H.264/SVC VIDEO TRANSMISSION OVER MULTIPATH ROUTING PROTOCOL IN AD HOC NETWORKS

Jiazi YI, Benoît PARREIN, Wissam HAMDACH

Université de Nantes, Nantes Atlantique Universités
IRCCyN, CNRS UMR 6597, Polytech'Nantes
Rue Christian Pauc - BP50609 44306 Nantes cedex 3 France
Email: {firstname.lastname}@univ-nantes.fr

ABSTRACT

The Scalable Video Coding (SVC) is an extension of the H.264/ AVC standard which allows temporal, spatial and quality scalability of video bitstreams. This paper proposes to make use of the multipath routing protocol to transmit H.264/SVC over ad hoc networks. The Multipath Optimized Link State Routing (MP-OLSR) protocol that we propose can forward the bitstream through different paths, and by using the scalable feature of SVC and Unequal Error Protection(UEP), the video quality can be further improved. An evaluation framework called *SVCEval* is built to simulate the SVC video transmission over different kinds of networks. The simulation results reveal that multipath routing combined with UEP can effectively enhance the quality of video transmission over ad hoc networks.

Index Terms— H.264/SVC, ad hoc network, multipath routing, QoS

I. INTRODUCTION

With the rapid development of the wireless network technology, the specifications on wireless LAN like 802.11a/b/g are becoming popular for video transmission. And larger networks with longer ranges can be achieved by multi-hop transmission, i.e. Mobile Ad Hoc NETwork technology (MANET). This kind of network is spontaneous, self-organized and self-maintained. Those features make it suitable for battle fields, disaster recovery and scenarios that fixed infrastructure is undesirable.

The dynamic topology and the unpredictable wireless environment are great challenges for routing the data over MANETs. So a lot of routing protocols have been proposed, such as Optimized Link State Routing (OLSR [1]) and Dynamic Source Routing (DSR [2]). However, those routing protocols still suffer from frequent route failures and make it impossible to forward packets reliably. It is even more difficult to provide video services which require large bandwidth and strong delay constraints in MANETs.

In the literature, there have been a lot of work to improve the quality of video transmission. In [3], the multiple description coding (MDC) and multiple path transport are combined for video and image transmission in MANETs. In [4], the author presents a multisource streaming approach to increase the robustness of real-time video transmission in MANETs. Another UEP scheme is proposed in [5] based on the estimation of the overall distortion of decoder reconstructed frames due to enhancement layer truncation, drift/error propagation and error concealment in the H.264/SVC. Our previous work in [6] also discussed the priority image and video transmission.

In this paper, we are specially interested in the network transmission of Scalable Video Coding (SVC). We propose the multipath routing approach with UEP to transmit H.264/SVC video stream over MANET to improve the video quality at the receiver. Multipath Optimized Link State Routing (MP-OLSR) is used as routing protocol. It is a multipath extension of OLSR, and can generate multiple node-disjoint or link-disjoint paths by using *Multipath Dijkstra Algorithm*. Based on the multipath routing, Finite Radon Transform (FRT) [7] can be used as UEP code. FRT is a discrete data projection method and Maximum Distance Separable (MDS) code. To evaluate the transmission of H.264/SVC, a video evaluation framework, *SVCEval*, is proposed to simulate the video bitstream over different kinds of networks. The simulation is taken in a MANET with different mobility and topology changes. The results reveal that the MP-OLSR can be better adapted to frequent topology changes and UEP with multipath routing can further improve the video quality at the receiver.

The contribution of this paper is double. Firstly, the multipath routing protocol with UEP coding is proposed for H.264/SVC transmission. Secondly, a video evaluation framework with great flexibility, called *SVCEval*, is built for quality evaluation. It can be used for various network architecture. The remainder of the paper is organized as follows. We introduce our MP-OLSR protocol with priority forward error correction coding in section II. The *SVCEval* framework for SVC video evaluation is presented in section III. In section IV, simulation and performance evaluation are performed. Finally, we conclude this paper in section V.

II. MULTIPATH OLSR FOR PRIORITY ERROR CORRECTION

II-A. Multipath Optimized Link State Routing

The MP-OLSR can be regarded as a kind of hybrid multipath routing protocol which combines the proactive and reactive features. It sends out *HELLO* and *TC* messages periodically to detect the network topology, just like OLSR. However, MP-OLSR does not always keep a routing table. It only computes the multiple routes when data packets need to be sent out. The functionality of MP-OLSR has four parts: *topology sensing*, *route computation*, *route recovery* and *loop detection*.

