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0-RTT TCP Convert Protocol
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Abstract

This document specifies an application proxy, called Transport Converter, to assist the deployment of TCP extensions such as Multipath TCP. This proxy is designed to avoid inducing extra delay when involved in a network-assisted connection (that is, 0-RTT).

This specification assumes an explicit model, where the proxy is explicitly configured on hosts.

-- Editorial Note (To be removed by RFC Editor)

Please update these statements with the RFC number to be assigned to this document: [This-RFC]

Please update TBA statements with the port number to be assigned to the 0-RTT TCP Convert Protocol.

Status of This Memo

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1. Introduction

Transport protocols like TCP evolve regularly [RFC7414]. TCP has been improved in different ways. Some improvements such as changing the initial window size [RFC6928] or modifying the congestion control scheme can be applied independently on clients and servers. Other improvements such as Selective Acknowledgements [RFC2018] or large windows [RFC7323] require a new TCP option or to change the semantics of some fields in the TCP header. These modifications must be deployed on both clients and servers to be actually used on the Internet. Experience with the latter TCP extensions reveals that their deployment can require many years. Fukuda reports in [Fukuda2011] results of a decade of measurements showing the deployment of Selective Acknowledgements, Window Scale and TCP Timestamps. [ANRW17] describes measurements showing that TCP Fast Open (TFO) [RFC7413] is still not widely deployed.

There are some situations where the transport stack used on clients (or servers) can be upgraded at a faster pace than the transport stack running on servers (or clients). In those situations, clients

would typically want to benefit from the features of an improved transport protocol even if the servers have not yet been upgraded and conversely. Performance Enhancing Proxies [RFC3135], and other service functions have been deployed as solutions to improve TCP performance over links with specific characteristics.

Recent examples of TCP extensions include Multipath TCP [RFC6824] or TCPINC [RFC8548]. Those extensions provide features that are interesting for clients such as wireless devices. With Multipath TCP, those devices could seamlessly use WLAN (Wireless Local Area Network) and cellular networks, for bonding purposes, faster handovers, or better resiliency. Unfortunately, deploying those extensions on both a wide range of clients and servers remains difficult.

More recently, experimentation of 5G bonding, which has very scarce coverage, has been conducted into global range of the incumbent 4G (LTE) connectivity in newly devised clients using Multipath TCP proxy. Even if the 5G and the 4G bonding by using Multipath TCP increases the bandwidth, it is as well crucial to minimize latency for all the way between endhosts regardless of whether intermediate nodes are inside or outside of the mobile core. In order to handle uRLLC (Ultra-Reliable Low-Latency Communication) for the next generation mobile network, Multipath TCP and its proxy mechanism such as the one used to provide Access Taffic Steering, Switching, and Splitting (ATSSS) must be optimised to reduce latency.

This document specifies an application proxy, called Transport Converter. A Transport Converter is a function that is installed by a network operator to aid the deployment of TCP extensions and to provide the benefits of such extensions to clients. A Transport Converter may provide conversion service for one or more TCP extensions. Which TCP extensions are eligible to the conversion service is deployment-specific. The conversion service is provided by means of the 0-RTT TCP Convert Protocol (Convert), that is an application-layer protocol which uses TCP port number TBA (Section 8).

The Transport Converter adheres to the main principles drawn in [RFC1919]. In particular, a Transport Converter achieves the following:

- Listen for client sessions;
- Receive from a client the address of the final target server;
- Setup a session to the final server;

- Relay control messages and data between the client and the server;

- Perform access controls according to local policies.

The main advantage of network-assisted conversion services is that they enable new TCP extensions to be used on a subset of the path between endpoints, which encourages the deployment of these extensions. Furthermore, the Transport Converter allows the client and the server to directly negotiate TCP options for the sake of native support along the full path.

The Convert Protocol is a generic mechanism to provide 0-RTT conversion service. As a sample applicability use case, this document specifies how the Convert Protocol applies for Multipath TCP. It is out of scope of this document to provide a comprehensive list of all potential conversion services. Applicability documents may be defined in the future.

This document does not assume that all the traffic is eligible to the network-assisted conversion service. Only a subset of the traffic will be forwarded to a Transport Converter according to a set of policies. These policies, and how they are communicated to endpoints, are out of scope. Furthermore, it is possible to bypass the Transport Converter to connect directly to the servers that already support the required TCP extension(s).

This document assumes an explicit model in which a client is configured with one or a list of Transport Converters (statically or through protocols such as [I-D.boucadair-tcpm-dhc-converter]). Configuration means are outside the scope of this document.

This document is organized as follows. We first provide a brief explanation of the operation of Transport Converters in Section 3. We describe the Convert Protocol in Section 4. We discuss in Section 5 how Transport Converters can be used to support different TCP extensions. We then discuss the interactions with middleboxes (Section 6) and the security considerations (Section 7).

Appendix A discusses how a TCP stack would need to support the protocol described in this document. Appendix B provides a comparison with SOCKS proxies that are already used to deploy Multipath TCP in some cellular networks (Section 2.2 of [RFC8041]).

2. 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

[RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Architecture

3.1. Functional Elements

The Convert Protocol considers three functional elements:

- Clients;
- Transport Converters;
- Servers.

A Transport Converter is a network function that relays all data exchanged over one upstream connection to one downstream connection and vice versa (Figure 1). The Transport Converter, thus, maintains state that associates one upstream connection to a corresponding downstream connection.

A connection can be initiated from both sides of the Transport Converter (Internet-facing interface, client-facing interface).

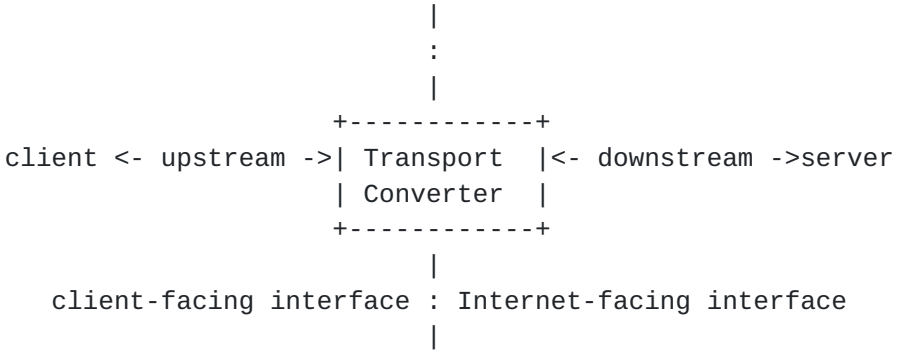


Figure 1: A Transport Converter Relays Data between Pairs of TCP Connections

Transport Converters can be operated by network operators or third parties. Nevertheless, this document focuses on the single administrative deployment case where the entity offering the connectivity service to a client is also the entity which owns and operates the Transport Converter.

A Transport Converter can be embedded in a standalone device or be activated as a service on a router. How such function is enabled is deployment-specific. A sample deployment is depicted in Figure 2.

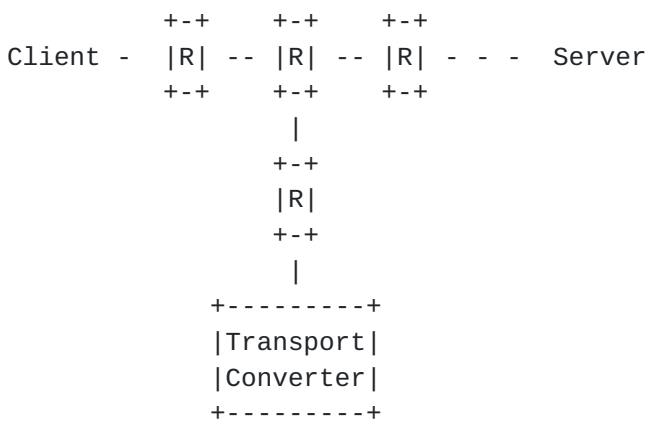


Figure 2: A Transport Converter Can Be Installed Anywhere in the Network

The architecture assumes that new software will be installed on the Client hosts to interact with one or more Transport Converters. Further, the architecture allows for making use of new TCP extensions even if those are not supported by a given server.

The Client is configured, through means that are outside the scope of this document, with the names and/or the addresses of one or more Transport Converters and the TCP extensions that they support. The procedure for selecting a Transport Converter among a list of configured Transport Converters is outside the scope of this document.

One of the benefits of this design is that different transport protocol extensions can be used on the upstream and the downstream connections. This encourages the deployment of new TCP extensions until they are widely supported by servers, in particular.

The architecture does not mandate anything on the server side.

Similar to address sharing mechanisms, the architecture does not interfere with end-to-end TLS connections [RFC8446] between the Client and the Server (Figure 3). In other words, end-to-end TLS is supported in the presence of a Converter.

