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Transport parameters for 0-RTT connections  
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## Abstract

QUIC 0-RTT transport features currently focuses on egress traffic optimization. This draft proposes a QUIC extension that improves the performance of ingress traffic.

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## 1. Introduction

QUIC 0-RTT transport features currently focus on egress traffic optimization. This draft proposes a QUIC extension to improve the performance of ingress traffic.

When clients resume a session to download a large document, the congestion control algorithms will require time to ramp-up the packet

rate. This document specifies a method that can improve traffic delivery and that allows a QUIC connection to avoid a slow Round-Trip Time (RTT)-based process to grow connection parameters such as the congestion window (CWND):

1. During a previous session, current RTT (`current_rtt`), CWND (`current_cwnd`) and client's current IP (`current_client_ip`) are stored as `saved_rtt`, `saved_cwnd` and `saved_client_ip`;
2. When resuming a session, the server might set the `current_rtt` and the `current_cwnd` to the `saved_rtt` and `saved_cwnd` of a previous connection.

This method applies to any QUIC resumed sessions: both `saved_session` and `recon_session` can be a 0-RTT QUIC connection or a 1-RTT QUIC connection.

This draft consider different solutions: (1) the saved parameters are not sent to the client; (2) the saved parameters are sent to the client and the client can not read them; (3) the saved parameters are sent to the client and the client can read them. There is no solution where the client can modify the parameters.

Sometimes the parameters of a previous session are not relevant, e.g.: (1) network conditions can change where using a previously computed CWND could increase congestion; (2) a client could convince a server to use a CWND much larger than required.

This draft:

1. proposes guidelines for how to safely apply the previously computed parameters to new sessions;
2. describes different implementation considerations in QUIC for the proposed method;
3. discusses the trade-off associated to the different implementation solutions.

### 1.1. Notations and terms

- o IW: Initial window (e.g. from [\[RFC6928\]](#));
- o `current_iw`: Current Initial window;
- o `recom_iw`: Recommended Initial window - it seems important to note that some Content Delivery Networks (CDNs) currently exploit a very high Initial Window (IW) [\[TMA18\]](#) for a local path;

- o BDP: defined below;
- o CWND: congestion window used by server (bytes allowed in flight by CC);
- o current\_cwnd : Current congestion window;
- o saved\_cwnd: Congestion window preserved from a previous connection;
- o RTT: Round-Trip Time;
- o current\_rtt: Current RTT;
- o saved\_rtt: RTT preserved from a previous connection.
- o client\_ip : IP address of the client
- o current\_client\_ip : Current IP address of the client
- o saved\_client\_ip : IP address of the client preserved from a previous connection;
- o remembered BDP parameters: combination of saved\_rtt and saved\_cwnd.
- o ITT : Interpacket Transmission Time
- o MSS : Maximum Message Size
- o AEAD : Authenticated Encryption with Associated Data
- o LRU : Least Recently Used

[RFC6349] defines the BDP as follows: "Derived from Round-Trip Time (RTT) and network Bottleneck Bandwidth (BB), the Bandwidth-Delay Product (BDP) determines the Send and Received Socket buffer sizes required to achieve the maximum TCP Throughput." This draft considers the Bandwidth-Delay Product (BDP) as estimated by the server which includes all buffering along the network path. A QUIC connection might not exactly reproduce the procedure detailed in [RFC6349] to measure the BDP. The server can exploit internal evaluations of the CWND and the to assess the BDP.

## 1.2. Requirements Language

The keywords "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. Safe jump start

### 2.1. Rationale behind the safety guidelines

The previously measured `saved_rtt` and `saved_cwnd` should not be used as-is to avoid potential congestion collapse:

- o Rationale #1: An Internet method needs to be robust to network conditions that can differ between sessions.
- o Rationale #2: Information sent by a malicious client would not be relevant since it might try to convince servers to use a `CWND` higher than required. This could increase congestion.

