Demonstration of a Video-aware Multicast Opportunistic Routing protocol over 802.11 two-hop mesh networks

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***Abstract*—In this demo paper, we demonstrate and evaluate a novel Opportunistic Routing (OR) protocol for video multicast, namely Video-aware Multicast Opportunistic Routing (ViMOR), over 802.11 two-hop mesh networks. OR exploits the broadcast nature of the wireless medium and offers spatial diversity among the receivers. ViMOR extends MORE, a state of the art OR algorithm, by orchestrating packet transmissions and prioritizing video traffic, in order to conform with video streaming requirements. For the demonstration and evaluation of the proposed scheme, we proceeded with the development of the implementation on NITOS wireless testbed. Results showed a significant increase in average video-perception quality, compared to MORE protocol. *Index Terms*—mesh network, opportunistic routing, network coding, multicast, video traffic, testbed implementation**

I. Introduction

In this work, we demonstrate an enhanced multicast OR protocol, that extends MORE approach with regard to adapt it to the video streaming requirements. In case of OR, contrary to the traditional routing, transmissions are broadcasted without MAC acknowledgements and retransmissions and as a result the duration of the packet forwarding process is upper limited and depends only on the controlled number of transmissions that source and relays attempt. Subsequently, OR is the most suitable choice for video multicast as forwarding on-time is of greater importance than reliability in video streaming.

MORE [1] is a MAC-independent OR protocol that applies network coding to randomly mix packets before forwarding them. More specifically, the source and relays forward linear combinations of the original packets contained in a batch, with random coefficients. The generated packets come with an additional header, which incorporates the selected coefficients, so as to make the retrieval of the original packets feasible. This random coding ensures that source and relays do not forward the same packets. Thus, there is no need of a special scheduler and MORE runs directly on top of 802.11, which makes it MAC-independent. Furthermore, MORE imposes reliability by employing an acknowledgement mechanism ensuring that the source and the relays do not stop transmitting coded packets until the destination decodes the whole batch. In detail, source transmits continuously, while each relay retransmits each received packet for a specific number of times.

II. ViMOR

We demonstrate a new OR protocol based on the design of MORE, named Video-aware Multicast Opportunistic Routing (ViMOR) [2]. ViMOR focuses on multicast scenarios, where all destinations are at most two-hop away from the source. The reason that led us to this decision is twofold: i) the performance of video wireless streaming over paths of three or more hops is degraded due to the fluctuations that increase as the paths get longer, and ii) the application of the transmissions policy by the source is infeasible in case of serving more than two-hop away destinations, since it is based on the link evaluations that should be on-line and updated. A mechanism inspired by the ETX estimation algorithm of Roofnet [3] is able to provide on-line link evaluations for the aforementioned topologies supported by ViMOR.

ViMOR **rejects the acknowledgement mechanism existing in** MORE that imposes the source and the relays to continuously generate and forward packets until source receives application layer acknowledgement from all destinations. Our scheme introduces the concept of a specific time period for forwarding a batch, called slot, which is calculated by the source taking account of the specific characteristics that the video sequence demonstrates. The forwarding process takes place only in this time interval, after the expiration of which, a new batch is forwarded. This mechanism achieves the on-time delivery of a batch, although it cannot guarantee that it will be successful. This is a desirable feature, since a lost batch causes a small drop in quality, which is acceptable in contrast to the delay of the whole video sequence.

The second contribution of ViMOR **is its enhanced transmissions policy.** In MORE protocol each node is assigned a *credit*, representing the number of transmissions each node will attempt for every packet it receives. ViMOR gives credit a different meaning and it is now interpreted as the total number of packet transmissions a node will attempt for the forwarding of a batch, independently of the number of the received packets. Since the aggregate credit of source and relays is upper bounded, depending on the aforementioned slot period, the physical transmission rate and packet size, the challenge that appears is to charge source and relays with the appropriate credit. In order to increase the individual throughput of each destination, ViMOR' s design of the credit

TABLE I
BASIC CONFIGURATION OF NITOS NODES

Model	Icarus nodes
CPU	Intel i7-2600 Proc., 8M Cache, at 3.40 GHz
RAM	Kingston 4 GB HYPERX BLU DDR3
Storage	Solid State Drive 60 GB
Wireless interfaces	two Atheros 802.11a/b/g/n (MIMO)
OS	3.2.0-31-generic Ubuntu precise
Driver	compat-wireless version 3.6.6-1-snpc

assignment policy aims to maximize the average probability of successful batch reception among all destinations. To achieve this, the credit assignment policy must provide the source with the highest possible credit in order to satisfy all one-hop destinations and at the same time provide each relay also with the highest possible credit to satisfy the two-hop destinations. ViMOR solves this optimization problem with a low-complexity algorithm.

Moreover, relays are forced to apply the *first-decode-then-transmit* policy, allowing them to transmit only after the successful decoding of a batch, in contrast to MORE, where relays transmit as soon as they receive a packet resulting in increased contention between the source and the relays.

The third contribution of ViMOR **is the introduction of a Priority Linear Coding mechanism (PLC)**, which prioritizes packets. Considering that video streaming consists of packets of varying significance, PLC offers the convenience to distinguish between packets containing segments of inter-decoded frames (P-frames and B-frames) and intra-encoded frames (I-frames). The latter are necessary for the decoding of the former and consequently they are treated as high priority packets. In ViMOR there exist two classes of packets, one of high priority that consists of packets containing as many as possible segments of intra-frames, and another one that contains all the packets of a batch.