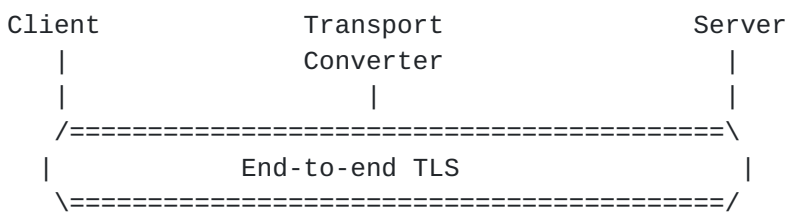


Figure 3: End-to-end TLS via a Transport Converter

It is out of scope of this document to elaborate on specific considerations related to the use of TLS in the Client-Converter connection leg to exchange Convert TLVs (in addition to the end-to-end TLS connection).

3.2. Theory of Operation

At a high level, the objective of the Transport Converter is to allow the use a specific extension, e.g., Multipath TCP, on a subset of the path even if the peer does not support this extension. This is illustrated in Figure 4 where the Client initiates a Multipath TCP connection with the Transport Converter (packets belonging to the Multipath TCP connection are shown with "===") while the Transport Converter uses a regular TCP connection with the Server.

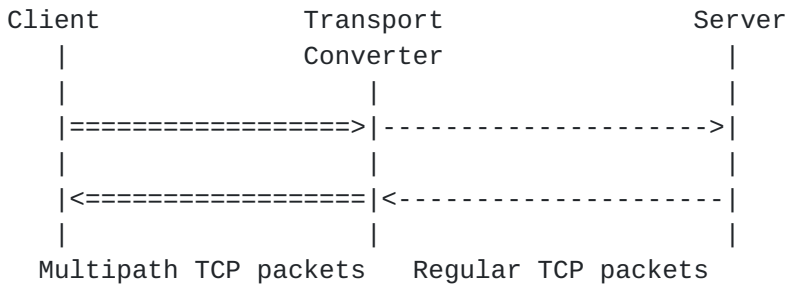


Figure 4: An Example of 0-RTT Network-Assisted MPTCP Connection

The packets belonging to the pair of connections between the Client and Server passing through a Transport Converter may follow a different path than the packets directly exchanged between the Client and the Server. Deployments should minimize the possible additional delay by carefully selecting the location of the Transport Converter used to reach a given destination.

When establishing a connection, the Client can, depending on local policies, either contact the Server directly (e.g., by sending a TCP SYN towards the Server) or create the connection via a Transport

Converter. In the latter case (that is, the conversion service is used), the Client initiates a connection towards the Transport Converter and indicates the IP address and port number of the Server within the connection establishment packet. Doing so enables the Transport Converter to immediately initiate a connection towards that Server, without experiencing an extra delay. The Transport Converter waits until the receipt of the confirmation that the Server agrees to establish the connection before confirming it to the Client.

The client places the destination address and port number of the Server in the payload of the SYN sent to the Transport Converter to minimize connection establishment delays. In accordance with [RFC1919], the Transport Converter maintains two connections that are combined together:

- the upstream connection is the one between the Client and the Transport Converter.

- the downstream connection is between the Transport Converter and the Server.

Any user data received by the Transport Converter over the upstream (or downstream) connection is relayed over the downstream (or upstream) connection. In particular, if the initial SYN message contains data in its payload (e.g., [RFC7413]), that data MUST be placed right after the Convert TLVs when generating the relayed SYN.

Figure 5 illustrates the establishment of an outbound TCP connection by a Client through a Transport Converter. The information shown between brackets denotes Convert Protocol messages described in Section 4.

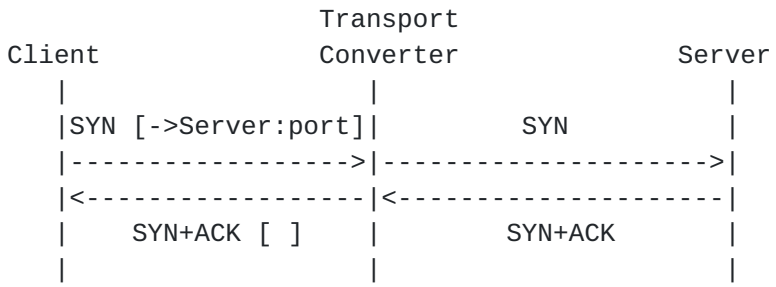


Figure 5: Establishment of a TCP Connection Through a Transport Converter (1)

The Client sends a SYN destined to the Transport Converter. The payload of this SYN contains the address and port number of the Server. The Transport Converter does not reply immediately to this SYN. It first tries to create a TCP connection towards the target

Server. If this upstream connection succeeds, the Transport Converter confirms the establishment of the connection to the Client by returning a SYN+ACK and the first bytes of the bytestream contain information about the TCP options that were negotiated with the Server. This information is sent at the beginning of the bytestream, either directly in the SYN+ACK or in a subsequent packet. For graphical reasons, the figures in this section show that the Transport Converter returns this information in the SYN+ACK packet. An implementation could also place this information in a packet that it sent shortly after the SYN+ACK.

The connection can also be established from the Internet towards a Client via a Transport Converter. This is typically the case when an application on the Client listens to a specific port (the Client hosts a server, typically).

A Transport Converter MAY operate in address preservation or address sharing modes as discussed in Section 5.4 of [I-D.nam-mptcp-deployment-considerations]. Which behavior to use by a Transport Converter is deployment-specific. If address sharing mode is enabled, the Transport Converter MUST adhere to REQ-2 of [RFC6888] which implies a default "IP address pooling" behavior of "Paired" (as defined in Section 4.1 of [RFC4787]) must be supported. This behavior is meant to avoid breaking applications that depend on the external address remaining constant.

Standard TCP ([RFC0793], Section 3.4) allows a SYN packet to carry data inside its payload but forbids the receiver from delivering it to the application until completion of the three-way-handshake. To enable applications to exchange data in a TCP handshake, this specification follows an approach similar to TCP Fast Open [RFC7413] and thus removes the constraint by allowing data in SYN packets to be delivered to the Transport Converter application.

As discussed in [RFC7413], such change to TCP semantic raises two issues. First, duplicate SYNs can cause problems for some applications that rely on TCP. Second, TCP suffers from SYN flooding attacks [RFC4987]. TFO solves these two problems for applications that can tolerate replays by using the TCP Fast Open option that includes a cookie. However, the utilization of this option consumes space in the limited TCP extended header. Furthermore, there are situations, as noted in Section 7.3 of [RFC7413] where it is possible to accept the payload of SYN packets without creating additional security risks such as a network where addresses cannot be spoofed and the Transport Converter only serves a set of hosts that are identified by these addresses.

For these reasons, this specification does not mandate the use of the TCP Fast Open option when the Client sends a connection establishment packet towards a Transport Converter. The Convert protocol includes an optional Cookie TLV that provides similar protection as the TCP Fast Open option without consuming space in the extended TCP header.

3.3. Sample Examples of Outgoing Converter-Assisted Multipath TCP Connections

As an example, let us consider how the Convert protocol can help the deployment of Multipath TCP. We assume that both the Client and the Transport Converter support Multipath TCP, but consider two different cases depending on whether the Server supports Multipath TCP or not.

As a reminder, a Multipath TCP connection is created by placing the MP_CAPABLE (MPC) option in the SYN sent by the Client.

Figure 6 describes the operation of the Transport Converter if the Server does not support Multipath TCP.

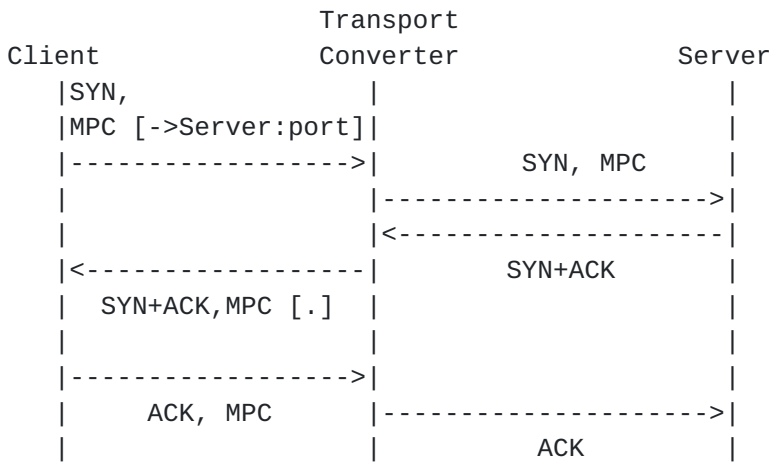


Figure 6: Establishment of a Multipath TCP Connection Through a Transport Converter towards a Server that Does Not Support Multipath TCP

The Client tries to initiate a Multipath TCP connection by sending a SYN with the MP_CAPABLE option (MPC in Figure 6). The SYN includes the address and port number of the target Server, that are extracted and used by the Transport Converter to initiate a Multipath TCP connection towards this Server. Since the Server does not support Multipath TCP, it replies with a SYN+ACK that does not contain the MP_CAPABLE option. The Transport Converter notes that the connection with the Server does not support Multipath TCP and returns the extended TCP header received from the Server to the Client.