### 2.2. Rationale #1: Variable network conditions

The server **MUST** check the validity of the `saved_rtt` and `saved_cwnd` parameters, whether they are sent by a client or stored at the server. Indeed, the following events make use of these parameters inappropriate:

- o IP address changes: If the client changes its IP address (i.e. `saved_client_ip` is different from `current_client_ip`), the different address indicates a different network path. This new path does not necessarily exhibit the same characteristics as the old one.
- o Lifetime of the extension: If the network conditions change, e.g., the path was not congested when BDP parameters were evaluated, but later the path experiences congestion for the next connection, the previously estimated parameters would not be valid.

There are different solutions for the variable network conditions:

- o Rationale #1 - Solution #1 : When resuming a session, set the `current_cwnd` and `current_rtt` to the `saved_cwnd` and `saved_rtt` parameters estimated from a previous connection.
- o Rationale #1 - Solution #2 : When resuming a session, implement a safety check to measure whether using the `saved_cwnd` and `saved_rtt`

parameters would not cause congestion over the path. In this case, the `current_cwnd` and `current_rtt` might not be set directly to the `saved_cwnd` and `saved_rtt`: the server might wait for the completion of the safety check before doing so.

[Section 3](#) describes various approaches for Rationale #1 - Solution #2.

### 2.3. Rationale #2: Malicious clients

The server **MUST** check the integrity of the `saved_rtt` and `saved_cwnd` parameters received from a client.

There are different solutions to avoid attacks by malicious clients:

- o Rationale #2 - Solution #1 : The server stores a local estimation of the CWND and RTT parameters as `saved_cwnd` and `saved_rtt`.
- o Rationale #2 - Solution #2 : The server sends the estimation of the CWND and RTT parameters to the client as `saved_cwnd` and `saved_rtt`. The information is encrypted by the server. The client resends the information when resuming a connection. The client can neither read nor modify the `saved_rtt` and `saved_cwnd` parameters.
- o Rationale #2 - Solution #3 : The server sends the estimation of the `saved_rtt` and `saved_cwnd` parameters to the client. The information includes integrity protection. The client resends the information when resuming a connection. The client can read, but can not modify, the `saved_rtt` and `saved_cwnd` parameters.

[Section 4](#) describes various implementation approaches for each of these solutions using local storage ( [Section 4.2](#) for Rationale #2 - Solution #1), NEW\_TOKEN Frame ( [Section 4.3](#) for Rationale #2 - Solution #2), BDP extension Frame ( [Section 4.4](#) for Rationale #2 - Solution #3).

### 2.4. Trade-off between the different solutions

This section provides a description of different implementation options and discusses their respective advantages and drawbacks. While there are some discussions for the solutions regarding Rationale #2, the server **MUST** consider Rationale #1 - Solution #2 and avoid Rationale #1 - Solution #1: the server **MUST** implement a safety check to measure whether the remembered BDP parameters (i.e. `saved_rtt` and `saved_cwnd`) are relevant or check that their usage would not cause congestion over the path.

#### 2.4.1. Security aspects

The client may send information related to the `saved_rtt` and `saved_cwnd` to the server with the BDP Frame extension using either Rationale #2 - Solution #2 or Rationale #2 - Solution #3. However, the server may not trust the client. Indeed, even if 0-RTT packets containing the BDP Frame are encrypted, a client could modify the values within the extension and encrypt the 0-RTT packet. Authentication mechanisms might not guarantee that the values are safe. The server could then need to also store the `saved_rtt` and `saved_cwnd` parameters.

A malicious client might modify the `saved_cwnd` parameter to convince the server to use a CWND much larger than required. Using the algorithms proposed in [Section 3](#), the server may reduce any intended harm and can check that part of the information provided by the client are valid. A supplementary check could decide not to use values that would be higher than those currently used by CDNs [\[TMA18\]](#).

Storing the BDP parameters locally at the server reduces the associated risks by allowing the client to transmit information related to the BDP of the path.

