieve certain video quality V_q.

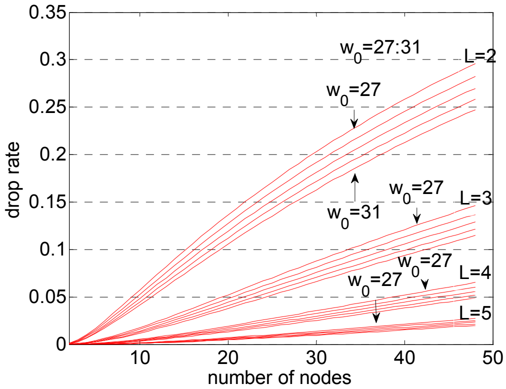

Figure 3: Video packet loss rate (under saturation condition and basic access mode).

However, as we notice in Figure 3, video packet-loss rate (P_{plv}) exceeds 10% when $L = 2, w_0 \in (27,31)$ and$N \in (20,48)$), which exceeds the requirement of ITU-T G.1070 and ITU-T J. 241.

For optimal 802.11 parameter IEEE settings we should choose large L and w_0 to achieve a reasonable V_q and have acceptable delay and jitter for a given network of size N. Otherwise the loss rate will be higher, and V_q will decline quickly.

3 CONCLUSIONS

In this paper, we discuss an inherent distortion of video quality in IEEE 802.11 wireless networks. Then we obtain a method to predict a quantitative video quality requirement with proper setting of the various design parameters of IEEE802.11 network. Our approach is based on using a two-dimensional Markov Chain models coupled with the use of ITU-T Recommendation G.1070.

We also discuss how to optimize the parameters setting of IEEE 802.11 network to minimize the video distortion. For optimal parameters setting we should choose large L and w_0 to achieve a certain required V_q for a given network size of N nodes.

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