Figure 7 considers a Server that supports Multipath TCP. In this case, it replies to the SYN sent by the Transport Converter with the MP_CAPABLE option. Upon reception of this SYN+ACK, the Transport Converter confirms the establishment of the connection to the Client and indicates to the Client that the Server supports Multipath TCP. With this information, the Client has discovered that the Server supports Multipath TCP natively. This will enable the Client to bypass the Transport Converter for the subsequent Multipath TCP connections that it will initiate towards this Server.

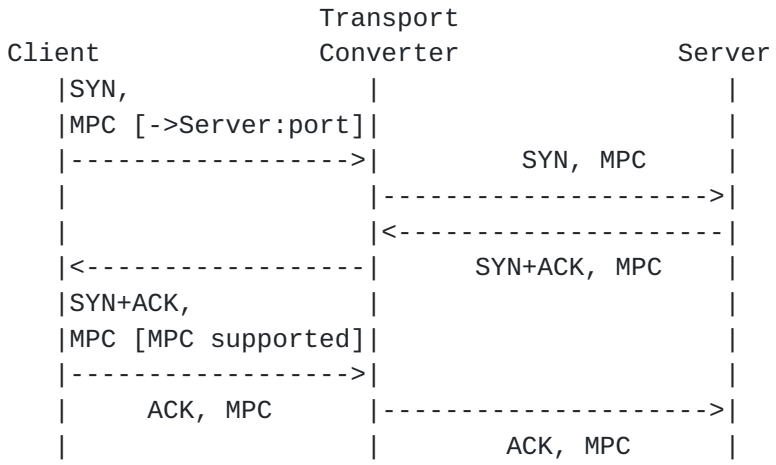


Figure 7: Establishment of a Multipath TCP Connection Through a Converter Towards an MPTCP-capable Server

3.4. Sample Example of Incoming Converter-Assisted Multipath TCP Connection

An example of an incoming Converter-assisted Multipath TCP connection is depicted in Figure 8. In order to support incoming connections from remote hosts, the Client may use PCP [RFC6887] to instruct the Transport Converter to create dynamic mappings. Those mappings will be used by the Transport Converter to intercept an incoming TCP connection destined to the Client and convert it into a Multipath TCP connection.

Typically, the Client sends a PCP request to the Converter asking to create an explicit TCP mapping for (internal IP address, internal port number). The Converter accepts the request by creating a TCP mapping (internal IP address, internal port number, external IP address, external port number). The external IP address and external port number will be then advertised using an out-of-band mechanism so that remote hosts can initiate TCP connections to the Client via the Converter. Note that the external and internal information may be the same.

Then, when the Converter receives an incoming SYN, it checks its mapping table to verify if there is an active mapping matching the destination IP address and destination port of that SYN. If an entry is found, the Converter inserts an MP_CAPABLE option and Connect TLV in the SYN packet, rewrites the source IP address to one of its IP addresses and, eventually, the destination IP address and port number in accordance with the information stored in the mapping. SYN-ACK and ACK will be then exchanged between the Client and the Converter to confirm the establishment of the initial subflow. The Client can add new subflows following normal Multipath TCP procedures.

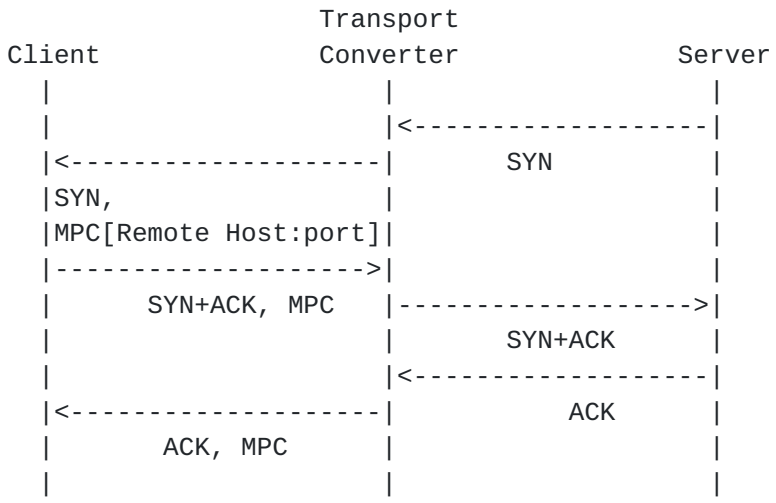


Figure 8: Establishment of an Incoming TCP Connection through a Transport Converter

It is out of scope of this document to define specific Convert TLVs to manage incoming connections. These TLVs can be defined in a separate document.

4. The Convert Protocol (Convert)

This section describes the messages that are exchanged between a Client and a Transport Converter. The Convert Protocol (Convert, for short) uses a 32 bits long fixed header that is sent by both the Client and the Transport Converter over each established connection. This header indicates both the version of the protocol used and the length of the Convert message.

4.1. The Convert Fixed Header

The Fixed Header is used to convey information about the version and length of the messages exchanged between the Client and the Transport Converter.

The Client and the Transport Converter MUST send the fixed-sized header, shown in Figure 9, as the first four bytes of the bytestream.

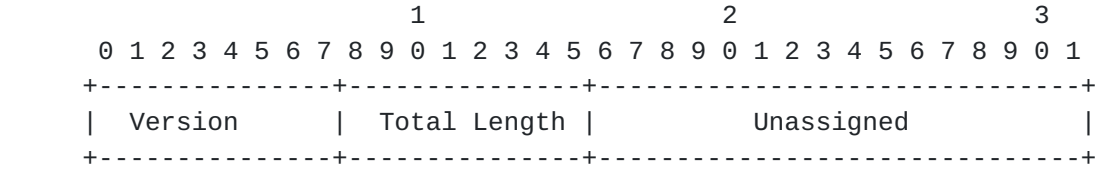


Figure 9: The Fixed-Sized Header of the Convert Protocol

The Version is encoded as an 8 bits unsigned integer value. This document specifies version 1. Version 0 is reserved by this document and MUST NOT be used.

The Total Length is the number of 32 bits word, including the header, of the bytestream that are consumed by the Convert messages. Since Total Length is also an 8 bits unsigned integer, those messages cannot consume more than 1020 bytes of data. This limits the number of bytes that a Transport Converter needs to process. A Total Length of zero is invalid and the connection MUST be reset upon reception of a header with such total length.

The Unassigned field MUST be set to zero in this version of the protocol. These bits are available for future use [RFC8126].

Data added by the Convert protocol to the TCP bytestream in the upstream connection is unambiguously distinguished from payload data in the downstream connection by the Total Length field in the Convert messages.

4.2. Convert TLVs

4.2.1. Generic Convert TLV Format

The Convert protocol uses variable length messages that are encoded using the generic TLV (Type, Length, Value) format depicted in Figure 10.

The length of all TLVs used by the Convert protocol is always a multiple of four bytes. All TLVs are aligned on 32 bits boundaries. All TLV fields are encoded using the network byte order.

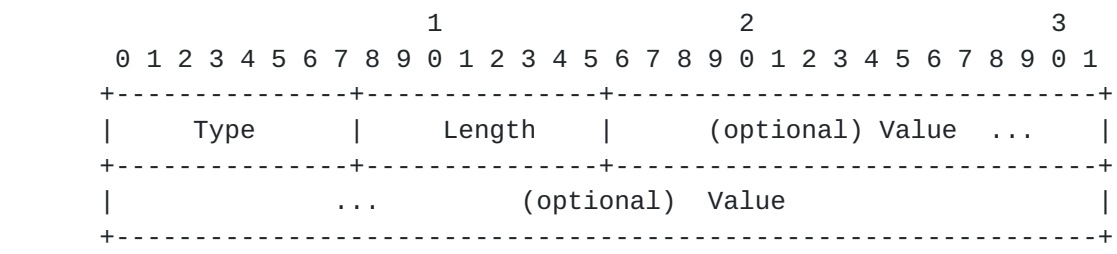


Figure 10: Convert Generic TLV Format

The Length field is expressed in units of 32 bits words. In general zero padding MUST be added if the value's length in bytes can not be expressed as 2+(4 * n).

A given TLV MUST only appear once on a connection. If two or more instances of the same TLV are exchanged over a Convert connection, the associated TCP connections MUST be closed.

4.2.2. Summary of Supported Convert TLVs

This document specifies the following Convert TLVs:

Type	Hex	Length	Description
1	0x1	1	Info TLV
10	0xA	Variable	Connect TLV
20	0x14	Variable	Extended TCP Header TLV
21	0x15	Variable	Supported TCP Extensions TLV
22	0x16	Variable	Cookie TLV
30	0x1E	Variable	Error TLV

Figure 11: The TLVs used by the Convert Protocol

Type 0x0 is a reserved valued. Implementations MUST discard messages with such TLV.

The Client can request the establishment of connections to servers by using the Connect TLV (Section 4.2.5). If the connection can be established with the final server, the Transport Converter replies with the Extended TCP Header TLV (Section 4.2.4). If not, the Transport Converter returns an Error TLV (Section 4.2.8) and then closes the connection.

As a general rule, when an error is encountered an Error TLV with the appropriate error code MUST be returned by the Transport Converter.