The *topology sensing* is to make the nodes aware of the topology information of the network. This part benefits from *MPRs* like OLSR. To get the topology information of the network, the nodes use *Topology sensing* which includes link sensing, neighbor detection and topology discovery, just like OLSR [1].

The *route computation* uses the *Multipath Dijkstra Algorithm* [8] to calculate the multipath based on the information obtained from the *topology sensing*. The source route (all the hops from the source to the destination) is saved in the header of the data packets. The algorithm make use of the cost functions to discover the node-disjoint or link-disjoint multiple paths according to the configuration.

The *topology sensing* and *route computation* make it possible to find multiple paths from source to destination. In the specification of the algorithm, the paths will be available and loop-free. However, in practice, the situation will be much more complicated due to the change of the topology and the instability of the wireless medium. So *route recovery* and *loop detection* are also proposed as auxiliary functionalities to improve the performance of the protocol. The *route recovery* can effectively reduce the packet loss, and the *loop detection* can be used to avoid potential loops in the network.

From the results obtained from the simulation and testbed, we can conclude that the Multipath OLSR can effectively improve the data delivery ratio and reduce the end-to-end delay. More details about the routing protocol can be found in our previous work in [9].

II-B. Unequal Error Protection Coding for Multipath Routing

A wide range of scalability (spatio-temporal and quality) can be achieved by using SVC. It allows removal of parts of the bit-stream and still get reasonable coding efficiency with reduced temporal, spatial or SNR resolution. This feature is very attractive for unstable network transmission because we can focus on the more important scalable layers to improve the final video quality. This can be achieved by using UEP.

We make use of an FEC code based on Finite Radon Transform (FRT) for UEP. It is a discrete data projection methods that are exactly invertible and are computed using simple addition operations. FRT differs significantly from Mojette transform [6] by providing equal size projection/packets. For detailed information, please refer to our latest results in [7].

Compared to the equal forward error correction, which applies equal redundancy to all the packets and increases the overhead significantly, the UEP can give a good balance between the error correction and network load by focusing on the most important packets. With FRT, the packets with higher priority can be assigned with higher redundancy and the coded projections can be distributed into disjoint multiple paths. So even when some of the packets are lost because of route failure, it is still possible to recover the original packet, as illustrated in figure 1.

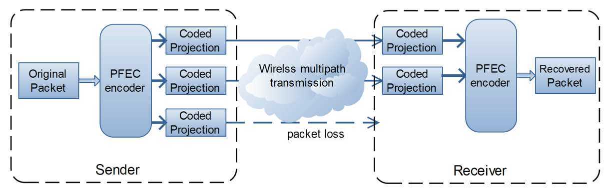

Fig. 1. Multipath transmission with UEP

To make use of priority FEC, it is important to know the priority of the packets in the video bitstream. For H.264/SVC bitstream, the scalability structure is defined by three syntax elements: *dependency_id*, *quality_id*, and *temporal_id*. The syntax element *dependency_id* denotes the spatial scalability inter-layer coding dependency hierarchy. The *quality_id* designates the quality level hierarchy of medium granularity scalability (MGS). The *temporal_id* indicates the temporal scalability hierarchy or the frame rate.

However, although those three variables can provide scalable information of the bitstream, no assumption on a relation between the priority of the packets and the values of *dependency_id*, *quality_id*, or *temporal_id* is explicitly made in the SVC draft.

To confirm the priority of different scalable layers, a packet-loss simulation is launched (more details about the video codec configuration can be found in section IV-A). A packet-loss simulator is made so that we can define the packet loss from a specified scalable layer (temporal, spatial or quality). Then the PSNR is measured to compare the packet loss from which layer has more impact on the video quality, which corresponds to higher priority.

Figure 2 presents the impact of packet loss from different temporal layer to the quality of the video (*t1* stands for the packet loss from layer with *temporal_id* equals *1*, etc.). As shown in the figure, with the same percentage of packet loss (over total packets) from different temporal layers, the packet loss from *t1* has the most impact on the video quality, and then is the *t2*, etc. The packet loss from *t4* and *t5* has the least impact.

