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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. A Transport Converter may provide conversion service for one or more TCP extensions. The conversion service is provided by means of the TCP Convert Protocol (Convert).

This protocol provides 0-RTT (Zero Round-Trip Time) conversion service since no extra delay is induced by the protocol compared to connections that are not proxied. Also, the Convert Protocol does not require any encapsulation (no tunnels, whatsoever).

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

Status of This Memo

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1. Introduction

1.1. The Problem

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 Acknowledgments [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 Acknowledgments, 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. Some assistance from the network to make use of these features is valuable. For example, 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 (MPTCP) [[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 hand-overs, or better resiliency. Unfortunately, deploying those extensions on both a wide range of clients and servers remains difficult.

More recently, 5G bonding experimentation has been conducted into global range of the incumbent 4G (LTE) connectivity using newly devised clients and a Multipath TCP proxy. Even if the 5G and the 4G bonding relying upon 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 Traffic Steering, Switching, and Splitting (ATSSS) must be optimized to reduce latency [[TS23501](#)].

1.2. Network-Assisted Connections: The Rationale

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 a dedicated TCP port number.

The Convert Protocol provides 0-RTT (Zero Round-Trip Time) conversion service since no extra delay is induced by the protocol compared to connections that are not proxied. Particularly, the Convert Protocol does not require extra signaling setup delays before making use of

the conversion service. The Convert Protocol does not require any encapsulation (no tunnels, whatsoever).

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

- o Listen for client sessions;
- o Receive from a client the address of the final target server;
- o Setup a session to the final server;
- o Relay control messages and data between the client and the server;
- o 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 extensions 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.

The use of a Transport Converter means that there is no end-to-end transport connection between the client and server. This could potentially create problems in some scenarios such as those discussed in [Section 4 of \[RFC3135\]](#). Some of these problems may not be

applicable, for example, a Transport Converter can inform a client by means of Network Failure (65) or Destination Unreachable (97) error messages ([Section 6.2.8](#)) that it encounters a failure problem; the client can react accordingly. An endpoint, or its network administrator, can assess the benefit provided by the Transport Converter service versus the risk. This is one reason why the Transport Converter functionality has to be explicitly requested by an endpoint.

This document is organized as follows. First, [Section 2](#) provides a brief overview of the differences between the well-known SOCKS protocol and the 0-RTT Convert protocol. [Section 4](#) provides a brief explanation of the operation of Transport Converters. Then, [Section 6](#) describes the Convert Protocol. [Section 7](#) discusses how Transport Converters can be used to support different TCP extensions. [Section 8](#) then discusses the interactions with middleboxes, while [Section 9](#) focuses on the security considerations. [Appendix A](#) describes how a TCP stack would need to support the protocol described in this document.

[2. Differences with SOCKSv5](#)

Several IETF protocols provide proxy services; the closest to the 0-RTT Convert protocol being the SOCKSv5 protocol [[RFC1928](#)]. This protocol is already used to deploy Multipath TCP in some cellular networks ([Section 2.2 of \[RFC8041\]](#)).

A SOCKS Client creates a connection to a SOCKS Proxy, exchanges authentication information, and indicates the IP address and port number of the target Server. At this point, the SOCKS Proxy creates a connection towards the target Server and relays all data between the two proxied connections. The operation of an implementation based on SOCKSv5 (without authentication) is illustrated in Figure 1.

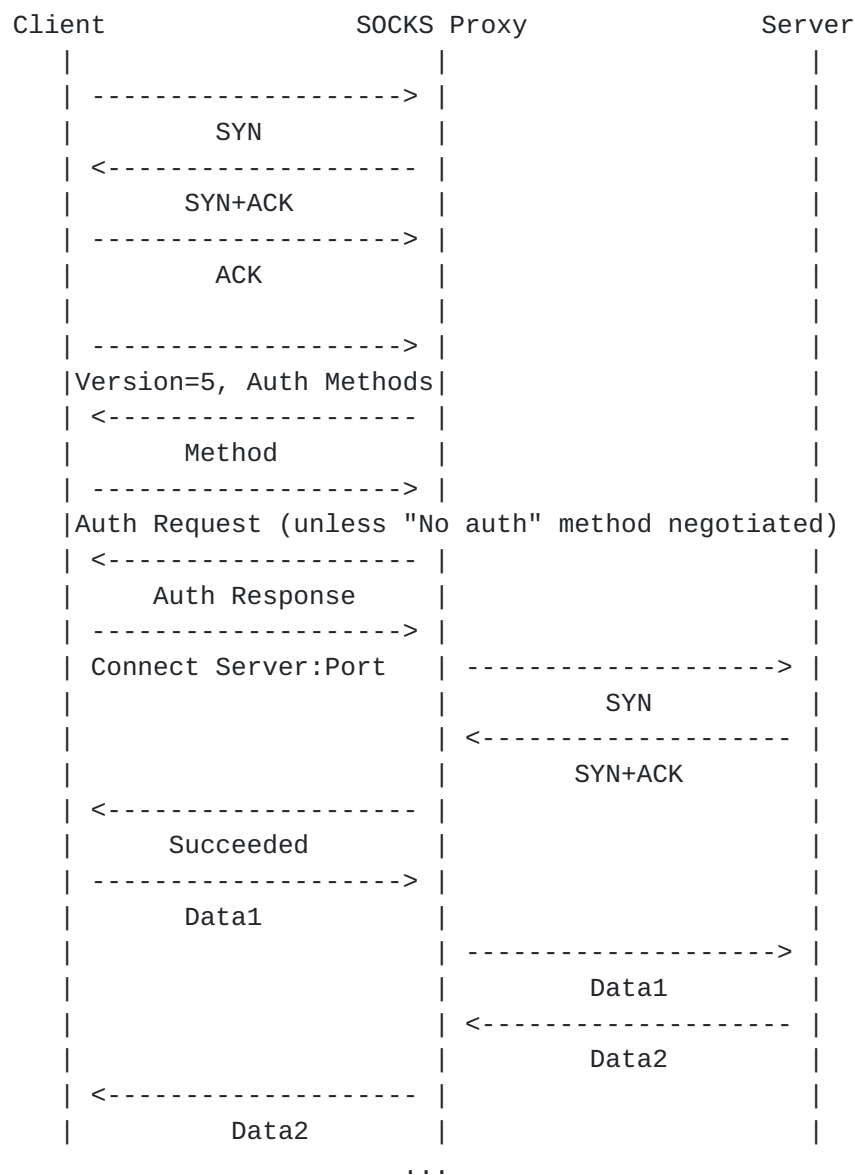


Figure 1: Establishment of a TCP Connection through a SOCKS Proxy
Without Authentication

When SOCKS is used, an "end-to-end" connection between a Client and a Server becomes a sequence of two TCP connections that are glued together on the SOCKS Proxy. The SOCKS Client and Server exchange control information at the beginning of the bytestream on the Client-Proxy connection. The SOCKS Proxy then creates the connection with the target Server and then glues the two connections together so that all bytes sent by the application (Client) to the SOCKS Proxy are relayed to the Server and vice versa.