4.2.3. The Info TLV

The Info TLV (Figure 12) is an optional TLV which can be sent by a Client to request the TCP extensions that are supported by a Transport Converter. It is typically sent on the first connection that a Client establishes with a Transport Converter to learn its capabilities. Assuming a Client is entitled to invoke the Transport Converter, the latter replies with the Supported TCP Extensions TLV described in Section 4.2.4.

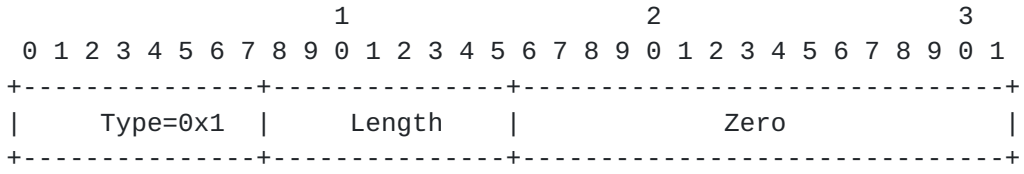


Figure 12: The Info TLV

4.2.4. Supported TCP Extensions TLV

The Supported TCP Extensions TLV (Figure 13) is used by a Transport Converter to announce the TCP options for which it provides a conversion service. A Transport Converter SHOULD include in this list the TCP options that it accepts from Clients and that it includes the SYN packets that it sends to initiate connections.

Each supported TCP option is encoded with its TCP option Kind listed in the "TCP Parameters" registry maintained by IANA.

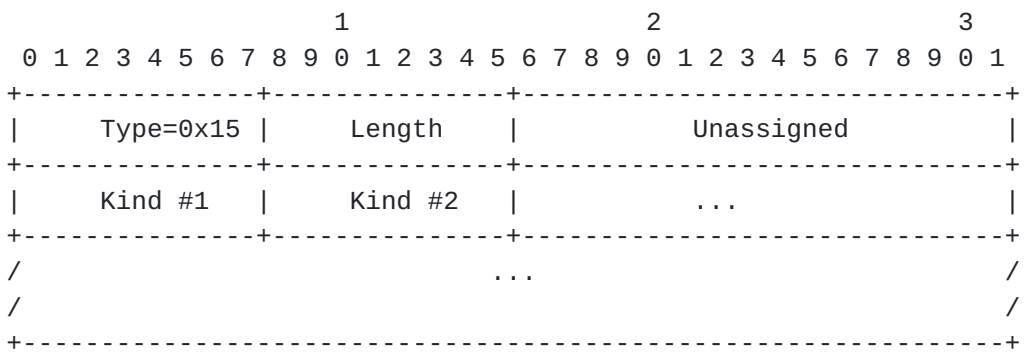


Figure 13: The Supported TCP Extensions TLV

TCP option Kinds 0, 1, and 2 defined in [RFC0793] are supported by all TCP implementations and thus MUST NOT appear in this list.

The list of Supported TCP Extension is padded with 0 to end on a 32 bits boundary.

For example, if the Transport Converter supports Multipath TCP, Kind=30 will be present in the Supported TCP Extensions TLV that it returns in response to Info TLV.

4.2.5. Connect TLV

The Connect TLV (Figure 14) is used to request the establishment of a connection via a Transport Converter. This connection can be from or to a client.

The 'Remote Peer Port' and 'Remote Peer IP Address' fields contain the destination port number and IP address of the Server, for outgoing connections. For incoming connections destined to a Client serviced via a Transport Converter, these fields convey the source port number and IP address.

The Remote Peer IP Address MUST be encoded as an IPv6 address. IPv4 addresses MUST be encoded using the IPv4-Mapped IPv6 Address format defined in [RFC4291]. Further, Remote Peer IP address field MUST NOT include multicast, broadcast, and host loopback addresses [RFC6890]. Connect TLVs witch such messages MUST be discarded by the Transport Converter.

We distinguish two types of Connect TLV based on their length: (1) the base Connect TLV has a length of 20 bytes and contains a remote address and a remote port, (2) the extended Connect TLV spans more than 20 bytes and also includes the optional 'TCP Options' field. This field is used to specify how specific TCP options should be advertised by the Transport Converter to the server.

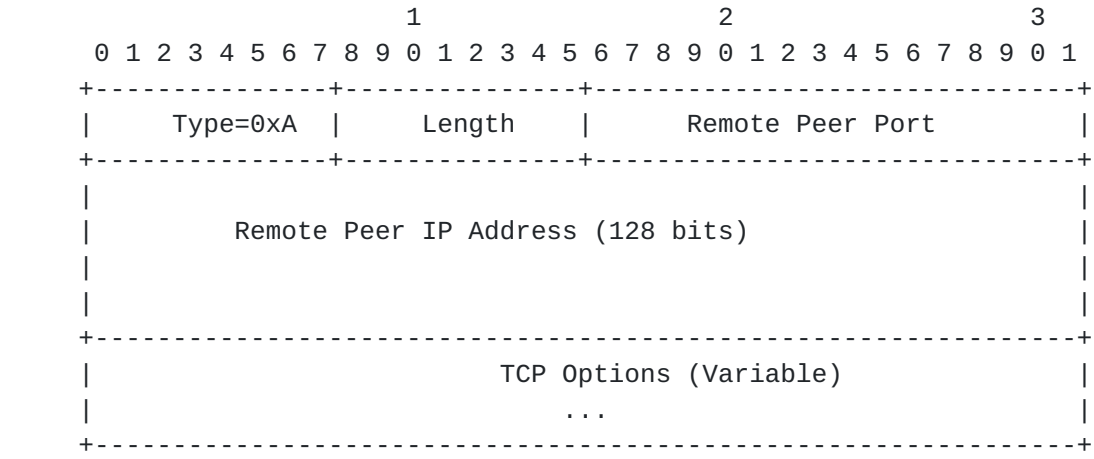


Figure 14: The Connect TLV

The 'TCP Options' field is a variable length field that carries a list of TCP option fields (Figure 15). Each TCP option field is

encoded as a block of 2+n bytes where the first byte is the TCP option Kind and the second byte is the length of the TCP option as specified in [RFC0793]. The minimum value for the TCP option Length is 2. The TCP options that do not include a length subfield, i.e., option types 0 (EOL) and 1 (NOP) defined in [RFC0793] MUST NOT be placed inside the TCP options field of the Connect TLV. The optional Value field contains the variable-length part of the TCP option. A length of two indicates the absence of the Value field. The TCP options field always ends on a 32 bits boundary after being padded with zeros.

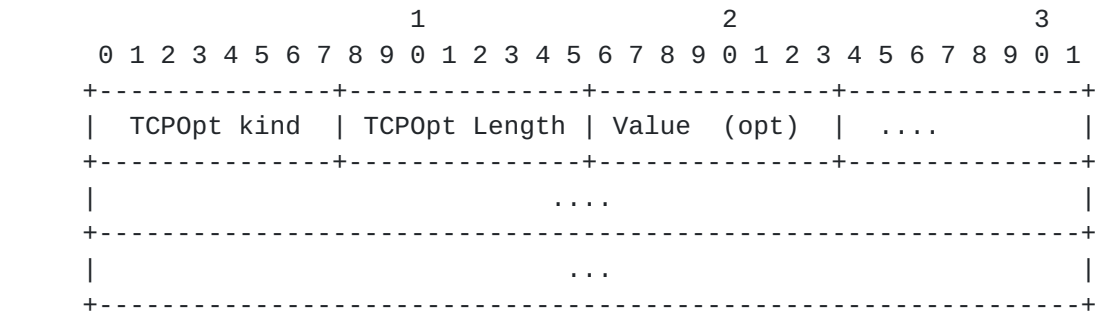


Figure 15: The TCP Options Field

Upon reception of a Connect TLV, and absent any policy (e.g., rate-limit) or resource exhaustion conditions, a Transport Converter attempts to establish a connection to the address and port that it contains. The Transport Converter MUST use by default the TCP options that correspond to its local policy to establish this connection. These are the options that it advertises in the Supported TCP Extensions TLV.

Upon reception of an extended Connect TLV, and absent any rate limit policy or resource exhaustion conditions, a Transport Converter MUST attempt to establish a connection to the address and port that it contains. It MUST include the options of the 'TCP Options' subfield in the SYN sent to the Server in addition to the TCP options that it would have used according to its local policies. For the TCP options that are listed without an optional value, the Transport Converter MUST generate its own value. For the TCP options that are included in the 'TCP Options' field with an optional value, it MUST copy the entire option for use in the connection with the destination peer. This feature is required to support TCP Fast Open.

The Transport Converter may discard a Connect TLV request for various reasons (e.g., authorization failed, out of resources, invalid address type). An error message indicating the encountered error is returned to the requesting Client (Section 4.2.8). In order to

prevent denial-of-service attacks, error messages sent to a Client SHOULD be rate-limited.

4.2.6. Extended TCP Header TLV

The Extended TCP Header TLV (Figure 16) is used by the Transport Converter to send to the Client the extended TCP header that was returned by the Server in the SYN+ACK packet. This TLV is only sent if the Client sent a Connect TLV to request the establishment of a connection.

