Cross-Layer Assisted Power and Rate Control for Video Transmission in Wireless Networks

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Abstract —In this paper, aiming to improve the quality of video transmission while satisfying the delay Quality of Service (QoS) requirements, we propose an efficient cross-layer assisted video transmission scheme by jointly considering the video coding rate and the available power resource. We jointly analyze the effects on the performance of video transmission from video coding rate at the application layer, queueing delay at the Media Access Control (MAC) layer, as well as the power control at the physical layer. Our objective is to minimize the sum distortion of all users under delay and power constraints. By a proper problem formulation, we can convert it into a convex one, which can be solved through utilizing the standard convex optimization technology. The performance of the proposed cross-layer assisted algorithm is evaluated through simulations. For performance comparison, we also present the simulation results of the artificial bee colony optimization algorithm and the fixed power optimization algorithm. Simulation results show that the proposed cross-layer assisted algorithm improves the video transmission quality considerably through the comparison with the other two algorithms.

Index Terms—Cross-layer design, video transmission, queueing theory, rate and power control, convex optimization technology, artificial bee colony algorithm

I. Introduction

Along with the increasing demands on multimedia application, video transmission is becoming one of the most popular services in future wireless networks [1], [2]. For video transmission, the Quality of Service (QoS) is an important parameter to measure the system performance. QoS can be Peak Signal to Noise Ratio (PSNR) or video distortion [3], [4], etc. And QoS performance can be affected by the transmit power, the channel fading at the physical layer, as well as the video coding rate at the application layer. Therefore, in order to improve the quality of video transmission, all these factors from different protocol layers should be taken into consideration.

The video coding rate has a large impact on the video transmission quality. On the one hand, since the video coding rate at the application layer is limited by the channel capacity at the physical layer, it should be no more than the channel capacity; otherwise the overlarge video coding rate may lead to long queue delay and thus decrease the QoS. On the other hand, if the video coding rate is too small, it may result in the underutilization of the network resources and may also cause high compression-introduced video distortion [5]. Therefore, to improve the video transmission quality and fully utilize the network resources, the video coding rate should be adjusted adaptively to match up to the channel capacity. In addition, both the transmit power and the channel fading impact the channel capacity, and further affect the decision of the optimal video coding rate. Hence, it is also important for users to jointly adjust their transmit power and video coding rate to maximize their video transmission quality of the whole network according to their dynamic wireless channel conditions.

Cross-layer based methods have been proposed to deal with the above issues in the literature [5]–[15]. For instance, a cross-layer adaptive rate control scheme was proposed for video transmission over Long Term Evolution (LTE) networks in [5]. In [7], a cross-layer scheme has been proposed through jointly considering path selection and rate allocation to minimize the video distortion. In [9], jointly optimal rate control and relay selection scheme has been considered for cross-layer video transmission. Reference [11] designed a cross-layer transmission strategy for cognitive radio system by taking the Automatic Repeat Request (ARQ) retransmission of the primary system at the link layer, and adaptive modulation and coding and power control at the physical layer. In addition, a cross-layer subcarrier and power allocation scheme was proposed for Orthogonal Frequency Division Multiple Access (OFDMA)-based cognitive radio video application systems. In addition, Reference [13] presented an adaptive Quality of Experience (QoE)-driven and forward error correction (FEC)-based mechanism to provide real-time video transmission for vehicular Ad-hoc networks. The authors in [14] presented a packet utility-based optimized cross-layer resource allocation, Modulation and Coding Scheme (MCS) selection, and packet scheduling algorithm for real time video transmission over High

Manuscript received September 3, 2015; revised February 17, 2016.
This work was supported in part by Shandong provincial key laboratory of wireless communication technologies, the International S&T Cooperation Program of China (2014DFA11640), the National Natural Science Foundation of China (No. 61371109 and 61271229), and the Distinguished Young Scientists Foundation of Shandong province (JQ201315).
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doi:10.12720/jcm.11.2.118-125

Speed Downlink Packet Access (HSDPA), where the packet utility was defined as a function of the packet urgency and the packet importance. In [15], we proposed a threshold-based transmission strategy for interference-aware cross-layer distributed video transmission in interference-limited ad hoc networks, where the transmission threshold and video coding rate were jointly optimized to improve the video transmission quality. Differing from the aforementioned work, in this work we focus on investigating the joint power and rate control to decrease the sum distortion of the multiple access network while satisfying the delay requirements of users.

