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**Session Traversal Utilities for NAT (STUN)  
draft-ietf-tram-stunbis-14**

Abstract

Session Traversal Utilities for NAT (STUN) is a protocol that serves as a tool for other protocols in dealing with Network Address Translator (NAT) traversal. It can be used by an endpoint to determine the IP address and port allocated to it by a NAT. It can also be used to check connectivity between two endpoints, and as a keep-alive protocol to maintain NAT bindings. STUN works with many existing NATs, and does not require any special behavior from them.

STUN is not a NAT traversal solution by itself. Rather, it is a tool to be used in the context of a NAT traversal solution.

This document obsoletes [RFC 5389](#).

Status of This Memo

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## [1.](#) Introduction

The protocol defined in this specification, Session Traversal Utilities for NAT, provides a tool for dealing with NATs. It provides a means for an endpoint to determine the IP address and port allocated by a NAT that corresponds to its private IP address and port. It also provides a way for an endpoint to keep a NAT binding alive. With some extensions, the protocol can be used to do connectivity checks between two endpoints [[I-D.ietf-ice-rfc5245bis](#)], or to relay packets between two endpoints [[RFC5766](#)].

In keeping with its tool nature, this specification defines an extensible packet format, defines operation over several transport protocols, and provides for two forms of authentication.

STUN is intended to be used in context of one or more NAT traversal solutions. These solutions are known as STUN usages. Each usage describes how STUN is utilized to achieve the NAT traversal solution. Typically, a usage indicates when STUN messages get sent, which optional attributes to include, what server is used, and what authentication mechanism is to be used. Interactive Connectivity Establishment (ICE) [[I-D.ietf-ice-rfc5245bis](#)] is one usage of STUN. SIP Outbound [[RFC5626](#)] is another usage of STUN. In some cases, a usage will require extensions to STUN. A STUN extension can be in the form of new methods, attributes, or error response codes. More information on STUN usages can be found in [Section 13](#).

Implementations and deployments of a STUN usage using TLS or DTLS should follow the recommendations in [[RFC7525](#)].

## [2.](#) Overview of Operation

This section is descriptive only.