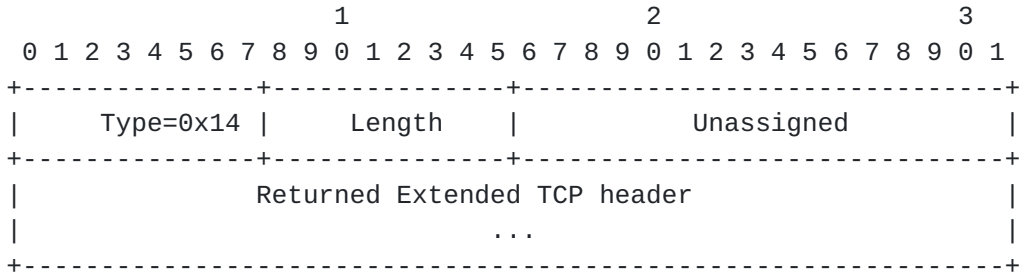


Figure 16: The Extended TCP Header TLV

The Returned Extended TCP header field is a copy of the extended header that was received in the SYN+ACK by the Transport Converter.

The Unassigned field MUST be set to zero by the transmitter and ignored by the receiver. These bits are available for future use [RFC8126].

4.2.7. The Cookie TLV

The Cookie TLV (Figure 17 is an optional TLV which use is similar to the TCP Fast Open Cookie [RFC7413]. A Transport Converter may want to verify that its Clients can receive the packets that it sends to prevent attacks from spoofed addresses. This verification can be done by using a Cookie that is bound to, for example, the IP address(es) of the Client. This Cookie can be configured on the Client by means that are outside of this document or provided by the Transport Converter as follows.

A Transport Converter that has been configured to use the optional Cookie TLV MUST verify the presence of this TLV in the payload of the received SYN. If this TLV is present, the Transport Converter MUST validate the Cookie by means similar to those in Section 4.1.2 of [RFC7413] (i.e., IsCookieValid). If the Cookie is valid, the connection establishment procedure can continue. Otherwise, the Transport Converter MUST return an Error TLV set to "Not Authorized" and close the connection.

If the received SYN did not contain a Cookie TLV, and cookie validation is required, the Transport Converter should compute a Cookie bound to this Client address and return a Convert message containing the fixed header, an Error TLV set to "Missing Cookie" and the computed Cookie and close the connection. The Client will react to this error by storing the received Cookie in its cache and attempt to reestablish a new connection to the Transport Converter that includes the Cookie.

The format of the Cookie TLV is shown in the below figure.

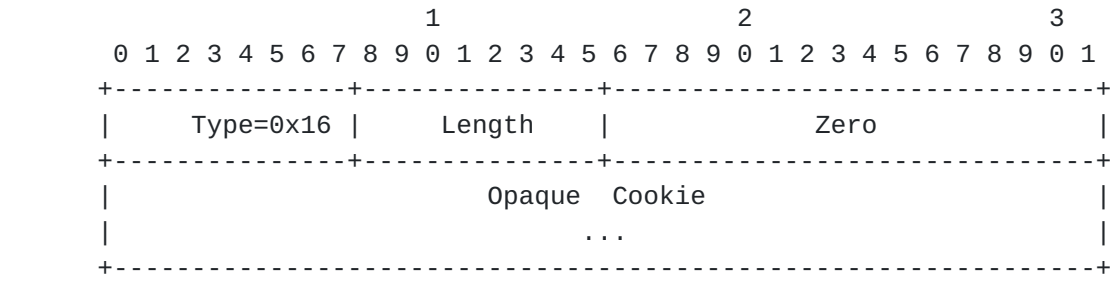


Figure 17: The Cookie TLV

4.2.8. Error TLV

The Error TLV (Figure 18) is used by the Transport Converter to provide information about some errors that occurred during the processing of Convert message. This TLV has a variable length. It appears after the Convert fixed-header in the bytestream returned by the Transport Converter. Upon reception of an Error TLV, a Client MUST close the associated connection.

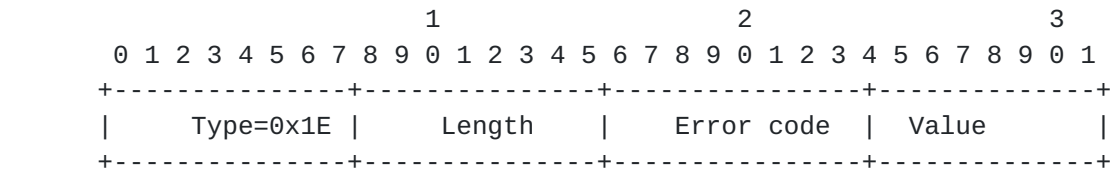


Figure 18: The Error TLV

Different types of errors can occur while processing Convert messages. Each error is identified by an Error code represented as an unsigned integer. Four classes of Error codes are defined:

- Message validation and processing errors (0-31 range): returned upon reception of an invalid message (including valid messages but with invalid or unknown TLVs).

- Client-side errors (32-63 range): the Client sent a request that could not be accepted by the Transport Converter (e.g., unsupported operation).

- Converter-side errors (64-95 range): problems encountered on the Transport Converter (e.g., lack of resources) which prevent it from fulfilling the Client's request.

- Errors caused by the destination server (96-127 range): the final destination could not be reached or it replied with a reset.

The following error codes are defined in this document:

- Unsupported Version (0): The version number indicated in the fixed header of a message received from a peer is not supported.

  This error code MUST be generated by a Transport Converter when it receives a request having a version number that it does not support.

  The value field MUST be set to the version supported by the Transport Converter. When multiple versions are supported by the Transport Converter, it includes the list of supported version in the value field; each version is encoded in 8 bits. The list of supported versions should be padded with zeros to end on a 32 bits boundary.

  Upon receipt of this error code, the client checks whether it supports one of the versions returned by the Transport Converter. The highest common supported version MUST be used by the client in subsequent exchanges with the Transport Converter.

- Malformed Message (1): This error code is sent to indicate that a message can not be successfully parsed and validated.

  Typically, this error code is sent by the Transport Converter if it receives a Connect TLV enclosing a multicast, broadcast, or loopback IP address.

  To ease troubleshooting, the value field MUST echo the received message shifted by one byte to keep to original alignment of the message.

- Unsupported Message (2): This error code is sent to indicate that a message type is not supported by the Transport Converter.

To ease troubleshooting, the value field MUST echo the received message shifted by one byte to keep to original alignment of the message.

- Missing Cookie (3): If a Transport Converter requires the utilization of Cookies to prevent spoofing attacks and a Cookie TLV was not included in the Convert message, the Transport Converter MUST return this error to the requesting client. The first byte of the value field MUST be set to zero and the remaining bytes of the Error TLV contain the Cookie computed by the Transport Converter for this Client.

  A Client which receives this error code MUST cache the received Cookie and include it in subsequent Convert messages sent to that Transport Converter.

- Not Authorized (32): This error code indicates that the Transport Converter refused to create a connection because of a lack of authorization (e.g., administratively prohibited, authorization failure, invalid Cookie TLV, etc.). The Value field MUST be set to zero.

  This error code MUST be sent by the Transport Converter when a request cannot be successfully processed because the authorization failed.

- Unsupported TCP Option (33): A TCP option that the Client requested to advertise to the final Server cannot be safely used.

  The Value field is set to the type of the unsupported TCP option. If several unsupported TCP options were specified in the Connect TLV, then the list of unsupported TCP options is returned. The list of unsupported TCP options MUST be padded with zeros to end on a 32 bits boundary.

- Resource Exceeded (64): This error indicates that the Transport Converter does not have enough resources to perform the request.

  This error MUST be sent by the Transport Converter when it does not have sufficient resources to handle a new connection. The Transport Converter may indicate in the Value field the suggested delay (in seconds) that the Client SHOULD wait before soliciting the Transport Converter for a new proxied connection. A Value of zero corresponds to a default delay of at least 30 seconds.

- Network Failure (65): This error indicates that the Transport Converter is experiencing a network failure to relay the request.

The Transport Converter MUST send this error code when it experiences forwarding issues to relay a connection. The Transport Converter may indicate in the Value field the suggested delay (in seconds) that the Client SHOULD wait before soliciting the Transport Converter for a new proxied connection. A Value of zero corresponds to a default delay of at least 30 seconds.

- Connection Reset (96): This error indicates that the final destination responded with a RST packet. The Value field MUST be set to zero.

- Destination Unreachable (97): This error indicates that an ICMP destination unreachable, port unreachable, or network unreachable was received by the Transport Converter. The Value field MUST echo the Code field of the received ICMP message.

Figure 19 summarizes the different error codes.

Error	Hex	Description
0	0x00	Unsupported Version
1	0x01	Malformed Message
2	0x02	Unsupported Message
3	0x03	Missing Cookie
32	0x20	Not Authorized
33	0x21	Unsupported TCP Option
64	0x40	Resource Exceeded
65	0x41	Network Failure
96	0x60	Connection Reset
97	0x61	Destination Unreachable

Figure 19: Convert Error Values

5. Compatibility of Specific TCP Options with the Conversion Service

In this section, we discuss how several standard track TCP options can be supported through the Convert protocol. The non-standard track options and the experimental options will be discussed in other documents.