Delay-constraint video transmission schemes have been considered in the literature [6], [8], [10], [16]. For instance, in [6], based on the M/M/1 queuing model, video packet loss rate was developed to capture the impact on the video quality from network congestion. Also based on the M/M/1 model, an adaptive retry-limit algorithm was proposed to enhance delay sensitive video quality over IEEE 802.11 WLANs in [8]. In [10], a more general M/G/1 queuing model was employed, where only the video encoder distortion was considered to model the video distortion. The authors in [16] adopt an intra-refreshment and adaptive slice partitioning for video encoding and then modeled the delay constrained video transmission using Markov decision process to find the optimal coding and modulation scheme. However, few of the aforementioned work focuses on studying the impact of joint power and video rate control on the quality of real-time video transmission based on M/G/1 queuing model. The joint optimization of video coding rate and physical resources based on the queue status is still an open problem.

To bridge the aforementioned research gap, in this work, we aim to develop a cross-layer control scheme to improve the quality of video transmission. In this scheme, we jointly consider the impact of the transmit power at the physical layer, the video coding rate at the application layer, as well as the queueing delay at the Media Access Control (MAC) layer on the video transmission quality. The main contributions of this paper are summarized as follows:

1) We develop a novel cross-layer assisted video transmission scheme through jointly controlling the video coding rate and the transmit power.

2) Based on the proposed cross-layer transmission scheme, we analyze the impacts of the transmit power at the physical layer, the queueing delay at the MAC layer, as well as the video coding rate at the application layer on the system performance.

3) We formulate the problem of minimizing sum distortion into a cross-layer optimization problem. And a global optimization algorithm is proposed to solve the optimization problem based on the convex optimization theory and reformulation-linearization technology.

The reminder of this paper is organized as follows. In Section II, the system models from different protocols are presented. The optimization problem is formulated in Section III. The proposed solution procedure is also included in this section. Simulation results and analysis are provided in Section IV to evaluate the performance of our proposed cross-layer scheme. Section V concludes the whole paper.

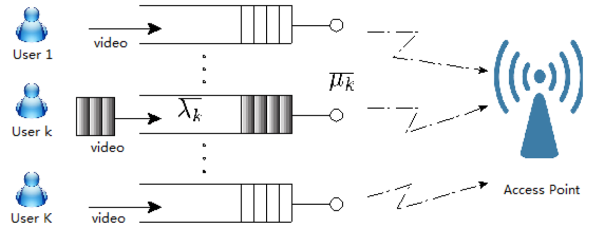


Fig. 1. System model based on the M/G/1 queue

II. System Model

We consider a wireless multiple-access network, where there are K users (denoted by a set $\mathcal{K}$) transmitting their video streams to one Access Point (AP) through single hop route as shown in Fig. 1. Assume that the network works in a steady state and each user transmits one video stream. The transmission process of video packet of each user can be modeled as a queueing process. The arrival video packets from video encoder are first buffered in a queue, where they are waiting to be transmitted over the wireless channel. Since the video transmission process of each user involves multiple parameters (e.g., video bit rate, queueing delay, transmission rate) from different protocol layers, we propose a cross layer transmission scheme to improve the performance of video transmission system. The information exchanges among different layers are modeled as follows.

