Performance Analysis of MPEG-4 Video Stream with FEC Error Recovery over IEEE 802.11 DCF WLANs

Cheng-Han Lin[1], Huai-Wen Zhang[2], Ce-Kuen Shieh[3]
Department of Electrical Engineering
National Cheng Kung University
Tainan, Taiwan, ROC
jhlin5@hpds.ee.ncku.edu.tw[1]
q36991013@mail.ncku.edu.tw[2]
shieh@ee.ncku.edu.tw[3]

Wen-Shyang Hwang[4, *]
Department of Electrical Engineering
National Kaohsiung University of Applied Sciences
Kaohsiung, Taiwan, ROC
wshwang@mail.ee.kuas.edu.tw[4, *]

Abstract—**Due to the increasing use of mobile and handheld devices, the performance of video streaming over wireless networks has emerged as an important concern in recent years. However, while many analytical models have been proposed for analyzing the system performance, these models do not take explicit account of the effects of error recovery. As a result, they fail to provide an accurate indication of the true video quality at the receiver end. Accordingly, this paper proposes a model for evaluating the performance of MPEG-4 video streaming with Forward Error Correction (FEC) over IEEE 802.11 Distributed Coordination Function (DCF) Wireless Local Area Networks (WLANs). The proposed model considers not only the effects of congestion and wireless frame losses, but also the FEC error recovery performance in improving the perceived video quality at the receiver end. The validity of the proposed model is demonstrated by comparing the predicted values of the Playable Frame Rate (PFR) with the results obtained from NS-2 simulations and two existing analytical models, respectively. The results confirm that the proposed model provides an accurate indication of the perceived quality of FEC-protected MPEG-4 video streaming over DCF WLANs.**

Keywords- FEC; DCF; video stream; WLAN

I. INTRODUCTION

Due to the convenience of wireless access, the use of mobile computers and smart phones has increased significantly in recent years. Furthermore, with the increasing coverage of Wireless Local Area Networks (WLANs), and the availability of ever greater data rates and bandwidth, the use of such devices to access Internet-based video streaming applications has become particularly common. Thus, the performance analysis of video streaming over wireless networks has emerged as an important issue in the multimedia communications field.

The IEEE 802.11 standard [1] lays down two transmission functions for media access over wireless channels, namely Distributed Coordination Function (DCF) and Point Coordination Function (PCF). In DCF, the default transmission function, the active wireless nodes compete for channel access and any contentions among them are resolved using the Binary Exponential Backoff (BEB) method. By contrast, in PCF, the communications within the network are coordinated by an Access Point (AP) in such a way as to achieve a collision-free service. In the DCF mode, the frames sent by an active station may fail to reach their destination due to collisions with the frames of other stations contending for the same channel. Moreover, attenuation, fading, scattering and interference from other active sources may also prevent a frame from reaching its destination. In other words, frame losses may occur as a result of both congestion and wireless link errors. FEC (Forward Error Correction) [2-6] is a widely used technique for recovering frame losses in wireless networks. In FEC schemes, the sender mitigates the effects of packet losses by transmitting redundant packets together with the source packets such that a block can still be reconstructed at the receiver end even if some of the packets within the block are lost during transmission.

The literature contains many models based on a two-dimensional Markov chain for analyzing the performance of IEEE 802.11 DCF networks [7-10]. One of the first models was presented by Bianchi [7]. For simplicity, the model assumed that the number of retransmissions of a lost frame is unlimited, i.e., the sender continues to retransmit lost frames until they are successfully received. By contrast, in the model proposed in [8], the frame retransmission limit prescribed in IEEE 802.11 DCF is taken into consideration, i.e., the frames are dropped by the sender if collisions occur repeatedly within the maximum retransmission period. However, the effects of wireless bit errors on the frame loss are ignored. Dong et al. [9] developed an enhanced model for obtaining accurate predictions of the IEEE 802.11 DCF performance over lossy channels. However, the frame retransmission limit was ignored. Ni et al. [10] presented a model in which the effects of both the frame retransmission limit and wireless bit errors were taken into account. In general, the analytical models presented in [7-10] focus on the system performance, but do not enable the video quality over IEEE 802.11 DCF WLANs to be directly assessed.

