QoE enhancement for H.264/SVC video transmission in MANET using MP-OLSR protocol

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***Abstract*—This paper addresses the problem of enhancing video service quality for Mobile Ad Hoc Networks (MANET) scenarios. We offer Multipath Optimized Link State (MP-OLSR) routing protocol for H.264/SVC bitstream forwarding in the MANET network. Besides the usage of a suitable routing protocol, the video quality can be further enhanced by using the scalable encoding feature of Scalable Video Coding (SVC) combined with Unequal Error Protection (UEP). SVC is an extension of the H.264/AVC video compression standard used for high-quality video bitstreams encoding, providing spatial, temporal and quality scalability. To evaluate video quality, the Video Quality Metric (VQM) is used.**

We chose 5 different video contents for our simulations characterized by various temporal and spatial complexities. These video references are taken from the Video Quality Expert Group (VQEG).

The results show that multipath routing combined with UEP can effectively improve the quality of video communication over MANET in terms of VQM and successful video decoding.

***Index Terms*—video communication over MANET, VQM, multipath routing, MP-OLSR, UEP**

I. INTRODUCTION

Mobile Ad hoc NETworks (MANET) are spontaneously formed, self-organized and self-configured networks. These features make them a feasible solution in scenarios where fixed infrastructure is impossible or too expensive to be deployed, such as battlefields and disaster recovery areas. In this context, the main difficulty is routing the data. In the past ten years, numerous protocols are designed and some are normalized e.g. OLSR [1]. Most of them are single path. We propose in this paper the multipath version of OLSRv2 called MP-OLSR [7]. MP-OLSR computes and maintains multiples routes despite mobility by staying compatible with its single path version OLSR. It exploits simultaneously all the available and valuable paths between source and destination to balance traffic load, reduce congestions and packet loss. In previous studies [7] [8], we highlighted the interest of MP-OLSR in terms of Quality of Service (QoS).

The motivation of this paper is in Quality of Experience (QoE) by choosing a relevant metric for H.264/SVC video services as VQM [6]. The experimentation is moreover extended to five video contents selected for their relevant spatial and temporal complexities. We demonstrate by simulations that coupling multiple paths with suitable unequal error protection guaranties better QoE for the received videos.

The remainder of this paper is organized as follows. Section II recalls main specifications of MP-OLSR. Section III describes how H.264/SVC is encapsulated and distributed to multiple paths with or without protection. Section III also describes the evaluation framework, called SVCEval used for results obtained in section IV. Section V concludes the work.

II. MULTIPATH OPTIMIZED LINK STATE ROUTING

MP-OLSR is a multipath extension of existing standard proactive OLSR. It is a hybrid multipath routing protocol which combines the proactive and reactive mechanisms. Like OLSR, it transmits *HELLO* and *TC* messages periodically to detect network topology as described in [1]. However, MP-OLSR does not always keep a routing table for every possible destination in the network: it only computes the multiple paths when there are data packets need to be sent out.

The functionality of MP-OLSR mainly includes two parts:

- *Topology Sensing* makes the nodes aware of the topology information of the network based on the transmission of *HELLO* and *TC* messages, like OLSR. It includes *link sensing*, *neighbor detection* and *topology discovery*. Through *topology sensing* each node in the network can get sufficient topology information to enable routing. By default, the link quality is measured by hop-count [1]. However, it can also be measured by other metrics such as Bit Error Rate (BER) or queue length.
- *Route Computation* makes use of *Multipath Dijkstra Algorithm* [8] to calculate multiple paths based on the information obtained from *topology sensing*. Punishment functions are used to generate link-disjoint or node-disjoint paths. Source routing is used for forwarding packets from source to the destination.

In addition to those two main functions, *Route Recovery* and *Loop Detection* are also specified to recover from route failure and detect possible loops in the network, which are important for the performance of the dynamic networks.

The multi-path generation method provides a flexible degree of node and/or link disjointness for the resulting paths. This feature brings the highest aggregated resources for the chosen paths and also a high degree of fault tolerance, neither nodes nor links being shared between the multi-path. Furthermore, it is compatible with the current OLSR standard, and is interoperable with other nodes running OLSR.

The results obtained from the simulation and testbed [7] show that MP-OLSR can achieve network load balancing trough flexible generation of multi-paths, effectively improving the data delivery ratios and also reducing the end-to-end transmission delay.