The Convert Protocol is also used on TCP proxies that relay data between an upstream and a downstream connection, but there are

important differences with SOCKSv5. A first difference is that the 0-RTT Convert protocol exchanges all the control information during the initial RTT. This reduces the connection establishment delay compared to SOCKS which requires two or more round-trip-times before the establishment of the downstream connection towards the final destination. In today's Internet, latency is an important metric and various protocols have been tuned to reduce their latency [[I-D.arkko-arch-low-latency](#)]. A recently proposed extension to SOCKS leverages the TFO (TCP Fast Open) option [[I-D.olteanu-intarea-socks-6](#)] to reduce this delay.

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 Server supports the required TCP extension(s). Neither SOCKSv5 [[RFC1928](#)] nor the proposed SOCKSv6 [[I-D.olteanu-intarea-socks-6](#)] provide such a feature.

A third difference is that a Transport Converter will only confirm the establishment of the connection initiated by the Client provided that the downstream connection has already been 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 0-RTT Convert protocol only allows the Client to specify the IP address/port number of the destination server and not a DNS name. We evaluated an alternate design 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.

3. 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.

4. Architecture & Behaviors

4.1. Functional Elements

The Convert Protocol considers three functional elements:

- o Clients;
- o Transport Converters;
- o Servers.

A Transport Converter is a network function that proxies all data exchanged over one upstream connection to one downstream connection and vice versa (Figure 2). 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, customer-facing interface).

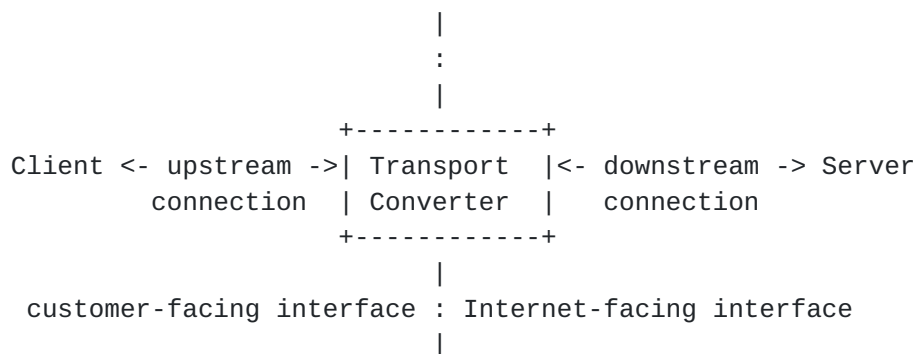


Figure 2: A Transport Converter Proxies Data between Pairs of TCP Connections

"Client" refers to a software instance embedded on a host that can reach a Transport Converter via its customer-facing interface. The "Client" can initiate connections via a Transport Converter (referred to as outgoing connections). Also, the "Client" can accept incoming connections via a Transport Converter (referred to as incoming 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.

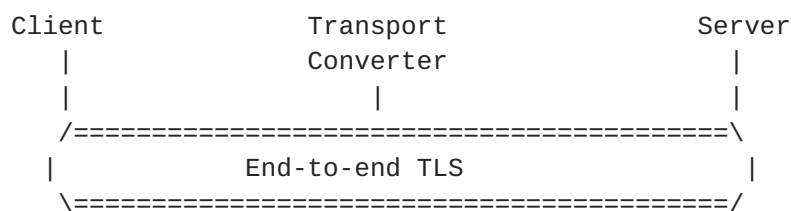
The architecture assumes that new software will be installed on the Client hosts to interact with one or more Transport Converters. Furthermore, the architecture allows for making use of new TCP extensions even if those are not supported by a given server.

A 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 SOCKS, 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.



* TLS messages exchanged between the Client and the Server are not shown.

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 messages (in addition to the end-to-end TLS connection).

4.2. 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.

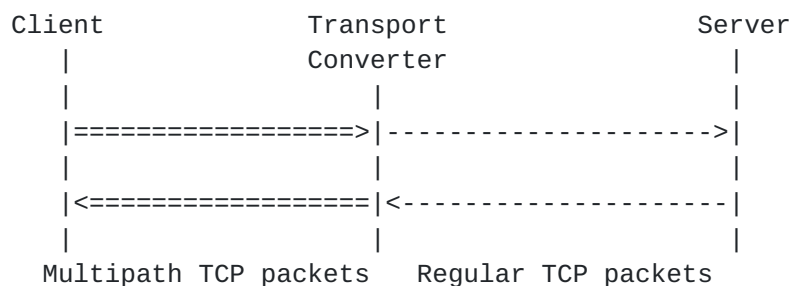


Figure 4: An Example of 0-RTT Network-Assisted Outgoing MPTCP Connection

The packets belonging to a connection established 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. The Transport Converter maintains two connections that are combined together:

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

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

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

Figure 5 illustrates the establishment of an outgoing TCP connection by a Client through a Transport Converter.

- o Note: The information shown between brackets in Figure 5 (and other figures in the document) refers to Convert Protocol messages described in [Section 6](#).

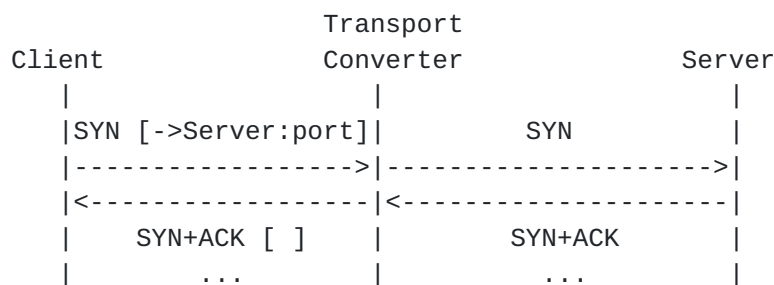


Figure 5: Establishment of an Outgoing TCP Connection Through a Transport Converter

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. Also, a state entry is instantiated for this connection. This state entry is used by the Converter to handle subsequent messages belonging to the connection.

