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RFC 9221

An Unreliable Datagram Extension to QUIC

Abstract

This document defines an extension to the QUIC transport protocol to add support for sending and receiving unreliable datagrams over a QUIC connection.

Status of This Memo

This is an Internet Standards Track document.

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Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc9221>.

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1. Introduction

The QUIC transport protocol [[RFC9000](#)] provides a secure, multiplexed connection for transmitting reliable streams of application data. QUIC uses various frame types to transmit data within packets, and each frame type defines whether the data it contains will be retransmitted. Streams of reliable application data are sent using STREAM frames.

Some applications, particularly those that need to transmit real-time data, prefer to transmit data unreliably. In the past, these applications have built directly upon UDP [RFC0768] as a transport and have often added security with DTLS [RFC6347]. Extending QUIC to support transmitting unreliable application data provides another option for secure datagrams with the added benefit of sharing the cryptographic and authentication context used for reliable streams.

This document defines two new DATAGRAM QUIC frame types that carry application data without requiring retransmissions.

1.1. Specification of Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Motivation

Transmitting unreliable data over QUIC provides benefits over existing solutions:

- Applications that want to use both a reliable stream and an unreliable flow to the same peer can benefit by sharing a single handshake and authentication context between a reliable QUIC stream and a flow of unreliable QUIC datagrams. This can reduce the latency required for handshakes compared to opening both a TLS connection and a DTLS connection.
- QUIC uses a more nuanced loss recovery mechanism than the DTLS handshake. This can allow loss recovery to occur more quickly for QUIC data.
- QUIC datagrams are subject to QUIC congestion control. Providing a single congestion control for both reliable and unreliable data can be more effective and efficient.

These features can be useful for optimizing audio/video streaming applications, gaming applications, and other real-time network applications.

Unreliable QUIC datagrams can also be used to implement an IP packet tunnel over QUIC, such as for a Virtual Private Network (VPN). Internet-layer tunneling protocols generally require a reliable and authenticated handshake followed by unreliable secure transmission of IP packets. This can, for example, require a TLS connection for the control data and DTLS for tunneling IP packets. A single QUIC connection could support both parts with the use of unreliable datagrams in addition to reliable streams.

3. Transport Parameter

Support for receiving the DATAGRAM frame types is advertised by means of a QUIC transport parameter (name=max_datagram_frame_size, value=0x20). The max_datagram_frame_size transport parameter is an integer value (represented as a variable-length integer) that represents the maximum size of a DATAGRAM frame (including the frame type, length, and payload) the endpoint is willing to receive, in bytes.

The default for this parameter is 0, which indicates that the endpoint does not support DATAGRAM frames. A value greater than 0 indicates that the endpoint supports the DATAGRAM frame types and is willing to receive such frames on this connection.

An endpoint **MUST NOT** send DATAGRAM frames until it has received the `max_datagram_frame_size` transport parameter with a non-zero value during the handshake (or during a previous handshake if 0-RTT is used). An endpoint **MUST NOT** send DATAGRAM frames that are larger than the `max_datagram_frame_size` value it has received from its peer. An endpoint that receives a DATAGRAM frame when it has not indicated support via the transport parameter **MUST** terminate the connection with an error of type `PROTOCOL_VIOLATION`. Similarly, an endpoint that receives a DATAGRAM frame that is larger than the value it sent in its `max_datagram_frame_size` transport parameter **MUST** terminate the connection with an error of type `PROTOCOL_VIOLATION`.

For most uses of DATAGRAM frames, it is **RECOMMENDED** to send a value of 65535 in the `max_datagram_frame_size` transport parameter to indicate that this endpoint will accept any DATAGRAM frame that fits inside a QUIC packet.

The `max_datagram_frame_size` transport parameter is a unidirectional limit and indication of support of DATAGRAM frames. Application protocols that use DATAGRAM frames **MAY** choose to only negotiate and use them in a single direction.

When clients use 0-RTT, they **MAY** store the value of the server's `max_datagram_frame_size` transport parameter. Doing so allows the client to send DATAGRAM frames in 0-RTT packets. When servers decide to accept 0-RTT data, they **MUST** send a `max_datagram_frame_size` transport parameter greater than or equal to the value they sent to the client in the connection where they sent them the `NewSessionTicket` message. If a client stores the value of the `max_datagram_frame_size` transport parameter with their 0-RTT state, they **MUST** validate that the new value of the `max_datagram_frame_size` transport parameter sent by the server in the handshake is greater than or equal to the stored value; if not, the client **MUST** terminate the connection with error `PROTOCOL_VIOLATION`.

Application protocols that use datagrams **MUST** define how they react to the absence of the `max_datagram_frame_size` transport parameter. If datagram support is integral to the application, the application protocol can fail the handshake if the `max_datagram_frame_size` transport parameter is not present.

4. Datagram Frame Types

DATAGRAM frames are used to transmit application data in an unreliable manner. The Type field in the DATAGRAM frame takes the form 0b0011000X (or the values 0x30 and 0x31). The least significant bit of the Type field in the DATAGRAM frame is the LEN bit (0x01), which indicates whether there is a Length field present: if this bit is set to 0, the Length field is absent and the Datagram Data field extends to the end of the packet; if this bit is set to 1, the Length field is present.

DATAGRAM frames are structured as follows:

```
DATAGRAM Frame {  
    Type (i) = 0x30..0x31,  
    [Length (i)],  
    Datagram Data (...),  
}
```

Figure 1: DATAGRAM Frame Format

DATAGRAM frames contain the following fields:

Length: A variable-length integer specifying the length of the Datagram Data field in bytes. This field is present only when the LEN bit is set to 1. When the LEN bit is set to 0, the Datagram Data field extends to the end of the QUIC packet. Note that empty (i.e., zero-length) datagrams are allowed.