III. H.264/SVC VIDEO COMMUNICATION OVER MULTIPLE PATHS USING UNEQUAL ERROR PROTECTION

A. H.264/SVC bitstream

With Scalable Video Coding (SVC), it is possible to embed multiple scalable layers with increasing spatial/temporal resolution and/or quality into a single video stream, allowing a wide range of scalability.

In our simulations, we use Joint Scalable Video Model (JSVM) to encode/decode the scalable video streams. Table I shows the configuration of the JSVM codec used in the experiments.

TABLE I
JSVM CONFIGURATION

JSVM version	9.8
Spatial scalability	Two layers with QCIF@25Hz base layer and CIF@25Hz enhancement layer
Temporal scalability	Five layers T_0...T_4 from 1.5 to 25 Hz
Group of pictures size	16
SliceMode	Fixed number of bytes per slice
Slice argument	1000

We encode the video streams using spatial and temporal scalability. The transmitted video stream is composed of two layers at 25 frames per second: a QCIF base layer and a CIF spatial enhancement layer. A Group of Pictures (GoP) consists of a key picture (P picture), and several hierarchically coded B pictures located between the key pictures.

B. H.264 protection and transmissions

To adapt a video bitstream to the various requirements of end users, network conditions and terminal capabilities, SVC allows progressive erasure of parts of the bitstream achieving reasonable coding efficiency with reduced resolution. Thus, the most important scalable layers can be protected in order to improve the processed video quality. To achieve this in the unstable environment of wireless comunications, we propose to use the Unequal Error Protection (UEP) based on Forward Error Correction (FEC) code with Maximum Distance Separable (MDS) property. Such code can be implemented by using the Finite Radon Transform (FRT) [4], which is a discrete data projection method that is exactly invertible, and is computed using simple addition operations. The complete coding scheme is outside the scope of this paper. Further details can be found in [4]. In the following paragraphs, we consider mainly the MDS property stating that if the coding stage produces n packets from k packets of message, the decoding stage is possible if at least k packets out of n are received. The first k coded packets are exactly message packets. Remaining $n-k$ packets are allowed to the redundancy.

Compared to the classical FEC, which applies equal redundancy to all the packets, UEP protects only the most important ones, achieving a good balance between the error correction and network load. UEP scheme assigns higher redundancy to the packets with higher priority, and the coded packets 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.

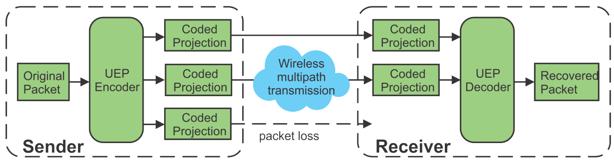

Fig. 1. Multipath transmission with UEP based on Finite Radon Transform (FRT)

In our scheme, transport units are coded projections related to the Radon operator. The number of necessary projections depends on the importance of the original packet within the packetstream.

Since the type of video can greatly influence the transmission performance, we choose five different video contents, with different spatial and temporal complexity. These contents are taken from the VQEG test sequences. UEP scheme is applied to each of the video streams as follows: temporal layer 1 and 2 are encoded using systematic code, each time the coder (at the sender) buffers 2 packets and generates 4 projections of that 2 packets. The decoder (at the receiver) is able to recover the original packets only if it receives at least 2 projections. The other layers are sent unprotected.

In SVC, the base layer with temporal id 0 contains the key pictures and the packets that belong to this layer are regarded as non discardable. The decoding of the video stream fails in case of this type of packet erasure. So, the non discardable packets should be transmitted on a reliable channel.

Because of the UEP redundancy, the protected packets have greater sizes (maximum of 1480 bytes with an average of 662 bytes) than the normal ones (maximum of 1000 bytes, average of 548 bytes). The maximum data rates among the enhancement layers, for the encoded videos, range from 642 kbit/s to 2080 kbit/s.

Here, we use UDP as the transport protocol for the simulations. At the application layer, the variable size video packets are sent to the destination with a constant transmission interval. An extension of multiple path TCP (MTCP) can be possible in a near future considering both academic works [3] and recent activities at the MPTCP working group at the IETF [2].

We implement and use SVCEval evaluation framework to monitor the transmission of H.264/SVC sequences over MANET. SVCEval couples the JSVM codec with a discrete event network simulator (Qualnet in our framework) as shown in Figure 2.