A. Physical Layer Transmission Model

Assume all users access the AP with Code Division Multiple Access (CDMA). The user $k \in \mathcal{K}$ transmits the video packet with power P_k under the maximum power constraint P_k^{max}, i.e., $P_k \leq P_k^{max}$. The signal to interference plus noise ratio (SINR) for user k is expressed as

$$SINR_k = \frac{\chi_k P_k G_k}{\sigma_k^2 + \sum_{j \neq k} P_j G_j} \tag{1}$$

where χ_k represents the spreading gain and G_k is the channel gain including the large scale path loss and small scale fading. σ_k^2 denotes the noise power of user k. The corresponding link capacity of user k is given as

$$C_k = B \log_2(1 + SINR_k) \tag{2}$$

where B is the channel bandwidth. To improve the quality of video transmission, same assumption as made in [10] that the network works in the high SINR region. This is reasonable since the large spreading gain is provided by the wireless networks utilizing CDMA technology. Therefore, the link capacity in (2) can be approximated as

$$C_k \approx B\log_2(\frac{\chi_k P_k G_k}{\sigma_k^2+\sum_{j\neq k}P_j G_j}) \tag{3}$$

B. MAC Layer Queue Model

The packet arrival process of user k is assumed to follow Poisson distribution with the parameter λ_k (packets per second) and the packets in a queue are served in a First in First out (FIFO) fashion. Let L_k and R_k represent the average length of one packet and the arrival video bit rate from the source of user k, respectively. Then, we have the average packet arrival rate,

$$\lambda_k = \frac{R_k}{L_k} \tag{4}$$

To improve the probability of packet successful transmission, an ARQ control protocol is considered. Assume that the retransmissions in ARQ protocol are independent and the FEC is not used. Therefore, the packet transmission time for user k is defined as

$$\tau_k = \frac{L_k}{C_k} + \xi_k \tag{5}$$

where ξ_k represents the time taken for user k to receive ACK/NACK from the AP. Similar to [17], we further assume ξ_k can be negligible compared to the value of L_k/C_k.

Denote P_e as the packet error rate due to channel transmission error. The probability mass function (pmf) of the service time S_k for user k to transmit one packet is expressed as

$$\Pr(S_k = m\tau_k) = P_e^{m-1}(1-P_e),\ \text{for } m = 1,2,\cdots \tag{6}$$

According to (6), the first and second moments of the service time S_k can be expressed as

$$\mathbb{E}\{S_k\} = \sum_{i=1}^{\infty} i\tau_k P_e^{i-1}(1-P_e) = \frac{\tau_k}{1-P_e} \tag{7}$$

$$\mathbb{E}\{S_k^2\} = \sum_{i=1}^{\infty} i^2\tau_k^2(1-P_e)P_e^{i-1} = \frac{\tau_k^2(1+P_e)}{(1-P_e)^2} \tag{8}$$

where $\mathbb{E}\{\cdot\}$ denotes expectation operator. Consequently, the average service rate of a queue for user k, denoted by μ_k, is

$$\mu_k = \frac{1}{\mathbb{E}\{\mathcal{S}_k\}} = \frac{1-P_e}{\tau_k} \tag{9}$$

Then, the queue utility factor ρ_k [18] can be expressed as

$$\rho_k = \frac{\lambda_k}{\mu_k} = \frac{R_k}{(1-P_e)C_k} \le 1 \tag{10}$$

where $\rho_k \le 1$, i.e., $R_k \le (1-P_e)C_k$, is required to keep the stability of the queue. Without loss of generality, the above process can be modeled as an M/G/1 queue system. According to the queueing theory [19], the average packet waiting delay W_k is expressed as follows

$$\begin{aligned}\mathbb{E}[W_k] =& \frac{\lambda_k\mathbb{E}[S_k^2]}{2(1-\lambda_k\mathbb{E}[S_k])}\\ =& \frac{(1+P_e)\lambda_k\tau_k^2}{2(1-P_e)(1-P_e-\lambda_k\tau_k)}\end{aligned} \tag{11}$$

Let T_k^{th} represent the delay QoS requirement of user k, i.e., video play-out deadline. According to the tail distribution in queueing theory [19], the packet loss probability due to exceeding the given play-out deadline, denoted by P_k^{dly}, can be calculated as

$$\begin{aligned}P_k^{dly} =& \Pr(W_k > T_k^{th})\\ =& \lambda_k\mathbb{E}[S_k]\exp(-\frac{T_k^{th}\lambda_k\mathbb{E}[S_k]}{\mathbb{E}[W_k]})\\ =& \frac{\lambda_k\tau_k}{1-P_e}\exp(-\frac{2T_k^{th}(1-P_e-\lambda_k\tau_k)}{(1+P_e)\tau_k})\end{aligned} \tag{12}$$

