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One Way Latency Considerations for Multipath in QUIC
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Abstract

   This document discusses the use of One Way Latency (OWL) for
   enhancing multipath transmission in QUIC. Several representative
   usages of OWL, such as congestion control mechanism, retransmission
   policy, crucial data scheduling are analyzed. Two kinds of OWL
   measurement approaches are also provided and compared. More
   explorations related with OWL will be researched to improve the
   performance of QUIC.

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Table of Contents

1. Introduction

   Round-trip time (RTT) is commonly used in congestion control and loss
   recovery mechanism for data transmission. Yet the key issue for data
   transmission is simply the delay of the data transmission along a
   path which does not include the return. The latency for uplink and
   downlink between two peers may be very different. RTT, which cannot
   accurately reflect the delay of the data transmission along a path,
   can be easily influenced by the latency in the opposite direction
   along that path. Therefore, the use of One Way Latency (OWL)
   [I-D.song-mptcp-owl] is proposed to describe the exact latency from
   the time that data is sent to the time data is received.

   Using the timestamps information in the ACK Frame of QUIC
   [I-D.ietf-quic-transport], the One Way Latency can be calculated in
   absolute value or in relative value. As multipath will be supported
   by QUIC, path selection based on One Way Latency can improve the
   performance of multipath in QUIC in several situations, such as
   congestion control, packet retransmission, crucial data scheduling,
   etc.

   We suggest discussing the necessary considerations of OWL in QUIC.
   In the following, possible usages of OWL in QUIC are analyzed, and
   then two kinds of OWL measurements are listed and compared.

2. Conventions and Terminology

   The key words "MUST", "MUST NOT", "GLUIRED", "SHALL","SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in [RFC2119].

   One Way Latency (OWL): the propagation delay between a sender and a
      receiver from the time a signal is sent to the time the signal is
      received.

3. Potential Usages of OWL in QUIC

   There are a number of potential uses of OWL, especially for multipath
   in QUIC. Although only 3 significant aspects are illustrated in this
   document, more explorations are still needed.

3.1. Crucial Data Scheduling

   During a transmission process, there are often some crucial data that
   need to be sent to the destination immediately. Examples of such
   crucial data are the key frame in multimedia, the high priority chunk
   of emergency communication, etc. One cannot guarantee the sequence
   of data arrival along multiple paths if only the RTTs of the multiple
   paths are used.

   The data rate in any given link can be asymmetric. In addition, the
   delay in a given direction can change according to the amount of
   packet queue. Therefore delay in a forward direction in a path is
   not necessarily the same as that in the reverse direction as
   exemplified in Figure 1.

```
       --------      OWL(s-to-c,path1)=16ms   <--------      \
      /                                                        \
     |      ----->   OWL(c-to-s,path1)= 5ms      -----        |
     |    /             RTT(path1)=21ms            \     |
     |   |                                          |   |
   +------+                                      +------+
   |      |----->   OWL(c-to-s,path2)= 8ms      -----|      |
   |Client|                                          |Server|
   |      |-----    OWL(s-to-c,path2)= 8ms      <-----|      |
   +------+            RTT(path2)=16ms              +------+
     |  |                                            |  |
     |   \                                          /   |
     |     ----->   OWL(c-to-s,path3)=10ms      -----       |
      \                                                    /
       --------      OWL(s-to-c,path3)= 8ms   <--------
                       RTT(path3)=18ms
```
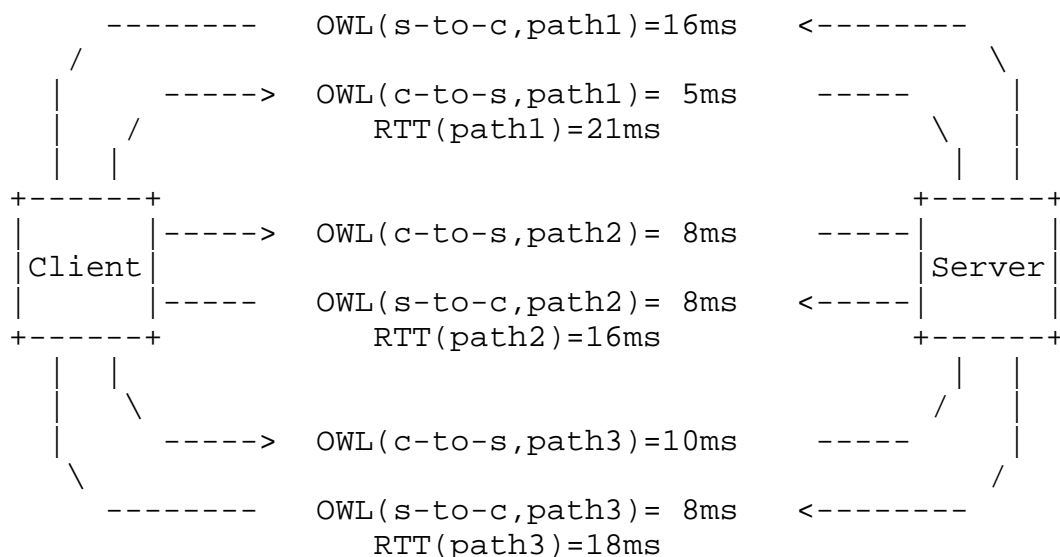
Figure 1. Example with 3 paths between the client and the server
with OWL as indicated in the figure. RTT information alone would
indicate to the client that the fastest path to the server is path 2,
followed by path 3, and then followed by path 1. path 2 is the
fastest, whereas OWL indicates to the client that the fastest path to
the server is path 1, followed by path 2, and then followed by path
3.