The connection can also be established from the Internet towards a Client via a Transport Converter (Figure 6). This is typically the case when the Client hosts an application server that listens to a specific port number. When the Converter receives an incoming SYN from a remote host, it checks if it can provide the conversion service for the destination IP address and destination port number of that SYN. The Transport Converter receives this SYN because it is, for example, on the path between the remote host and the Client or it

provides address sharing service for the Client. If the check fails, the packet is silently ignored by the Converter. If the check is successful, the Converter tries to initiate a TCP connection towards the Client from its own address and using its configured TCP options. In the SYN that corresponds to this connection attempt, the Transport Convert inserts a TLV message that indicates the source address and port number of the remote host. A transport session entry is created by the Converter for this connection. SYN+ACK and ACK will be then exchanged between the Client, the Converter, and remote host to confirm the establishment of the connection. The Converter uses the transport session entry to proxy packets belonging to the connection.

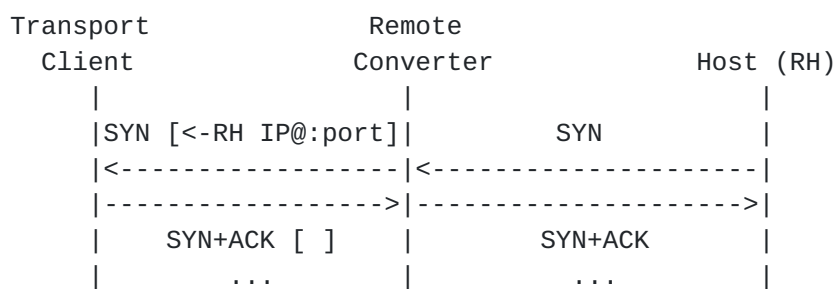


Figure 6: Establishment of an Incoming TCP Connection Through a Transport Converter

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 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 TCP header. Furthermore, this design allows for the use of longer cookies than [\[RFC7413\]](#).

If the downstream (or upstream) connection fails for some reason (excessive retransmissions, reception of an RST segment, etc.), then the Converter reacts by forcing the tear-down of the upstream (or downstream) connection.

The same reasoning applies when the upstream connection ends with an exchange of FIN packets. In this case, the Converter should also terminate the downstream connection by using FIN packets. If the downstream connection terminates with the exchange of FIN packets, the Converter should initiate a graceful termination of the upstream connection.

4.3. Data Processing at the Transport Converter

As mentioned in [Section 4.2](#), the Transport Converter acts as a TCP proxy between the upstream connection (i.e., between the Client and the Transport Converter) and the downstream connection (i.e., between the Transport Converter and the Server).

The control messages, discussed in [Section 6](#), establish state (called, transport session entry) in the Transport Converter that will enable it to proxy between the two TCP connections.

The Transport Converter uses the transport session entry to proxy packets belonging to the connection. An implementation example of a transport session entry for TCP connections is shown in Figure 7.

$$(C,c) \leftrightarrow (T,t), (S,s), \text{Lifetime}$$

Where:

- * C and c are the source IP address and source port number used by the Client for the upstream connection.
- * S and s are the Server's IP address and port number.
- * T and t are the source IP address and source port number used by the Transport Converter to proxy the connection.
- * Lifetime is the validity lifetime of the entry as assigned by the Converter.

Figure 7: An Example of Transport Session Entry (TCP)

Clients send packets bound to connections eligible to the conversion service to the provisioned Transport Converter and destination port

number. This applies for both control messages and data. Additional information is supplied by Clients to the Transport Converter by means of Convert messages as detailed in [Section 6](#). User data can be included in SYN or non-SYN messages. User data is unambiguously distinguished from Convert TLVs by a Transport Converter owing to the Convert Fixed Header in the Convert messages ([Section 6.1](#)). These Convert TLVs are destined to the Transport Converter and are, thus, removed by the Transport Converter when proxying between the two connections.

Upon receipt of a packet that belongs to an existing connection between a Client and the Transport Converter the Converter proxies the user data to the Server using the information stored in the corresponding transport session entry. For example, in reference to Figure 7, the Transport Converter proxies the data received from (C, c) downstream using (T,t) as source transport address and (S,s) as destination transport address.

A similar process happens for data sent from the Server. The Converter acts as a TCP proxy and sends the data to the Client relying upon the information stored in a transport session entry. The Converter associates a lifetime with state entries used to bind an upstream connection with its downstream connection.

When Multipath TCP is used between the Client and the Transport Converter, the Converter maintains more state (e.g. information about the subflows) for each Multipath TCP connection. The procedure described above continues to apply except that the Converter needs to manage the establishment/termination of subflows and schedule packets among the established ones. These operations are part of the Multipath TCP implementation. They are independent of the Convert protocol that only processes the Convert messages in the beginning of the bytestream.

A Transport Converter may operate in address preservation mode (that is, the Converter does not rewrite the source IP address (i.e., $C=T$)) or address sharing mode (that is, an address pool is shared among all Clients serviced by the Converter (i.e., $C \neq T$)); refer to [Section 4.4](#) for more details. 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 source address remaining constant.

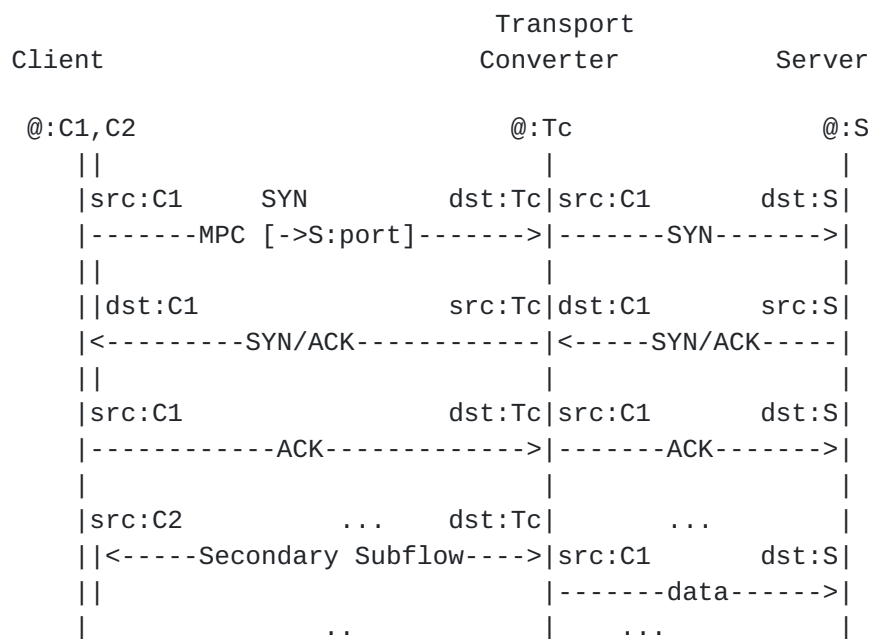
4.4. Address Preservation vs. Address Sharing

The Transport Converter is provided with instructions about the behavior to adopt with regards to the processing of source addresses of outgoing packets. The following sub-sections discusses two deployment models for illustration purposes. It is out of the scope of this document to make a recommendation.