Lets α to be equal with the proportion of high priority packets in a batch. Each relay' s credit is assigned to each class according to α. Specifically, the first α transmissions of the relay are linear combinations of the high priority packets, while the remaining are linear combinations of all packets. The source operates without prioritizing packets. On the other hand, receivers perform two parallel decoding processes, each one for each priority class. So, even if the decoding of the whole batch is not successful, the receiver is still capable of decoding the most important packets thus receiving a lower quality video which is better than nothing.

III. DEMONSTRATION SETUP

The implementation of ViMOR routing scheme is based on the Click framework [4], which offers easy to develop, flexible and configurable modular routers. Click modular router is comprised from packet processing modules called elements, that implement simple router functions. In this work, we extend and modify the Click based implementation of the MORE routing algorithm, introducing the aforementioned contributions for video streaming.

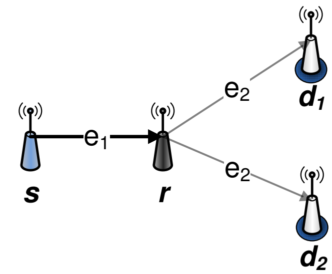

Fig. 1. A topology with 4 NITOS nodes used in the demonstration.

The deployment and evaluation of ViMOR takes place at the NITOS testbed [5], where we conduct experiments in various topologies with specific features. NITOS is a non-RF-isolated wireless outdoor testbed, so we use 802.11a to eliminate interference, since commercial 802.11 products in Greece use only 802.11b/g. The specifications of the NITOS nodes that we use for the experiments are depicted in Table I.

Since it is impossible to find the desired conditions, in order to demonstrate and evaluate ViMOR, in a testbed with stationary nodes, we reproduce them with the use of a distributed packet filtering mechanism, that we further explain. More particularly, we select NITOS nodes that are close to each other, shaping a full mesh connected topology with robust links (transmission error probabilities very close to zero). Then, we apply a packet filter to each one of these nodes, allowing a received packet to pass through with a specific probability, according to the transmitter's identifier. This mechanism enables the full control of the connectivity map, providing us with the ability to replicate any lossy link. The topology of our experimental setup is illustrated in Figure 1. Each link represents a communication channel for direct transmission from a given node to another one, and is labeled by its error transmission rate.

Source, relay and destinations are the s, r and d_1, d_2 nodes respectively. The e_1 and e_2 values are the corresponding transmission error probabilities of the source and relay nodes. The performance of both MORE and ViMOR is expected to be highly insensitive to different batch sizes, as it is presented in [1]. Although a batch size of 64 packets imposes the largest overhead in packet transmission, since it uses longer headers, it enables the most accurate estimation of the redundancy packets that a transmitter should use. Therefore we use this batch size. The main configuration parameters are that RTS/CTS is disabled, as it happens in most real networks, and all nodes use 6 Mbps as physical transmission rate. Finally we configure the packet payload to be equal to 1470 bytes.

In our demonstration we compare ViMOR and MORE protocols by streaming the video sequence of *foreman* with CIF resolution, encoded in H.264 with GOP size of 10 frames, containing only I/P-frames (not B-frames). For the comparison we use the PSNR metric for the received video quality at the destinations. The quality of the H.264 compression (in particular quantization) is such that the average size of a compressed GOP is almost equal to the batch size, while the

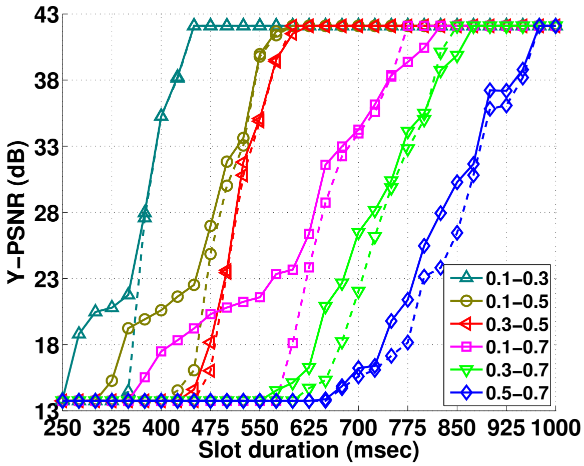

Fig. 2. Performance evaluation of ViMOR comparing to MORE. The indicator of each plot shows the e_1 and e_2 probabilities, where the solid line is for ViMOR and the dashed for MORE.

size of each I-frame is approximately the $\alpha = 1/3$ proportion of the whole GOP size. We demonstrate our scheme for various time slots and consequently for various frame ratios, considering a time slot equals to the quotient of the division between the GOP size and the frame ratio (e.g., for a GOP size of 10 frames and frame ratio of 25 fps the corresponding time slot equals to 400 ms). In case of a lost frame, receivers replace it with the previous one (we always provide the first frame to all destinations). Subsequently, in the extreme case that nothing is received from a destination, the corresponding perceived video corresponds to a sequence of repeated frames that are the same with the first one. For MORE protocol, we consider each late arriving frame as a lost one.

The demonstration is conducted in almost lossless links, where we configure the transmission error probabilities using different pairs of probability values as requested by the audience. As mentioned before, we evaluate the two protocols in respect to PSNR metric which is presented live, for each received GOP. In Figure 2, results for the aforementioned comparison are depicted which clearly display ViMOR 's outperformance of MORE, for various couples of e_1 and e_2 probabilities.

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