The results indicate that with our current configuration of JSVM codec, the *t1* packets have the highest priority, and the *t4* and *t5* packets have the lowest priority. This hierarchy will be used in the following for priority coding.

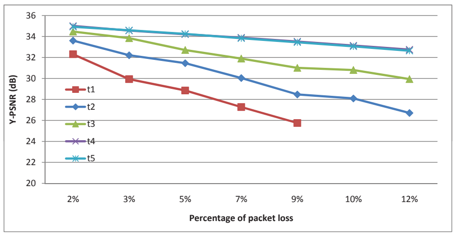

Fig. 2. The impact of packet loss from different temporal layer to the quality of the *soccer* video

III. EVALUATION FRAMEWORK FOR H.264/SVC

To evaluate the quality of the video transmission over a specified network, the most straightforward method, of course, is to build such kind of network and evaluate the video transmission over it. However, this will be costly and time consuming. So most of the time, network simulations are employed for the evaluation.

From the network point of view, a lot of network simulators are widely used , such as NS2 and Qualnet. And for the video, there are generally three ways to characterize an encoded video for network simulation: *video bitstream*, *video traffic model* [10] and *video trace* [11].

Currently, most of the study in H.264/SVC video quality and error concealment such as in [12] is based on error patterns. This scheme can define a specified loss rate in the bitstream and it is very useful and efficient for the error resilient study. However, it is not sufficient if one wants to simulation the video transmission over a specified network.

To evaluate the H.264/SVC transmission over different kinds of networks, especially ad hoc networks, we proposed a evaluation framework *SVCEval* as shown in figure 3. It is based on the SVC reference software JSVM and make use of the Qualnet simulator for the network simulation.

At the video sender, the YUV file is encoded by the JSVM encoder, and the .264 bitstream is generated. Then the *BitStreamExtractor* is used to generate the bitstream trace from the given bitstream. It is a text file which specifies the parameters of each packet inside the bitstream. Those parameters include the start position of the packet inside the bitstream, the length of the packets, the values of dependency_id (LId), temporal_level (TId) and quality_level (QId) for the packet, the type of the packet and two flag which indicate whether the packet is discardable or truncatable. A *Traffic Generator* is written to generate the input traffic trace file for Qualnet simulation, which includes mainly the packet

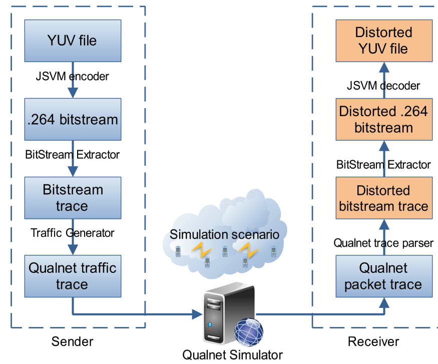

Fig. 3. The evaluation framework *SVCEval* for H.264/SVC

rate and size. The simulator will take the traffic trace file and run the simulation according the configuration of scenarios to simulate different kinds of networks.

At the video receiver, a packet trace file is produced by the simulator. The packet trace file records all the operation on each packet in each node and each layer (so normally hundreds of MBytes). A *QualnetTraceParser* is developed to analyse the trace to detect which packets are lost and which packets are properly received. For real-time transmission, we can set a delay threshold to discard the packets that timed out. The trace parser can generate the *distorted bitstream trace*, and then we use the *BitstreamExtractor* and *JSVM decoder* to have the distorted YUV file after the video transmission. Then we can evaluate the quality of video with different metrics such as PSNR or Mean Opinion Score (MOS).

IV. PERFORMANCE ANALYSIS

IV-A. Test Conditions and Network Scenario

To demonstrate the performance of multipath routing of the H.264/SVC video transmission over ad hoc networks, we performed the simulation based on the evaluation framework proposed. The football sequence with high and irregular motion is used as a sample. The configuration of the JSVM codec is as follows.

- JSVM 9.8.
- Two layers with based layer QCIF@30Hz and enhancement layer CIF@30Hz.
- Group of picture size is 16.
- *SliceMode* is set to *fixed number of bytes per slice*, with *SliceArgument* set to 1000.