Datagram Data: The bytes of the datagram to be delivered.

5. Behavior and Usage

When an application sends a datagram over a QUIC connection, QUIC will generate a new DATAGRAM frame and send it in the first available packet. This frame **SHOULD** be sent as soon as possible (as determined by factors like congestion control, described below) and **MAY** be coalesced with other frames.

When a QUIC endpoint receives a valid DATAGRAM frame, it **SHOULD** deliver the data to the application immediately, as long as it is able to process the frame and can store the contents in memory.

Like STREAM frames, DATAGRAM frames contain application data and **MUST** be protected with either 0-RTT or 1-RTT keys.

Note that while the `max_datagram_frame_size` transport parameter places a limit on the maximum size of DATAGRAM frames, that limit can be further reduced by the `max_udp_payload_size` transport parameter and the Maximum Transmission Unit (MTU) of the path between endpoints. DATAGRAM frames cannot be fragmented; therefore, application protocols need to handle cases where the maximum datagram size is limited by other factors.

5.1. Multiplexing Datagrams

DATAGRAM frames belong to a QUIC connection as a whole and are not associated with any stream ID at the QUIC layer. However, it is expected that applications will want to differentiate between specific DATAGRAM frames by using identifiers, such as for logical flows of datagrams or to distinguish between different kinds of datagrams.

Defining the identifiers used to multiplex different kinds of datagrams or flows of datagrams is the responsibility of the application protocol running over QUIC. The application defines the semantics of the Datagram Data field and how it is parsed.

If the application needs to support the coexistence of multiple flows of datagrams, one recommended pattern is to use a variable-length integer at the beginning of the Datagram Data field. This is a simple approach that allows a large number of flows to be encoded using minimal space.

QUIC implementations **SHOULD** present an API to applications to assign relative priorities to DATAGRAM frames with respect to each other and to QUIC streams.

5.2. Acknowledgement Handling

Although DATAGRAM frames are not retransmitted upon loss detection, they are ack-eliciting ([RFC9002]). Receivers **SHOULD** support delaying ACK frames (within the limits specified by `max_ack_delay`) in response to receiving packets that only contain DATAGRAM frames, since the sender takes no action if these packets are temporarily unacknowledged. Receivers will continue to send ACK frames when conditions indicate a packet might be lost, since the packet's payload is unknown to the receiver, and when dictated by `max_ack_delay` or other protocol components.

As with any ack-eliciting frame, when a sender suspects that a packet containing only DATAGRAM frames has been lost, it sends probe packets to elicit a faster acknowledgement as described in Section 6.2.4 of [RFC9002].

If a sender detects that a packet containing a specific DATAGRAM frame might have been lost, the implementation **MAY** notify the application that it believes the datagram was lost.

Similarly, if a packet containing a DATAGRAM frame is acknowledged, the implementation **MAY** notify the sender application that the datagram was successfully transmitted and received. Due to reordering, this can include a DATAGRAM frame that was thought to be lost but, at a later point, was received and acknowledged. It is important to note that acknowledgement of a DATAGRAM frame only indicates that the transport-layer handling on the receiver processed the frame and does not guarantee that the application on the receiver successfully processed the data. Thus, this signal cannot replace application-layer signals that indicate successful processing.

5.3. Flow Control

DATAGRAM frames do not provide any explicit flow control signaling and do not contribute to any per-flow or connection-wide data limit.

The risk associated with not providing flow control for DATAGRAM frames is that a receiver might not be able to commit the necessary resources to process the frames. For example, it might not be able to store the frame contents in memory. However, since DATAGRAM frames are inherently unreliable, they **MAY** be dropped by the receiver if the receiver cannot process them.

5.4. Congestion Control

DATAGRAM frames employ the QUIC connection's congestion controller. As a result, a connection might be unable to send a DATAGRAM frame generated by the application until the congestion controller allows it [RFC9002]. The sender **MUST** either delay sending the frame until the controller allows it or drop the frame without sending it (at which point it **MAY** notify the application). Implementations that use packet pacing (Section 7.7 of [RFC9002]) can also delay the sending of DATAGRAM frames to maintain consistent packet pacing.

Implementations can optionally support allowing the application to specify a sending expiration time beyond which a congestion-controlled DATAGRAM frame ought to be dropped without transmission.

6. Security Considerations

The DATAGRAM frame shares the same security properties as the rest of the data transmitted within a QUIC connection, and the security considerations of [RFC9000] apply accordingly. All application data transmitted with the DATAGRAM frame, like the STREAM frame, **MUST** be protected either by 0-RTT or 1-RTT keys.

Application protocols that allow DATAGRAM frames to be sent in 0-RTT require a profile that defines acceptable use of 0-RTT; see Section 5.6 of [RFC9001].

The use of DATAGRAM frames might be detectable by an adversary on path that is capable of dropping packets. Since DATAGRAM frames do not use transport-level retransmission, connections that use DATAGRAM frames might be distinguished from other connections due to their different response to packet loss.

7. IANA Considerations

7.1. QUIC Transport Parameter

This document registers a new value in the "QUIC Transport Parameters" registry maintained at <<https://www.iana.org/assignments/quic>>.

Value: 0x20

Parameter Name: max_datagram_frame_size

Status: permanent

Specification: RFC 9221

7.2. QUIC Frame Types

This document registers two new values in the "QUIC Frame Types" registry maintained at <<https://www.iana.org/assignments/quic>>.

Value: 0x30-0x31
Frame Name: DATAGRAM
Status: permanent
Specification: RFC 9221

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8.1. Normative References

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