Using the results of OWL measurement, the sender can easily select
the faster path, in terms of the latency in the forward direction,
for crucial data transmission. Moreover, the acknowledgements of
these crucial data can be sent on the path with minimum latency in
the reverse direction. Piggyback is then also useful when in duplex
communication mode.

3.2. Congestion Control

Congestion in a given direction does not necessarily imply congestion
also in the reverse direction.

```
          --------    No congestion (path 1)    <--------   \
        /                                                     \
       |      ----->  Congestion    (path 1)      -----        |
       |    /                                         \    |   |
       |   |                                           |   |
     +------+                                       +------+
     |Client|                                       |Server|
     +------+                                       +------+
       |   |                                          |   |
       |     \                                       /  |   |
       |      ----->  No congestion (path 2)     -----     |
        \                                                   /
          --------    Congestion    (path 2)    <--------
```
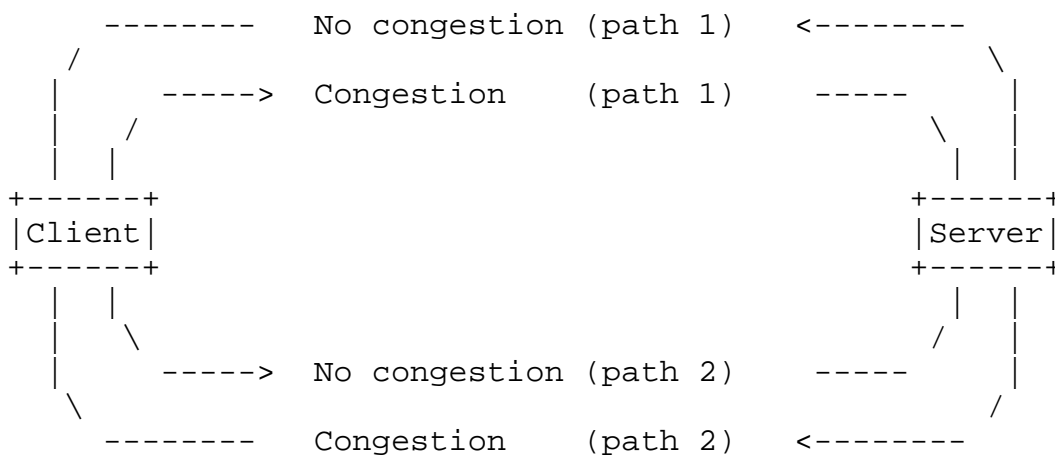
Figure 2. Example of a congestion situation with 2 paths between the
client and the server. There is congestion from client to server
along path 1 and also from server to client along path 2. RTT
information alone will indicate congestion in both paths, whereas OWL
information will show the client that path 2 is the more lightly
loaded path to get to the server.

Network congestion in a given direction can be better described using
OWL rather than using RTT. Especially when the congestion can be a
situation in a unidirectional path, the congestion in the path from a
client to a server is different from the congestion in the path from
the server to the client. The RTT cannot accurately reflect the
delay of interest for data transmission along a path. For multipath
in QUIC, the client needs to choose a more lightly loaded path to
send packets [RFC6356]. It will then be unwise to compare the RTT
among different paths, and it should instead compare the OWL among
the paths.