4.4.1. Address Preservation

In this model, the visible source IP address of a packet proxied by a Transport Converter to a Server is an IP address of the end host (Client). No dedicated IP address pool is provisioned to the Transport Converter, but the the Transport Converter is located on the path between the Client and the Server.

For Multipath TCP, the Transport Converter preserves the source IP address used by the Client when establishing the initial subflow. Data conveyed in secondary subflows will be proxied by the Transport Converter using the source IP address of the initial subflow. An example of a proxied Multipath TCP connection with address preservation is shown in Figure 8.



Legend:

Tc: IP address used by the Transport Converter on its customer-facing interface.

Figure 8: Example of Address Preservation

The Transport Converter must be on the forwarding path of incoming traffic. Because the same (destination) IP address is used for both proxied and non-proxied connections, the Transport Converter should not drop incoming packets it intercepts if no matching entry is found for the packets. Unless explicitly configured otherwise, such packets are forwarded according to the instructions of a local forwarding table.

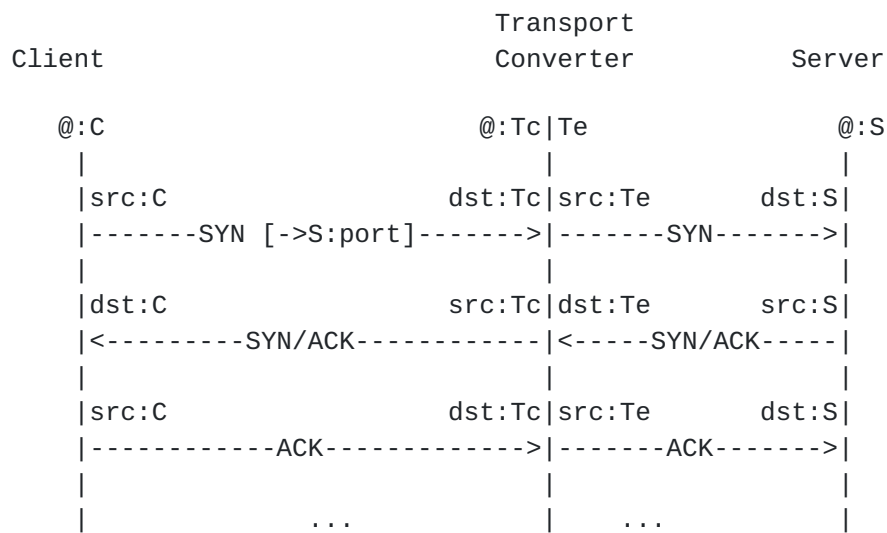
4.4.2. Address/Prefix Sharing

A pool of global IPv4 addresses is provisioned to the Transport Converter along with possible instructions about the address sharing ratio to apply (see [Appendix B of \[RFC6269\]](#)). An address is thus shared among multiple clients.

Likewise, rewriting the source IPv6 prefix [[RFC6296](#)] may be used to ease redirection of incoming IPv6 traffic towards the appropriate Transport Converter. A pool of IPv6 prefixes is then provisioned to the Transport Converter for this purpose.

Adequate forwarding policies are enforced so that traffic destined to an address of such pool is intercepted by the appropriate Transport Converter. Unlike [Section 4.4.1](#), the Transport Converter drops incoming packets which do not match an active transport session entry.

An example is shown in Figure 9.



Legend:

Tc: IP address used by the Transport Converter for its customer-facing interface.

Te: IP address used by the Transport Converter for its Internet-facing interface.

Figure 9: Address Sharing

5. Sample Examples

5.1. 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 10 describes the operation of the Transport Converter if the Server does not support Multipath TCP.

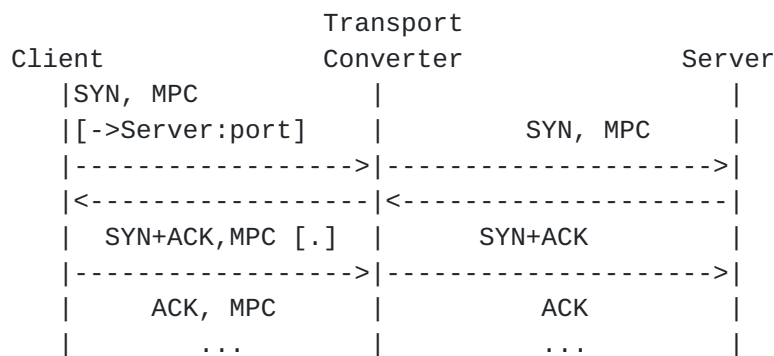


Figure 10: Establishment of a Multipath TCP Connection through a Transport Converter towards a Server that does not support Multipath TCP

The Client tries to initiate a Multipath TCP connection by sending a SYN with the MP_CAPABLE option (MPC in Figure 10). 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.

Note that, if the TCP connection is reset for some reason, the Converter tears down the Multipath TCP connection by transmitting a MP_FASTCLOSE. Likewise, if the Multipath TCP connection ends with the transmission of DATA_FINS, the Converter terminates the TCP connection by using FIN segments. As a side note, given that with Multipath TCP, RST only has the scope of the subflow and will only close the concerned subflow but not affect the remaining subflows, the Converter does not terminate the downstream TCP connection upon receipt of an RST over a Multipath subflow.

Figure 11 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. This will enable the Client to bypass the Transport Converter for the subsequent Multipath TCP connections that it will initiate towards this Server.

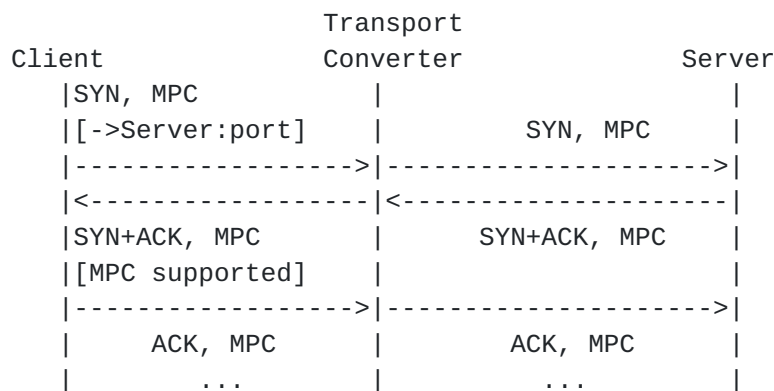


Figure 11: Establishment of a Multipath TCP Connection through a Converter towards an MPTCP-capable Server

5.2. Incoming Converter-Assisted Multipath TCP Connection

An example of an incoming Converter-assisted Multipath TCP connection is depicted in Figure 12. 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 no entry is found, the Converter silently ignores the message. 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.