In most previous studies on the quality of MPEG-4 video streaming over wireless networks [11-13], the video quality was evaluated using only network-level parameters, e.g., the packet loss rate or the packet delay. In [12-13], Ziviani and Ke proposed a new performance metric, designated as the

*Correspondence to: W.-S. Hwang is with the Department of Electrical Engineering, National Kaohsiung University of Applied Sciences, Taiwan R.O.C. (email: wshwang@mail.ee.kuas.edu.tw)

Decodable Frame Rate (DFR), for analyzing the video quality of MPEG-4 video streaming over WLANs. However, the assumptions regarding the wireless transmission were overly simple (e.g., an average packet loss rate across the network). Lin et al. [14] proposed a more realistic model in which the effects on the frame losses of wireless channel errors and transmission collisions were both taken into account. However, as with the models presented in [12-13], the effects of error recovery on the MPEG video streaming quality were not considered.

This paper proposes an analytical model for evaluating the performance of MPEG-4 video streaming over IEEE 802.11 DCF WLANs with FEC error protection. In evaluating the video quality, the model considers both congestion losses and wireless channel losses. In addition, the model takes account of the FEC error recovery performance in improving the perceived video quality at the receiver end. Finally, the model enforces the frame retransmission constraint prescribed in IEEE 802.11 DCF. The validity of the proposed model is verified by comparing the analytical results for the Playable Frame Rate (PFR) with those obtained via NS-2 simulations and two existing analytical models, respectively.

The remainder of this paper is organized as follows. Section II reviews the background of the proposed model, including the IEEE 802.11 DCF transmission mode, the FEC error correction scheme and the MPEG-4 video structure. Section III introduces the proposed performance evaluation model. Section IV demonstrates the validity of the proposed model. Finally, Section V presents some brief concluding remarks and indicates the intended direction of future research.

II. BACKGROUND

A. IEEE 802.11 DCF

In IEEE 802.11 DCF, each station competes for channel access based on the channel state and contention window size. If the channel is busy, the station senses the channel condition continuously. If the channel remains idle for a period of time equal to the Distributed Inter-Frame Space (DIFS), the station initializes a backoff timer and defers transmission for a randomly-selected backoff interval from the contention window size. The backoff timer is decremented by one for every sensed idle time slot and is frozen when the channel is sensed to be busy. The backoff timer is reactivated when the channel is sensed to remain idle once again for more than one DIFS period, and the station attempts to transmit a packet when the backoff timer reaches zero.

In DCF, the contention window size is determined using an exponential backoff scheme known as Binary Exponential Backoff (BEB). In BEB, the contention window is doubled each time a station experiences a transmission collision, but is reset to its minimum value (CW_{min}) whenever a successful transmission occurs. When initiating the transmission of a new packet, the station randomly assigns the backoff timer in the interval of [0, CW_{min} - 1].

In accordance with the discussions above, the variation of the DCF contention window (CW) size can be represented as follows:

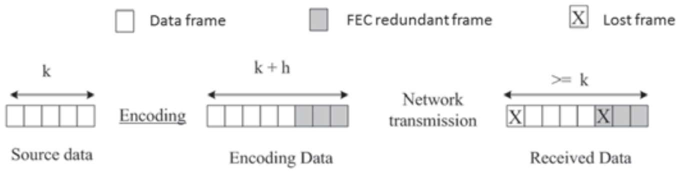

Figure 1. FEC protocol.

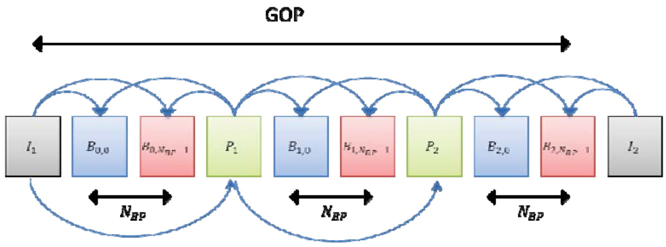

Figure 2. MPEG GOP structure, GOP (2, 6).

$$CW = \begin{cases} 2^i \times CW_{\min} & \text{if collision} \\ CW_{\min} & \text{if successful} \end{cases}$$

where i is the total number of failed transmissions of a packet. Following each failed transmission, CW is doubled until a maximum value of $CW_{max} = 2^m \times CW_{min}$ is reached, where m is the maximum number of retransmission attempts. Once CW reaches CW_{max}, it remains at this value until it is reset to CW_{min} as a result of either a successful packet transmission or the packet being dropped due to the packet retransmission limit.

