Optimization of Network Overhead for Transport Layer Coding

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Abstract

This paper studies limitation of time a packet stays in the network when using transport layer coding. It's being studied dependence of message delivery probability from packet live time. It's being estimated network overhead decrease at the expense of deletion of deferred packets. An approach of packet live time selection is proposed.

Index Terms: Transport Layer Coding, Network Utilization, Network Delay.

I. Introduction

Originally transport layer coding was presented in works [1], [2]. At first we need to recall briefly an idea of transport layer coding.

Consider a packet-switched network. Assume all messages arrived to the network are devided into k packets of length m symbols. We will treat packets as elements of $GF(2^m)$ and will encode every message using 2^m-ary (n,k) code. As a result, we will obtain encoded messages consisting of n packets. If we will use an MDS code, for example Reed-Solomon code, then it's enough to receive any k packets of n in order to reconstruct message on the destination node. If packets go through different independent routes transport layer coding makes it possible to decrease message delay [2] because it's enough to receive only k fastest packets.

In original work it's considered that packets are being transmitted until they reach a destination node. It means that even after message reconstruction redundant packets are still in the network. A novelty of this work is in limitation of packet's live time. The longest time a packet could stay in the network we will call packet live time and denote as T_{TTL}. If packet stays in the network for T_{TTL} time and hasn't been delivered to destination node then it will be deleted on intermediate node. Simulation is used in this work in order to examine how probability of message delivery depends on packet live time and to calculate number of deleted packets. An approach of packet live time selection for given network is proposed.

II. Network model

A network model used in this paper is based on the Kleinrock's model [3]. The network consists of N nodes. Channels assumed to be absolutely noiseless and reliable. Network topology is set using an adjacency matrix. Channels capacities are set using matrix C. A value in $C[i][j]$ is a capacity of channel from node i to node j. Network nodes store packets and pick routes for them. In this work a multi-packet transmission is considered. Every message consists of n packets. Messages that appear in the network at node i and intended for node j produce the Poisson flow with intensity $I[i][j]$, where I is a matrix of intensities. It's assumed that packets that belong to the same message are injected into the network at the same time. For packets from one message different routes are being picked. Selection of routes is going on every intermediate node. If several possible channels could be used in order to deliver packet to it's recipient then first free channel is being selected. It is assumed that packet delay in the network has exponential distribution with rate parameter $1/(\mu C[i][j])$, where $1/\mu$ is an average packet length.

III. Selection of packet TTL

Consider a packet that appeared in the network at node s and intended for node d. Assume that there are n routes between s and d. Let's denote packet transmission time from node s to node d using route i as T^i_{sd}. It's proposed to select packet live time using one of two equations:

$$T_{TTL} = \frac{1}{n}\sum_{i=1}^{n} T^i_{sd} \tag{1}$$

or

$$T_{TTL} = \max_{1 \le i \le n} T^i_{sd} \tag{2}$$

Equation (1) is more suitable for the networks where packet delay differs not so much for different routes. For example, the networks with high connectivity. Equation (2) is more suitable for the networks where packet delay differs too much for different routes. For example, the networks with low connectivity.

For the real network it's also possible to calculate packet live time using equations (1), (2). Consider a mesh network. It's known that it uses Hybrid Wireless Mesh Protocol (HWMP) as a default routing protocol [4]. It uses Airtime Link Metric for route selection. This metric could be calculated by the following equation:

$$c_a = \frac{(O + B_t/r)}{1 - p_{err}}, \tag{3}$$

where O is a channel access and protocol overheads, B_t is a number of bits in test packet, r is a channel rate, p_{err} is bit error rate. HWMP finds only one best route in terms of metric, but it's possible to modify it in such a way that it will find n best routes. Metric c_a describes a transmission time over one channel. The sum of c_a values over all channels of route i could give us T^i_{sd}. After that equations (1), (2) could be used in order to calculate packe live time.

IV. Simulation results

The results are presented here correspond to network model with 10 nodes and low network utilization. The network topology was chosen randomly. A code rate for transport layer coding was selected in such a way that benefit from transport layer coding in terms of message delay would be the largest. For generated network a code rate 0.6 was chosen.

A curve on figure 1 shows message delivery probability against picked packet TTL. Message delivery probability is a probability of successful delivery of k packets to the destination node (for successful message reconstruction it's needed to receive any k packets from initially sent n packets). Graph on figure 1 was built using an exhaustive search over packet live times. For every value of packet live time it was obtained message delivery probability using simulation technique. A separate point on the graph is marked out. This point corresponds to packet live time that was selected using proposed in section III approach. One could see rather high message delivery probability corresponds to selected packet live time.

A curve on figure 1 shows message delivery probability against amount of deleted packets. Number of deleted packet is presented in percents from overall number of transmitted packets. A marked out point on the graph corresponds to the proposed approach.

