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C. Huitema  
Private Octopus Inc.  
M. Shore  
Fastly  
A. Mankin  
Salesforce  
S. Dickinson  
Sinodun IT  
J. Iyengar  
Google  
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**Specification of DNS over Dedicated QUIC Connections**  
**draft-huitema-quic-dnsquic-01**

Abstract

This document describes the use of QUIC to provide transport privacy for DNS. The encryption provided by QUIC has similar properties to that provided by TLS, while QUIC transport eliminates the head-of-line blocking issues inherent with TCP and provides more efficient error corrections than UDP. DNS over QUIC has privacy properties similar to DNS over TLS specified in [RFC7858](#), and performance similar to classic DNS over UDP.

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## [1.](#) Introduction

Domain Name System (DNS) concepts are specified in [\[RFC1034\]](#). This document presents a mapping of the DNS protocol [\[RFC1035\]](#) over QUIC transport [\[I-D.ietf-quic-transport\]](#). The goals of this mapping are:

1. Provide the same DNS privacy protection as DNS over TLS [\[RFC7858\]](#). This includes to option for the client to authenticate the server by means of an authentication domain name [\[I-D.ietf-dprive-dtls-and-tls-profiles\]](#).
2. Provide an improved level of source address validation for DNS servers compared to DNS over UDP [\[RFC1035\]](#).
3. Provide a transport that is not constrained by path MTU limitations on the size of DNS responses it can send.
4. Explore the potential performance gains of using QUIC as a DNS transport, versus other solutions like DNS over UDP [\[RFC1035\]](#) or DNS over TLS [\[RFC7858\]](#).
5. Participate in the definition of QUIC protocols and API, by outlining a use case for QUIC different from HTTP over QUIC [\[I-D.ietf-quic-http\]](#).

In order to achieve these goals, the focus is limited to the "stub to recursive resolver" scenario also addressed by [\[RFC7858\]](#), that is the protocol described here works for queries and responses between stub clients and recursive servers. The specific non-goals are:

1. No attempt is made to support zone transfers [\[RFC5936\]](#), as these are not relevant to the stub to recursive resolver scenario.
2. No attempt is made to evade potential blocking of DNS over QUIC traffic by middleboxes.

Users interested in zone transfers should continue using TCP based solutions. Users interested in evading middleboxes should consider using solutions like DNS over HTTPS [\[I-D.hoffman-dns-over-http\]](#) [\[I-D.hoffman-dns-in-existing-http2\]](#), or DNS in existing QUIC connections [\[I-D.hoffman-dns-in-existing-quic\]](#).



Specifying the transmission of an application over QUIC requires to specify how the application messages are mapped to QUIC streams, and generally how the application will use QUIC. This is done for HTTP in [[I-D.ietf-quic-http](#)]. The purpose of this document is to define the way DNS can be transmitted over QUIC.

In this document, [Section 4](#) presents the reasoning that guided the proposed design. [Section 5](#) specifies the actual mapping of DNS over QUIC. [Section 6](#) presents guidelines on the implementation, usage and deployment of DNS over QUIC.

## **[2.](#) Key Words**

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

## **[3.](#) Terminology**

The term DNS/QUIC is used interchangeably with 'DNS over QUIC' throughout this document.

TODO: Make this usage more consistent.

## **[4.](#) Design Considerations**

This section and its subsection present the design guidelines that were used for the proposed mapping of DNS over QUIC. This section is informative in nature.

### **[4.1.](#) Scope is Limited to the Stub to Resolver Scenario**

Usage scenarios for the DNS protocol can be broadly classified in three groups: stub to recursive resolver, recursive resolver to authoritative server, and server to server. This design focuses only on the "stub to recursive resolver" scenario following the approach taken in [[RFC7858](#)] and [[I-D.ietf-dprive-dtls-and-tls-profiles](#)].

QUESTION: Should this document specify any aspects of configuration of discoverability differently to DNS over TLS?

