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Network coding-based approach for efficient video streaming over MANET☆

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ABSTRACT

Video streaming over mobile ad-hoc networks is becoming a highly important application for reliably delivering the content between the user and the content storage node. The key challenge is, hence, to address the impact of the user mobility on the quality of the delivered video. Accordingly, the pioneering concept of network coding (NC) emerges as a promising approach for improving the video transmission quality mainly in multicast mobile environment. This work focuses on improving the Quality of Service of video streaming over mobile ad-hoc networks using random NC. We consider video coded by the widely-used H264/SVC codec that generates packets with different priorities and provides traffic differentiation using the IEEE 802.11e MAC. Intuitively, focusing on lowering the error transmission of high priority packets leads to enhance the video streaming quality. Accordingly, this work develops and proposes a new scalable transmission scheme that decreases the loss of high priority packets. Our approach, named Extended Multicast Scalable Video Transmission using Classification-Scheduling Algorithms and Network Coding over MANET (and denoted EMSCNC), adopts a cross layer design between the H.264/SVC codec, the network and MAC layers. Moreover, we develop an analytical framework allowing the performance evaluation in terms of throughput, delay, and packet delivery ratio. Simulation results validate our analytical model and confirm the substantial performance improvement brought by our approach.

1. Introduction

Mobile ad-hoc networks (MANET) are characterized by unstable network topology. Also, wireless communication between MANET nodes has a broadcasting nature which may produce redundant packets and create a broadcast storm problem. Consequently, new approaches based on network coding (NC) have been proposed to address these problems. NC combines many packets in one coded packets instead of using the typical forwarding techniques of store and forward. It greatly improves the transmission performance by reducing the number of packet transmissions. Hence, it provides less delivery delay and higher data throughput.

NC was introduced in [6,7] for wired multicasting transmission where it was shown that it may achieve higher throughput than traditional routing solutions by linearly combining data packets at intermediate nodes. Later, linear network coding scheme [8,9] and random network coding [10,11] have been investigated to improve the transmission performance in different networking scenarios. The challenges resulted from bandwidth constraint and the dynamic topology of MANET makes the multicast and multi-hop supported routing hot research topics. Additionally, scalable video coding (SVC) approach is applied to enable efficient video streaming. H.264/SVC [12] is widely-used to effectively compress the video. It provides temporal, spatial and quality scalabilities. H.264/SVC packets have different priorities. High-priority packets are the most important for guaranteeing high video transmission quality.

A random network coding for MANET named CodeCast is proposed in [13]. It is able to achieve high throughput with low overhead and low latency. However, CodeCast has its own limitations, such as assuming constant bit-rate video, equal-size packets, etc. Also, it does not increase the probability of recovering high priority packets but provides the same loss probability for all the video packets regardless of their priority. Authors in [14] aimed at improving Codecast by proposing a new network coding based scheme (E-Codecast) to maximize the overall video quality at all destinations under the constraint of network capacity. In fact they proposed a low-complexity optimization algorithm to optimize the packet forwarding frequency and to support scalable video coding.

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By simulation, authors show that their scheme is capable of increasing the network resource efficiency and video quality.

A network coding-based real-time multicast (NCRM) protocol is proposed in [15] for MANET to reduce the energy consumption. It combines the PUMA (protocol for unified multicasting through announcement) approach [16] with random linear network coding (RLNC). PUMA allows eliminating the unnecessary packets in order to reduce the network overhead and the end-to-end-delay. NCRM can both reduce the energy consumption and increase the throughput. Moreover, it is shown to be robust in high mobility and high density environment. However, this approach proposes to simultaneously send the whole block of coded packets which may lead to large delays, serious network congestions and low packet delivery ratios.

To address the low packet delivery ratio and low delay, a new scheme (named PNCRM) was proposed in [17] combining partial network coding [18] and the real-time PUMA. PNCRM is based on RLNC but each vector of packets is transmitted partially. It significantly increases the reliability and throughput. Anyhow, it performs poorly in multicasting scenarios with high traffic load.

The state-of-the-art survey shows that several approaches allow implementing NC in MANET. Since it is difficult to frequently update the network topology, mainly in high-mobility environment, RLNC is more suitable for ensuring high throughput and low network load. Although NC improves the throughput and the loss ratio, it does not guarantee to recover high priority packets. High-priority packet (considering H.264/SVC codec) loss is a basic QoS parameter for video coding in MANET. Additionally, some packets could be lost so that the Global Coefficient Matrix (GCM) [15] associated with RLNC cannot have the full rank for inversion to decode the packets at the receiver nodes.

