An Improved SVC Algorithm to Optimize the Rate of Distortion over MANETs

Yongzhi WANG

College of Computer Science, Hunan Institute of Science and Technology, Yueyang, Hunan, 414000, China.

Abstract — Current advances in technology mean multimedia applications like video is becoming increasingly more important in mobile ad hoc networks. To transmit video information quickly and without errors in networks with different packet loss rates is a key technical problem. In this paper, the encoding problem of rate distortion optimization with JSVM (Joint Scalable Video Model) is studied according to H.264 SVC (Scalable Video Coding) standard framework. Then to satisfy the characteristics of high bit error rate during video transmission using MANETs, an improved algorithm using SVC video encoding to optimize distortion rate is proposed. The algorithm can adjust quantization parameters according to the detected channel packet loss rate to be more suitable for video communication over networks with different packet loss rates. Simulation results show that the video streams encoded by the improved algorithm have good transmission behavior in MANET with high bit error rate and frequent link changes, and achieves better decoded video image quality.

Keywords - Scalable Video Coding, JSVM, Rate-distortion Optimization, Mobile Ad Hoc Network.

I. INTRODUCTION

At present, multimedia application like video is becoming more and more important in the network communication with the quick development of the computer network and multimedia technology. Digital video encoding technology has been a hot issue in the research of network video communication to solve the contradiction between a large amount of multimedia video data and existing network communication ability [1,2]. Mobile Ad Hoc Network (MANET) usually has the characteristics of narrow transmission bandwidth, high bit error rate and frequent link changes and so on, but video stream transmission has a strict requirement for bandwidth, and it is sensitivity to end-to-end delay, packet loss and bit error. Traditional video encoding technology can eliminate the time correlation of image sequences, and it can get high compression ratio, but the video stream encoded has a poor anti-interference ability. So it seems to be very important for the video to compress the video properly to enhance its robustness to the change of the error and packet loss before the transmission of video stream [3]. In order to adapt the video stream to a variety of network environment and user's requirements, Scalable Video Coding (SVC) is becoming a hot research issue in the field of video encoding recently [4, 5].

It can encode video stream into a base layer containing the main information and a (or many) enhancement layer containing detail and texture by using H.264 SVC, so the decoded video can be got with different rate, resolution and quality. As a result, SVC encoding has a very flexible application, and good network adaptability. But H.264 SVC also has the disadvantages of low encoding efficiency and high decoding complexity. Based on the test data provided by the German HHI website, it is obvious that the efficiency of SVC video compression using the current SVC video encoder JSVM-11 is 10% lower than that of video compressed into a single stream under the same conditions [6]. In light of the JSVM technical documentation it can also be seen that SVC video encoding doesn’t considering the impact of channel distortion when adjust the quantization parameter of each frame in real time according to source distortion so that it is too hard to get optimal video quality by using such encoded mode in MANET with high packet loss rate.

In this paper, the SVC rate distortion optimization encoding problem of JSVM is studied according to H.264 SVC standard framework, and in response to the characteristic of high bit error rate during video transmission in MANETs, an improved algorithm about SVC video encoding which could optimize MANET distortion rate is proposed. Adjust quantization parameter in real time according to the detected channel packet loss rate to get better quality of decoded video images.

II. RATE-DISTORTION OPTIMIZATION ENCODING MODE OF JSVM

JSVM encoder divide each video frame into a number of Marco blocks (MB) with the same size, which is the basic encoding unit, and it can take many encoding modes such as skip, inter, intra to each MB, it can also set encoding parameters like quantization step size, motion vector accuracy for each MB. The optimization function of JSVM based on the distortion rate can be expressed as,

\[ J = D + \lambda R \]  

(1)

In the function, D is encoding distortion, R is encoding rate, \( \lambda \) is Lagrange multiplier, and \( \lambda \) is a function of quantization parameter \( Q \) in H264 SVC, which means,

\[ \bar{\lambda} = 0.85 \times 2^{Q/3} \]  

(2)
For Q, JSVM has provided a simplified algorithm for selecting quantization parameter,

\[ Q_x = Q_{\text{ orig}} + (k \times 0 ? 2 : 0) - 1.7 \times (N - 1 - k) \]
\[ Q_x = \min(51, \max(0, \text{round}(Q_{x})) \]  

(3)

For given encoding mode \( \lambda \) and Q, the encoding mode selection strategy of Mb is

\[ J_{\text{ enc}}(y,c,\text{mode}|Q) = SJ_{\text{ enc}}(y,c,\text{mode}|Q) + \lambda_{\text{mode}}(R_{\text{ enc}}(y,c,\text{mode}|Q) \]  

(4)

And \( y \) represents the brightness, \( c \) is the chroma, SSD is defined as the square sum of the image distortion, and \( \lambda_{\text{mode}} \) is the Lagrange multiplier for the corresponding encoding mode.