C. Application Layer Distortion Model

In this paper, the Mean Square Error (MSE) rate-distortion [20] is adopted to model the video distortion, which is widely used to characterize the video streaming [6], [9]. According to the rate distortion model proposed in [6], the overall video distortion for arbitrary user k can be expressed as

$$\begin{aligned}D_k =& D_k^{enc} + D_k^{loss}\\ =& \underbrace{D_{0,k} + \frac{\theta_k}{(R_k-R_{0,k})}}_{D_k^{enc}} + \underbrace{\nu_k(P_e + P_k^{dly})}_{D_k^{loss}}\\ =& D_{0,k} + \frac{\theta_k}{(R_k-R_{0,k})} + \nu_k P_e\\ &+ \nu_k\frac{R_k}{(1-P_e)C_k}\exp(-\frac{2T_k^{th}((1-P_e)C_k-R_k)}{(1+P_e)L_k})\end{aligned} \tag{13}$$

where D_k^{enc} represents the distortion introduced by lossy video compression. D_k^{loss} denotes the distortion caused by the packet loss where the second-order term $P_k^{dly}P_e$ is neglected, which is acceptable when the overall packet loss rate is low or moderate. R_k is the bit rate of the video stream of user k, and $D_{0,k}$, θ_k, $R_{0,k}$ are video-specific parameters of user k. Note that these video-specific parameters can be estimated by using nonlinear regression techniques [6]. ν_k indicates the sensitivity of a video sequence to packet loss. It can also be measured offline or estimated by nonlinear regression methods. It is worthy noting that the parameters from the physical layer, MAC layer as well as the application layer have been integrated into (13).

III. Problem Formulation and Solution

As our objective is to maximize the video quality of the network, i.e., minimize the sum distortions of all users, under the constraints of delay and maximal transmit power. Based on the distortion model described in (13), the optimization problem is formulated and the solution is given accordingly.

A. Problem Formulation

Based on the aforementioned analysis, the problem to minimize the sum distortion of all users can be formulated into a cross-layer assisted optimization problem by jointly considering the video coding rate, queueing delay constraint as well as the transmit power limit. Hence, the optimization problem is formulated as

$$\min_{\mathbf{R},\mathbf{P}} \quad \sum_{k=1}^{K} D_k \tag{14}$$

$$s.t. \quad 0 < P_k \leq P_k^{max}, \forall k \tag{15}$$

$$R_{0,k} < R_k \leq (1-P_e)C_k, \ \forall k \tag{16}$$

$$C_k = B\log_2\left(\frac{\chi_k P_k G_k}{\sigma_k^2 + \sum_{j\neq k} P_j G_j}\right), \ \forall k \tag{17}$$

where $\mathbf{R} = [R_1, R_2, \cdots, R_K]$ and $\mathbf{P} = [P_1, P_2, \cdots, P_K]$ are the rate and power optimization vector, respectively. The constraint in (15) denotes the power limit of each user. (16) Indicates that the video coding rate should not be more than the link effective transmission capacity to guarantee the stability of queue.

B. Proposed Solution

The optimization problem formulated in (14)-(17) is a nonlinear and non-convex problem. In general, such optimization problem is NP-hard and difficult to be solved in a polynomial time. To solve it, D_k in (14) should be transformed to a convex version. Introduce a new variable Y_k as

$$Y_k = \nu_k \frac{R_k}{(1-P_e)C_k} \exp\left(-\frac{2T_k^{th}((1-P_e)C_k - R_k)}{(1+P_e)L_k}\right) \tag{18}$$