#### 2.4.2. Interoperability and use-cases

If the server stores a resumption ticket for each client to protect against replay on a third party IP, it could also store the IP address (i.e. `saved_client_ip`) and BDP parameters (i.e. `saved_rtt` and `saved_cwnd`) of the previous session of the client.

In cases where the BDP Frame extension is exploited, the approach of storing the BDP parameters locally at the server can provide a cross-check of the BDP parameters sent by a client. The server can anyway enable a safe jump start, but without the BDP Frame extension, the client does not have the choice of accepting it or not.

While storing local values related to the BDP would help in improving the ingress for 0-RTT connections, not using a BDP Frame extension may reduce the interest of the approach where (1) the client knows the BDP estimations done at the server, (2) the client decides to accept or reject ingress optimization, (3) the client tunes application level requests.

### 2.4.3. Summary

As a summary, the approach of local storage of values is more secure and the BDP Frame extension provides more information to the client and more interoperability. The Figure 1 provides a summary of the advantages and drawbacks of each approach.

Rationale	Solution	Advantage	Drawback	Comment
#1 Variable Network	#1 set current_* to saved_*	Ingress optim.	Risks of adding congestion	MUST NOT implement
	#2 Implement safety check	Reduce risks of adding congestion	Negative impact on ingress optim.	MUST implement <a href="#">Section 3</a>
#2 Malicious client	#1 Local storage	Enforced security	Client can not decide to reject Malicious server could fill client's buffer Limited use-cases	<a href="#">Section 4.2</a>
	#2 NEW_TOKEN	Save resource at server Opaque token protected	Malicious client may change token even if protected Malicious server could fill client's buffer Server may not trust client	<a href="#">Section 4.3</a>
	#3 BDP extension	Extended use-cases Save resource	Malicious client may change BDP	



		at server	even if	
		Client can	protected	
		read and decide	Server may not	
		to reject	trust client	
		BDP extension		
		protected		
				<a href="#">Section 4.4</a>

Figure 1: Comparing solutions

### 3. Safety guidelines

The safety guidelines are designed to avoid a server adding excessive congestion to an already congested path. The following mechanisms should help in fulfilling this objective:

- o The server SHOULD compare the measured transport parameters (in particular `current_rtt`) of the 0-RTT connection with those of the 1-RTT connection (in particular `saved_rtt`);
- o The server SHOULD NOT consider the `saved_cwnd` parameter if there is any loss of packet during the first transmission of data;
- o The server MUST NOT send more than a recommended maximum IW (`recom_iw`) in the first transmission of data. This value could be based on a local understanding of the path characteristics and what is deployed in CDNs [TMA18].

The proposed mechanisms SHOULD be limited by any rate-limitation mechanisms of QUIC, such as flow control mechanisms or amplification attacks prevention. In particular, the maximum number of packets that can be sent without acknowledgment needs to be chosen to avoid the creation and the increase of congestion for the path. Moreover, this extension should not be an opportunity for the current connection to be a vector of an amplification attack. The address validation process, used to prevent amplification attacks, SHOULD be performed [RFC9000].

The following mechanisms could be implemented:

- o Exploit a standard IW:
  1. The server sends the first data packet using the IW - this can be considered a safe starting point for an unknown path, which avoids adding congestion to the path;

2. If the reception of IW exhibits characteristics that resemble those of a recent previous session from the client (i.e.  $\text{current\_rtt} < 1.2 * \text{saved\_rtt}$  and all the data was acknowledged), the method permits the sender to consider the `saved_cwnd` as an input to adapt `current_cwnd` and help rapidly determine a new safe rate;
  3. The sender needs to avoid a burst of packets being sent as a result of a step-increase in the congestion window [RFC9000]. Pacing the packets as a function of the `current_rtt` can provide this additional safety during the period in which the `CWND` is increased by the method.
- o Identify a relevant pacing rhythm:
- \* The server estimates the pacing rhythm using `saved_rtt` and `saved_cwnd`. The Interpacket Transmission Time (ITT) is determined by the ratio between the current Maximum Message Size (MSS) for packets and the ratio between the `saved_cwnd` and `saved_rtt`. A tunable safety margin might be introduced to avoid sending more than a recommended maximum IW (`recom_iw`):  
  
+ `current_iw = min(recom_iw, saved_cwnd)`  
  
+ `ITT = MSS / (current_iw / saved_rtt)`
  - \* When the IW is acknowledged, the server falls back to a standard slow-start mechanism.