5.1. Base TCP Options

Three TCP options were initially defined in [RFC0793]: End-of-Option List (Kind=0), No-Operation (Kind=1) and Maximum Segment Size (Kind=2). The first two options are mainly used to pad the TCP extended header. There is no reason for a client to request a

Transport Converter to specifically send these options towards the final destination.

The Maximum Segment Size option (Kind=2) is used by a host to indicate the largest segment that it can receive over each connection. This value is function of the stack that terminates the TCP connection. There is no reason for a Client to request a Transport Converter to advertise a specific MSS value to a remote server.

A Transport Converter MUST ignore options with Kind=0, 1 or 2 if they appear in a Connect TLV. It MUST NOT announce them in a Supported TCP Extensions TLV.

5.2. Window Scale (WS)

The Window Scale option (Kind=3) is defined in [RFC7323]. As for the MSS option, the window scale factor that is used for a connection strongly depends on the TCP stack that handles the connection. When a Transport Converter opens a TCP connection towards a remote server on behalf of a Client, it SHOULD use a WS option with a scaling factor that corresponds to the configuration of its stack. A local configuration MAY allow for WS option in the proxied message to be function of the scaling factor of the incoming connection.

There is no benefit from a deployment viewpoint in enabling a Client of a Transport Converter to specifically request the utilisation of the WS option (Kind=3) with a specific scaling factor towards a remote Server. For this reason, a Transport Converter MUST ignore option Kind=3 if it appears in a Connect TLV. It MUST NOT announce it in a Supported TCP Extensions TLV.

5.3. Selective Acknowledgements

Two distinct TCP options were defined to support selective acknowledgements in [RFC2018]. This first one, SACK Permitted (Kind=4), is used to negotiate the utilisation of selective acknowledgements during the three-way handshake. The second one, SACK (Kind=5), carries the selective acknowledgements inside regular segments.

The SACK Permitted option (Kind=4) MAY be advertised by a Transport Converter in the Supported TCP Extensions TLV. Clients connected to this Transport Converter MAY include the SACK Permitted option in the Connect TLV.

The SACK option (Kind=5) cannot be used during the three-way handshake. For this reason, a Transport Converter MUST ignore option

Kind=5 if it appears in a Connect TLV. It MUST NOT announce it in a TCP Supported Extensions TLV.

5.4. Timestamp

The Timestamp option was initially defined in [RFC1323] and later refined in [RFC7323]. It can be used during the three-way handshake to negotiate the utilization of timestamps during the TCP connection. It is notably used to improve round-trip-time estimations and to provide protection against wrapped sequence numbers (PAWS). As for the WS option, the timestamps are a property of a connection and there is limited benefit in enabling a client to request a Transport Converter to use the timestamp option when establishing a connection to a remote server. Furthermore, the timestamps that are used by TCP stacks are specific to each stack and there is no benefit in enabling a client to specify the timestamp value that a Transport Converter could use to establish a connection to a remote server.

A Transport Converter MAY advertise the Timestamp option (Kind=8) in the TCP Supported Extensions TLV. The clients connected to this Transport Converter MAY include the Timestamp option in the Connect TLV but without any timestamp.

5.5. Multipath TCP

The Multipath TCP options are defined in [RFC6824]. [RFC6824] defines one variable length TCP option (Kind=30) that includes a subtype field to support several Multipath TCP options. There are several operational use cases where clients would like to use Multipath TCP through a Transport Converter [IETFJ16]. However, none of these use cases require the Client to specify the content of the Multipath TCP option that the Transport Converter should send to a remote server.

A Transport Converter which supports Multipath TCP conversion service MUST advertise the Multipath TCP option (Kind=30) in the Supported TCP Extensions TLV. Clients serviced by this Transport Converter may include the Multipath TCP option in the Connect TLV but without any content.

5.6. TCP Fast Open

The TCP Fast Open cookie option (Kind=34) is defined in [RFC7413]. There are two different usages of this option that need to be supported by Transport Converters. The first utilization of the TCP Fast Open cookie option is to request a cookie from the server. In this case, the option is sent with an empty cookie by the client and the server returns the cookie. The second utilization of the TCP

Fast Open cookie option is to send a cookie to the server. In this case, the option contains a cookie.

A Transport Converter MAY advertise the TCP Fast Open cookie option (Kind=34) in the Supported TCP Extensions TLV. If a Transport Converter has advertised the support for TCP Fast Open in its Supported TCP Extensions TLV, it needs to be able to process two types of Connect TLV. If such a Transport Converter receives a Connect TLV with the TCP Fast Open cookie option that does not contain a cookie, it MUST add an empty TCP Fast Open cookie option in the SYN sent to the remote server. If such a Transport Converter receives a Connect TLV with the TCP Fast Open cookie option that contains a cookie, it MUST copy the TCP Fast Open cookie option in the SYN sent to the remote server.

5.7. TCP User Timeout

The TCP User Timeout option is defined in [RFC5482]. The associated TCP option (Kind=28) does not appear to be widely deployed.

5.8. TCP-AO

TCP-AO [RFC5925] provides a technique to authenticate all the packets exchanged over a TCP connection. Given the nature of this extension, it is unlikely that the applications that require their packets to be authenticated end-to-end would want their connections to pass through a converter. For this reason, we do not recommend the support of the TCP-AO option by Transport Converters. The only use cases where it could make sense to combine TCP-AO and the solution in this document are those where the TCP-AO-NAT extension [RFC6978] is in use.

A Transport Converter MUST NOT advertise the TCP-AO option (Kind=29) in the Supported TCP Extensions TLV. If a Transport Converter receives a Connect TLV that contains the TCP-AO option, it MUST reject the establishment of the connection with error code set to "Unsupported TCP Option", except if the TCP-AO-NAT option is used.

5.9. TCP Experimental Options

The TCP Experimental options are defined in [RFC4727]. Given the variety of semantics for these options and their experimental nature, it is impossible to discuss them in details in this document.

6. Interactions with Middleboxes

The Convert Protocol is designed to be used in networks that do not contain middleboxes that interfere with TCP. Under such conditions, it is assumed that the network provider ensures that all involved on-

path nodes are not breaking TCP signals (e.g., strip TCP options, discard some SYNs, etc.).

Nevertheless, and in order to allow for a robust service, this section describes how a Client can detect middlebox interference and stop using the Transport Converter affected by this interference.

Internet measurements [IMC11] have shown that middleboxes can affect the deployment of TCP extensions. In this section, we only discuss the middleboxes that modify SYN and SYN+ACK packets since the Convert Protocol places its messages in such packets.

Consider a middlebox that removes the SYN payload. The Client can detect this problem by looking at the acknowledgement number field of the SYN+ACK returned by the Transport Converter. The Client MUST stop to use this Transport Converter given the middlebox interference.

As explained in [RFC7413], some CGNs (Carrier Grade NATs) can affect the operation of TFO if they assign different IP addresses to the same end host. Such CGNs could affect the operation of the TFO Option used by the Convert Protocol. As a reminder CGNs, enabled on the path between a Client and a Transport Converter, must adhere to the address preservation defined in [RFC6888]. See also the discussion in Section 7.1 of [RFC7413].

7. Security Considerations

7.1. Privacy & Ingress Filtering

The Transport Converter may have access to privacy-related information (e.g., subscriber credentials). The Transport Converter is designed to not leak such sensitive information outside a local domain.

Given its function and its location in the network, a Transport Converter has access to the payload of all the packets that it processes. As such, it MUST be protected as a core IP router (e.g., [RFC1812]).

Furthermore, ingress filtering policies MUST be enforced at the network boundaries [RFC2827].

This document assumes that all network attachments are managed by the same administrative entity. Therefore, enforcing anti-spoofing filters at these network ensures that hosts are not sending traffic with spoofed source IP addresses.

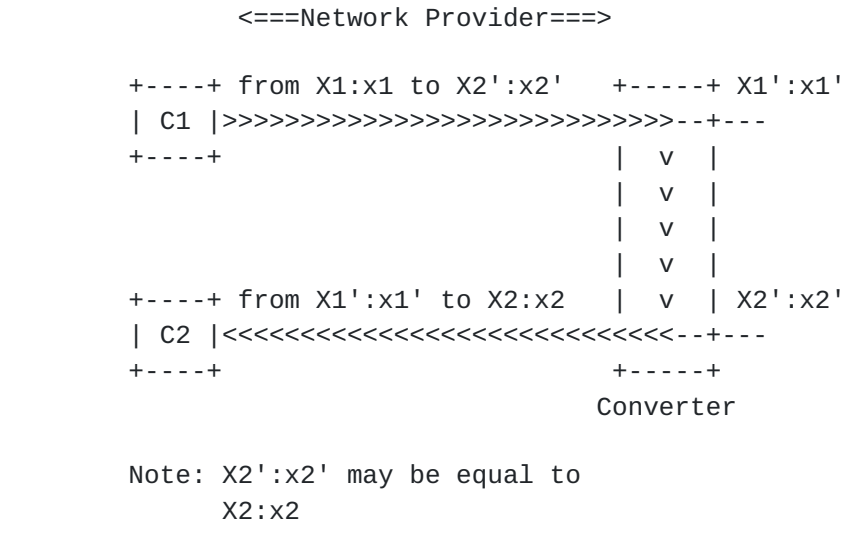
7.2. Authorization

The Convert Protocol is intended to be used in managed networks where end hosts can be identified by their IP address.