B. Forward Error Correction (FEC)

The FEC protection mechanism enables the receiver to correct errors / losses in the received data without the need for any further interaction with the sender. The basic principle of FEC entails transmitting redundant frames (h) in addition to the source packets (k). The FEC approach is shown schematically in Fig. 1. As shown, k frames of source data are coded at the sender together with h redundant frames in such a way as to produce a total of n frames of coded data. Thus, provided that any k frames (source or redundant) are received at the receiver end, the source data can be successfully reconstructed. Since FEC schemes enable the recovery of source data frames which would otherwise be lost, the effective loss rate in the transmission network is lower than the actual loss rate, and thus the perceived quality of the video stream at the receiver end is improved.

In FEC codecs, the redundant packets are derived from the original packets using conventional coding theory techniques. Of the various error correcting codes available, Reed-Solomon (RS) code [15-16] has attracted particular interest since its use is explicitly recommended in the Internet Engineering Task Force (IETF) Real-time Transport Protocol (RTP). Accordingly, the present study also assumes the use of RS code in developing the proposed analytical model.

C. MPEG -4 Video Structure

In MPEG-4 coding, the video sequence is decomposed into a series of consecutive smaller units known as a Group of Pictures (GOP). Each GOP contains three types of frame arranged in a periodic sequence, namely Intra-coded (I), Predictive (P), and Bidirectional (B). I-frames are simply still images within the sequence which are independently encoded without reference to any other frames. Meanwhile, P-frames are forward predicted based on the relative information provided by the previous I-frame or P-frame. Finally, B-frames are encoded based on the relative information provided by both the preceding I- or P-frame and the following I- or P-frame.

Fig. 2 shows a typical GOP structure within an MPEG-4 video sequence. Let N_P represent the number of P-frames in the GOP, N_B represent the number of B-frames in the GOP, and N_{BP} represent the distance between the I- (or P-) frame to the next P-frame. Any GOP structure can therefore be uniquely identified by the notation GOP (N_P, N_B). For example, the structure shown in Fig. 2 is designated as GOP (2, 6). In other words, the frame sequence is as follows: 'IBBPBBPBB'.

In performing video streaming over wireless networks, the encoded video frames are segmented into small MAC data frames in accordance with the maximum transmission unit (MTU) of the network. Of all the frames received at the receiver end, some frames may not be decodable. In general, two different types of undecodable video frame exist: (1) ***direct undecodable frames***, i.e., an insufficient number of MAC frames belonging to the video frame are received to decode the frame; and (2) ***indirect undecodable frames***, i.e., the loss of a dependent frame prevents the decoding of the received frame.

III. PROPOSED ANALYTICAL MODEL

This section describes the analytical model proposed in this study for estimating the perceived quality of MPEG-4 video streaming over IEEE 802.11 DCF WLANs with FEC error protection. The section commences by analyzing the effects of transmission losses (e.g., collision losses and wireless losses) on the performance of DCF WLANs. The proposed analytical model is then formally introduced and derived.

A. Performance Analysis of IEEE 802.11 DCF WLANs

In IEEE 802.11 DCF, the loss of a transmission frame can be caused by two factors: (i) collision loss: resulting from channel access contention; and (ii) wireless loss: resulting from wireless interference. For each transmission attempt, the failure probability (P_f) of a frame is constant and independent, irrespective of the number of retransmissions. Thus, the probability of frame transmission failure can be expressed as

$$P_f = 1-(1-P_C)\times(1-P_E) = P_C+P_E-P_C\times P_E \quad (1)$$

where P_C and P_E represent the frame loss probabilities due to collision and wireless errors, respectively. (Note that all of the notations used in the proposed analytical model are described in Table I.) Assuming that the data frame corruption and ACK frame corruption events are independent, it follows that

$$P_E = P_{E\_data} + P_{E\_ACK} - P_{E\_data}\times P_{E\_ACK} \quad (2)$$

where P_{E_data} and P_{E_ACK} are the Frame Loss Probabilities (FLPs) of the data frame and ACK frame, respectively. Assuming that the bit errors are uniformly distributed over the whole frame, P_{E_data} and P_{E_ACK} can be expressed respectively as

$$P_{E\_data} = 1-\left(1-P_{E\_bit}\right)^{data\_length} \quad (3)$$

$$P_{E\_ACK} = 1-\left(1-P_{E\_bit}\right)^{ACK\_length} \quad (4)$$

where P_{E_bit} is the Bit Error Probability (BEP) of the wireless channel.