The mode selection of reference frame of video, prediction method of optimal Inter/Intra, and the Inter/Intra follow the principle of minimum rate distortion cost function. It can be seen that this encoding method is based on the error-free channel, and using this encoding mode may cause a bad error resilience of the video because it doesn’t consider the effect of packet loss channels, though it considers the problem of encoding quantization distortion problem based on source distortion.

III. IMPROVED STRATEGY OF SVC VIDEO ENCODING BASED ON MANETS

A. LINK PACKET LOSS RATE IN WIRELESS NETWORKS

There are two main reasons for the loss of data packets, overflow in buffer queue of the sender and failure of transmission in MAC layer. Use the competitive graph model [7] and M/M/1/K queuing system model [8, 9] which is shown in figure 1, and assume that the data packets are sequentially entered into the queue according to the Poisson distribution. The description of [9] and the simulation experiments prove that the channel packet loss rate of the wireless network can be effectively estimated by the formula (5). In this paper, this method is used to predict the channel packet loss rate of MANET.

Packet loss rate \( p \) can be expressed as,

\[ p = \pi + (1 - \pi)P_{c}^{m} \]  

(5)

In which, \( \pi \) presents the probability of queue overflow, \( P_{c} \) presents the probability of the failure of sending data generated by the collision, \( m \) is the number of retransmission due to failures.

The relationship between the distortion and the code rate is shown with Lagrange multiplier \( \lambda \), it can affect the efficiency of video encoding a lot with choosing different quantization parameter Q. \( \lambda \) in (1) is a Lagrange multiplier based on the error-free channel, without considering the packet loss channel distortion. Referring to the characteristics of packet loss channel, the Lagrange multiplier \( \lambda \) can be deduced under links with different packet loss rates,

\[ \lambda = (1 - p)\lambda^{'(p)} \]  

(6)

Where the \( \lambda^{'(p)} \) is the Lagrange multiplier defined by JSVM. From (2) it is easy to know that it is a function of Q.

B. MODIFIED LAGRANGE MULTIPLIER

The relationship between the distortion and the code rate is shown with Lagrange multiplier \( \lambda \), it can affect the efficiency of video encoding a lot with choosing different quantization parameter Q. \( \lambda \) in (1) is a Lagrange multiplier based on the error-free channel, without considering the packet loss channel distortion. Referring to the characteristics of packet loss channel, the Lagrange multiplier \( \lambda \) can be deduced under links with different packet loss rates,

\[ \lambda = (1 - p)\lambda^{'(p)} \]  

(6)

Where the \( \lambda^{'(p)} \) is the Lagrange multiplier defined by JSVM. From (2) it is easy to know that it is a function of Q.

C. ALGORITHM DESCRIPTION

According to the above description, this paper makes improvements to the SVC video encoding of JSVM, introduces different Lagrange multipliers, and proposes a SVC video encoding strategy suitable for the transmission on MANETs,

1) In the encoder, seek the best encoding mode and rate distortion optimization model of each MB,

\[ \begin{cases} R \leq B \\ \min \{D_{\text{mode}}(y,c,\text{mode}|Q) + \lambda_{\text{mode}}(R_{\text{mode}}(y,c,\text{mode}|Q) \]  

(7)

2) Traverse all the modes, and the Lagrange minimization function of packet loss channel can be got obviously.

\[ \min_{\text{mode}}(J_{\text{mode}}) = \min_{\text{mode}}[D_{\text{mode}}(y,c,\text{mode}|Q) + \lambda \times R_{\text{mode}}(y,c,\text{mode}|Q)] \]  

(8)

The \( \lambda^{'(p)} \) is the Lagrange multiplier in the packet loss network environment, D (mode) presents the distortion rate of MB under a certain mode, R (mode) refers to the bit number corresponding to encoding a MB in the mode.

3) Substitute values of all the mode into equation (8), calculate the optimal mode for encoding, and then use the JSVM encoder to get D and R of each MB under corresponding mode (D is directly calculated by the original video and decoding video, while the R is obtained after the encoder encoding using the relevant quantization parameters Q and decoding).
4) For the given \( \lambda \) and \( Q \), the encoding mode selection strategy of MB's encoding mode is

\[
J_{\text{enc}}(y,c,\text{mode}| Q) = SSD(y,c,\text{mode}| Q) + \lambda_{\text{mode}} R(y,c,\text{mode}| Q)
\]

(9)

In which, \( \lambda_{\text{mode}} \) is Lagrange multiplier of the corresponding encoding mode.

IV. SIMULATION AND EVALUATION

A. Simulation Test of IP Network with Different Packet Loss Rate

The platform is JSVM9.18, the test video sequence is foreman, GOP size is set to 32, and the entropy coding mode is CAVLC. The basic layer is 176 * 144 QCIF, and its frame rate is 15 fps. The enhancement layer is 352 * 288 CIF, and its frame rate is 30 fps. The establishment of packet loss channel is from a typical ITU error code error file [10], and the error rate is 5%, 10% and 20%, the error concealment method is the former frame copy mode. In order to meet the requirements of statistical average, the length of the simulation test sequence is more than 4000 frames in every packet dropout mode, and the PSNR value is the average value of the video stream decoded at the receiving end.