No attempt is made to address the recursive to authoritative scenarios. Authoritative resolvers are discovered dynamically through NS records. It is noted that at the time of writing work is ongoing in the DPRIVE working group to attempt to address the analogous problem for DNS over TLS [[I-D.bortzmeyer-dprive-step-2](#)]. In the absence of an agreed way for authoritative to signal support for QUIC transport, recursive resolvers would have to resort to some



trial and error process. At this stage of QUIC deployment, this would be mostly errors, and does not seem attractive. This could change in the future.

The DNS protocol is also used for zone transfers. In the zone transfer scenario ([RFC5936]), the client emits a single AXFR query, and the server responds with a series of AXFR responses. This creates a unique profile, in which a query results in several responses. Supporting that profile would complicate the mapping of DNS queries over QUIC streams. Zone transfers are not used in the stub to recursive scenario that is the focus here, and seem to be currently well served by the DNS over TCP. There is no attempt to support them in this proposed mapping of DNS to QUIC.

#### **4.2. Provide DNS Privacy**

DNS privacy considerations are described in [RFC7626]. [RFC7858] defines how to mitigate some of these issues by transmitting DNS messages over TLS and TCP and [I-D.ietf-dprive-dtls-and-tls-profiles] specifies Strict and Opportunistic profiles for DNS over TLS including how stub resolvers can authenticate recursive resolvers.

QUIC connection setup includes the negotiation of security parameters using TLS, as specified in [I-D.ietf-quic-tls], enabling encryption of the QUIC transport. Transmitting DNS messages over QUIC will provide essentially the same privacy protections as [RFC7858] and [I-D.ietf-dprive-dtls-and-tls-profiles]. Further discussion on this is provided in [Section 8](#).

#### **4.3. Design for Minimum Latency**

QUIC is specifically designed to reduce the delay between HTTP queries and HTTP responses. This is achieved through three main components:

1. Support for 0-RTT data during session resume.
2. Support for advanced error recovery procedures as specified in [I-D.ietf-quic-recovery].
3. Mitigation of head-of-line blocking by allowing parallel delivery of data on multiple streams.

The mapping of DNS to QUIC will take advantage of these features in three ways:





1. Optional support for sending 0-RTT data during session resume (the security and privacy implications of this are discussed in later sections).
2. Long-lived QUIC connections over which multiple DNS transactions are performed, generating the sustained traffic required to benefit from advanced recovery features.
3. Mapping of each DNS Query/Response transaction to a separate stream, to mitigate head-of-line blocking.

These considerations will be reflected in the mapping of DNS traffic to QUIC streams in [Section 5.2](#).

#### **[4.4. Development of QUIC Protocols and API](#)**

QUIC is defined as a layered protocol, with application specific mapping layered on top of the generic QUIC transport. The only mapping defined at this stage is HTTP over QUIC [[I-D.ietf-quic-http](#)]. Adding a different mapping for a different application contributes to the development of QUIC.

HTTP/QUIC uses a dedicated control channel on a long-lived stream to maintain connection state beyond the lifetime of individual requests, such as relative priority of requests, settings, and other metadata. These additional capabilities come at the cost of some complexity, and also some performance since the control stream is exposed to head-of-line blocking.

In this document a different design is deliberately explored, in which there is no control stream. Clients and servers can initiate queries as determined by the DNS application logic, opening new streams as necessary. This provides for maximum parallelism between queries, as noted in [Section 4.3](#). It also places constraints on the API. Client and servers will have to be notified of the opening of a new stream by their peer. Instead of orderly closing the control stream, client and server will have to use orderly connection closure mechanisms and manage the potential loss of data if closing on one end conflicts with opening of a stream on the other end.

QUESTION: The server originated PUSH requests are expected to be delivered in order. Is it possible to guarantee this order without a control stream?



#### **4.5. No Specific Middlebox Bypass Mechanism**

Being different from HTTP over QUIC is a design choice. The advantage is that the mapping can be defined for minimal overhead and maximum performance. The downside is that the difference can be noted by firewalls and middleboxes. There may be environments in which HTTP over QUIC will be allowed, but DNS over QUIC will be disallowed and blocked by these middle boxes.

