QUIC
Internet-Draft
Intended status: Experimental
Expires: October 11, 2019

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April 9, 2019

# The QUIC Loss Bits
# draft-ferrieuxhamchaoui-quic-lossbits-00

## Abstract

This document specifies the addition of loss bits to the QUIC transport protocol and describes how to use them to measure and locate packet loss.

## Note to Readers

This document specifies an experimental delta to the QUIC transport protocol.

## Status of This Memo

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## 1. Introduction

Packet loss is a hard and pervasive problem of day-to-day network operation, and locating them is crucial to timely resolution of crippling end-to-end throughput issues. To this effect, in a TCP-dominated world, network operators have been heavily relying on information present in clear in TCP headers: sequence and acknowledgement numbers, and SACK when enabled. By passive on-path observation, these allow for quantitative estimation of packet loss. Additionally, the lossy segment (upstream or downstream from the observation point) is unambiguous; this is crucial as it gives the ability to quickly home in on the offending segment, by moving the passive observer around.

In the QUIC context, the equivalent transport headers being encrypted, such observation is not possible. To restore network operators' ability to maintain QUIC clients experience, this document adds two explicit loss bits to the QUIC short header, named "Q" (sQuare signal) and "R" (Retransmit). Together, these bits allow the observer to estimate upstream and downstream loss, enabling the same dichotomic search as with TCP.

## 2. Passive Loss measurement

The proposed mechanisms enable loss measurement from observation points on the network path throughout the lifetime of a connection. End-to end loss as well as segmental loss (upstream or downstream from the observation point) are measurable thanks to two dedicated bits in short packet headers, named loss bits. The loss bits therefore appear only after version negotiation and connection establishment are completed.

### 2.1. Proposed Short Header Format Including Loss Bits

As of the current editor's version of [QUIC-TRANSPORT], two bits are "reserved" in the first byte of short headers. This proposal naturally fits in there, allocating these two bits as Q and R. Of course, the very purpose of Q and R being to enable on-path observation, the current restrictions about their encryption and zero value should be lifted in QUIC versions supporting this proposal.

### 2.2. Semantics

The semantics of these bits are as follows:

Q: The sQuare bit is toggled every N outgoing packets as explained below in Section 2.2.1.

R: The Retransmit bit is set to 0 or 1 according to the not-yet-disclosed-lost-packets counter, as explained below in Section 2.2.2.

#### 2.2.1. Setting the sQuare Bit on Outgoing Packets

Each endpoint independently maintains a sQuare value, 0 or 1, during a block of N outgoing packets (e.g. N=64), and sets the sQuare bit in the short header to the currently stored value when a packet with a short header is sent out. The sQuare value is initiated to 0 at each endpoint, client and server, at connection start. This mechanism thus delineates slots of N packets with the same marking. Observation points can estimate the upstream losses by simply counting the number of packets during a half period of the square signal, as described in Section 3.

#### 2.2.2. Setting the Retransmit Bit on Outgoing Packets

Each endpoint, client and server, independently maintains a not-yet-disclosed-lost-packets counter and sets the Retransmit bit of short header packets to 0 or 1 accordingly. The not-yet-disclosed-lost-packets counter is initialized to 0 at each endpoint, client and server, at connection start, and reflects packets considered lost by

the QUIC machinery, the content of which is pending for retransmission. When a packet is declared lost by the QUIC retransmission machinery (see [QUIC-RECOVERY]) the not-yet-disclosed-lost-packets counter is incremented by 1. When a packet with a short header is sent out by an end-point, its retransmit bit is set to 0 when the not-yet-disclosed-lost-packets counter is equal to 0. Otherwise, the packet is sent out with a retransmit bit set to 1 and the not-yet-disclosed-lost-packets counter is decremented by 1. Thus, the retransmit bit performs unary encoding of the amount of loss: observation points can estimate the number of packets considered lost by the QUIC transmission machinery in a given direction by counting packets in this direction with a retransmit bit equal to 1.