This follows the idea of [RFC4782], [I-D.irtf-icrg-sallantin-initial-spreading] and [CONEXT15].

While safety recommendations are necessary, it seems important to note that some Content Delivery Networks (CDNs) currently exploit a very high Initial Window (IW) [TMA18] for a local path.

## 4. Implementation considerations

### 4.1. Rationale behind the different implementation options

Using `NewSessionTickets` messages of TLS is a solution that could have been envisioned. The idea would have been to add a `'bdp_metada'` field in the `NewSessionTickets` that the client could read. The sole extension currently defined in TLS1.3 that can be seen by the client is `max_early_data_size` (see section 4.6.1 of [RFC8446]). However, in the general design of QUIC, TLS sessions are managed by the TLS stacks.

Three distinct approaches are presented: sending an opaque blob to the client that it may retransmit for future connection (see [Section 4.3](#)), enable a local storage of BDP related values (see [Section 4.2](#)) and a BDP Frame extension (see [Section 4.4](#)).

#### 4.2. Independent local storage of values

This approach independently lets both a client and a server remember their BDP parameters:

- o During a 1-RTT session, the endpoint stores the RTT (as the `saved_rtt`) and CWND (as the `saved_cwnd`) together with the session resume ticket. The client can also store the IP address of the server.
- o The server maintains a table of previously issued tickets, indexed by the random ticket identifier that is used to guarantee uniqueness of the Authenticated Encryption with Associated Data (AEAD) encryption. Old tokens are removed from the table using the Least Recently Used (LRU) logic. For each ticket identifier, the table holds the RTT and CWND (i.e. `saved_rtt` and `saved_cwnd`), and also the IP address of the client (i.e. `saved_client_ip`).

During the 0-RTT session, the endpoint wait for the first RTT measurement from the peer's IP address. This is used to verify that the `current_rtt` has not significantly changed from the `saved_rtt`, and hence is an indication that the BDP information applies to the path that is currently being used.

If this RTT is confirmed (e.g.  $\text{current\_rtt} < 1.2 * \text{saved\_rtt}$ ), the endpoint also verifies that an initial window of data has been acknowledged without requiring retransmission. This second check is used to detect a path with significant incipient congestion (i.e. where it would not be safe to update the CWND based on the `saved_cwnd`). In practice, this could be realized by a proportional increase in the CWND, where the increase is  $(\text{saved\_cwnd} / \text{IW}) * \text{proportion\_of\_IW\_currently\_ACKed}$ .

#### 4.3. Using NEW\_TOKEN frames

Using NEW\_TOKEN Frames, the server could send a token to the client through a NEW\_TOKEN Frame. The token is an opaque blob and the client can not read its content (see [section 19.7 of \[RFC9000\]](#)). The client sends the received token in the header of an Initial packet for future connection.

#### 4.4. BDP Frame

This section proposes the exploitation of a new Frame, the BDP Frame. The BDP Frame MUST be contained in 0-RTT packets if sent by the client. The BDP Frame MUST be contained in 1-RTT packets if sent by the server. The BDP Frame MUST be considered in the congestion control and its data may not be limited by flow control limits. The server MAY send multiple BDP Frames in both 1-RTT and 0-RTT connections. The client may send BDP Frames during 1-RTT and 0-RTT connections.