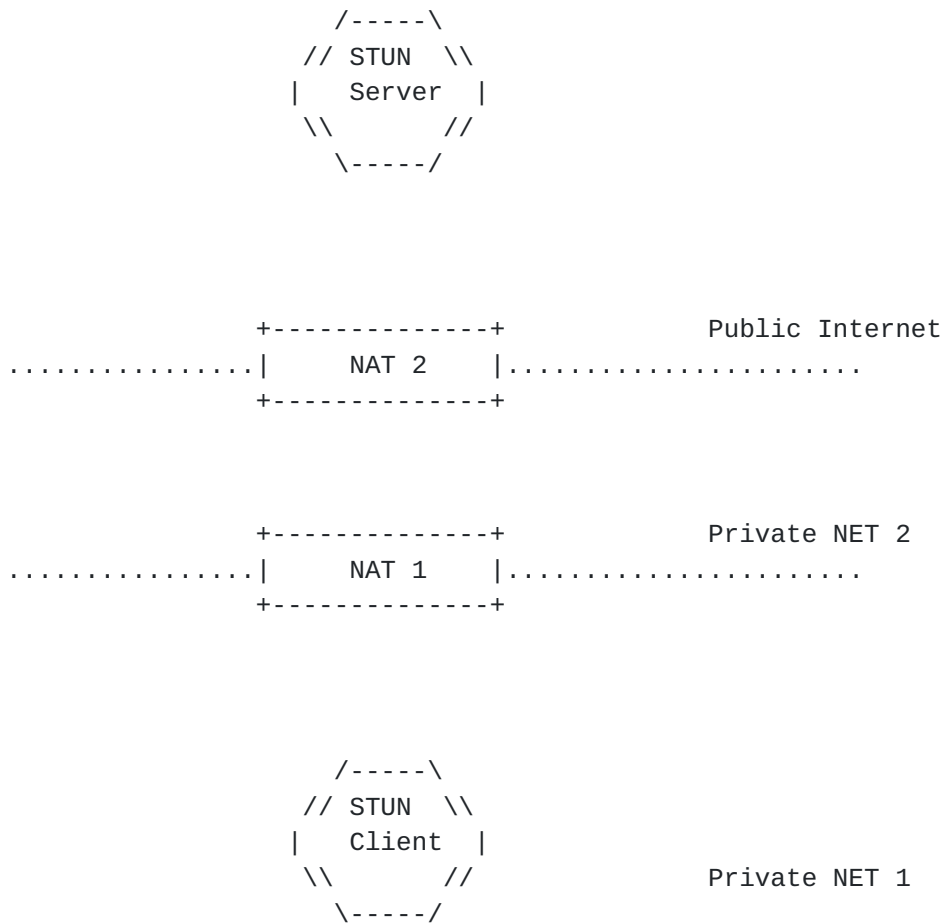


Figure 1: One Possible STUN Configuration

One possible STUN configuration is shown in Figure 1. In this configuration, there are two entities (called STUN agents) that implement the STUN protocol. The lower agent in the figure is the client, and is connected to private network 1. This network connects to private network 2 through NAT 1. Private network 2 connects to the public Internet through NAT 2. The upper agent in the figure is the server, and resides on the public Internet.

STUN is a client-server protocol. It supports two types of transactions. One is a request/response transaction in which a client sends a request to a server, and the server returns a response. The second is an indication transaction in which either agent -- client or server -- sends an indication that generates no response. Both types of transactions include a transaction ID, which is a randomly selected 96-bit number. For request/response transactions, this transaction ID allows the client to associate the response with the request that generated it; for indications, the transaction ID serves as a debugging aid.



All STUN messages start with a fixed header that includes a method, a class, and the transaction ID. The method indicates which of the various requests or indications this is; this specification defines just one method, Binding, but other methods are expected to be defined in other documents. The class indicates whether this is a request, a success response, an error response, or an indication. Following the fixed header comes zero or more attributes, which are Type-Length-Value extensions that convey additional information for the specific message.

This document defines a single method called Binding. The Binding method can be used either in request/response transactions or in indication transactions. When used in request/response transactions, the Binding method can be used to determine the particular "binding" a NAT has allocated to a STUN client. When used in either request/response or in indication transactions, the Binding method can also be used to keep these "bindings" alive.

In the Binding request/response transaction, a Binding request is sent from a STUN client to a STUN server. When the Binding request arrives at the STUN server, it may have passed through one or more NATs between the STUN client and the STUN server (in Figure 1, there were two such NATs). As the Binding request message passes through a NAT, the NAT will modify the source transport address (that is, the source IP address and the source port) of the packet. As a result, the source transport address of the request received by the server will be the public IP address and port created by the NAT closest to the server. This is called a reflexive transport address. The STUN server copies that source transport address into an XOR-MAPPED-ADDRESS attribute in the STUN Binding response and sends the Binding response back to the STUN client. As this packet passes back through a NAT, the NAT will modify the destination transport address in the IP header, but the transport address in the XOR-MAPPED-ADDRESS attribute within the body of the STUN response will remain untouched. In this way, the client can learn its reflexive transport address allocated by the outermost NAT with respect to the STUN server.

In some usages, STUN must be multiplexed with other protocols (e.g., [[I-D.ietf-ice-rfc5245bis](#)], [[RFC5626](#)]). In these usages, there must be a way to inspect a packet and determine if it is a STUN packet or not. STUN provides three fields in the STUN header with fixed values that can be used for this purpose. If this is not sufficient, then STUN packets can also contain a FINGERPRINT value, which can further be used to distinguish the packets.