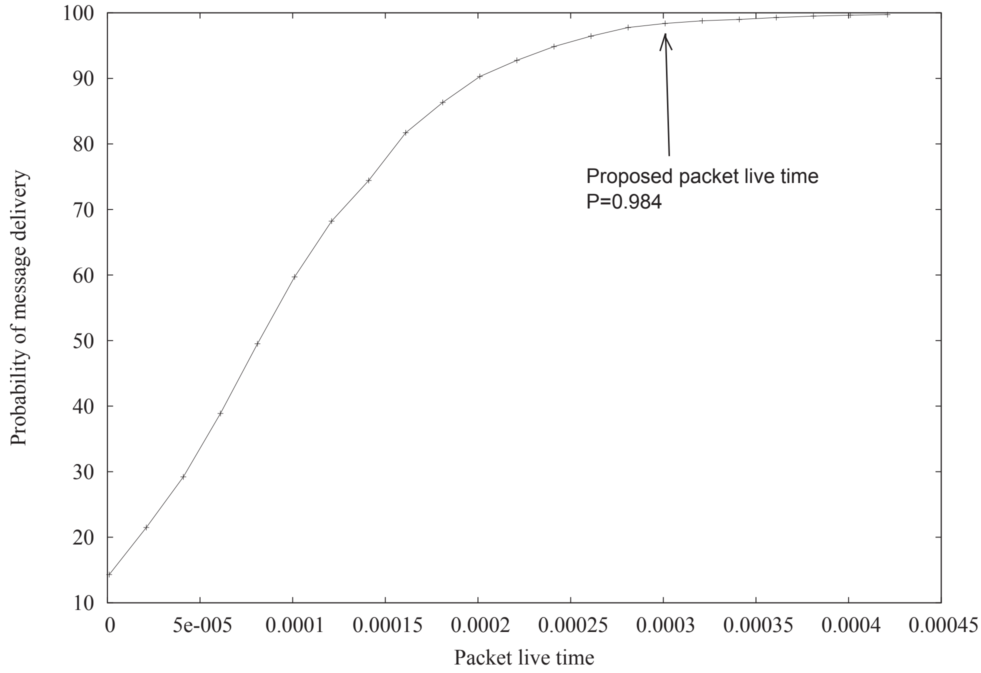

Fig. 1. Message delivery probability against picked packet TTL.

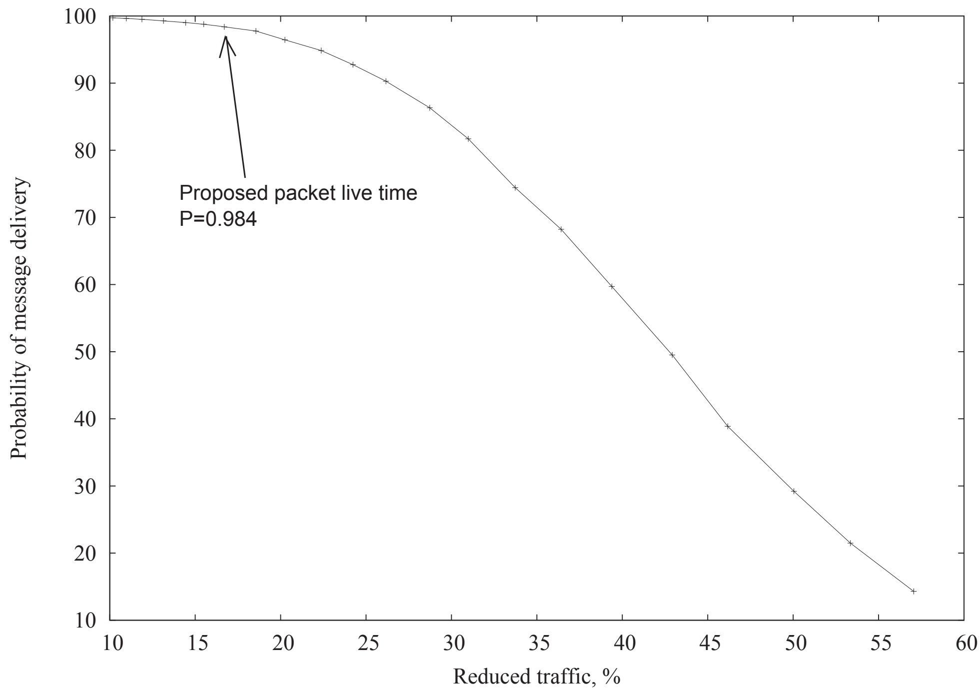

Fig. 2. Message delivery probability against amount of dropped traffic.

V. Conclusion

This paper introduced a limitation of time a packet stays in the network when using transport layer coding. It was obtained dependency of message delivery probability from packet live time (fig. 1). For different values of message delivery probability it was shown amount of traffic that would reach selected packet live time (fig. 2). Presented in this paper figures show that introduction of packet live time could help to decrease network overhead for transport layer coding and at the same time preserve rather high message delivery probability. Network traffic decrease should make message delay even smaller, thereby increasing benefit from transport layer coding.

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