In DCF, a frame transmission attempt is made only when the backoff timer falls to zero. However, collisions may occur if multiple active stations commence transmission simultaneously. In calculating the collision loss rate, it is assumed that each frame collides with a constant and independent probability, P_C. Under steady-state conditions, each station transmits a frame with probability τ. Consequently, the collision probability for any station competing for channel access is equal to

$$P_C = 1-\left(1-\tau\right)^{n-1} \quad (5)$$

Combining Eq. (1) and Eq. (5), the probability of a frame transmission failure is obtained as

$$P_f = 1-\left(1-P_E\right)\times\left(1-\tau\right)^{n-1} \quad (6)$$

In the analytical model proposed in this study, the maximum backoff stage (m) is assumed to be equal to the maximum retransmission time. Hence, a frame will be dropped when the contention window is at its maximum size and a loss occurs as the result of either a collision event or wireless errors. From the model presented in [10], the probability τ of an active station transmitting in a randomly-chosen time slot is given by

$$\tau = \frac{2\times\left(1-2\times P_f\right)\times\left(1-P_f^{\,m+1}\right)}{\left(1-P_f\right)\times CW_{min}\times\left(1-\left(2\times P_f\right)^{m+1}\right)+\left(1-2\times P_f\right)\times\left(1-P_f^{\,m+1}\right)} \quad (7)$$

Equations (6) and (7) represent a nonlinear system with two unknown variables, τ and P_f. In Eq. (1), P_f denotes the failure probability each time a frame transmission is attempted over the DCF WLAN. However, frame retransmission increases the probability of a particular frame being successfully received. In developing the proposed analytical model, an assumption is made that each frame can be transmitted a maximum of T_{max} times before being discarded by the sender. The effective failure probability of each frame is therefore given by

$$P_{effective} = \sum_{i=0}^{T_{max}} \binom{T_{max}}{i}\times\left(P_C^{\,i}\right)\times\left(\left(1-P_C\right)\times P_e\right)^{T_{max}-i} \quad (8)$$

B. Analytical Model for MPEG-4 Video Streaming with FEC Error Recovery

In practical FEC-protected DCF WLANs, the redundant data are derived from the original source data using a variety of different error correcting codes. As described in Section II.B, it is assumed in this study, that the redundant data are derived using Reed-Solomon (R-S) erasure code [15-16]. Given the use of R-S code at the FEC codec and an effective frame loss probability of $P_{effective}$, the probability of a successful frame transmission is given as follows [17]:

$$B(n,k,P_{effective}) = \sum_{i=k}^{n}\left[\binom{n}{i}(1-P_{effective})^{i} \times (P_{effective})^{n-i}\right], \tag{9}$$

where $\binom{n}{i}$ denotes all possible combinations of the i frames successfully received within a block, irrespective of whether these frames are original source frames or FEC-generated redundant frames. According to the MPEG video structure shown in Fig. 2, the successful transmission probabilities of the I-, P- and B-frames in the GOP are given respectively as

$$\begin{aligned} Q_I &= B(S_I + S_{IR}, S_I, P_{effective}) \\ Q_P &= B(S_P + S_{PR}, S_P, P_{effective}) \\ Q_B &= B(S_B + S_{BR}, S_B, P_{effective}), \end{aligned} \tag{10}$$

where S_I, S_P and S_B are the number of MAC I-, P- and B-frames, respectively; while S_{IR}, S_{PR} and S_{BR} are the number of redundant I-, P- and B-frames, respectively.

The authors in [17] proposed a performance metric designated as the Playable Frame Rate (PFR) for evaluating the quality of video streaming over lossy networks. The PFR is defined as the ratio of the expected number of decodable video frames at the receiver to the total number of video frames transmitted by the sender. (Note that the PFR is computed on a per-second basis.) The effective GOP transmission rate can be computed as

$$G = \frac{R_F}{1 + N_P + N_B}, \tag{11}$$

where N_P and N_B are the number of P- and B-frames in the GOP, respectively, and R_F is the encoding frame rate per second.