#### 2.2.3. Resetting state on CID change

When sending the first packet of a given connection with a new connection ID, each endpoint resets its sQuare value and not-yet-disclosed-lost-packets counter to zero. This eliminates the possibility for transient sQuare or Retransmit bit state to be used to link flows across connection migration or ID change.

## 3. Using the loss bits for Passive Loss Measurement

### 3.1. End-to-end loss

The Retransmit bit mechanism merely reflects the number of packets considered lost by the sender QUIC stack with a slight delay. In case of fast retransmit due to repeted acknowlegments of a packet, this delay is at least equal to the one way delay in the reverse direction. It is larger otherwise (eg RTO). The retransmit mechanism alone suffices to estimate the end-to-end losses; similar to TCP passive loss measurement, its accuracy depends on the loss affecting the retransmit-bit-marked packets, which are in themselves proof of previous loss.

### 3.2. Upstream loss

During a QUIC connection lifetime, the sQuare bit mechanism delineates slots of N packets with the same marking. When focusing on the sQuare bit of consecutive packets in a direction, this mechanism sketches a periodic square signal which toggles every N packets. On-path observers can then estimate the upstream losses by simply counting the number of packets during a half period (level 0 or level 1) of the square signal. Packets with a long header are not marked, but yet taken into account by the sender when counting the N outgoing packets before its next toggle. Observers should assign long header packets to the pending slot if possible (i.e. up to N

packets counted in this slot), to the next one otherwise. Thus, slots with less than N packets, whatever their header length, generally denote upstream loss. As with TCP passive detection based on missing sequence numbers, this estimation may become inaccurate in case of packet reordering which blurs the edges of the square signal ; heuristics may be proposed to filter out this noise in the observation points.

The slot size N should be carefully chosen : too short, it becomes very sensitive to packet reordering and loss. Too large, short connections may end before completion of the first square slot, ruining any loss estimation. Slots of 64 packets are suggested as a reasonable trade-off.

### 3.3. Downstream loss

The Retransmit bit mechanism can be coupled with the sQuare bit mechanism to estimate downstream losses. Indeed, passive observers can infer downstream losses by difference between end-to-end and upstream losses.

The sQuare bit mechanism allows for observers to compute loss measurement at the end of every half square signal period (level 0 or level 1).

The Retransmit bit mechanism provides for the end-to-end loss after reaction of the sender stack.

On-path observers can estimate upstream and downstream loss at various scales, from the square slot level to the connection lifetime level.

Note that observers should perform a loose synchronisation between the sQuare and the Retransmit measurements when accurate evolution of segmental loss over connection lifetime is sought, so as to compare the same portion of the packet stream.

### 3.4. Bidirectional flows

The Q and R bits sent by one endpoint cover loss of packets sent by the same endpoint, allowing a midpoint observer to estimate loss in that direction; no specific cooperation is needed between the endpoints beyond negotiating a QUIC version that supports this proposal. Hence, the server will be enabling troubleshooting of the download path, and the client will work for the upload path. This allows to be confident about getting a useful signal in asymmetric situations: clients may for example implement Q and R improperly, the

download path will still be debuggable as long as servers do it right.

It should also be noted that the method does not suffer from the natural asymmetry in packet rate of a typical download or upload scenario. Indeed, although there are often fewer acknowledgements than payload-bearing packets, the unary encoding by R of payload loss is borne by the payload stream itself. This allows to report loss in the important direction in both a timely and accurate fashion without sampling or quantization.

## 4. Security and Privacy Considerations

The loss bits are intended to expose loss to observers along the path, so the privacy considerations for the loss bits are essentially the same as those for passive loss measurement in general. Loss gives no hint on customer geolocalisation; moreover, reset of loss accounting state on CID changes prevents linkability.

## 5. IANA Considerations

An IANA registry has been suggested for QUIC versions. In support of the fully negotiated status of the proposed extension, a natural way of deploying this feature would be through such a registered version.

## 6. Acknowledgments

The sQuare Bit was originally specified by Kazuho Oku in early proposals for loss measurement.

## 7. Normative References

[QUIC-RECOVERY]
Iyengar, J., Ed. and I. Swett, Ed., "QUIC Loss Detection and Congestion Control".

[QUIC-TRANSPORT]
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