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SORT:
A System for Adaptive Transmission of Video Over Delay Tolerant Networks

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ABSTRACT

In challenging environments, opportunistic networks can provide limited communication features in a delay tolerant manner. It is extremely difficult to transmit large data like videos in such environments, as delay may be hours and part of the information may be lost. This article proposes a novel system that uses partial information from prior communication to estimate the network congestion and delay. The video is compressed and packetized using scalable video coding (SVC). Extensions to Spray-and-Wait routing protocols are analyzed to ensure better delivery video quality and lower wastage. Through simulation, including real-world traces, performance of the proposed solutions under multiple scenarios is evaluated. Experimental results show that adaptive control reduces overall delay and minimizes wastage while improving the quality of video at the receiver. Adaptive SVC transmissions demonstrate almost three times increase in decoded content, as compared to non-SVC transmission.

KEYWORDS

Application Layer Adaptation, Data Forwarding, Delay Tolerant Networks, Media Aware Network Elements, Scalable Video Streaming

1. INTRODUCTION

Wireless ad-hoc networks and mobile ad-hoc networks (MANET) can have network partitions, because of node mobility. Delay and disruption tolerant networks (DTN) are a sub-field of MANET, where the end-to-end connectivity does not exist on a regular basis (Fall, 2003). While mobility broke MANET, the contacts between mobile nodes completes the network for DTN over time (which can be in the order of hours or even days in some cases). Instead of store-and-forward techniques, these networks rely on store-carry-forward. Such a communication approach may also use multiple replicas of the content to ensure better delivery rates and lower delays. This replication can lead to resource exhaustion (e.g., bandwidth, storage or power in case of portable devices). DTN based routing has been widely researched (Cao & Sun, 2012), with applications in defense, disaster management scenario, inter-planetary networks, etc.

Similar to the evolution of networks, video communication technology has also progressed. Early digital video networks would typically broadcast the video, for prior published content and one-way broadcast of live events. Digital TV offerings (including digital cable TV, Satellite-based TV services) are early examples of this. Subsequently, as internet penetration increased, other platforms

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like Netflix, YouTube, etc., started providing content individually to each user (i.e., unicast). Parallel to this, real-time video communication also evolved, initially in one-to-one mode and later in conference mode supporting multiple sources. Examples of such communication platforms are WebEx, Skype, FaceTime, WhatsApp, Duo, etc. In all these scenarios, end users view the video on heterogeneous platforms connected over a variety of networks. Since the display resolution, buffering and decoding capabilities may vary, the original video may need to be adapted for different receivers. SVC (Unanue et al., 2011) is one of the approaches, which uses the multi-layer encoding of content, to satisfy the needs of the different network and device capabilities. The base layer (BL) has the lowest demands on resources while providing a minimal quality. Addition enhancement layers (EL) help to improve the quality of the decoded video, on devices that have better resources like network bandwidth, screen resolution, processing power, etc.

There is a significant increase in opportunistic capture of content in multiple domains like law enforcement, disaster response, transport, defense, wildlife, agriculture, etc. Here the communication delay may be of the order of minutes to hours. Affordable smartphones and other portable devices with integrated camera have helped increase this trend. Trono et al. (2015) and Shibata and Uchida (2017) have explored multimedia applications, which are both delay and loss tolerant for disaster management scenarios.

In opportunistic networks, the destination may only receive parts of multimedia content. Further, the acknowledgments convey information only about that part of the network, over which the successful delivery of content and acknowledgment has happened. Such path limitations mean that both the source and the destination can only get a partial view of the network. This partial view of the network is used to adapt subsequent transmission from the sender, to maintain video quality without overloading the network. The algorithm adapts three aspects for subsequent transmission – SVC operating points (i.e., number of SVC layers transmitted by source); replication count for different layers; and time-to-live (TTL) for different layers. Savings from the adaptation can be redistributed, by increasing the copy count of the transmitted layers. The adaptation is purely on the end host and does not rely on a modification of the routing protocols. This paper uses Spray-and-Wait (SNW) as the routing protocol (Spyropoulos, Psounis, & Raghavendra, 2005).

The proposed system is named SORT (SNW based adaptive video transmission using operating point, replication count and time-to-live). For scenarios where it is feasible to have media-aware network elements (MANE) (Schierl et al., 2007), authors implemented layer awareness to SNW routing for all nodes and analyzed its performance.

This work extends authors prior work (Thakur, 2020). The additional contributions of this paper are:

1. Experiments and analysis of overheads and buffer occupancy;
2. Explore the impact of extensions to SNW routing protocols on SVC media flow;
3. Analyse the impact of different scenarios (including mobility pattern, load and node density) on SVC media flows.

This work can be applied to multiple domains that may need opportunistic video capture. For large transitionary gatherings, the opportunistically collected video provides excellent input for trend analysis, including posterior monitoring and investigations (Trono, 2015). Monitoring of events in remote locations (e.g., elections or exams in sparsely populated areas) is another application where such an approach, backed with tamper-resistant local storage for few hours can provide an efficient enhancement for ensuring that no malpractices take place. This work can also be coupled with energy saving approaches like those proposed by Celebi et al. (2019), for infrastructure based dense 5G solutions.

The structure of rest of the document is as follows: Section 2 is an overview of scalable video compressions and prior work done regarding the transmission of video over delay tolerant networks. Section 3 presents the details of the proposed systems. Section 4 covers the experimental

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