For denoting simplicity, define three constants, i.e., $a_k = D_{0,k} + \nu_k P_e$, $b_k = \nu_k/(1-P_e)$ and $l_k = 2T_k^{th}/(L_k(1+P_e))$. Then, the original optimization problem in (14)-(17) can be rewritten as

$$\min_{\mathbf{R},\mathbf{Y}} \quad \sum_{k=1}^{K} a_k + \frac{\theta_k}{(R_k - R_{0,k})} + Y_k \tag{19}$$

$$s.t. \quad 0 < P_k \leq P_k^{max}, \ \forall k \tag{20}$$

$$R_{0,k} < R_k \leq (1-P_e)C_k, \ \forall k \tag{21}$$

$$C_k = B\log_2\left(\frac{\chi_k P_k G_k}{\sigma_k^2 + \sum_{j\neq k} P_j G_j}\right), \ \forall k \tag{22}$$

$$Y_k \geq b_k \frac{R_k}{C_k} \exp(l_k R_k - (1-P_e) l_k C_k), \ \forall k \tag{23}$$

It can be easily proved that the new objective function (19) is convex with respect to variables R_k and Y_k by checking the positive of its second-order derivative. The constraints (20) and (21) are both affine functions with respect to R_k and C_k. In addition, the constraint in (22) is a log-convex function, and it can be transformed into convex by making the substitution $\xi_k = \log(P_k)$ [21].

Consequently, the equivalent expression of (22) is given as

$$\begin{aligned} C_k = &\underbrace{\frac{B}{\log(2)}\{\log(\chi_k G_k) + \xi_k\}}_{(\mathcal{A})} \\ &\underbrace{-\log\left(\sigma_k^2 + \sum_{j\neq k} G_j \exp(\xi_j)\right)\frac{B}{\log(2)}}_{(\mathcal{B})} \end{aligned} \tag{24}$$

where the term $(\mathcal{B})$ is a concave function with respect to ξ_j and the term $(\mathcal{A})$ is an affine function with respect to ξ_k. Hence, C_k is already a concave function. The condition in (23) is still non-convex. Taking logarithm operation on both sides of (23), it is expressed as

$$\begin{aligned} \log(Y_k) \geq &\underbrace{\log(b_k) + l_k R_k}_{(\mathcal{C})} \\ &+ \underbrace{\log(R_k)}_{(\mathcal{D})} \underbrace{- \log(C_k) - (1-P_k) l_k C_k}_{(\mathcal{F})} \end{aligned} \tag{25}$$

where the terms $(\mathcal{C})$ and $(\mathcal{F})$ are both convex function with respect to R_k and C_k, while the term $(\mathcal{D})$ is still concave. To solve the optimization problem by using the existing standard optimization method, the term $(\mathcal{D})$ should be convex too. Applying the Reformulation-Linearization Technology (RLT) [22] as shown in [7], $(\mathcal{D})$ is linearized. Finally, the original optimization problem is transformed into the following convex version

$$\begin{aligned} \min_{\xi,\mathbf{R},\mathbf{Y}} : \quad & \sum_{k=1}^{K} a_k + \frac{\theta_k}{(R_k - R_{0,k})} + Y_k \\ s.t. : \quad & (20), \ (21), \ (24), \ (25). \end{aligned} \tag{26}$$

Now, the reformulated optimization problem can be solved by the standard convex optimization techniques [21], [23].

IV. Simulation Results and Analysis

Consider the system model described in Section II, simulation results are presented in this section to evaluate the performance of the proposed cross-layer assisted video transmission scheme. For clarity, we first show the effects of video coding rate and transmit power on video distortion model when there exists one user in the network. Then, the performance evaluations of the proposed cross-layer assisted optimization algorithm are illustrated through comparison with other two existing algorithms when there are multiple users in the network.

A. Simulation Setup

During the simulations, two kinds of video sequences, i.e., Foreman (FM) (representing intensive rate variability characteristic) and Mother and Daughter (MD) (representing moderate rate variability characteristic) [6], are employed to test the performance of the proposed optimization algorithm. Their corresponding parameters are shown in Table I. It is assumed that the network suffers from both large scale and small scale fading. When carrying out the simulations, the path loss exponent is set to 4, the bandwidth B is set to 15 KHz and the spreading gain of each user is 256. Same as [10], the average packet length of each video sequence is assumed to be 100 bits. The power limit of each user and noise power are set to be 1000 mW and 10^{-7} mW, respectively. In addition, the packet error rate P_e is predefined as 0.01. CVX software packet [23] is employed to solve the transformed convex optimization problem in (26).