The UEP scheme is applied to the video stream. The layers with *temporal_id* 1 and 2 are encoded using systematic code. Each time at the sender, the coder will buffer 2 packets, and generate 3 projections. At the receiver, the decoder needs 2 projections to recover the original packets. The rest of the layers are not coded and transmitted in its original form (i.e. not protected). The layer with *temporal_id* 0 are regarded as *non discardable* packets, so we assume those packets are transmitted along reliable channel.

For the network configuration, Qualnet 5.0 is employed for network simulation. The detailed parameters are listed in Table I for the purpose of repeatability. Those parameters are widely used in WiFi devices and simulation studies.

Table I. Simulator Parameter Set

Parameter	Values
Simulator	Qualnet 5.0
Routing Protocol	OLSRv2 and MP-OLSR
Simulation area	1500m × 1500m
Number of nodes	80
Mobility	RWP, max speed 0-10m/s
Simulation Time	100 seconds
Application Packet size	512 bytes
Transmission Interval	0.1 s
MAC Protocol	IEEE 802.11
Physical Layer Model	PHY 802.11b
Pathloss Model	Two Ray Ground
Shadowing Model	Constant
Shadowing Mean	4.0 dB
Transmission Range	270m
Data Rate	11Mbps

IV-B. Simulation Results

Figure 4 compares the delivery ratio of OLSR and MP-OLSR with or without UEP coding. The four configurations have almost the same performance at low speed, but the delivery ratio of single path routing (OLSR and OLSR_FEC) decreases quickly as the mobility increases. This is because as the links become more unstable, the MP-OLSR could take benefits from the multipath routing.

The UEP could slightly increase the delivery ratio of MP-OLSR (about 1%), but not significant for OLSR. This is because: firstly, in the network, the packet loss is continuous most of the time because of congestion or route failure. If the single path routing is applied, all the projections from the coded packets are lost continuously in the same route, and FEC is not helpful in this situation. With multiple paths, the projections are distributed in the disjoint paths and forwarded to the destination independently. The FEC can still work even some of the routes failed as illustrated in figure 3. Secondly, it is inevitable that the FEC coding will increase the network load even priority coding strategy is employed because the redundancy is added in the packets to protect the data. This will increase the packet loss and maybe results in worse video quality in the end for single path routing (for example, the 5m/s and 6m/s for OLSR_FEC). This problem is less serious for multipath routing because it can provide higher overall bandwidth.

Figure 5 compares the quality of the video transmission by using different kinds of protocols. Compared to OLSR, MP-OLSR has worse quality in very low-mobility scenarios (1m/s and 2m/s). As the node speed increases, the quality of OLSR drops quickly and MP-OLSR outperforms OLSR.

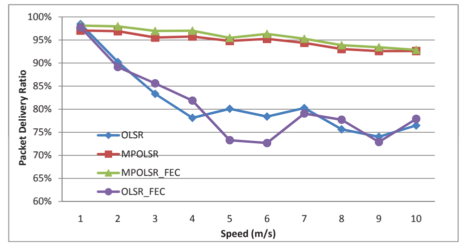

Fig. 4. The delivery ratio of different protocols (with or with out FEC code)

This result is consistent with the conclusion from our previous work that the single path routing might have better delivery ratio than MP-OLSR in the network with very less topology changes. However, in these low-mobility scenarios, the MP-OLSR can make use of single path also because the MP-OLSR is compatible with OLSR.

Although the improvement of the MP-OLSR with priority FEC coding (MPOLSR_FEC) in delivery ratio is not obvious, the MPOLSR_FEC can effectively improve the video quality by 2 dB on average. It is because the packets with high priority (*temporal_id* equals *1* or *2*) are better protected with UEP. The overhead produced by UEP is 15% with our configuration. If the Equal Error Protection (EEP) is applied, the overhead will be up to 50%. In fact, the simulations of EEP is also taken, but did not provide significant improvement (even worse in high mobility scenarios). Although the EEP offered more redundancy, it also injected more load to the network, which will bring down the network performance.

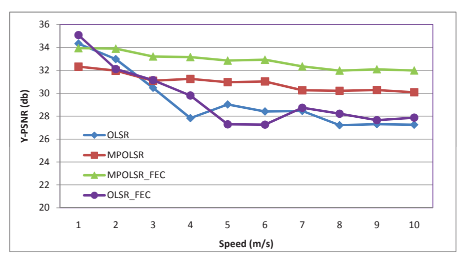

Fig. 5. The quality of video transmission through the different protocols (with or with out FEC code)

Figure 6 presents the screenshots of three frames from the scenario of seed 6, with max speed of 4m/s. The MP-OLSR with UEP provided the best video quality and OLSR suffers from the most packet loss. The frames displayed by OLSR are delayed because the *frame copy* error concealment method is used. In this way, the previous frames are copied if there is too much packet loss.