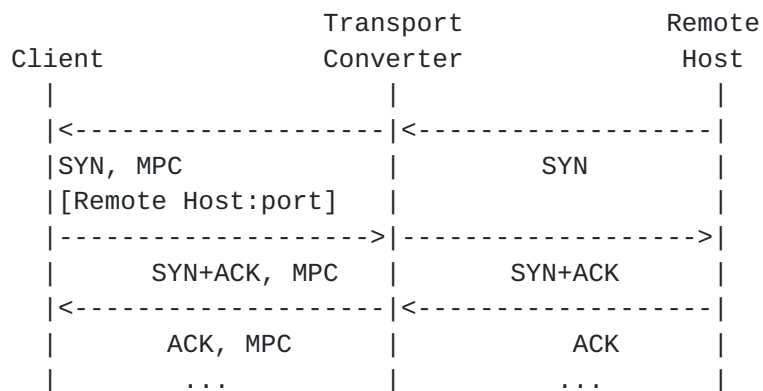


Figure 12: Establishment of an Incoming Multipath TCP Connection through a Transport Converter

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.

6. The Convert Protocol (Convert)

This section defines the Convert Protocol (Convert, for short) messages that are exchanged between a Client and a Transport Converter.

The Transport Converter listens on a dedicated TCP port number for Convert messages from Clients. That port number is configured by an administrator.

Convert messages MUST be included as the first bytes of the bytestream. All Convert messages starts with a 32 bits long fixed header ([Section 6.1](#)) followed by one or more Convert TLVs (Type, Length, Value) ([Section 6.2](#)).

- o Implementation note 1: Several implementers expressed concerns about the use of TFO. As a reminder, 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, the Convert Protocol supports the utilization of a Cookie that is placed in the SYN payload. This provides the same level of protection as a TFO Cookie in environments where such protection is required.
- o Implementation note 2: Error messages are not included in RST but sent in the bytestream. Implementers have indicated that

processing RST on clients was difficult on some platforms. This design simplifies client implementations.

6.1. The Convert Fixed Header

The Convert Protocol 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.

The Client and the Transport Converter MUST send the fixed-sized header, shown in Figure 13, as the first four bytes of the bytestream.

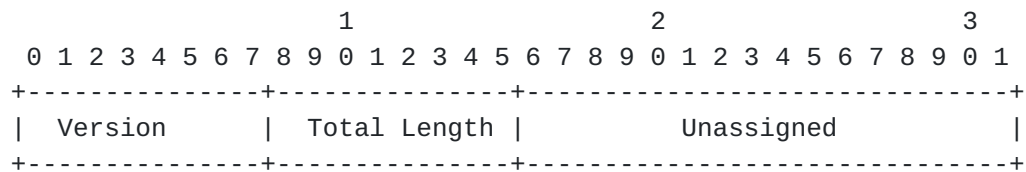


Figure 13: The Convert Fixed Header

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.

The Total Length field unambiguously marks the number of 32 bits words that carry Convert TLVs in the beginning of the bytestream.

6.2. Convert TLVs

6.2.1. Generic Convert TLV Format

The Convert Protocol uses variable length messages that are encoded using the generic TLV format depicted in Figure 14.

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.

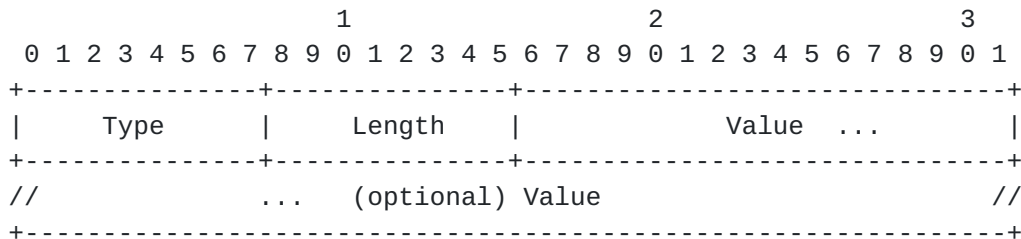


Figure 14: Convert Generic TLV Format

The Length field covers Type, Length, and Value fields. It is expressed in units of 32 bits words. If necessary, Value MUST be padded with zeroes so that the length of the TLV is a multiple of 32 bits.

A given TLV MUST only appear once on a connection. If a Client receives two or more instances of the same TLV over a Convert connection, it MUST reset the associated TCP connection. If a Converter receives two or more instances of the same TLV over a Convert connection, it MUST return a Malformed Message Error TLV and close the associated TCP connection.

6.2.2. 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 15: The TLVs used by the Convert Protocol

Type 0x0 is a reserved value. If a Client receives a TLV of type 0x0, it MUST reset the associated TCP connection. If a Converter receives a TLV of type 0x0, it MUST return an Unsupported Message Error TLV and close the associated TCP connection.

Implementations MUST reset the connection upon reception of messages with such TLV.

The Client typically sends in the first connection it established with a Transport Converter the Info TLV ([Section 6.2.3](#)) to learn its capabilities. Assuming the Client is authorized to invoke the Transport Converter, the latter replies with the Supported TCP Extensions TLV ([Section 6.2.4](#)).

The Client can request the establishment of connections to servers by using the Connect TLV ([Section 6.2.5](#)). If the connection can be established with the final server, the Transport Converter replies with the Extended TCP Header TLV ([Section 6.2.6](#)). If not, the Transport Converter returns an Error TLV ([Section 6.2.8](#)) and then closes the connection. The Transport Converter MUST NOT send a RST immediately after the detection of an error to let the Error TLV reach the Client. As explained later, the Client will anyway send a RST upon reception of the Error TLV.

When an error is encountered an Error TLV with the appropriate error code MUST be returned by the Transport Converter.

6.2.3. The Info TLV

The Info TLV (Figure 16) 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 6.2.4](#).