TABLE I: VIDEO PARAMETERS

Video stream	$D_{0,k}$	θ_k	$R_{0,k}$	κ_k	T_k^{th}
FM	0.38	2537	18.3(kb/s)	750	150(ms)
MD	-1.18	858	0.67(kb/s)	30	150(ms)

TABLE II: PARAMETERS SETTINGS OF ABC ALOGRITHM

Parameter settings of ABC algorithm	
Swarm size	20
Limit	40
Number of onlookers	10
Number of employed bees	10
Number of scouts	1
Maximum number of cycles	1000

B. Effects of Video Coding Rate and Transmit Power on Video Distortion

The effects of video coding rate and transmit power on the video distortion model shown in (13) are firstly investigated under different video sequences (FM and MD). Results are shown in Fig. 2 and Fig. 3, respectively. The results of the two figures are achieved when there exists only one user in the network. In both figures, the distortion performance is shown when the video coding rate varies from their minimum coding rate to their corresponding effective channel capacity and the transmit power varies from minimum transmission power to maximum power. And the delay requirement is 1/30 s. From Fig. 2 and Fig. 3, it can be observed that video distortion increases drastically when the value of video coding rate is over-high or over-low under any given transmit power. This is because the over-high coding rate may lead to long queue delay and the over-low rate may cause high compression-introduced video distortion. In addition, there exists an optimal video coding rate to make video distortion minimum for any given transmit power as shown in Fig. 2 and Fig. 3. In other words, when the transmit power is fixed, the video distortion is a convex function with respect to the video coding rate, which is also consistent with the theoretical analysis made in Section II.

Moreover, from Fig. 2 and Fig. 3, we can see that video distortion decreases as the transmit power increases when video coding rate is given. This is because an increase in transmit power also leads to an increase in effective channel capacity (i.e., the service rate of a video queue) and further results in a decrease in packet loss rate caused by exceeding the maximum delay constraint. In addition, it can be seen that the performance improvement becomes smaller as the transmit power continues to increase under given video coding rate. This is because the service rate is still mismatched with the given video coding rate although the service rate is improved by increasing transmitting power. This also implies that video distortion is more sensitive to video coding rate than transmit power for the distortion model (13). Therefore, the video coding rate should be adjusted to match up with the channel service rate in order to minimize the video distortion. In addition, through comparing the two figures, it can be seen that the values of distortion for FM and MD are different even given the same coding rate and transmit power. This is due to the different parameter characterizations for the two sequences as shown in Table I.