It is recognized that this might be a problem, but there is currently no indication on how widespread that problem might be. It might be that the problem will be so acute that the only realistic solution would be to communicate with independent recursive resolvers using DNS over HTTPS, or maybe DNS over HTTP over QUIC. Or it might be that the problem is rare enough and the performance gains significant enough that the correct solution is to use DNS over QUIC most of the time, and to fall back on DNS over HTTPS some of the time. Measurements and experimentations will inform that decision. In between, we believe that a clean design is most likely to inform the QUIC development, as explained in [Section 4.4](#).

### **5. Specifications**

#### **5.1. Connection Establishment**

DNS/QUIC connections are established as described in [\[I-D.ietf-quic-transport\]](#). During connection establishment, DNS/QUIC support is indicated by selecting the ALPN token "dq" in the crypto handshake.

##### **5.1.1. Draft Version Identification**

\*RFC Editor's Note:\* Please remove this section prior to publication of a final version of this document.

Only implementations of the final, published RFC can identify themselves as "dq". Until such an RFC exists, implementations MUST NOT identify themselves using this string.

Implementations of draft versions of the protocol MUST add the string "-" and the corresponding draft number to the identifier. For example, [draft-huitema-quic-dnsquic-001](#) is identified using the string "dq-h01".



### **5.1.2. Port Selection**

By default, a DNS server that supports DNS/QUIC MUST listen for and accept QUIC connections on the dedicated UDP port TBD (number to be defined in [Section 9](#), unless it has mutual agreement with its clients to use a port other than TBD for DNS over QUIC. In order to use a port other than TBD, both clients and servers would need a configuration option in their software.

By default, a DNS client desiring to use DNS over QUIC with a particular server MUST establish a QUIC connection to UDP port TBD on the server, unless it has mutual agreement with its server to use a port other than port TBD for DNS over QUIC. Such another port MUST NOT be port 53 or port 853. This recommendation against use of port 53 for DNS over QUIC is to avoid confusion between DNS over QUIC and DNS over UDP as specified in [\[RFC1035\]](#). Similarly, using port 853 would cause confusion between DNS over QUIC and DNS over DTLS as specified in [\[RFC8094\]](#).

### **5.2. Stream Mapping and Usage**

The mapping of DNS traffic over QUIC streams takes advantage of the QUIC stream features detailed in Section 10 of [\[I-D.ietf-quic-transport\]](#).

The stub to resolver DNS traffic follows a simple pattern in which the client sends a query, and the server provides a response. This design specifies that for each subsequent query on a QUIC connection the client MUST select the next available client stream, in conformance with Section 10.2 of [\[I-D.ietf-quic-transport\]](#).

The client MUST send the DNS query over the selected stream, and MUST indicate through the STREAM FIN mechanism that no further data will be sent on that stream.

The server MUST send the response on the same stream, and MUST indicate through the STREAM FIN mechanism that no further data will be sent on that stream.

Therefore, a single client initiated DNS transaction consumes a single stream. This means that the client's first query occurs on QUIC stream 3, the second on 5, and so on.

DNS query and responses are formatted as specified in [\[RFC1035\]](#). In contrast with DNS over TCP [\[RFC7766\]](#) and DNS over TLS [\[RFC7858\]](#), these messages are sent without a two bytes length field prepended.



### **5.2.1. Server Initiated Transactions**

There are planned traffic patterns in which a server sends unsolicited queries to a client, such as for example PUSH messages defined in [[I-D.ietf-dnssd-push](#)]. When a server wishes to send such queries it MUST select the next available server stream, in conformance with Section 10.2 of [[I-D.ietf-quic-transport](#)].

The server MUST send the DNS query over the selected stream, and MUST indicate through the STREAM FIN mechanism that no further data will be sent on that stream.

The client MUST send the response on the same stream, and MUST indicate through the STREAM FIN mechanism that no further data will be sent on that stream.