Stronger mutual authentication schemes MUST be defined to use the Convert Protocol in more open network environments. One possibility is to use TLS to perform mutual authentication between the client and the Converter. That is, use TLS when a Client retrieves a Cookie from the Converter and rely on certificate-based client authentication, pre-shared key based [RFC4279] or raw public key based client authentication [RFC7250] to secure this connection.

If the authentication succeeds, the Converter returns a cookie to the Client. Subsequent Connect messages will be authorized as a function of the content of the Cookie TLV.

In deployments where network-assisted connections are not allowed between hosts of a domain (i.e., hairpinning), the Converter may be instructed to discard such connections. Hairpinned connections are thus rejected by the Transport Converter by returning an Error TLV set to "Not Authorized". Absent explicit configuration otherwise, hairpinning is enabled by the Converter (see Figure 20.


<===Network Provider===>
+----+ from X1:x1 to X2':x2'
| C1 |>>>

7.3. Denial of Service

Another possible risk is the amplification attacks since a Transport Converter sends a SYN towards a remote Server upon reception of a SYN from a Client. This could lead to amplification attacks if the SYN sent by the Transport Converter were larger than the SYN received from the Client or if the Transport Converter retransmits the SYN. To mitigate such attacks, the Transport Converter SHOULD rate limit the number of pending requests for a given Client. It SHOULD also avoid sending to remote Servers SYNs that are significantly longer than the SYN received from the Client. Finally, the Transport Converter SHOULD only retransmit a SYN to a Server after having received a retransmitted SYN from the corresponding Client. Means to protect against SYN flooding attacks MUST also be enabled [RFC4987].

7.4. Traffic Theft

Traffic theft is a risk if an illegitimate Converter is inserted in the path. Indeed, inserting an illegitimate Converter in the forwarding path allows traffic interception and can therefore provide access to sensitive data issued by or destined to a host. Converter discovery and configuration are out of scope of this document.

7.5. Multipath TCP-specific Considerations

Multipath TCP-related security threats are discussed in [RFC6181] and [RFC6824].

The operator that manages the various network attachments (including the Transport Converters) can enforce authentication and authorization policies using appropriate mechanisms. For example, a non-exhaustive list of methods to achieve authorization is provided hereafter:

- The network provider may enforce a policy based on the International Mobile Subscriber Identity (IMSI) to verify that a user is allowed to benefit from the aggregation service. If that authorization fails, the Packet Data Protocol (PDP) context/bearer will not be mounted. This method does not require any interaction with the Transport Converter.

- The network provider may enforce a policy based upon Access Control Lists (ACLs), e.g., at a Broadband Network Gateway (BNG) to control the hosts that are authorized to communicate with a Transport Converter. These ACLs may be installed as a result of RADIUS exchanges, e.g., [I-D.boucadair-radext-tcpm-converter]. This method does not require any interaction with the Transport Converter.

- A device that embeds a Transport Converter may also host a RADIUS client that will solicit an AAA server to check whether connections received from a given source IP address are authorized or not [I-D.boucadair-radext-tcpm-converter].

A first safeguard against the misuse of Transport Converter resources by illegitimate users (e.g., users with access networks that are not managed by the same provider that operates the Transport Converter) is the Transport Converter to reject Multipath TCP connections received on its Internet-facing interfaces. Only Multipath TCP connections received on the customer-facing interfaces of a Transport Converter will be accepted.

8. IANA Considerations

8.1. Convert Service Port Number

IANA is requested to assign a TCP port number (TBA) for the Convert Protocol from the "Service Name and Transport Protocol Port Number Registry" available at https://www.iana.org/assignments/service-names-port-numbers/service-names-port-numbers.xhtml.

8.2. The Convert Protocol (Convert) Parameters

IANA is requested to create a new "The Convert Protocol (Convert) Parameters" registry.

The following subsections detail new registries within "The Convert Protocol (Convert) Parameters" registry.

8.2.1. Convert Versions

IANA is requested to create the "Convert versions" sub-registry. New values are assigned via IETF Review (Section 4.8 of [RFC8126]).

The initial values to be assigned at the creation of the registry are as follows:

Version	Description	Reference
0	Reserved by this document	[This-RFC]
1	Assigned by this document	[This-RFC]

8.2.2. Convert TLVs

IANA is requested to create the "Convert TLVs" sub-registry. The procedure for assigning values from this registry is as follows:

- The values in the range 1-127 can be assigned via IETF Review.
- The values in the range 128-191 can be assigned via Specification Required.
- The values in the range 192-255 can be assigned for Private Use.

The initial values to be assigned at the creation of the registry are as follows:

Code	Name	Reference
0	Reserved	[This-RFC]
1	Info TLV	[This-RFC]
10	Connect TLV	[This-RFC]
20	Extended TCP Header TLV	[This-RFC]
21	Supported TCP Extension TLV	[This-RFC]
22	Cookie TLV	[This-RFC]
30	Error TLV	[This-RFC]

8.2.3. Convert Error Messages

IANA is requested to create the "Convert Errors" sub-registry. Codes in this registry are assigned as a function of the error type. Four types are defined; the following ranges are reserved for each of these types:

- Message validation and processing errors: 0-31
- Client-side errors: 32-63
- Transport Converter-side errors: 64-95
- Errors caused by destination server: 96-127

The procedure for assigning values from this sub-registry is as follows:

- 0-191: Values in this range are assigned via IETF Review.

o 192-255: Values in this range are assigned via Specification Required.

The initial values to be assigned at the creation of the registry are as follows:

Error	Hex	Description	Reference
0	0x00	Unsupported Version	[This-RFC]|
1	0x01	Malformed Message	[This-RFC]|
2	0x02	Unsupported Message	[This-RFC]|
3	0x03	Missing Cookie	[This-RFC]|
32	0x20	Not Authorized	[This-RFC]|
33	0x21	Unsupported TCP Option	[This-RFC]|
64	0x40	Resource Exceeded	[This-RFC]|
65	0x41	Network Failure	[This-RFC]|
96	0x60	Connection Reset	[This-RFC]|
97	0x61	Destination Unreachable	[This-RFC]|

Figure 21: The Convert Error Codes

9. Acknowledgements

Although they could disagree with the contents of the document, we would like to thank Joe Touch and Juliusz Chroboczek whose comments on the MPTCP mailing list have forced us to reconsider the design of the solution several times.

We would like to thank Raphael Bauduin, Stefano Secci, Anandatirtha Nandugudi and Gregory Vander Schueren for their help in preparing this document. Nandini Ganesh provided valuable feedback about the handling of TFO and the error codes. Thanks to them.

Thanks to Yuchung Cheng and Praveen Balasubramanian for the discussion on supplying data in SYNs.

This document builds upon earlier documents that proposed various forms of Multipath TCP proxies [I-D.boucadair-mptcp-plain-mode], [I-D.peirens-mptcp-transparent] and [HotMiddlebox13b].

From [I-D.boucadair-mptcp-plain-mode]:

Many thanks to Chi Dung Phung, Mingui Zhang, Rao Shoaib, Yoshifumi Nishida, and Christoph Paasch for their valuable comments.

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9.1. Contributors

Bart Peirens contributed to an early version of the document.

As noted above, this document builds on two previous documents.

The authors of [I-D.boucadair-mptcp-plain-mode] were:

- Mohamed Boucadair
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10. Change Log

This section to be removed before publication.

- 00 : initial version, designed to support Multipath TCP and TFO only
- 00 to -01 : added section Section 5 describing the support of different standard tracks TCP options by Transport Converters, clarification of the IANA section, moved the SOCKS comparison to the appendix and various minor modifications
- 01 to -02: Minor modifications
- 02 to -03: Minor modifications
- 03 to -04: Minor modifications
- 04 to -05: Integrate a lot of feedback from implementors who have worked on client and server side implementations. The main modifications are the following :
  - TCP Fast Open is not strictly required anymore. Several implementors expressed concerns about this requirement. The TFO Cookie protects from some attack scenarios that affect open servers like web servers. The Convert protocol is different and as discussed in RFC7413, there are different ways to protect from such attacks. Instead of using a TFO cookie inside the TCP options, which consumes precious space in the extended TCP header, this version supports the utilisation of a Cookie that is placed in the SYN payload. This provides the same level of protection as a TFO Cookie in environments were such protection is required.
  - the Boostrap procedure has been simplified based on feedback from implementers
  - Error messages are not included in RST segments anymore but sent in the bytestream. Implementors have indicated that

processing such segments on clients was difficult on some platforms. This change simplifies client implementations.