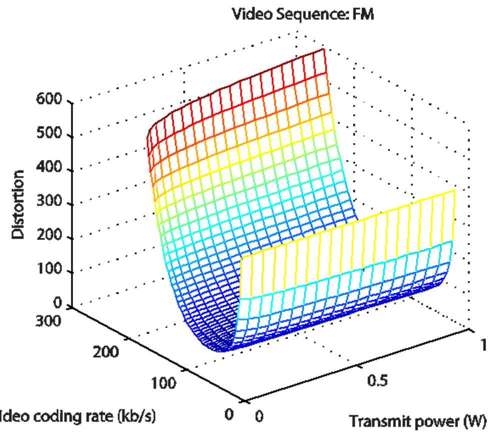


Fig. 2. Distortion of single user transmitting FM video sequence

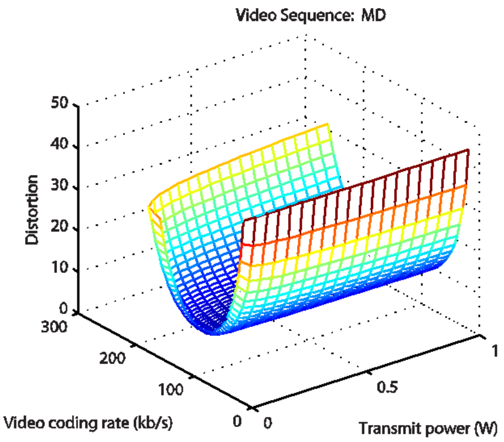
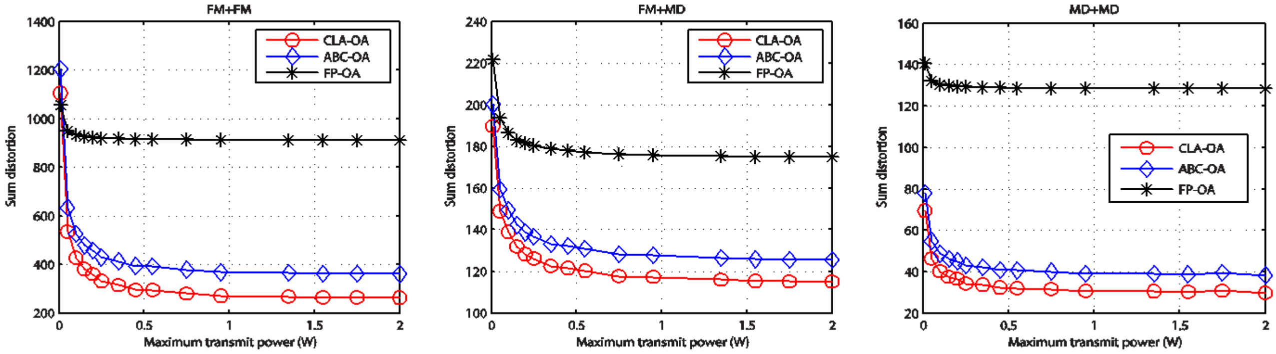


Fig. 3. Distortion of single user transmitting MD video sequence

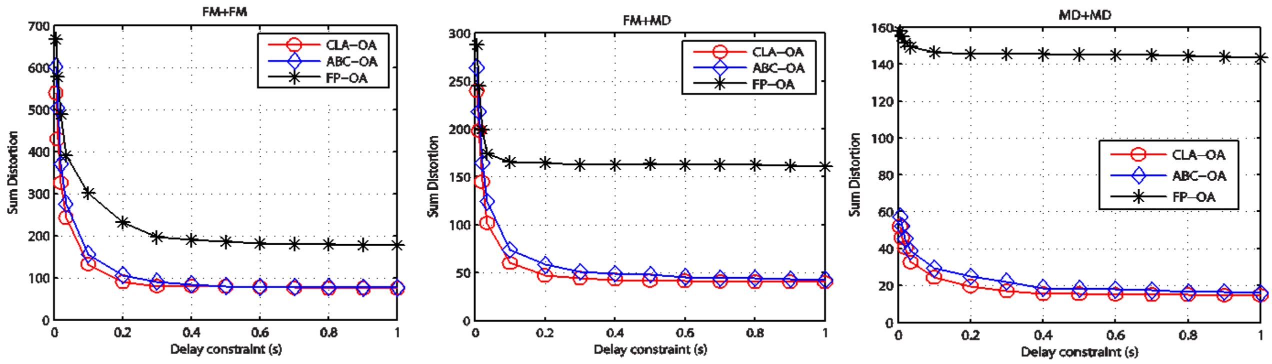
C. Performance Evaluations of the Proposed Cross-Layer Assisted Optimization Algorithm

For demonstration clarity, we assume there are two users simultaneously transmitting video streams in the network when carrying out the simulation. However, it is worth mentioning that different number of users in the network does not affect the conclusions we obtain in this work. For comparison purpose, we also present the simulation results of two other optimization algorithms as baselines. The first algorithm is artificial bee colony (ABC) optimization algorithm (namely *ABC-OA*), which is an optimization algorithm based on the intelligent behavior of honey bee swarm and is usually utilized to solve multidimensional and multi-modal optimization problems. For detailed and complete understanding of the *ABC-OA*, the readers are referred to [24]–[27]. The control parameters adopted in this work for *ABC-OA* are given in Table II. The other algorithm is fixed power optimization algorithm (namely *FP-OA*), where the transmit power of each user is given and only the video coding rate of each user can be optimized when solving the formulated optimization problem in (14)-(17). In addition, for simplicity, our proposed cross layer assisted convex optimization algorithm in Section III-B is named as *CLA-OA*.