Therefore a single server initiated DNS transaction consumes a single stream. This means that the servers's first query occurs on QUIC stream 2, the second on 4, and so on.

### **5.2.2. Stream Reset**

Stream transmission may be abandoned by either party, using the stream "reset" facility. A stream reset indicates that one party is unwilling to continue processing the transaction associated with the stream. The corresponding transaction MUST be abandoned. A Server Failure (SERVFAIL, [[RFC1035](#)]) SHOULD be notified to the initiator of the transaction.

## **5.3. Closing the DNS over QUIC Connection**

QUIC connections are closed using the CONNECTION\_CLOSE mechanisms specified in [[I-D.ietf-quic-transport](#)]. Connections can be closed at the initiative of either the client or the server (also see [Section 6.6.2](#)). The party initiating the connection closure SHOULD use the QUIC GOAWAY mechanism to initiate a graceful shutdown of a connection.

The transactions corresponding to stream number higher than indicated in the GO AWAY frames MUST be considered failed. Similarly, if streams are still open when the CONNECTION\_CLOSE is received, the corresponding transactions MUST be considered failed. In both cases, a Server Failure (SERVFAIL, [[RFC1035](#)]) SHOULD be notified to the initiator of the transaction.





#### **5.4. Connection Resume and 0-RTT**

A stub resolver MAY take advantage of the connection resume mechanisms supported by QUIC transport [[I-D.ietf-quic-transport](#)] and QUIC TLS [[I-D.ietf-quic-tls](#)]. Stub resolvers SHOULD consider potential privacy issues associated with session resume before deciding to use this mechanism. These privacy issues are detailed in [Section 8.2](#).

When resuming a session, a stub resolver MAY take advantage of the 0-RTT mechanism supported by QUIC. The 0-RTT mechanism MUST NOT be used to send data that is not "replayable" transactions. For example, a stub resolver MAY transmit a Query as 0-RTT, but MUST NOT transmit an Update.

### **6. Implementation Requirements**

#### **6.1. Authentication**

For the stub to recursive resolver scenario, the authentication requirements are the same as described in [[RFC7858](#)] and [[I-D.ietf-dprive-dtls-and-tls-profiles](#)]. There is no need to authenticate the client's identity in either scenario.

#### **6.2. Fall Back to Other Protocols on Connection Failure**

If the establishment of the DNS over QUIC connection fails, clients SHOULD attempt to fall back to DNS over TLS and then potentially clear text, as specified in [[RFC7858](#)] and [[I-D.ietf-dprive-dtls-and-tls-profiles](#)], depending on their privacy profile.

DNS clients SHOULD remember server IP addresses that don't support DNS over QUIC, including timeouts, connection refusals, and QUIC handshake failures, and not request DNS over QUIC from them for a reasonable period (such as one hour per server). DNS clients following an out-of-band key-pinned privacy profile ([[RFC7858](#)]) MAY be more aggressive about retrying DNS over QUIC connection failures.

#### **6.3. Response Sizes**

DNS over QUIC does not suffer from the limitation on the size of responses that can be delivered as DNS over UDP [[RFC1035](#)] does, since large responses will be sent in separate STREAM frames in separate packets.

QUESTION: However, this raises a new issue because the responses sent over QUIC can be significantly larger than those sent over TCP



(65,635 bytes). According to [[I-D.ietf-quic-transport](#)] "The largest offset delivered on a stream - the sum of the re-constructed offset and data length - MUST be less than  $2^{64}$ ". Should a specific limit be applied for DNS over QUIC responses or not?

#### **[6.4.](#) DNS Message IDs**

QUESTION: Should we include the restrictions 'When sending multiple queries over a QUIC connection, clients MUST NOT reuse the DNS Message ID of an in-flight query on that connection in order to avoid Message ID collisions.'

And similarly, for 'Clients MUST match outstanding queries using the Message ID and if the response contains a question section, the client MUST match the QNAME, QCLASS, and QTYPE fields.'. In other words should we involve the stream ID in message matching or not?

#### **[6.5.](#) Padding**

There are mechanisms specified for both padding individual DNS messages [[RFC7830](#)], [[I-D.ietf-dprive-padding-policy](#)] and padding within QUIC packets (see Section 8.6 of [[I-D.ietf-quic-transport](#)]), which may contain multiple frames.

QUESTION: What should the padding guidelines be here?

#### **[6.6.](#) Connection Handling**

[RFC7766] provides updated guidance on DNS over TCP much of which is applicable to DNS over QUIC. This section attempts to specify how those considerations apply to DNS over QUIC.

##### **[6.6.1.](#) Connection Reuse**

Historic implementations of DNS stub resolvers are known to open and close TCP connections for each DNS query. To avoid excess QUIC connections, each with a single query, clients SHOULD reuse a single QUIC connection to the recursive resolver.

In order to achieve performance on par with UDP, DNS clients SHOULD send their queries concurrently over the QUIC streams on a QUIC connection. That is, when a DNS client sends multiple queries to a server over a QUIC connection, it SHOULD NOT wait for an outstanding reply before sending the next query.



### **6.6.2. Connection Close**

In order to amortize QUIC and TLS connection setup costs, clients and servers SHOULD NOT immediately close a QUIC connection after each response. Instead, clients and servers SHOULD reuse existing QUIC connections for subsequent queries as long as they have sufficient resources. In some cases, this means that clients and servers may need to keep idle connections open for some amount of time.

Under normal operation DNS clients typically initiate connection closing on idle connections; however, DNS servers can close the connection if the idle timeout set by local policy is exceeded. Also, connections can be closed by either end under unusual conditions such as defending against an attack or system failure/reboot.

Clients and servers that keep idle connections open MUST be robust to termination of idle connection by either party. As with current DNS over TCP, DNS servers MAY close the connection at any time (perhaps due to resource constraints). As with current DNS over TCP, clients MUST handle abrupt closes and be prepared to reestablish connections and/or retry queries.

### **6.6.3. Idle Timeouts**

Proper management of established and idle connections is important to the healthy operation of a DNS server. An implementation of DNS over QUIC SHOULD follow best practices for DNS over TCP, as described in [\[RFC7766\]](#). Failure to do so may lead to resource exhaustion and denial of service.

This document does not make specific recommendations for timeout values on idle connections. Clients and servers should reuse and/or close connections depending on the level of available resources. Timeouts may be longer during periods of low activity and shorter during periods of high activity. Current work in this area may also assist DNS over TLS clients and servers in selecting useful timeout values [\[RFC7828\]](#) [\[I-D.ietf-dnsop-session-signal\]](#) [\[TDNS\]](#).

TODO: Clarify what timers (idle timeouts, response timeouts) apply at the stream level and at the connection level.

TODO: QUIC provides an efficient mechanism for resuming connections, including the possibility of sending 0-RTT data. Does that change the tradeoff? Is it plausible to use shorter timers than specified for TCP?



## **7. Security Considerations**

The security considerations of DNS over QUIC should be comparable to those of DNS over TLS [[RFC7858](#)].

## **8. Privacy Considerations**

DNS over QUIC is specifically designed to protect the DNS traffic between stub and resolver from observations by third parties, and thus protect the privacy of queries from the stub. However, the recursive resolver has full visibility of the stub's traffic, and could be used as an observation point, as discussed in [[RFC7626](#)]. These considerations do not differ between DNS over TLS and DNS over QUIC and are not discussed further here.

QUIC incorporates the mechanisms of TLS 1.3 [[I-D.ietf-tls-tls13](#)] and this enables QUIC transmission of "Zero RTT" data. This can provide interesting latency gains, but it raises two concerns:

1. Adversaries could replay the zero-RTT data and infer its content from the behavior of the receiving server.
2. The zero-RTT mechanism relies on TLS resume, which can provide linkability between successive client sessions.

These issues are developed in [Section 8.1](#) and [Section 8.2](#).