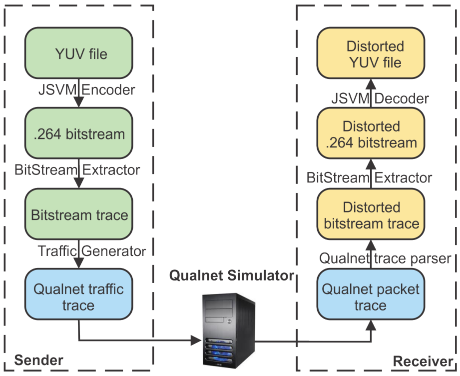

Fig. 2. The evaluation framework *SVCEval* for H.264/SVC coupling JSVM codec and discrete event network simulator

TABLE II
QUALNET SIMULATOR PARAMETER SET

Parameter	Values
Simulator	Qualnet 5.01
Routing Protocol	OLSRv2, MP-OLSR, MP-OLSR-UEP
Simulation area	1200m × 1200m
Number of nodes	49
Nodes placement	Random
Mobility	RWP, max speed 0-10m/s
Simulation Time	300 seconds
Average Packet size	Variable
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

C. VQM as the video quality metric

Because the conventional video quality metrics (PSNR in particular) do not take into account the spatial and temporal properties of the human visual perception, a proper video quality evaluation metric was needed.

VQM was developed by the National Telecommunications and Information Administration (NTIA) and the Institute of Telecommunication Sciences (ITS) to provide an objective measurement for perceived video quality. VQM measures the perceptual effects of video impairments including blurring, unnatural motion, global noise, block distortion and color distortion and combines them into a single metric. Test results show that VQM has a high correlation (0.91) [5] with subjective video quality assessment. VQM has been adopted by ANSI as an objective video quality standard [6]. In this paper we use the batch version of VQM and NTIA General Model to compute the VQM values.

The scale of VQM is between 0 and 1. Zero means that no impairment is visible (reference quality) and one means that the video clip has the worst quality. For extremely distorted videos, VQM may exceed one. In this study, we will consider a VQM value below 0.3 as an empiric threshold to determine a set of acceptable received videos.

IV. PERFORMANCE ANALYSIS

A. Network scenario

We use Qualnet 5.01 version as a discrete event network simulator. The detailed parameters for the network configuration are listed in Table II.

For the simulations we design a MANET composed of 49 randomly placed nodes in a 1200 square meters topology. We consider this topology as a good trade off between a quite dense MANET and computational complexity. The speed of the nodes is from 1 m/s to 10 m/s. A background traffic provided by 6 CBR sources randomly distributed over the grid slightly overload the mobile network. The CBR packet size is 512 bytes and the transmission interval is 0.067s.

Five different VQEG test sequences are used for the transmissions: ”Aspen”, ”Burnzoom”, ”Highway”, ”Shadowboxing”, and ”Skatefar”. These sequences contain 285 frames each and they target a variety of spatial and temporal activities. We selected the video sequences to ensure a great difference between the video contents: high spatial detail, high motion and/or rapid scene cuts, high/low contrast, high/low brightness and colorful scenes.

B. Simulation Results

Figures 3 to 7 show the QoE results for the 5 considered videos supported by the 3 tested routing protocols: OLSRv2, MP-OLSR and MP-OLSR-UEP. One hundred simulations were executed for each routing protocol and video. One point in a graph corresponds to the average VQM value obtained for 10 different mobility patterns at a specified node speed (we will see at the end of this section that among those ten VQM values some decoding fails). Multipath protocols provide better QoE in general. Usually, received videos are completely acceptable with VQM values smaller than 0.3 while videos with VQM greater than 0.3 have distortions that start to be annoying for the viewer.

It can be seen that single path OLSRv2 delivers videos with a lot of artifacts measured by VQM. In particular, ”Shadowboxing” sequence which contains rapid motion is rendered with unacceptable values with roughly 0.7 VQM difference with multiple paths versions. These results are correlated with QoS monitoring. Indeed, single path routing protocol provides only about 75% of PDR while multipath protocols delivers 90% of PDR for the tested videos. In terms of delay, multipath routing provides approximately ten times lower delays than single path routing. These QoS results make multipath routing suitable for different kind of interactive video services such as video streaming or video conferences.