(a) (b) (c)

Fig. 4. Sum distortion of the three algorithms w.r.t. maximum transmits power in the case of three kinds of traffic conditions. (a) Two users transmit the same kind of video stream, i.e., FM. (b) Two users transmit different kinds of video stream, i.e., FM and MD. (c) Two users transmit the same kind of video stream, i.e., MD.



(a) (b) (c)

Fig. 5. Sum distortion of the three algorithms w.r.t. maximum transmits power in the case of three kinds of traffic conditions. (a) Two users transmit the same kind of video stream, i.e., FM. (b) Two users transmit different kinds of video stream, i.e., FM and MD. (c) Two users transmit the same kind of video stream, i.e., MD. (a) Two users transmit the same kind of video stream, i.e., FM. (b) Two users transmit different kinds of video stream, i.e., FM and MD. (c) Two users transmit the same kind of video stream, i.e., MD.

The performance of the proposed *CLA-OA* in terms of sum distortion is investigated by comparing with the other two algorithms, i.e., *ABC-OA* and *FP-OA*. Results obtained under different transmit power limits are shown in Fig. 4 with three kinds of traffic conditions, i.e., both users transmit FM video sequence, one user transmits FM video sequence and another one transmits MD video sequence, and both users transmit MD video sequence. For *FP-OA*, the transmit power of each user is set to be the maximum transmit power. For fair comparison, the delay constraints for the three algorithms are set to be same, i.e., 1/30 s. From Fig. 4, we can see that our proposed *CLA-OA* always achieves the best performance in terms of the sum distortion with different traffic conditions, which demonstrates the validity of our proposed CLA-OA. In addition, *FP-OA* always obtains the worst performance in terms of sum distortion. This is because *FP-OA* with given power cannot be adaptive to the dynamic network conditions while the rest two algorithms can be adaptive to the dynamic network conditions through jointly optimizing video coding rate and transmit power. Furthermore, the performance of our proposed *CLA-OA* is always better than that of *ABC-OA*. This is because the solution of *ABC-OA* is not optimal due to the non-convex property of the formulated optimization problem in (14)-(17). Moreover, in Fig. 4, it can be observed that the performance improvement of the three algorithms becomes more and more smaller along with the increase of transmit power limit. This is because increasing the transmit power of each user will introduce additional interference between each other.

The sum distortion performance of three algorithms with respect to different delay requirements is also investigated in the case of three kinds of traffic conditions, i.e., both users transmit FM video sequence, one user transmits FM video sequence and another one transmits MD video sequence, and both users transmit MD video sequence. Results are included in Fig. 5. The results of three algorithms are achieved by setting the transmit power to be 1000 mW. In addition, the delay requirement varies from 10 ms to 1000 ms. From Fig. 5, we can see that our proposed *CLA-OA* always obtains the best performance under different traffic conditions and *FP-OA* always achieves the worst performance in terms of sum distortion, which is consistent with the results shown in Fig. 4. This also further demonstrates the validity of our proposed optimization algorithm. Furthermore, Fig. 5 also reveals that the sum distortions of the three algorithms increase as the delay requirement becomes stringent, which is because the packet loss rate caused by exceeding the maximum delay deadline increases along with the increase of delay requirement.

V. CONCLUSIONS

In this paper, a cross-layer assisted video transmission scheme has been proposed to minimize the sum distortion of the whole network. The closed-form expressions for the queuing delay and overall packet loss rate have been derived based on the M/G/1 queuing model. Taking the video coding rate, queueing delay and transmit power control into account, the optimization problem has been formulated to minimize the sum distortion of all users in the multi-access wireless network. Considering the formulated problem is non-convex, it has been transformed into convex and the optimal solution has also been achieved based on the convex optimization techniques. Simulation results show the proposed cross-layer assisted algorithm is effective in improving the sum distortion of the network through the comparisons with other two algorithms.

ACKNOWLEDGMENT

The authors would like to thank Dr. Zhangyu Guan at Northeastern University in Boston for the invaluable discussions. This work was supported in part by the International S&T Cooperation Program of China (2014DFA11640), the National Natural Science Foundation of China (No. 61371109 and 61271229), and the Distinguished Young Scientists Foundation of Shandong province (JQ201315).

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