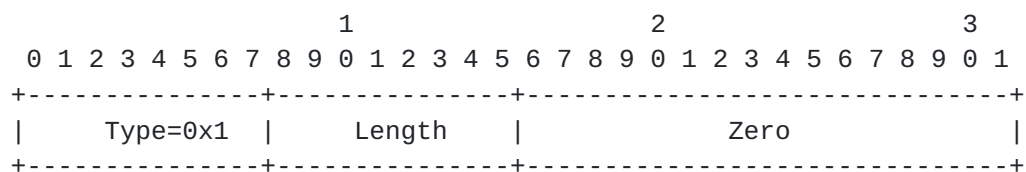


Figure 16: The Info TLV

6.2.4. Supported TCP Extensions TLV

The Supported TCP Extensions TLV (Figure 17) 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 supports in outgoing SYNs.

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

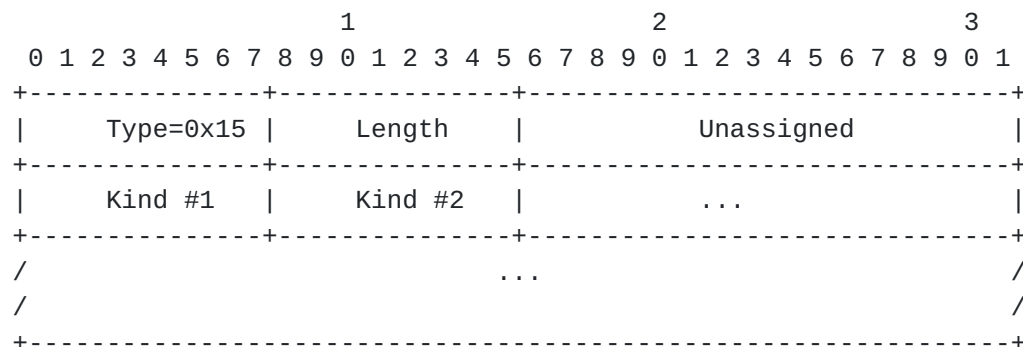


Figure 17: The Supported TCP Extensions TLV

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 Extensions 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.

6.2.5. Connect TLV

The Connect TLV (Figure 18) 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 of the SYN packet received by the Transport Converter from the server.

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](#)]. If a Converter receives a Connect TLVs with such invalid addresses, it MUST reply with a Malformed Message Error TLV and close the associated TCP connection.

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 (Figure 18), (2) the Extended Connect TLV spans more than 20 bytes and also includes the optional 'TCP Options' field (Figure 19). This field is used to request the advertisement of specific TCP options to the server.

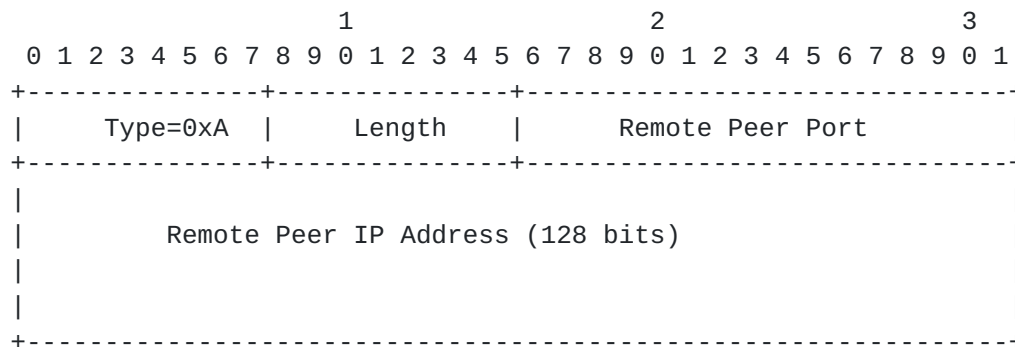


Figure 18: The Base Connect TLV

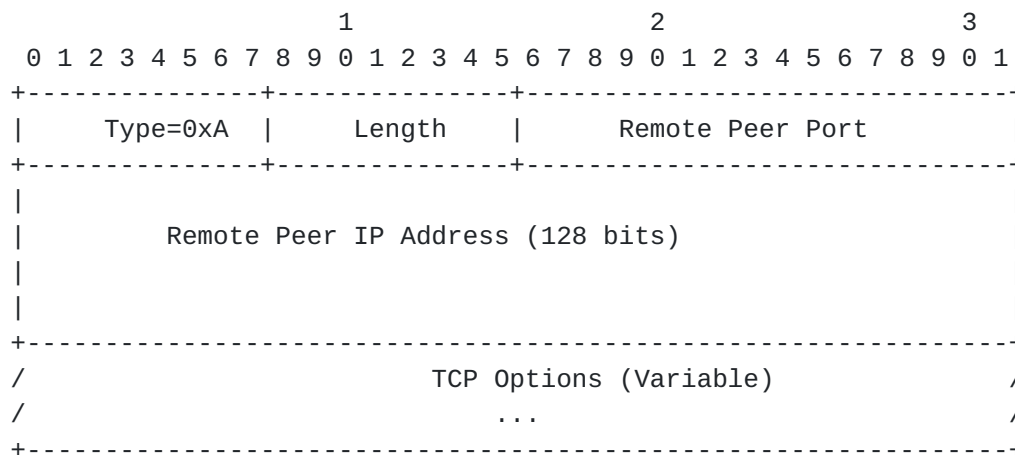


Figure 19: The Extended Connect TLV

The 'TCP Options' field is a variable length field that carries a list of TCP option fields (Figure 20). 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 sub-field, 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.

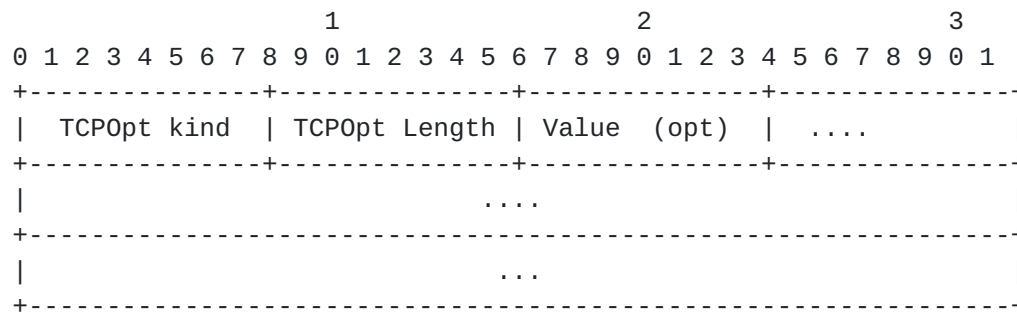


Figure 20: The TCP Options Field

Upon reception of a Base 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, a Transport Converter first checks whether it supports the TCP Options listed in the 'TCP Options' field. If not, it returns an error message ([Section 6.2.8](#)). If the above check succeeded 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 in the SYN that it sends to the Server the options listed in the 'TCP Options' sub-field and the TCP options that it would have used according to its local policies. For the TCP options that are included in the TCP Options field 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 in the SYN sent to the remote server. This feature is required to support TCP Fast Open. See [Section 7](#) for a detailed discussion of the different types of TCP options.