As we can see in figures 3 to 7, VQM is not really sensitive to the mobility in the range of observed speeds i.e 1 m/s to 10 m/s for all tested routing protocols but PDR. Indeed, if PDR decreases slightly with the mobility as expected, VQM remains quite stable despite the speed of the nodes. SVC stream seems to allow a few packet losses if those packets are not mandatory to the decoding. This could change of course in an other range of speeds. In this current study, we can distinguish nevertheless

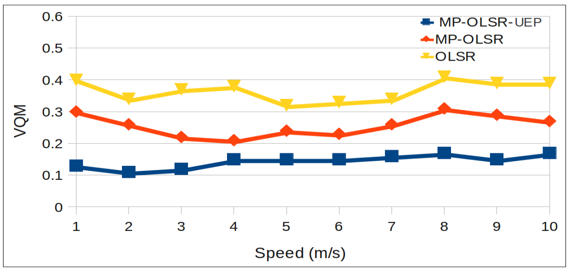

Fig. 3. VQM results for Aspen sequence

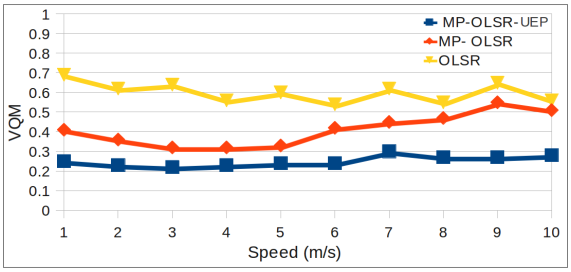

Fig. 4. VQM results for Burnzoom sequence

the tested routing protocols that promote multiple paths in conclusion.

The PDR remains almost identical for MP-OLSR and MP-OLSR-UEP. However, MP-OLSR-UEP provides better QoE in terms of VQM than MP-OLSR. This is consistent with the UEP protection that targets packet loss first in less important data packets increasing the final video quality. It is important to precise that applying UEP over single path as OLSRv2 does not bring satisfaction at all because in case of route failure all the projections from the original packets are lost. It is the redundancy and the spatial diversity together that improve the global resiliency of the video bitstream.

V. Conclusion

In this paper we present the QoE monitoring and also an enhancement scheme for H.264/SVC video transmission over multipath routing protocol for MANET. When combined with an UEP scheme, the proposed protocol delivers excellent video quality, also providing very good QoS parameters (around 90% PDR and end-to-end delay 10 times smaller than single path version with values around 25 ms) and no decoding failure rate. In the future we plan to deploy the proposed scheme on our real MP-OLSR testbed.

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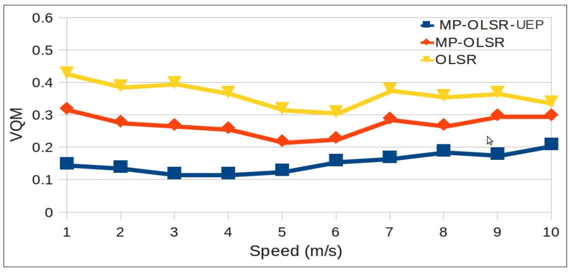

Fig. 5. VQM results for Highway sequence

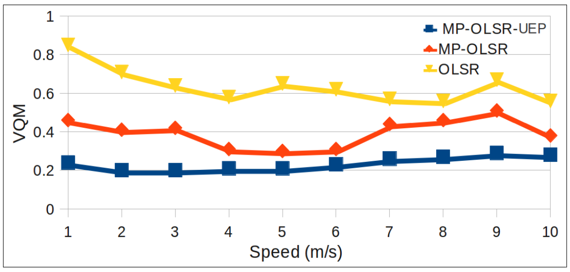

Fig. 6. VQM results for Shadowboxing sequence

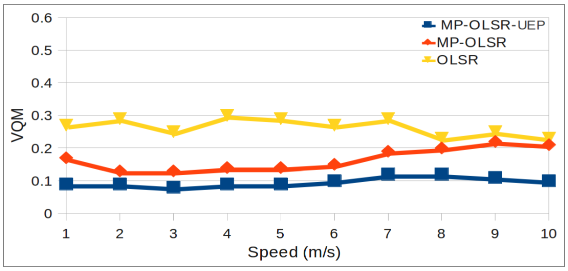

Fig. 7. VQM results for Skatefar sequence

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