* Many minor editorial changes to clarify the text based on implementors feedback.

o 05 to -06: Many clarifications to integrate the comments from the chairs in preparation to the WGLC:

* Updated IANA policy to require "IETF Review" instead of "Standard Action"

* Call out explicilty that data in SYNs are relayed by the Converter

* Reiterate the scope

* Hairpinning behavior can be disabled (policy-based)

* Fix nits

o 07:

* Update the text about supplying data in SYNs to make it clear that a constraint defined in RFC793 is relaxed folloiwng the same rationale as in RFC7413.

* Nits

* Added Appendix A on example Socket API changes

11. Example Socket API Changes to Support the 0-RTT Convert Protocol

11.1. Active Open (Client Side)

On the client side, the support of the 0-RTT Converter protocol does not require any other changes than those identified in Appendix A of [RFC7413]. Those modifications are already supported by multiple TCP stacks.

As an example, on Linux, a client can send the 0-RTT Convert message inside a SYN by using sendto with the MSG_FASTOPEN flag as shown in the example below:

```
s = socket(AF_INET, SOCK_STREAM, 0);

sendto(s, buffer, buffer_len, MSG_FASTOPEN,
               (struct sockaddr *) &server_addr, addr_len);
```

The client side of the Linux TCP TFO can be used in two different modes depending on the host configuration (sysctl tcp_fastopen variable):

- 0x1: (client) enables sending data in the opening SYN on the client.
- 0x4: (client) send data in the opening SYN regardless of cookie availability and without a cookie option.

By setting this configuration variable to 0x5, a Linux client using the above code would send data inside the SYN without using a TFO option.

11.2. Passive Open (Converter Side)

The Converter needs to enable the reception of data inside the SYN independently of the utilisation of the TFO option. This implies that the Transport Converter application cannot rely on the TFO cookies to validate the reachability of the IP address that sent the SYN. It must rely on other techniques, such as the Cookie TLV described in this document, to verify this reachability.

[RFC7413] suggested the utilisation of a TCP_FASTOPEN socket option the enable the reception of SYNs containing data. Later, Appendix A of [RFC7413], mentionned:

Traditionally, accept() returns only after a socket is connected. But, for a Fast Open connection, accept() returns upon receiving SYN with a valid Fast Open cookie and data, and the data is available to be read through, e.g., recvmsg(), read().

To support the 0-RTT Convert protocol, this behaviour should be modified as follows:

> Traditionally, accept() returns only after a socket is connected. But, for a Fast Open connection, accept() returns upon receiving a SYN with data, and the data is available to be read through, e.g., recvmsg(), read(). The application that receives such SYNs with data must be able to validate the reachability of the source of the SYN and also deal with replayed SYNs.

The Linux server side can be configured with the following sysctls:

- 0x2: (server) enables the server support, i.e., allowing data in a SYN packet to be accepted and passed to the application before 3-way handshake finishes.

o 0x200: (server) accept data-in-SYN w/o any cookie option present.

However, this configuration is system-wide. This is convenient for typical Transport Converter deployments where no other applications relying on TFO are collocated on the same device.

Recently, the TCP_FASTOPEN_NO_COOKIE socket option has been added to provide the same behaviour on a per socket basis. This enables a single host to support both servers that require the TFO cookie and servers that do not use it.

12. Differences with SOCKSv5

At a first glance, the solution proposed in this document could seem similar to the SOCKS v5 protocol [RFC1928] which is used to proxy TCP connections. The Client creates a connection to a SOCKS proxy, exchanges authentication information and indicates the destination address and port of the final server. At this point, the SOCKS proxy creates a connection towards the final server and relays all data between the two proxied connections. The operation of an implementation based on SOCKSv5 is illustrated in Figure 22.

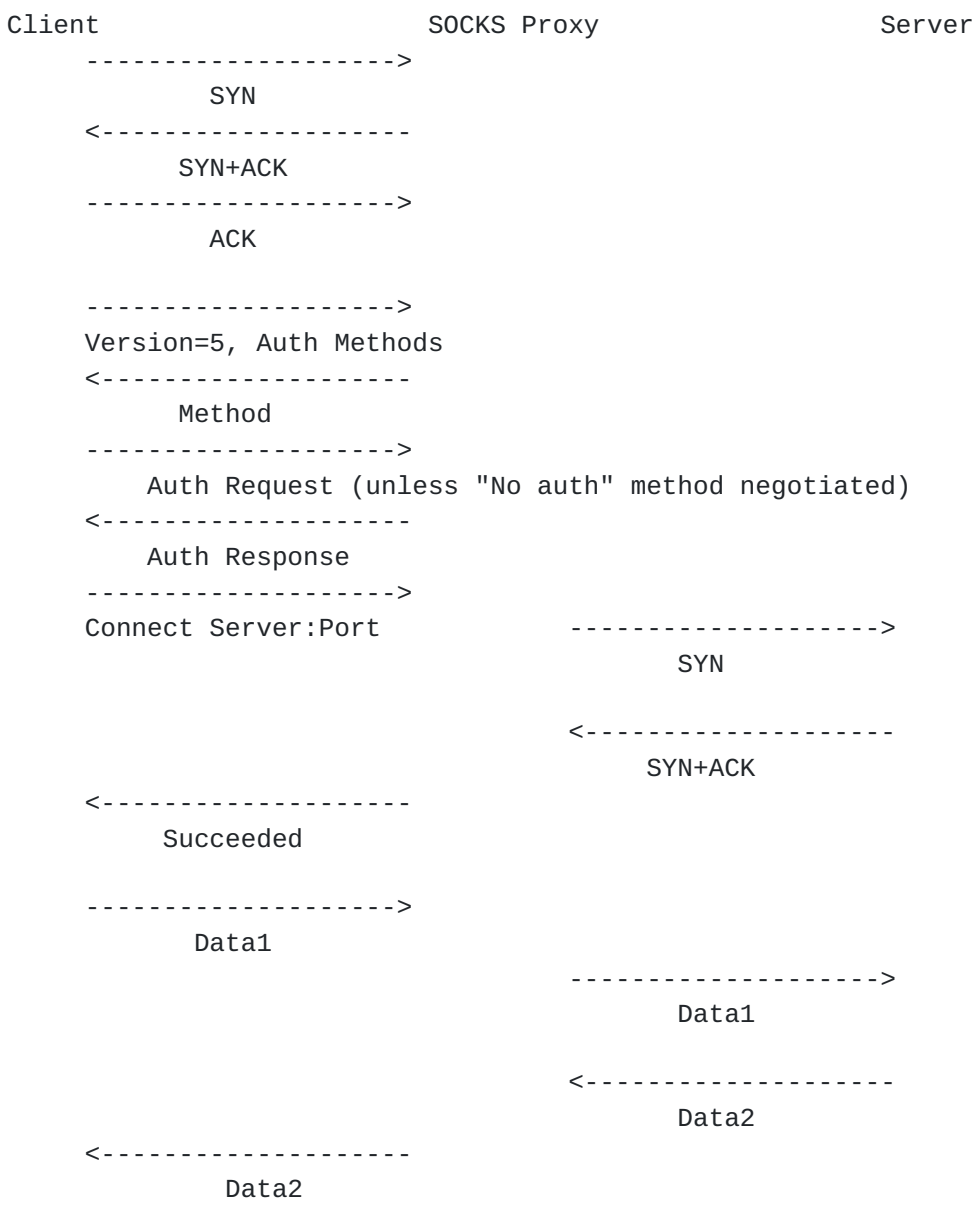


Figure 22: Establishment of a TCP connection through a SOCKS proxy without authentication

The Convert protocol also relays data between an upstream and a downstream connection, but there are important differences with SOCKSv5.

A first difference is that the Convert protocol exchanges all control information during the three-way handshake. This reduces the connection establishment delay compared to SOCKS that requires two or more round-trip-times before the establishment of the downstream connection towards the final destination. In today's Internet, latency is a important metric and various protocols have been tuned

to reduce their latency [I-D.arkko-arch-low-latency]. A recently proposed extension to SOCKS also leverages the TFO option [I-D.olteanu-intarea-socks-6].

A second difference is that the Convert protocol explicitly takes the TCP extensions into account. By using the Convert protocol, the Client can learn whether a given TCP extension is supported by the destination Server. This enables the Client to bypass the Transport Converter when the destination supports the required TCP extension. Neither SOCKS v5 [RFC1928] nor the proposed SOCKS v6 [I-D.olteanu-intarea-socks-6] provide such a feature.

A third difference is that a Transport Converter will only accept the connection initiated by the Client provided that the downstream connection is accepted by the Server. If the Server refuses the connection establishment attempt from the Transport Converter, then the upstream connection from the Client is rejected as well. This feature is important for applications that check the availability of a Server or use the time to connect as a hint on the selection of a Server [RFC8305].

A fourth difference is that the Convert protocol only allows the client to specify the address/port of the destination server and not a DNS name. We evaluated an alternate design for the Connect TLV that included the DNS name of the remote peer instead of its IP address as in SOCKS [RFC1928]. However, that design was not adopted because it induces both an extra load and increased delays on the Transport Converter to handle and manage DNS resolution requests.

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