3.3. Packet Retransmission

Continuous Multipath Transmission (CMT) increases throughput by
concurrently transferring new data from a source to a destination
host via multiple paths. However, when a packet is lost, Receive
Buffer Blocking (RBB) will occur as illustrated in Figure 3.

```
                    Stream 5, Offset    0, Length 500 (lost)
           -----> Stream 5, Offset 1000, Length 500 (rcvd) -----
          /        Stream 5, Offset 2000, Length 500 (rcvd)     \
        |                                                        |
      +------+                                          +--------+
      |Sender|                                          |Receiver|
      +------+                                          +--------+
        |                                                        |
         \       Stream 5, Offset  500, Length 500 (rcvd)       /
           -----> Stream 5, Offset 1500, Length 500 (rcvd) -----
                    Stream 5, Offset 2500, Length 500 (rcvd)
```
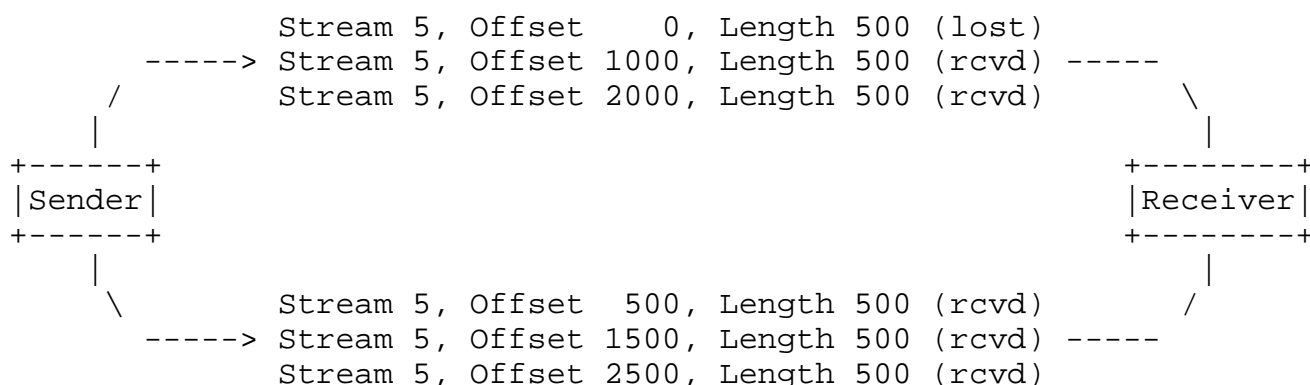
Figure 3. Example of Receive Buffer Blocking: The packet containing
octets 0-499 in Stream ID=5 is lost. On the other hand the packets
containing Octets 500-999, 1000-1499, 1500-1999, 2000-2499 in Stream
ID=5 have all been received. The octets 500-2000 are then all
buffered at the receiver, and are blocked by the missing octets
0-499.

Therefore, the sender needs to select a suitable path to retransmit
ASAP. Using the results of OWL measurement, the sender can quickly
determine the specific path with minimum forward latency. RBB can
then be relieved as soon as the receiver obtains the most needed
frames in the retransmitted packet(s) and submits them to the upper
layer.

4. OWL Measurement

   Two kinds of OWL measurement approaches are available: absolute value
   measurement and relative value measurement.

   To obtain the absolute value of OWL, the primary condition of
   measurement is clock synchronization. Using Network Time Protocol
   (NTP) [RFC5905], end hosts can calibrate the local clock with the
   remote NTP server. The additional information or optional
   capabilities can even be added via extension fields in the standard
   NTP header [RFC7822]. The calibration accuracy can reach to the
   millisecond level in less congested situations. The obvious burden
   here is to persuade the end hosts to initialize the NTP option.

   Obtaining the relative value of OWL is more than enough in some
   circumstances to establish applications on top of it. When
   retransmission is needed, for example, the sender may only care about
   which path has the minimum forward latency. When bandwidth is being
   estimated, the difference of forward latency, i.e. delta latency,
   among all available paths is needed. By exchanging with
   correspondent end host the local timestamps of receiving and sending
   the packets, both sides could obtain the relative value of OWL.

The considerations to obtain the absolute values are the extra protocol requirement and synchronization accuracy. However, using the absolute values is more convenient for its applications. On the contrary, the relative measurement only needs to send timestamps in the acknowledgment and there is no need to worry about the clock synchronization.

5. Security Considerations

   TBD

6. IANA Considerations

   This document presents no IANA considerations.

7. References

7.1. Normative References

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