The Transport Converter may refuse a Connect TLV request for various reasons (e.g., authorization failed, out of resources, invalid address type, unsupported TCP option). An error message indicating the encountered error is returned to the requesting Client ([Section 6.2.8](#)). In order to prevent denial-of-service attacks, error messages sent to a Client SHOULD be rate-limited.

6.2.6. Extended TCP Header TLV

The Extended TCP Header TLV (Figure 21) is used by the Transport Converter to return to the Client the TCP options that were returned by the Server in the SYN+ACK packet. A Transport Converter **MUST** return this TLV if the Client sent an Extended Connect TLV and the connection was accepted by the server.

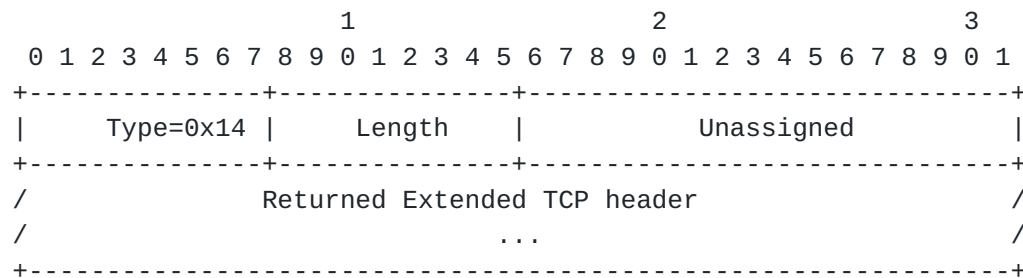


Figure 21: The Extended TCP Header TLV

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

The Unassigned field **MUST** be set to zero by the sender and ignored by the receiver.

6.2.7. The Cookie TLV

The Cookie TLV (Figure 22) is an optional TLV which is similar to the TCP Fast Open Cookie [RFC7413]. A Transport Converter may want to verify that a Client 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 **MAY** 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 first issuing a reset to terminate the connection. It also stores the received Cookie in its cache and attempts to reestablish a new connection to the Transport Converter that includes the Cookie TLV.

The format of the Cookie TLV is shown in Figure 22.

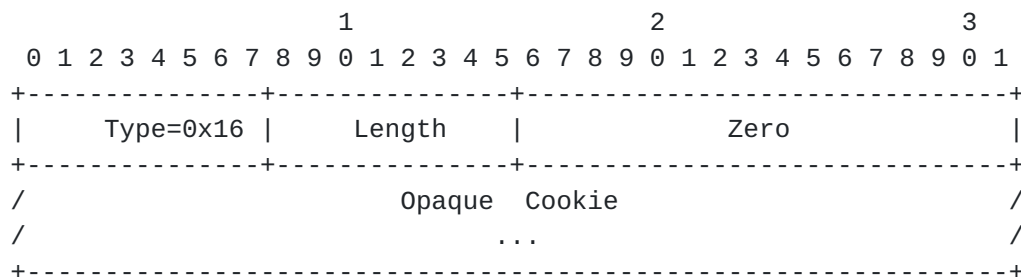


Figure 22: The Cookie TLV

6.2.8. Error TLV

The Error TLV (Figure 23) is meant to provide information about some errors that occurred during the processing of a Convert message. This TLV has a variable length. Upon reception of an Error TLV, a Client MUST reset the associated connection.

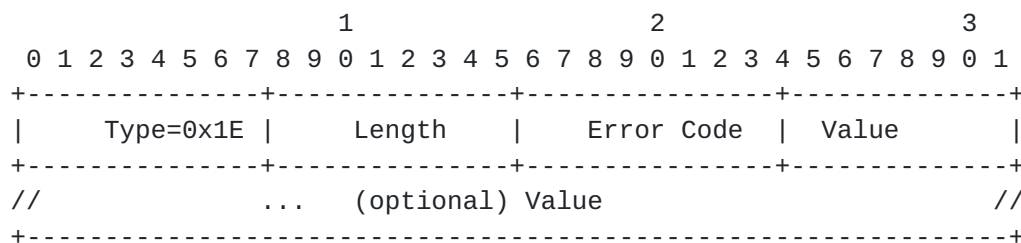


Figure 23: The Error TLV

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:

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

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

- o 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 peer (e.g. 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 peer. When multiple versions are supported by the peer, 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 remote peer (e.g., Client) checks whether it supports one of the versions returned by the peer. The highest common supported version MUST be used by the remote peer in subsequent exchanges with the peer.

- o Malformed Message (1): This error code is sent to indicate that a message received from a peer cannot 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.

- o Unsupported Message (2): This error code is sent to indicate that a message type received from a Client is not supported.

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

- o 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 SHOULD cache the received Cookie and include it in subsequent Convert messages sent to that Transport Converter.

- o 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.

- o 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.

- o 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.

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

The Transport Converter **MUST** send this error code when it experiences forwarding issues to proxy 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.

- o Connection Reset (96): This error indicates that the final destination responded with an RST packet. The Value field **MUST** be set to zero.
- o 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 24 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 24: Convert Error Values

7. Compatibility of Specific TCP Options with the Conversion Service

In this section, we discuss how several deployed standard track TCP options can be supported through the Convert Protocol. The other TCP options will be discussed in other documents.

7.1. 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 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.

7.2. Window Scale (WS)

The Window Scale (WS) 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 utilization 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.

7.3. Selective Acknowledgments

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

7.4. Timestamp

The Timestamp option [[RFC7323](#)] 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.

7.5. Multipath TCP

The Multipath TCP options are defined in [[RFC6824](#)]. [[RFC6824](#)] defines one variable length TCP option (Kind=30) that includes a sub-type 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.

7.6. 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.

7.7. 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.

8. 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 focus the

middleboxes that modify the payload since the Convert Protocol places its messages at the beginning of the bytestream.

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

Consider now a middlebox that drops SYN/ACKs with a payload. The Client won't be able to establish a connection via the Transport Converter. The case of a middlebox that removes the payload of SYN+ACKs or from the packet that follows the SYN+ACK (but not the payload of SYN) can be detected by a Client. This is hinted by the absence of a valid Convert message in the response.

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 cookie validation 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 \[RFC7413\]](#).

9. Security Considerations

9.1. 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.