In MPEG-4 video streaming, the I-frames are always decodable provided that they are successfully transmitted since they are encoded independently of any of the other frames in the GOP. As a result, the PFR for I-frames is equal to the number of I-frames transmitted successfully over the network. In other words, the PFR is given simply as

$$R_I = G \times Q_I. \tag{12}$$

P-frames are decodable only if they are successfully transmitted and the dependent preceding I- or P-frame is also decodable. Thus, the PFR for P-frames is given by

$$\begin{aligned} R_{P1} &= R_I \times Q_P \\ R_{P2} &= R_{P1} \times Q_P = R_I \times {Q_P}^2 \\ &\ldots \\ R_{PN_P} &= R_{PN_P-1} \times Q_P = R_I \times {Q_P}^{N_P}. \end{aligned} \tag{13}$$

TABLE I. NOTATIONS USED IN THE PROPOSED ANALYTICAL MODEL

P_f	Probability of MAC frame transmission failure.
P_E	Probability of MAC frame loss due to wireless error.
P_C	Probability of MAC frame loss due to collision.
P_{E_data}	Probability of MAC data frame loss.
P_{E_ACK}	Probability of ACK frame loss.
P_{E_bit}	Bit Error Probability (BEP).
T_{max}	Maximum number of retransmissions of MAC frame
$P_{effective}$	Effective loss rate of MAC frame given maximum number of retransmissions equal to T_{max}
Q_I, Q_P, Q_B	Probabilities of successful I-, P-, and B-frame transmission.
S_I, S_P, S_B	Numbers of MAC I-, P-, and B-frames.
S_{IR}, S_{PR}, S_{BR}	Numbers of FEC redundant I-, P-, and B- frames.
N_P, N_B	Numbers of P- and B-frames in GOP.
R_F	Encoding frame rate per second.
G	Effective GOP transmission rate.
R_I, R_P, R_B	Playable frame rates of I-, P-, and B-frames over entire video sequence.
R	Overall playable frame rate of FEC-protected MPEG video stream.

As a result, the PFR for all the P-frames in the entire video sequence is equal to

$$R_P = \sum_{i=1}^{N_P} R_{Pi} = G \times Q_I \times \frac{Q_P - {Q_P}^{N_P+1}}{1-Q_P}. \tag{14}$$

B-frames are decodable only if they are successfully transmitted and the dependent preceding and succeeding I- or P-frames are both decodable. Consecutive B-frames depend on the same I- and P-frames and therefore have the same PFR. Consequently, consecutive B frames can be treated as a single B group. The final B group depends on both the preceding P-frame and the succeeding I-frame. Therefore, the PFR of the B-frames is given by

$$\begin{aligned} R_{Bij} &= R_{Pi+1} \times Q_B \quad && when \quad 0 \le i \le N_P - 1 \\ R_{Bij} &= R_{Pi} \times Q_B \times Q_I \quad && when \quad i = N_P. \end{aligned} \tag{15}$$

Consequently, the PFR of all the B-frames in the video sequence is equal to

$$R_B = N_{BP} \times \sum_{i=0}^{N_P} R_{Bi0} = N_{BP} \times G \times Q_I \times Q_B \times \left(\frac{Q_P - {Q_P}^{N_P+1}}{1-Q_P} + Q_I \times {Q_P}^{N_P}\right). \tag{16}$$

Clearly, the overall PFR for a FEC-Protected MPEG video stream is equal to the sum of the PFRs of the I-, P- and B-frames, respectively. That is,

$$\begin{aligned} R &= R_I + R_P + R_B \\ &= G \times Q_I \times \left(1 + \frac{Q_P - {Q_P}^{N_P+1}}{1-Q_P} + N_{BP} \times Q_B \times \left(\frac{Q_P - {Q_P}^{N_P+1}}{1-Q_P} + Q_I \times {Q_P}^{N_P}\right)\right). \end{aligned} \tag{17}$$

TABLE II. PARAMETER SETTINGS [7].