The previously mentioned arguments motivate us to focus on minimizing the high priority packet loss for real time traffic in MANET. The main contributions of this paper are summarized as follows:

- We propose a new scheme named Extended Multicast Scalable Video Transmission using Classification Scheduling Algorithms and Network Coding over MANET (and denoted EMSCNC). It is an extension of our previous schemes named MSVT_CSA_NC [1].
- The proposed scheme adopts a cross layer design, achieves high performance and outperforms the state-of-the-art algorithms.
- This paper provides analytical models to estimate the average end-to-end delay, throughput and packet delivery ratio of EMSCNC.
- The proposed models are validated using numerical analysis as well as simulations.

The main characteristics of the proposed algorithm are:

- It integrates the H.264 scalable video coding (SVC), which is a more promising strategy than constant bit-rate video coding scheme.
- It minimizes the high priority packet loss by guaranteeing a successful reception of packets from the base layer (I or P frames). The authors in [3] describes thoroughly the H.264/SVC standard.
- It proposes a network coding scheme that, for the first time, provides the same block size for all the packets of one GOP.
- It creates coded packets based on their priorities by using an inter-layer compensation algorithm.

Our proposed scheme, EMSCNC, requires two workflows associated respectively to the source-node and intermediate (relay) node. The workflow on the source-node provide two algorithms: i) a classification algorithm that adjusts the *block_size* parameter of RLNC based on an inter-layer compensation; ii) and encoding algorithm to form blocks as a function of packets priorities. The second workflow, associated to the intermediate node, focuses on improving the decoding process.

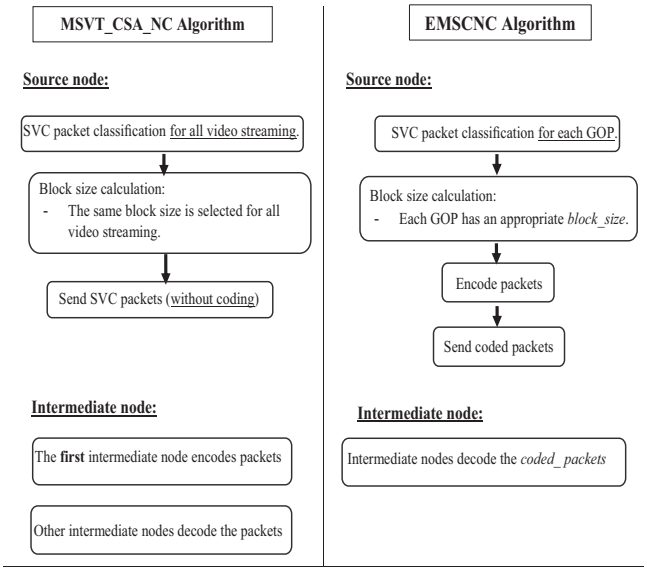

Fig. 1. MSVT_CSA_NC Vs EMSCNC.

The remainder of this paper is organized as follows. Section 2, illustrates the important difference between EMSCNC and the previous approach MSVT_CSA_NC. Section 3 summarizes the network model used to analyze the new scheme. The proposed transmission scheme is outlined in Section 4. In Section 5, simulation results validates our analytical results in Section 6. Finally, section 7 draws the concluding remarks.

2. MSVT_CSA_NC Vs EMSCNC

Our previous proposed approach named Multicast Scalable Video Transmission using Classification-Scheduling Algorithms and Network Coding over MANET (and denoted MSVT_CSA_NC), adopts also a cross layer solution between H.264/SVC codec, network and MAC layers. The difference between MSVT_CSA_NC and EMSCNC solution are at the source and intermediate nodes processing. For MSVT_CSA_NC, the source node performs a classification algorithm to adjust the block_size parameter of RLNC. The intermediate-node focuses on enhancing the RLNC and making it able to form blocks according to packets priorities. On the other hand for EMSCNC, the source node performs (i) packet classification and dynamic bloc size calculation based on inter-layer compensation, and ii) packet encoding process. These two functionalities are performed for each GOP. The intermediate node decodes the coded packet generated by the source node and re-encodes it before forwarding it. Comparing both solutions, we can also highlight that:

- EMSCNC provides the same block size for the packets of one GOP, contrarily to MSVT_CSA_NC where all the svc packets have the same size. Hence EMSCNC is able to guaranty an efficient coding that ensure a minimum loss of high priority packet.
- The loss of one packet in MSVT_CSA_NC increases the number of out-of-block packets whereas in EMSCNC it increases the same number for the same GOP only.
- EMSCNC reduces the end-to-end delay compared to MSVT_CSA_NC.

A comparison summery of the two schemes is depicted in Fig. 1: