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Proxying UDP in HTTP

Abstract

This document describes how to proxy UDP in HTTP, similar to how the HTTP CONNECT method allows proxying TCP in HTTP. More specifically, this document defines a protocol that allows an HTTP client to create a tunnel for UDP communications through an HTTP server that acts as a proxy.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at <https://ietf-wg-masque.github.io/draft-ietf-masque-connect-udp/draft-ietf-masque-connect-udp.html>. Status information for this document may be found at <https://datatracker.ietf.org/doc/draft-ietf-masque-connect-udp/>.

Discussion of this document takes place on the MASQUE Working Group mailing list (<mailto:masque@ietf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/masque/>.

Source for this draft and an issue tracker can be found at <https://github.com/ietf-wg-masque/draft-ietf-masque-connect-udp>.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

While HTTP provides the CONNECT method (see [Section 9.3.6](#) of [[HTTP](#)]) for creating a TCP [[TCP](#)] tunnel to a proxy, prior to this specification it lacked a method for doing so for UDP [[UDP](#)] traffic.

This document describes a protocol for tunnelling UDP to a server acting as a UDP-specific proxy over HTTP. UDP tunnels are commonly used to create an end-to-end virtual connection, which can then be secured using QUIC [[QUIC](#)] or another protocol running over UDP. Unlike CONNECT, the UDP proxy itself is identified with an absolute URL containing the traffic's destination. Clients generate those URLs using a URI Template [[TEMPLATE](#)], as described in [Section 2](#).

This protocol supports all existing versions of HTTP by using HTTP Datagrams [[HTTP-DGRAM](#)]. When using HTTP/2 [[HTTP/2](#)] or HTTP/3 [[HTTP/3](#)], it uses HTTP Extended CONNECT as described in [[EXT-CONNECT2](#)] and [[EXT-CONNECT3](#)]. When using HTTP/1.x [[HTTP/1.1](#)], it uses HTTP Upgrade as defined in [Section 7.8](#) of [[HTTP](#)].

1.1. Conventions and Definitions

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.

In this document, we use the term "UDP proxy" to refer to the HTTP server that acts upon the client's UDP tunnelling request to open a UDP socket to a target server, and generates the response to this request. If there are HTTP intermediaries (as defined in [Section 3.7](#) of [[HTTP](#)]) between the client and the UDP proxy, those are referred to as "intermediaries" in this document.

Note that, when the HTTP version in use does not support multiplexing streams (such as HTTP/1.1), any reference to "stream" in this document represents the entire connection.

2. Client Configuration

HTTP clients are configured to use a UDP proxy with a URI Template [[TEMPLATE](#)] that has the variables "target_host" and "target_port". Examples are shown below:

```
https://example.org/.well-known/masque/udp/{target_host}/{target_port}/  
https://proxy.example.org:4443/masque?h={target_host}&p={target_port}  
https://proxy.example.org:4443/masque{?target_host,target_port}
```

Figure 1: URI Template Examples

The following requirements apply to the URI Template:

*The URI Template **MUST** be a level 3 template or lower.

- *The URI Template **MUST** be in absolute form, and **MUST** include non-empty scheme, authority and path components.
- *The path component of the URI Template **MUST** start with a slash "/".
- *All template variables **MUST** be within the path or query components of the URI.
- *The URI template **MUST** contain the two variables "target_host" and "target_port" and **MAY** contain other variables.
- *The URI Template **MUST NOT** contain any non-ASCII unicode characters and **MUST** only contain ASCII characters in the range 0x21-0x7E inclusive (note that percent-encoding is allowed; see [Section 2.1](#) of [\[URI\]](#)).
- *The URI Template **MUST NOT** use Reserved Expansion ("+" operator), Fragment Expansion ("#" operator), Label Expansion with Dot-Prefix, Path Segment Expansion with Slash-Prefix, nor Path-Style Parameter Expansion with Semicolon-Prefix.

Clients **SHOULD** validate the requirements above; however, clients **MAY** use a general-purpose URI Template implementation that lacks this specific validation. If a client detects that any of the requirements above are not met by a URI Template, the client **MUST** reject its configuration and abort the request without sending it to the UDP proxy.

Since the original HTTP CONNECT method allowed conveying the target host and port but not the scheme, proxy authority, path, nor query, there exist clients with proxy configuration interfaces that only allow the user to configure the proxy host and the proxy port. Client implementations of this specification that are constrained by such limitations **MAY** attempt to access UDP proxying capabilities using the default template, which is defined as: "https://\$PROXY_HOST:\$PROXY_PORT/.well-known/masque/udp/{target_host}/{target_port}/" where \$PROXY_HOST and \$PROXY_PORT are the configured host and port of the UDP proxy respectively. UDP proxy deployments **SHOULD** offer service at this location if they need to interoperate with such clients.

3. Tunnelling UDP over HTTP

To allow negotiation of a tunnel for UDP over HTTP, this document defines the "connect-udp" HTTP Upgrade Token. The resulting UDP tunnels use the Capsule Protocol (see [Section 3.2](#) of [\[HTTP-DGRAM\]](#)) with HTTP Datagrams in the format defined in [Section 5](#).

To initiate a UDP tunnel associated with a single HTTP stream, a client issues a request containing the "connect-udp" upgrade token. The target of the tunnel is indicated by the client to the UDP proxy via the "target_host" and "target_port" variables of the URI Template, see [Section 2](#). If the request is successful, the UDP proxy commits to converting received HTTP Datagrams into UDP packets and vice versa until the tunnel is closed.

When sending its UDP proxying request, the client **SHALL** perform URI Template expansion to determine the path and query of its request. target_host supports using DNS names, IPv6 literals and IPv4 literals. Note that IPv6 scoped addressing zone identifiers are not supported. Also note that this URI Template expansion requires using percent-encoding, so for example if the target_host is "2001:db8::42", it will be encoded in the URI as "2001%3Adb8%3A%3A42".

By virtue of the definition of the Capsule Protocol (see [Section 3.2](#) of [[HTTP-DGRAM](#)]), UDP proxying requests do not carry any message content. Similarly, successful UDP proxying responses also do not carry any message content.

3.1. UDP Proxy Handling

Upon receiving a UDP proxying request:

- *if the recipient is configured to use another HTTP proxy, it will act as an intermediary: it forwards the request to another HTTP server. Note that such intermediaries may need to reencode the request if they forward it using a version of HTTP that is different from the one used to receive it, as the request encoding differs by version (see below).

- *otherwise, the recipient will act as a UDP proxy: it extracts the "target_host" and "target_port" variables from the URI it has reconstructed from the request headers, and establishes a tunnel by directly opening a UDP socket to the requested target.

Unlike TCP, UDP is connection-less. The UDP proxy that opens the UDP socket has no way of knowing whether the destination is reachable. Therefore, it needs to respond to the request without waiting for a packet from the target. However, if the target_host is a DNS name, the UDP proxy **MUST** perform DNS resolution before replying to the HTTP request. If errors occur during this process, the UDP proxy **MUST** reject the request and **SHOULD** send details using an appropriate "Proxy-Status" header field [[PROXY-STATUS](#)] (for example, if DNS resolution returns an error, the proxy can use the dns_error Proxy Error Type from [Section 2.3.2](#) of [[PROXY-STATUS](#)]).

UDP proxies can use connected UDP sockets if their operating system supports them, as that allows the UDP proxy to rely on the kernel to only send it UDP packets that match the correct 5-tuple. If the UDP proxy uses a non-connected socket, it **MUST** validate the IP source address and UDP source port on received packets to ensure they match the client's request. Packets that do not match **MUST** be discarded by the UDP proxy.

The lifetime of the socket is tied to the request stream. The UDP proxy **MUST** keep the socket open while the request stream is open. If a UDP proxy is notified by its operating system that its socket is no longer usable (for example, this can happen when an ICMP "Destination Unreachable" message is received, see [Section 3.1](#) of [[ICMP6](#)]), it **MUST** close the request stream. UDP proxies **MAY** choose to close sockets due to a period of inactivity, but they **MUST** close the request stream when closing the socket. UDP proxies that close sockets after a period of inactivity **SHOULD NOT** use a period lower than two minutes, see [Section 4.3](#) of [[BEHAVE](#)].

A successful response (as defined in [Section 3.3](#) and [Section 3.5](#)) indicates that the UDP proxy has opened a socket to the requested target and is willing to proxy UDP payloads. Any response other than a successful response indicates that the request has failed, and the client **MUST** therefore abort the request.

UDP proxies **MUST NOT** introduce fragmentation at the IP layer when forwarding HTTP Datagrams onto a UDP socket; overly large datagrams are silently dropped. In IPv4, the Don't Fragment (DF) bit **MUST** be set if possible, to prevent fragmentation on the path. Future extensions **MAY** remove these requirements.

Implementers of UDP proxies will benefit from reading the guidance in [[UDP-USAGE](#)].

3.2. HTTP/1.1 Request

When using HTTP/1.1 [[HTTP/1.1](#)], a UDP proxying request will meet the following requirements:

- *the method **SHALL** be "GET".
- *the request **SHALL** include a single "Host" header field containing the origin of the UDP proxy.
- *the request **SHALL** include a "Connection" header field with value "Upgrade" (note that this requirement is case-insensitive as per [Section 7.6.1](#) of [[HTTP](#)]).
- *the request **SHALL** include an "Upgrade" header field with value "connect-udp".

A UDP proxying request that does not conform to these restrictions is malformed. The recipient of such a malformed request **MUST** respond with an error, and **SHOULD** use the 400 (Bad Request) status code.

For example, if the client is configured with URI Template "https://example.org/.well-known/masque/udp/{target_host}/{target_port}/" and wishes to open a UDP proxying tunnel to target 192.0.2.6:443, it could send the following request:

```
GET https://example.org/.well-known/masque/udp/192.0.2.6/443/ HTTP/1.1
Host: example.org
Connection: Upgrade
Upgrade: connect-udp
Capsule-Protocol: ?1
```

Figure 2: Example HTTP/1.1 Request

In HTTP/1.1, this protocol uses the GET method to mimic the design of the WebSocket Protocol [[WEBSOCKET](#)].

3.3. HTTP/1.1 Response

The UDP proxy **SHALL** indicate a successful response by replying with the following requirements:

- *the HTTP status code on the response **SHALL** be 101 (Switching Protocols).
- *the response **SHALL** include a "Connection" header field with value "Upgrade" (note that this requirement is case-insensitive as per [Section 7.6.1](#) of [[HTTP](#)]).
- *the response **SHALL** include a single "Upgrade" header field with value "connect-udp".
- *the response **SHALL** meet the requirements of HTTP responses that start the Capsule Protocol; see [Section 3.2](#) of [[HTTP-DGRAM](#)].

If any of these requirements are not met, the client **MUST** treat this proxying attempt as failed and abort the connection.

For example, the UDP proxy could respond with:

```
HTTP/1.1 101 Switching Protocols
Connection: Upgrade
Upgrade: connect-udp
Capsule-Protocol: ?1
```

Figure 3: Example HTTP/1.1 Response

3.4. HTTP/2 and HTTP/3 Requests

When using HTTP/2 [[HTTP/2](#)] or HTTP/3 [[HTTP/3](#)], UDP proxying requests use Extended CONNECT. This requires that servers send an HTTP Setting as specified in [[EXT-CONNECT2](#)] and [[EXT-CONNECT3](#)], and that requests use HTTP pseudo-header fields with the following requirements:

- *The ":method" pseudo-header field **SHALL** be "CONNECT".
- *The ":protocol" pseudo-header field **SHALL** be "connect-udp".
- *The ":authority" pseudo-header field **SHALL** contain the authority of the UDP proxy.
- *The ":path" and ":scheme" pseudo-header fields **SHALL NOT** be empty. Their values **SHALL** contain the scheme and path from the URI Template after the URI template expansion process has been completed.

A UDP proxying request that does not conform to these restrictions is malformed (see [Section 8.1.1](#) of [[HTTP/2](#)] and [Section 4.1.2](#) of [[HTTP/3](#)]).

For example, if the client is configured with URI Template "https://example.org/.well-known/masque/udp/{target_host}/{target_port}/" and wishes to open a UDP proxying tunnel to target 192.0.2.6:443, it could send the following request:

```
HEADERS
:method = CONNECT
:protocol = connect-udp
:scheme = https
:path = /.well-known/masque/udp/192.0.2.6/443/
:authority = example.org
capsule-protocol = ?1
```

Figure 4: Example HTTP/2 Request

3.5. HTTP/2 and HTTP/3 Responses

The UDP proxy **SHALL** indicate a successful response by replying with the following requirements:

- *the HTTP status code on the response **SHALL** be in the 2xx (Successful) range.

*the response **SHALL** meet the requirements of HTTP responses that start the Capsule Protocol; see [Section 3.2](#) of [[HTTP-DGRAM](#)].

If any of these requirements are not met, the client **MUST** treat this proxying attempt as failed and abort the request.

For example, the UDP proxy could respond with:

```
HEADERS
:status = 200
capsule-protocol = ?1
```

Figure 5: Example HTTP/2 Response

3.6. Note About Draft Versions

[[RFC editor: please remove this section before publication.]]

In order to allow implementations to support multiple draft versions of this specification during its development, we introduce the "connect-udp-version" header field. When sent by the client, it contains a list of draft numbers supported by the client (e.g., "connect-udp-version: 0, 2"). When sent by the UDP proxy, it contains a single draft number selected by the UDP proxy from the list provided by the client (e.g., "connect-udp-version: 2"). Sending this header field is **RECOMMENDED** but not required. The "connect-udp-version" header field is a [List Structured Field](#). Each list member **MUST** be an Integer.

4. Context Identifiers

The mechanism for proxying UDP in HTTP defined in this document allows future extensions to exchange HTTP Datagrams that carry different semantics from UDP payloads. Some of these extensions can augment UDP payloads with additional data, while others can exchange data that is completely separate from UDP payloads. In order to accomplish this, all HTTP Datagrams associated with UDP Proxying request streams start with a context ID, see [Section 5](#).

Context IDs are 62-bit integers (0 to $2^{62}-1$). Context IDs are encoded as variable-length integers, see [Section 16](#) of [[QUIC](#)]. The context ID value of 0 is reserved for UDP payloads, while non-zero values are dynamically allocated: non-zero even-numbered context IDs are client-allocated, and odd-numbered context IDs are proxy-allocated. The context ID namespace is tied to a given HTTP request: it is possible for a context ID with the same numeric value to be simultaneously allocated in distinct requests, potentially with different semantics. Context IDs **MUST NOT** be re-allocated within a given HTTP namespace but **MAY** be allocated in any order. The context ID allocation

restrictions to the use of even-numbered and odd-numbered context IDs exist in order to avoid the need for synchronisation between endpoints. However, once a context ID has been allocated, those restrictions do not apply to the use of the context ID: it can be used by any client or UDP proxy, independent of which endpoint initially allocated it.

Registration is the action by which an endpoint informs its peer of the semantics and format of a given context ID. This document does not define how registration occurs. Future extensions **MAY** use HTTP header fields or capsules to register contexts. Depending on the method being used, it is possible for datagrams to be received with Context IDs which have not yet been registered, for instance due to reordering of the packet containing the datagram and the packet containing the registration message during transmission.

5. HTTP Datagram Payload Format

When HTTP Datagrams (see [Section 2](#) of [\[HTTP-DGRAM\]](#)) are associated with UDP proxying request streams, the HTTP Datagram Payload field has the format defined in [Figure 6](#). Note that when HTTP Datagrams are encoded using QUIC DATAGRAM frames [\[DGRAM\]](#), the Context ID field defined below directly follows the Quarter Stream ID field which is at the start of the QUIC DATAGRAM frame payload (see [Section 2.1](#) of [\[HTTP-DGRAM\]](#)).

```
UDP Proxying HTTP Datagram Payload {  
    Context ID (i),  
    Payload (..),  
}
```

Figure 6: UDP Proxying HTTP Datagram Format

Context ID: A variable-length integer (see [Section 16](#) of [\[QUIC\]](#)) that contains the value of the Context ID. If an HTTP/3 Datagram which carries an unknown Context ID is received, the receiver **SHALL** either drop that datagram silently or buffer it temporarily (on the order of a round trip) while awaiting the registration of the corresponding Context ID.

Payload: The payload of the datagram, whose semantics depend on value of the previous field. Note that this field can be empty.

UDP packets are encoded using HTTP Datagrams with the Context ID set to zero. When the Context ID is set to zero, the Payload field contains the unmodified payload of a UDP packet (referred to as "data octets" in [\[UDP\]](#)).

By virtue of the definition of the UDP header [\[UDP\]](#), it is not possible to encode UDP payloads longer than 65527 bytes. Therefore, endpoints **MUST NOT** send HTTP Datagrams with a Payload field longer

than 65527 using Context ID zero. An endpoint that receives an HTTP Datagram using Context ID zero whose Payload field is longer than 65527 **MUST** abort the corresponding stream. If a UDP proxy knows it can only send out UDP packets of a certain length due to its underlying link MTU, it has no choice but to discard incoming HTTP Datagrams using Context ID zero whose Payload field is longer than that limit. If the discarded HTTP Datagram was transported by a DATAGRAM capsule, the receiver **SHOULD** discard that capsule without buffering the capsule contents.

If a UDP proxy receives an HTTP Datagram before it has received the corresponding request, it **SHALL** either drop that HTTP Datagram silently or buffer it temporarily (on the order of a round trip) while awaiting the corresponding request.

Note that buffering datagrams (either because the request was not yet received, or because the Context ID is not yet known) consumes resources. Receivers that buffer datagrams **SHOULD** apply buffering limits in order to reduce the risk of resource exhaustion occurring. For example, receivers can limit the total number of buffered datagrams, or the cumulative size of buffered datagrams, on a per-stream, per-context, or per-connection basis.

A client **MAY** optimistically start sending UDP packets in HTTP Datagrams before receiving the response to its UDP proxying request. However, implementers should note that such proxied packets may not be processed by the UDP proxy if it responds to the request with a failure, or if the proxied packets are received by the UDP proxy before the request and the UDP proxy chooses to not buffer them.

6. Performance Considerations

Bursty traffic can often lead to temporally correlated packet losses, which in turn can lead to suboptimal responses from congestion controllers in protocols running over UDP. To avoid this, UDP proxies **SHOULD** strive to avoid increasing burstiness of UDP traffic: they **SHOULD NOT** queue packets in order to increase batching.

When the protocol running over UDP that is being proxied uses congestion control (e.g., [[QUIC](#)]), the proxied traffic will incur at least two nested congestion controllers. The underlying HTTP connection **MUST NOT** disable congestion control unless it has an out-of-band way of knowing with absolute certainty that the inner traffic is congestion-controlled.

If a client or UDP proxy with a connection containing a UDP proxying request stream disables congestion control, it **MUST NOT** signal Explicit Congestion Notification (ECN) [[ECN](#)] support on that connection. That is, it **MUST** mark all IP headers with the Not-ECT

codepoint. It **MAY** continue to report ECN feedback via QUIC ACK_ECN frames or the TCP "ECE" bit, as the peer may not have disabled congestion control.

When the protocol running over UDP that is being proxied uses loss recovery (e.g., [QUIC]), and the underlying HTTP connection runs over TCP, the proxied traffic will incur at least two nested loss recovery mechanisms. This can reduce performance as both can sometimes independently retransmit the same data. To avoid this, UDP proxying **SHOULD** be performed over HTTP/3 to allow leveraging the QUIC DATAGRAM frame.

6.1. MTU Considerations

When using HTTP/3 with the QUIC Datagram extension [DGRAM], UDP payloads are transmitted in QUIC DATAGRAM frames. Since those cannot be fragmented, they can only carry payloads up to a given length determined by the QUIC connection configuration and the path MTU. If a UDP proxy is using QUIC DATAGRAM frames and it receives a UDP payload from the target that will not fit inside a QUIC DATAGRAM frame, the UDP proxy **SHOULD NOT** send the UDP payload in a DATAGRAM capsule, as that defeats the end-to-end unreliability characteristic that methods such as Datagram Packetization Layer Path MTU Discovery (DPLPMTUD) depend on [DPLPMTUD]. In this scenario, the UDP proxy **SHOULD** drop the UDP payload and send an ICMP "Packet Too Big" message to the target, see [Section 3.2](#) of [ICMP6].

6.2. Tunneling of ECN Marks

UDP proxying does not create an IP-in-IP tunnel, so the guidance in [ECN-TUNNEL] about transferring ECN marks between inner and outer IP headers does not apply. There is no inner IP header in UDP proxying tunnels.

Note that UDP proxying clients do not have the ability in this specification to control the ECN codepoints on UDP packets the UDP proxy sends to the target, nor can UDP proxies communicate the markings of each UDP packet from target to UDP proxy.

A UDP proxy **MUST** ignore ECN bits in the IP header of UDP packets received from the target, and **MUST** set the ECN bits to Not-ECT on UDP packets it sends to the target. These do not relate to the ECN markings of packets sent between client and UDP proxy in any way.

7. Security Considerations

There are significant risks in allowing arbitrary clients to establish a tunnel to arbitrary targets, as that could allow bad actors to send traffic and have it attributed to the UDP proxy. HTTP

servers that support UDP proxying ought to restrict its use to authenticated users.

There exist software and network deployments that perform access control checks based on the source IP address of incoming requests. For example, some software allows unauthenticated configuration changes if they originated from 127.0.0.1. Such software could be running on the same host as the UDP proxy, or in the same broadcast domain. Proxied UDP traffic would then be received with a source IP address belonging to the UDP proxy. If this source address is used for access control, UDP proxying clients could use the UDP proxy to escalate their access privileges beyond those they might otherwise have. This could lead to unauthorized access by UDP proxying clients unless the UDP proxy disallows UDP proxying requests to vulnerable targets, such as the UDP proxy's own addresses and localhost, link-local, multicast, and broadcast addresses. UDP proxies can use the `destination_ip_prohibited` Proxy Error Type from [Section 2.3.5](#) of [\[PROXY-STATUS\]](#) when rejecting such requests.

UDP proxies share many similarities to TCP CONNECT proxies when considering them as infrastructure for abuse to enable denial of service attacks. Both can obfuscate the attacker's source address from the attack target. In the case of a stateless volumetric attack (e.g., a TCP SYN flood or a UDP flood), both types of proxies pass the traffic to the target host. With stateful volumetric attacks (e.g., HTTP flooding) being sent over a TCP CONNECT proxy, the proxy will only send data if the target has indicated its willingness to accept data by responding with a TCP SYN-ACK. Once the path to the target is flooded, the TCP CONNECT proxy will no longer receive replies from the target and will stop sending data. Since UDP does not establish shared state between the UDP proxy and the target, the UDP proxy could continue sending data to the target in such a situation. While a UDP proxy could potentially limit the number of UDP packets it is willing to forward until it has observed a response from the target, that provides limited protection against denial of service attacks when attacks target open UDP ports where the protocol running over UDP would respond, and that would be interpreted as willingness to accept UDP by the UDP proxy. Such a packet limit could also cause issues for valid traffic.

The security considerations described in [Section 4](#) of [\[HTTP-DGRAM\]](#) also apply here. Since it is possible to tunnel IP packets over UDP, the guidance in [\[TUNNEL-SECURITY\]](#) can apply.

8. IANA Considerations

8.1. HTTP Upgrade Token

This document will request IANA to register "connect-udp" in the "HTTP Upgrade Tokens" registry maintained at <https://www.iana.org/assignments/http-upgrade-tokens>.

Value: connect-udp

Description: Proxying of UDP Payloads

Expected Version Tokens: None

Reference: This document

8.2. Well-Known URI

This document will request IANA to register "masque" in the "Well-Known URIs" registry maintained at <https://www.iana.org/assignments/well-known-uris>.

URI Suffix: masque

Change Controller: IETF

Reference: This document

Status: permanent (if this document is approved)

Related Information: Includes all resources identified with the path prefix `"/.well-known/masque/udp/"`

9. References

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