Packet payload (L_{data})	8184 bits	**Slot time**	50 µs
ACK (L_{ACK})	240 bits	**DIFS**	128µs
MAC header	272 bits	**SIFS**	28µs
PHY header	128 bits	**CW_{min}**	32
Channel Data Rate	1 Mbps	**T_{max}**	5
BEP (P_{E_bit})	10^{-5}	**C_I**	3.91
N_P	3	**C_P**	2.05
N_B	8	**C_B**	1.52

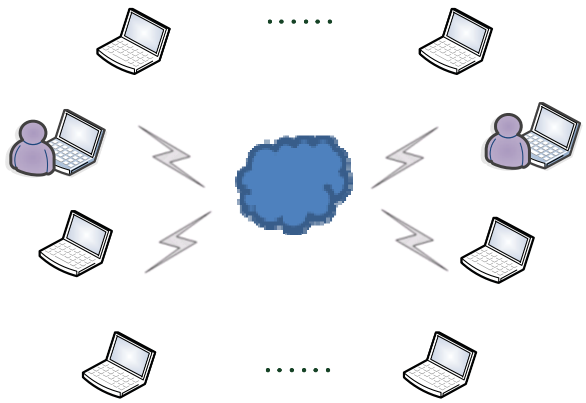

Figure 3. Simulation topology.

IV. NUMERICAL RESULTS

In this section, the proposed analytical model is validated by comparing the predicted results for the PFR with the analytical results obtained from the models presented in [8, 9] and the NS-2 simulation results presented by [18]. The considered network topology is shown in Fig. 3. In comparing the PFR results of the various methods, the number of wireless nodes within the network was varied in the range of 5 to 50. As described in Section III, the model proposed in this study takes account of both the retransmission limitation and the effects of channel errors. By contrast, the models presented in [8, 9] consider only one of these features but not both. Moreover, the proposed model considers the PFR performance of a video stream delivered over a FEC-protected WLAN, whereas the models in [8, 9] ignore the effects of FEC error recovery.

The parameter settings used in the analytical models and simulations are shown in Table II. In modeling the network performance, it was assumed that the wireless stations operated under saturation conditions, i.e., each station always had a packet available for transmission. Furthermore, an assumption was made that video traffic was sent from a randomly selected node and received by a randomly chosen destination node. Meanwhile, the other nodes in the network were assumed to transmit UDP flows at a constant bit rate (CBR). The experiments were performed using the "Mr. Bean" video trace [19]. The video sequence comprised 89126 frames (i.e., 7428 I-frames, 22282 P-frames, and 59416 B-frames) with a GOP structure of IBBPBBPBBPBB (N_P=3, N_B=8). In transmitting the frames, the maximum packet size was set to 1000 bytes.

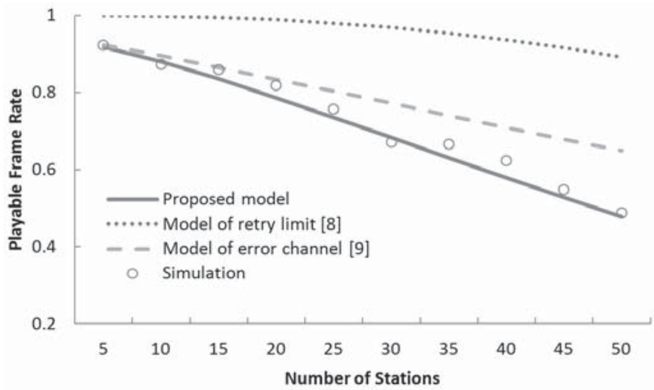

Figure 4. Variation of PFR with number of active stations given poor channel condition (BEP = 10^{-4}).

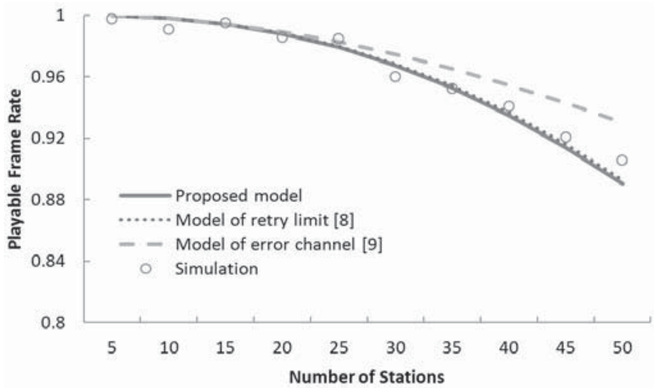

Figure 5. Variation of PFR with number of active stations given good channel condition (BEP = 10^{-6}).