### **8.1. Privacy Issues With 0RTT data**

The zero-RTT data can be replayed by adversaries. That data may triggers a query by a recursive resolver to an authoritative resolvers. Adversaries may be able to pick a time at which the recursive resolver outgoing traffic is observable, and thus find out what name was queried for in the 0-RTT data.

This risk is in fact a subset of the general problem of observing the behavior of the recursive resolver discussed in [[RFC7626](#)]. The attack is partially mitigated by reducing the observability of this traffic. However, the risk is amplified for 0-RTT data, because the attacker might replay it at chosen times, several times.

The recommendation in [[I-D.ietf-tls-tls13](#)] is that the capability to use 0-RTT data should be turned off by default, on only enabled if the user clearly understands the associated risks.

QUESTION: Should 0-RTT only be used with Opportunistic profiles (i.e. disabled by default for Strict only)?





## **8.2. Privacy Issues With Session Resume**

The QUIC session resume mechanism reduces the cost of reestablishing sessions and enables zero-RTT data. There is a linkability issue associated with session resume, if the same resume token is used several times, but this risk is mitigated by the mechanisms incorporated in QUIC and in TLS 1.3. With these mechanisms, clients and servers can cooperate to avoid linkability by third parties. However, the server will always be able to link the resumed session to the initial session. This creates a virtual long duration session. The series of queries in that session can be used by the server to identify the client.

Enabling the server to link client sessions through session resume is probably not a large additional risk if the client's connectivity did not change between the sessions, since the two sessions can probably be correlated by comparing the IP addresses. On the other hand, if the addresses did change, the client SHOULD consider whether the linkability risk exceeds the privacy benefits. This evaluation will obviously depend on the level of trust between stub and recursive.

## **9. IANA Considerations**

### **9.1. Registration of DNS over QUIC Identification String**

This document creates a new registration for the identification of DNS over QUIC in the "Application Layer Protocol Negotiation (ALPN) Protocol IDs" registry established in [[RFC7301](#)].

The "dq" string identifies DNS over QUIC:

Protocol: DNS over QUIC

Identification Sequence: 0x64 0x71 ("dq")

Specification: This document

### **9.2. Reservation of Dedicated Port**

IANA is required to add the following value to the "Service Name and Transport Protocol Port Number Registry" in the System Range. The registry for that range requires IETF Review or IESG Approval [[RFC6335](#)], and such a review was requested using the early allocation process [[RFC7120](#)] for the well-known UDP port in this document. Since port 853 is reserved for 'DNS query-response protocol run over TLS' consideration is requested for reserving port 953 for 'DNS query-response protocol run over QUIC'.



Service Name	domain-s
Transport Protocol(s)	TCP/UDP
Assignee	IESG
Contact	IETF Chair
Description	DNS query-response protocol run over QUIC
Reference	This document

## **10. Acknowledgements**

This document liberally borrows text from [[I-D.ietf-quic-http](#)] edited by Mike Bishop, and from [[RFC7858](#)] authored by Zi Hu, Liang Zhu, John Heidemann, Allison Mankin, Duane Wessels, and Paul Hoffman.

The privacy issue with 0-RTT data and session resume were analyzed by Daniel Kahn Gillmor (DKG) in a message to the IETF "DPRIV" working group [[DNS0RTT](#)].

Thanks to our wide cast of supporters.

## **11. References**

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#### Authors' Addresses

Christian Huitema  
Private Octopus Inc.  
Friday Harbor WA 98250  
U.S.A

Email: [huitema@huitema.net](mailto:huitema@huitema.net)

Melinda Shore  
Fastly

Email: [mshore@fastly.com](mailto:mshore@fastly.com)

Allison Mankin  
Salesforce

Email: [amankin@salesforce.com](mailto:amankin@salesforce.com)



Sara Dickinson  
Sinodun IT  
Magdalen Centre  
Oxford Science Park  
Oxford OX4 4GA  
U.K.

Email: [sara@sinodun.com](mailto:sara@sinodun.com)

Jana Iyengar  
Google

Email: [jri@google.com](mailto:jri@google.com)

