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Technical Considerations for Transport Layer Protocols Optimization for Satellite Networks (T4SAT)

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Abstract

This document analyses the gaps of the existing transport layer technologies and provides technical considerations for Transport Layer Protocols Optimization for Satellite Networks (T4SAT).

Status of This Memo

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1. Introduction

It demands high-bandwidth and high-throughput data transmission in LEO (Low Earth Orbit) satellite networks as described in [I-D.yang-tsvwg-leo-transport-req]. The performance of transport protocols will be impacted by the unique characteristics such as networks-highly dynamic topologies, long and variable propagation delays and time-varying channel errors. The optimization of transport layer technologies in LEO satellite networks should consider:

*the congestion control algorithms should be optimized to adapt the increasing bursty packet loss and significant delay variability.

*the congestion control should decouple channel errors from congestion signals while adapting to rapid topology changes.

*the ACK mechanism should adapt the transport layer to reduce spurious retransmissions.

This document analyses the gaps of the existing transport layer technologies and provides technical considerations for Transport Layer Protocols Optimization for Satellite Networks (T4SAT).

2. Definition of Terms

This document uses the terms defined in [I-D.yang-tsvwg-leo-transport-req]:

3. Technical Considerations for T4SAT

3.1. Optimization of Congestion Control Algorithms

As per [I-D.yang-tsvwg-leo-transport-req], frequent handovers and connection switching will increase packet loss ratio (e.g. over 60%). The congestion control algorithms should be selected and optimized to tolerate the high packet loss ratio and predict bandwidth to control the congestion before the queues overflow.

Bottleneck Bandwidth and Round-trip propagation time (BBR) is a congestion-based congestion control algorithm for TCP, which actively measures bottleneck bandwidth (BtlBw) and round-trip propagation time (RTprop) based on the model to calculate the bandwidth delay product (BDP) and then to adjust the transmission rate to maximize throughput and minimize latency. In LEO satellite networks, the dynamic topology could add significant delay variability beyond the inherent propagation latency and it also consumes valuable satellite capacity. The congestion control algorithms should be optimized to adapt seamlessly to latency variations and RTT fluctuation based on precise RTT measurements.

3.2. Enhancement of Congestion Notification

As per [I-D.yang-tsvwg-leo-transport-req], random packet loss will lead to the failure of congestion control mechanisms. For example, when receiving a congestion notification with packet loss, the loss-based congestion control algorithms, such as Congestion-based Upon Bandwidth-Information (CUBIC), will reduce the congestion window and the throughput will dramatically decrease.

In LEO satellite networks, the packet loss will be divided into channel-error loss and congestion-based loss. The time-varying channel-error loss will occur when packets are corrupted or dropped due to physical layer impairments in the communication channel. It needs to retransmit the lost packets without reducing congestion window. The congestion notification should distinguish channel-error loss and congestion-based loss. Explicit Congestion Notification (ECN) can be used to achieve an end-to-end congestion notification and the type of packet loss could be encoding in the ECN markings.

3.3. Adaptations of Transport Protocols

As per [I-D.yang-tsvwg-leo-transport-req], long and variable propagation delay is one of unique characteristics in LEO satellite networks. The propagation delays (e.g.20-150ms RTT) are higher exceeding the terrestrial networks. The Retransmission Timeout (RTO) mechanism will frequently misinterpret propagation delay as congestion. The acknowledgments (ACKs) are not arriving on time, leading to unnecessary congestion window reduction and packet retransmissions. Moreover, asymmetric uplink and downlink capacities cause ACK congestion and buffer overflows. The ACK mechanism in LEO satellite networks should adapt the transport layer to give ACKs higher priority during handovers and guarantee ACK delivery even during orbital transitions, reducing spurious retransmissions caused by orbital motion.

4. Security Considerations

To be discussed in future versions of this document.

5. IANA Considerations

Currently this document does not make an IANA requests.

6. Informative References

[I-D.yang-tsvwg-leo-transport-req]
Yang, F. and T. Tsou, "Transport Layer Protocol Requirement for LEO satellite", Work in Progress, Internet-Draft, draft-yang-tsvwg-leo-transport-req-00, 16 March 2025, <https://datatracker.ietf.org/doc/html/draft-yang-tsvwg-leo-transport-req-00>.

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