A. *Model Validation*

As the number of nodes in the network increases, the number of collisions also increases. The greater number of collisions causes more packets to be lost, and thus the PFR reduces, as shown in Figs. 4 ~ 7. It is noted in Figs. 4 ~ 7 that the PFR predictions obtained using the model proposed in this study are in better agreement with the simulation results than those obtained from the analytical models presented in [8,9]. For a bad channel condition (BEP = 10^{-4}, Fig. 4), most of the frame losses are the result of wireless losses. In the model proposed in [8], channel errors are not considered, and thus the PFR is overstated. Furthermore, since channel errors are ignored, the model predicts an identical PFR performance irrespective of the channel condition (see Figs. 4 and 5 corresponding to BEP = 10^{-4} and BEP = 10^{-6}, respectively). In the model presented in [9], the number of retransmissions is assumed to be unlimited, and thus the PFR is overstated for both channel conditions.

In the case of a good channel condition (BEP = 10^{-6}, Fig. 5), most of the frame losses are the result of channel contention. Due to the very low error rate, the PFR predictions of the current model and the model presented in [8], respectively, are very similar. However, in general, the results presented in Figs. 4 and 5 show that the proposed model provides a more reliable and robust evaluation of the perceived quality of FEC-protected MPEG-4 video streaming over 802.11 DCF WLANs

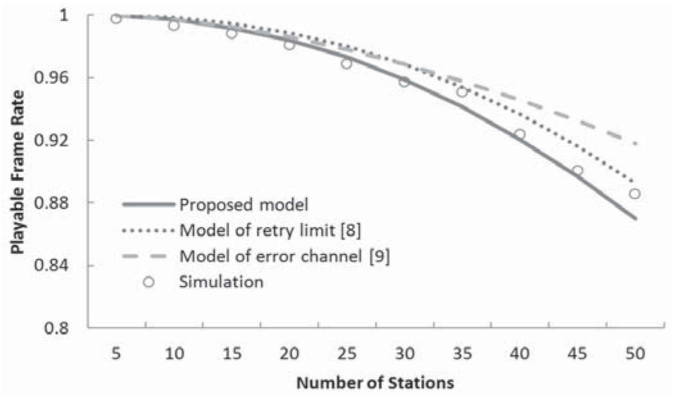

Figure 6. Variation of PFR with number of active stations given m = 4 frame retransmission opportunities.

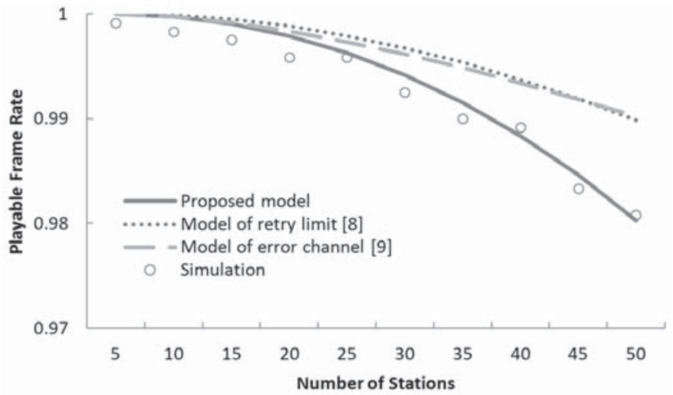

Figure 7. Variation of PFR with number of active stations given m = 6 frame retransmission opportunities.