![Figure 2. Comparison of the Rate Distortion Curves in IP Network with 5% Packet Loss Rate.](image)

Figure 2 and figure 3 compare the rate distortion curve at the decoder side when the packet loss rate is 5% and 10% respectively of the IP network transmitting the foreman video sequence. It can be seen that with the increase of the probability of packet loss, the PSNR value of the receiving end video dramatically decreases, and the channel distortion has a great influence on the decoding quality of the video stream. Because the improved algorithm considers the channel distortion effect in the code, it chooses the reasonable optimization of rate by adaptively adjusting the Lagrange multiplier, and enhances the robustness of video bit error and packet loss changes, its decoding video signal to noise ratio is higher compared with JSVM algorithm at the same bit rate conditions.

B. Simulation Test under MANETs Network Environment

A simulation environment is built in the NS-2 platform, and the simulation parameters are shown in table 1 and table 2. The video encoder is JSVM9.18. Test video sequences: Foreman, the size of GOP is 32 frames, the entropy encoding mode is CAVLC. Base layer is 176X144 QCIF, the frame rate is 15 fps; enhance layer is 352X288 CIF, frame rate is 30fps. Error concealment mode is previous frame copy mode. In order to meet the requirements of the statistical average, the length of each simulation test sequence is more than 4000 frames.

![Figure 3. Comparison of the Rate Distortion Curves in IP Network with 10% Packet Loss Rate.](image)

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space size</td>
<td>800*600</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>30</td>
</tr>
<tr>
<td>Simulation time</td>
<td>1000 s</td>
</tr>
<tr>
<td>Movement model</td>
<td>Random waypoint</td>
</tr>
<tr>
<td>MAC</td>
<td>802.11</td>
</tr>
<tr>
<td>RF transmission range</td>
<td>250 m</td>
</tr>
<tr>
<td>Routing protocol</td>
<td>AOMDV</td>
</tr>
<tr>
<td>Node speed</td>
<td>[0,18] m/s</td>
</tr>
</tbody>
</table>
TABLE II. SIMULATION PARAMETERS OF WIRELESS NODES.

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC header</td>
<td>272 bits</td>
</tr>
<tr>
<td>PHY header</td>
<td>128 bits</td>
</tr>
<tr>
<td>Packet payload</td>
<td>8184 bits</td>
</tr>
<tr>
<td>CW</td>
<td>[32,1024] bits</td>
</tr>
<tr>
<td>Slot time</td>
<td>20 ms, 28 ms</td>
</tr>
<tr>
<td>SIFS</td>
<td>128 ms</td>
</tr>
<tr>
<td>DIFS</td>
<td>50</td>
</tr>
<tr>
<td>Size of MAC queue</td>
<td>4</td>
</tr>
<tr>
<td>Retransmission limit</td>
<td>4</td>
</tr>
</tbody>
</table>

Create different node movement scenarios, transmit the same video sequence under the condition of same topology and same code rate, test the encoding efficiency of the two algorithms, collect the average PSNR of video in decoding end, use the average value of the 6 test as the PSNR value.

200 motion scenes are set up by setting different nodes translational speed, and tested the communication performance of JSVM as well as the improved encoding algorithm in MANET respectively. From figure 4 it is apparent that in the environment where nodes are with a low speed, the link has strong reliability, the network topology is relatively stable, the bit error rate of the channel is low, and the encoding efficiency of the improved algorithm is similar to that of JSVM. With the speed of nodes increasing, the packet loss rate of video transmission is rising rapidly, decoding efficiency reduce, while improved algorithm optimize adjustment to distortion channel, as a result, the encoded video shows better fault-tolerant capability, and decoding video has a better quality.

Figure 5 shows the rate distortion curve of transmitting foreman video sequence in the MANET where the nodes are with the speed of 12m/s. With the packet loss probability increasing, the quality of video stream decoding is decreased. Because the effect of channel distortion is considered, the improved algorithm chose a reasonable code rate optimization model through the adaptive Lagrange multipliers, and it enhance the robustness of video bit error and packet loss changes, so that the noise-signal ratio of decoding video is higher when compared with JSVM at the same bit rate conditions.

V. CONCLUSION

According to H.264 SVC standard framework, the SVC rate distortion optimization encoding problem of JSVM is studied, and in response to the characteristic of high bit error rate during video transmission in MANET, an improved algorithm about SVC video encoding which could optimize MANET distortion rate is proposed. This algorithm can adjust quantization parameter according to the detected channel packet loss rate. Simulation experiment results illustrate that the video streams encoded by improved algorithm show good performance in the transmission in MANET with high bit error rate and link change, and better decoded video image quality can be received in the same conditions.

ACKNOWLEDGMENT

This work was financially supported by the Hunan Province Natural Science Foundation of P.R. China (Grant No. 14JJ4060).
REFERENCES