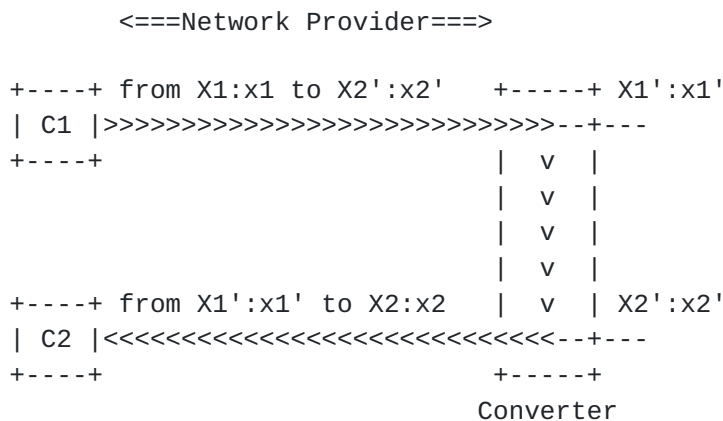
9.2. Authorization

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 25.



Note: $X_2':x_2'$ may be equal to $X_2:x_2$

Figure 25: Hairpinning Example

See below for authorization considerations that are specific for Multipath TCP.

9.3. 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 should also be enabled (e.g., [Section 3 of \[RFC4987\]](#)).

9.4. 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.

9.5. Authentication Considerations

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:

- o 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 TCP converter 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 for authorization matters.
- o 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 for authorization matters.

- o 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 Convert connections received on its Internet-facing interfaces. Only Convert connections received on the customer-facing interfaces of a Transport Converter will be accepted.

[10.](#) IANA Considerations

Note to the RFC Editor: Please replace "THISRFC" in the following sub-sections with the RFC number to be assigned to this document.

[10.1.](#) Convert Service Name

IANA is requested to assign a service name 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>.

Service Name:	convert
Port Number:	N/A
Transport Protocol(s):	TCP
Description:	0-RTT TCP Convert Protocol
Assignee:	IESG <iesg@ietf.org>
Contact:	IETF Chair <chair@ietf.org>
Reference:	THISRFC

Clients may use this service name to feed the procedure defined in [[RFC2782](#)] to discover the IP address(es) and the port number used by the Transport Converters of a domain.

[10.2.](#) The Convert Protocol (Convert) Parameters

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

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

Registration requests for the 128-191 range (for both "Convert TLVs" and "Convert Error Messages" sub-registries) are evaluated after a three-week review period on the tcp-convert-review@ietf.org mailing

list, on the advice of one or more Designated Experts. However, to allow for the allocation of values prior to publication, the Designated Experts may approve registration once they are satisfied that such a specification will be published. New registration requests should be sent in the form of an email to the review mailing list; the request should use an appropriate subject (e.g., "Request to register 0-RTT Convert TLV: example" or "Request to register 0-RTT Convert Error Message: example"). IANA will only accept new registrations from the Designated Experts, and will check that review was requested on the mailing list in accordance with these procedures.

Within the review period, the Designated Experts will either approve or deny the registration request, communicating this decision to the review list and IANA. Denials should include an explanation and, if applicable, suggestions as to how to make the request successful. Registration requests that are undetermined for a period longer than 21 days can be brought to the IESG's attention (using the iesg@ietf.org mailing list) for resolution.

The Designated Expert is expected to ascertain the existence of suitable documentation as described in [Section 4.6 of \[RFC8126\]](#) and to verify that the document is permanently and publicly available. The Designated Expert is also expected to check the clarity of purpose and use of the requested code points.

Also, criteria that should be applied by the Designated Experts includes determining whether the proposed registration duplicates existing functionality, whether it is likely to be of general applicability or whether it is useful only for a private use, and whether the registration description is clear. IANA must only accept registry updates to the 128-191 range (for both "Convert TLVs" and "Convert Error Messages" sub-registries) from the Designated Experts and should direct all requests for registration to the review mailing list. It is suggested that multiple Designated Experts be appointed. In cases where a registration decision could be perceived as creating a conflict of interest for a particular Expert, that Expert should defer to the judgment of the other Experts.

[10.2.1.](#) 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	THISRFC
1	Assigned by this document	THISRFC

[10.2.2.](#) Convert TLVs

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

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

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

Code	Name	Reference
0	Reserved	THISRFC
1	Info TLV	THISRFC
10	Connect TLV	THISRFC
20	Extended TCP Header TLV	THISRFC
21	Supported TCP Extension TLV	THISRFC
22	Cookie TLV	THISRFC
30	Error TLV	THISRFC

[10.2.3.](#) 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:

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

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

- o 0-127: Values in this range are assigned via IETF Review.
- o 128-191: Values in this range are assigned via Specification Required.
- o 192-255: Values in this range are reserved for Private Use.

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

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

Figure 26: The Convert Error Codes

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[Appendix A](#). Example Socket API Changes to Support the 0-RTT Convert Protocol

[A.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):

- o 0x1: (client) enables sending data in the opening SYN on the client.
- o 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.

A.2. Passive Open (Converter Side)

The Converter needs to enable the reception of data inside the SYN independently of the utilization 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 utilization of a TCP_FASTOPEN socket option to enable the reception of SYNs containing data. Later, [Appendix A of \[RFC7413\]](#), mentioned:

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 behavior 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:

- o 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 behavior 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.

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Many thanks to Mirja Kuehlewind for the detailed AD review.

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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Contributors

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

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Change Log

This section to be removed before publication.

- o 00 : initial version, designed to support Multipath TCP and TFO only
- o 00 to -01 : added section [Section 7](#) 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
- o 01 to -02: Minor modifications

- o 02 to -03: Minor modifications
- o 03 to -04: Minor modifications
- o 04 to -05: Integrate a lot of feedback from implementers who have worked on client and server side implementations. The main modifications are the following :
 - * TCP Fast Open is not strictly required anymore. Several implementers 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 utilization of a Cookie that is placed in the SYN payload. This provides the same level of protection as a TFO Cookie in environments where such protection is required.
 - * the Bootstrap procedure has been simplified based on feedback from implementers
 - * Error messages are not included in RST segments anymore but sent in the bytestream. Implementers 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 implementers 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 explicitly 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 following the same rationale as in [RFC7413](#).
- * Nits
- * Added [Appendix A](#) on example Socket API changes
- o 08:
 - * Added short discussion on the termination of connections
- o 09:
 - * Address various comments received during last call
- o 10-13:
 - * Changes to address the comments from Phil: Add a new section to group data plane considerations in one place + add a new appendix with more details on address modes + rearrange the MPTCP text.
- o 14: fixed nits (the shepherd write-up)
- o 15: Various clarifications in the text to address the detailed comments provided by Mirja Kuehlewind

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