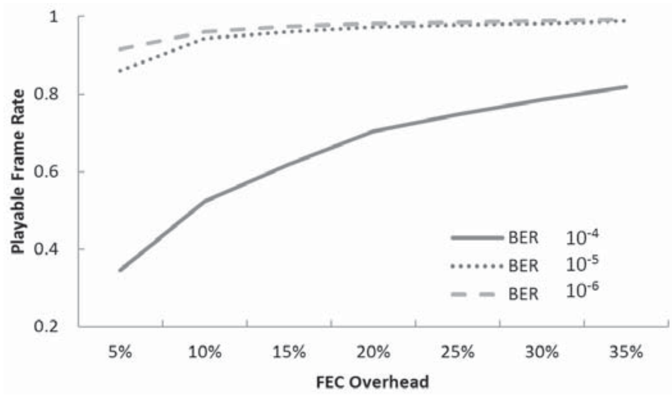

Figure 8. Variation of PFR with FEC overhead as function of BER. (Node = 20, m=5)

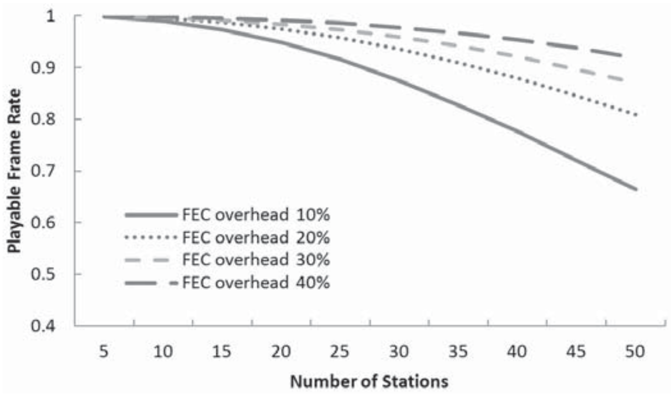

Figure 9. Variation of PFR with number of stations as function of FEC overhead. (BER=10^{-5}, m=5)

under typical (i.e., varying) wireless channel conditions.

As shown in Figs. 6 and 7, the PFR increases (i.e., the perceived video quality improves) as the maximum number of retransmissions (m) is increased. The PFR results obtained from the proposed model are in good agreement with the simulation results for both values of m. For m = 4, the analytical models presented in [8, 9] both overestimate the PFR (see Fig. 6). For a given number of stations, the PFR prediction of the model in [9] is higher than that of the model in [8] due to the assumption of an unlimited number of retransmissions. However, given a greater number of retransmission opportunities (e.g., m = 6), all of the stations are able to transmit most of their packets successfully. Therefore, as shown in Fig. 7, the PFR predictions of the two analytical models are very similar; even under heavy network load conditions.

B. Performance Analysis of Video Stream given FEC Error Recovery

In this sub-section, the proposed analytical model is used to evaluate the effect of the FEC error recovery mechanism on the perceived MPEG-4 video streaming quality in IEEE 802.11 DCF WLANs under various network conditions. Fig. 8 shows the variation of the PFR with the FEC overhead as a function of the bit error rate (BER). Note that the FEC overhead is defined as the ratio of the number of FEC redundant frames to the total number of frames (source plus FEC redundant). In other words, a 20% FEC overhead implies that one redundant frame is transmitted with every four source frames. As expected, for all values of the BER, the video quality improves with an increasing FEC overhead due to the greater successful decoding probability. However, given a poor channel condition (BEP = 10^{-4}), the video quality is seriously degraded even when a large number of redundant packets are injected into the transmission stream since many packets (both source and redundant) are lost during the transmission process.

Fig. 9 shows the effect of the FEC overhead on the perceived quality of the video stream under various network loads. Under light network loads (i.e., $n \leq 10$), the video quality is relatively unaffected by the number of redundant frames added to the source frames. However, given a larger number of active stations, the collision probability increases, and thus a higher FEC overhead results in a lower effective frame loss rate and an improved video quality.

V. CONCLUSION

This paper has proposed an analytical model for evaluating the video quality of MPEG-4 video streaming over FEC-protected IEEE 802.11 DCF WLANs. The proposed model considers not only the effects of congestion and wireless frame losses, but also the performance of the FEC error recovery mechanism in improving the perceived video quality at the receiver end. The validity of the proposed model has been confirmed by comparing the predicted results for the Playable Frame Rate (PFR) with the results obtained from NS-2 simulations and two existing analytical models, respectively. The results have confirmed the ability of the proposed model to yield an accurate prediction of the perceived quality of MPEG-4 video streaming over DCF WLANs with FEC protection. In a future study, the proposed model will be extended to the case of channel interference [20-21] over IEEE 802.11e [22-23] based networks with QoS support.

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