##### 4.4.1. BDP Frame Format

A BDP Frame is formatted as shown in Figure 2.

```
BDP Frame {  
    Type (i) = 0xXXX,  
    Lifetime (i),  
    Saved CWND (i),  
    Saved RTT (i),  
    Saved IP,  
}
```

Figure 2: BDP Frame Format

A BDP Frame contains the following fields:

- o Lifetime (extension\_lifetime): The extension\_lifetime is a value in milliseconds, encoded as a variable length integer. This follows the idea of NewSessionTicket of TLS [RFC8446]. This represents the validity in time of this extension.
- o Saved CWND (saved\_cwnd): The saved\_cwnd is a value in bytes, encoded as a variable length integer. The bytes in flight measured on the previous connection by the server (or CWND). The previous values of bytes\_in\_flight defined in [RFC9002], recon\_bytes\_in\_flight could be used to determine this value.
- o Saved RTT (saved\_rtt): The saved\_rtt is a value in milliseconds, encoded as a variable length integer. This could be set to the min\_rtt defined in [RFC9002], saved\_rtt can be set to min\_rtt. The min\_rtt parameter might not track a decreasing RTT: the min\_rtt that is reported here might not be the actual minimum RTT measured during the 1-RTT connection, but usually reflects the characteristics of the path latency.

- o Saved IP (`saved_client_ip`) : The `saved_client_ip` could be set to the IP address of the client. The IP address of the client can be encoded as the `preferred_address` parameter [RFC9000].

#### 4.4.2. Extension activation

The client can accept the transmission of BDP Frames from the server by using the following `enable_bdp` transport extension.

`enable_bdp (0xTBD)`: in the 1-RTT connection, the client indicates to the server that it wishes to receive BDP extension Frames for improving ingress of 0-RTT connection. The default value is 0. Values strictly above 3 are invalid, and receipt of these values MUST be treated as a connection error of type `TRANSPORT_PARAMETER_ERROR`.

- o 0: Default value. If the client does not send this parameter, the server considers that the client does not support or does not wish to activate the BDP extension.
- o 1: The client indicates to the server that it wishes to receive BDP Frame and activates the ingress optimization for the 0-RTT connection.
- o 2: The client indicates that it does not wish to receive BDP Frames but activates ingress optimization.
- o 3: The client indicates that it wishes to receive BDP Frames but does not activate ingress optimization.

This Transport Parameter is encoded as per [Section 18 of \[RFC9000\]](#).

## 5. Discussion

### 5.1. BDP extension protected as much as `initial_max_data`

The BDP metadata parameters are measured by the server during a previous connection. The BDP extension is protected by the mechanism that protects the exchange of the 0-RTT transport parameters. For version 1 of QUIC, the BDP extension is protected using the mechanism that already protects the "`initial_max_data`" parameter. This is defined in sections 4.5 to 4.7 of [RFC9001]. This provides the server with a way to verify that the parameters proposed by the client are the same as those that the server sent to the client during the previous connection.

## 5.2. Other use-cases

### 5.2.1. Optimizing client's requests

In a case with Dynamic Adaptive Streaming over HTTPS (DASH), clients might encounter issues in knowing the available path capacity or DASH can encounter issues in reaching the best available video playback quality. The client requests could then be adapted and specific traffic could utilize information from the path characteristics (such as encouraging the client to increase the quality of video chunks, to fill the buffers and avoid video blocking or to send high quality adds).

In other cases, applications may provide additional services if clients can know the server's estimation of the path characteristics.

### 5.2.2. Sharing transport information across multiple connections

There can be benefit in sharing transport information across multiple connections. [I-D.ietf-tcpm-2140bis] considers the sharing of transport parameters between TCP connections originating from the same host. The proposal in this document has the advantage of storing server-generated information at the client and not requiring the server to retain additional state for each client.

## 6. Acknowledgments

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## 7. IANA Considerations

TBD: Text is required to register the BDP Frame and the enable\_bdp transport parameter. Parameters are registered using the procedure defined in [RFC9000].

## 8. Security Considerations

Security considerations are discussed in [Section 5](#) and in [Section 3](#).

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