Frame 1 Frame 2 Frame 3

(a) MPOLSR_FEC

Frame 1 Frame 2 Frame 3

(b) MPOLSR

Frame 1 Frame 2 Frame 3

(c) OLSR

Fig. 6. Screenshots of the *football* video sequence from scenario of seed 6, 4m/s

V. CONCLUSION

In this paper, we proposed a method to transmit H.264/SVC video stream over MANET by using a multipath routing protocol, called MP-OLSR. The FRT is combined with MP-OLSR for unequal error protection. With UEP, the data with higher priority can be better protected over the packet lossy networks. The *SVCEval* is built as an evaluation framework for H.264/SVC video network transmission. Based on the JSVM and the Qualnet network simulator, it can provide great flexibility and more realistic scenarios by simulating the video transmission over different kinds of networks.

The results from the simulation show that the multipath routing is more adapted to network topology changes. And with UEP, the video quality can be significantly improved (by 2 dB in Y-PSNR in our experiment scenarios) without introducing much network load.

We are in the process of optimization of allocation of the redundancy for different scalable layers. Distribution of the coded projections into the multiple paths based on the route quality information are also open topics in the future. The subjective measurement for video quality will be also considered.

VI. REFERENCES

[1] T. Clausen and P. Jacquet, "IETF Request for Comments: 3626, Optimized Link State Routing Protocol OLSR," October 2003.

[2] David B. Johnson, Y. Hu, and David A. Maltz, "IETF Request for Comments: 4728, The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4," February 2007.

[3] Doo-Man Chung Nitin Gogate, Shivendra S. Panwar, and Yao Wang, "Supporting image and video applications in a multihop radio environment using path diversity and multiple description coding," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 12, pp. 777–792, September 2002.

[4] Thomas Schierl, Karsten Ganger, Cornelius Hellge, and Thomas Wiegand, "SVC-Based Multisource Streaming over Robust Video Transmission in Mobile ad hoc Networks," *IEEE Wireless Communications*, pp. 96–103, October 2006.

[5] E. Maani and A.K. Katsaggelos, "Unequal error protection for robust streaming of scalable video over packet lossy networks," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 20, pp. 407–416, March 2010.

[6] Benoît Parrein, Fadi Boulos, Patrick Le Callet, and Jean Pierre Guédon, "Priority image and video encoding transmission based on a discrete radon transform," in *IEEE 16th International Packet Video Workshop*, Lausanne, Switzerland, 2007.

[7] Nicolas Normand, Imants Svalbe, Benoît Parrein, and Andrew Kingston, "Erasure Coding with the Finite Radon Transform," in *IEEE Wireless Communications & Networking Conference*, Sydney, Australia, 2010.

[8] Jiazi Yi, Eddy Cizeron, Salima Hamma, and Benoit Parrein, "Simulation and performance analysis of MP-OLSR for mobile ad hoc networks," in *IEEE WCNC: Wireless Communications and Networking Conference*, Las Vegas, USA, juin 2008.

[9] Jiazi YI, Asmaa ADNANE, Sylvain DAVID, and Benoît PARREIN, "Multipath optimized link state routing for mobile ad hoc networks," *Ad Hoc Networks*, vol. 9, no. 1, pp. 28–47, 2011.

[10] D. P. Heyman and T. V. Lakshamn, "Methods for Performance Evalluation of VBR Video Traffic Models," *IEEE/ACM Trans. Net.*, vol. 4, pp. 40–8, 1996.

[11] Jirka Klaue, Berthold Rathke, and Adam Wolisz, "Evalvid - a framework for video transmission and quality evaluation," in *13th International Conference on Modelling Techniques and Tools for Computer Performance*, Illinois, USA, 2003.

[12] Yi Guo, Ying Chen, Ye-Kui Wang, Houqiang Li, Miska Hannuksela, and Moncef Gabbouj, "Error resilient coding and error concealment in scalable video coding," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 19, 2009.