STUN defines a set of optional procedures that a usage can decide to use, called mechanisms. These mechanisms include DNS discovery, a redirection technique to an alternate server, a fingerprint attribute



for demultiplexing, and two authentication and message-integrity exchanges. The authentication mechanisms revolve around the use of a username, password, and message-integrity value. Two authentication mechanisms, the long-term credential mechanism and the short-term credential mechanism, are defined in this specification. Each usage specifies the mechanisms allowed with that usage.

In the long-term credential mechanism, the client and server share a pre-provisioned username and password and perform a digest challenge/response exchange inspired by (but differing in details) to the one defined for HTTP [[RFC7616](#)]. In the short-term credential mechanism, the client and the server exchange a username and password through some out-of-band method prior to the STUN exchange. For example, in the ICE usage [[I-D.ietf-ice-rfc5245bis](#)] the two endpoints use out-of-band signaling to exchange a username and password. These are used to integrity protect and authenticate the request and response. There is no challenge or nonce used.

### **3. Terminology**

In this document, the key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" are to be interpreted as described in [[RFC2119](#)] and indicate requirement levels for compliant STUN implementations.

### **4. Definitions**

**STUN Agent:** A STUN agent is an entity that implements the STUN protocol. The entity can be either a STUN client or a STUN server.

**STUN Client:** A STUN client is an entity that sends STUN requests and receives STUN responses. A STUN client can also send indications. In this specification, the terms STUN client and client are synonymous.

**STUN Server:** A STUN server is an entity that receives STUN requests and sends STUN responses. A STUN server can also send indications. In this specification, the terms STUN server and server are synonymous.

**Transport Address:** The combination of an IP address and port number (such as a UDP or TCP port number).

**Reflexive Transport Address:** A transport address learned by a client that identifies that client as seen by another host on an IP network, typically a STUN server. When there is an intervening NAT between the client and the other host, the reflexive transport



address represents the mapped address allocated to the client on the public side of the NAT. Reflexive transport addresses are learned from the mapped address attribute (MAPPED-ADDRESS or XOR-MAPPED-ADDRESS) in STUN responses.

**Mapped Address:** Same meaning as reflexive address. This term is retained only for historic reasons and due to the naming of the MAPPED-ADDRESS and XOR-MAPPED-ADDRESS attributes.

**Long-Term Credential:** A username and associated password that represent a shared secret between client and server. Long-term credentials are generally granted to the client when a subscriber enrolls in a service and persist until the subscriber leaves the service or explicitly changes the credential.

**Long-Term Password:** The password from a long-term credential.

**Short-Term Credential:** A temporary username and associated password that represent a shared secret between client and server. Short-term credentials are obtained through some kind of protocol mechanism between the client and server, preceding the STUN exchange. A short-term credential has an explicit temporal scope, which may be based on a specific amount of time (such as 5 minutes) or on an event (such as termination of a SIP dialog). The specific scope of a short-term credential is defined by the application usage.

**Short-Term Password:** The password component of a short-term credential.

**STUN Indication:** A STUN message that does not receive a response.

**Attribute:** The STUN term for a Type-Length-Value (TLV) object that can be added to a STUN message. Attributes are divided into two types: comprehension-required and comprehension-optional. STUN agents can safely ignore comprehension-optional attributes they don't understand, but cannot successfully process a message if it contains comprehension-required attributes that are not understood.

**RT0:** Retransmission TimeOut, which defines the initial period of time between transmission of a request and the first retransmit of that request.





## 5. STUN Message Structure

STUN messages are encoded in binary using network-oriented format (most significant byte or octet first, also commonly known as big-endian). The transmission order is described in detail in [Appendix B of \[RFC0791\]](#). Unless otherwise noted, numeric constants are in decimal (base 10).

All STUN messages MUST start with a 20-byte header followed by zero or more Attributes. The STUN header contains a STUN message type, magic cookie, transaction ID, and message length.

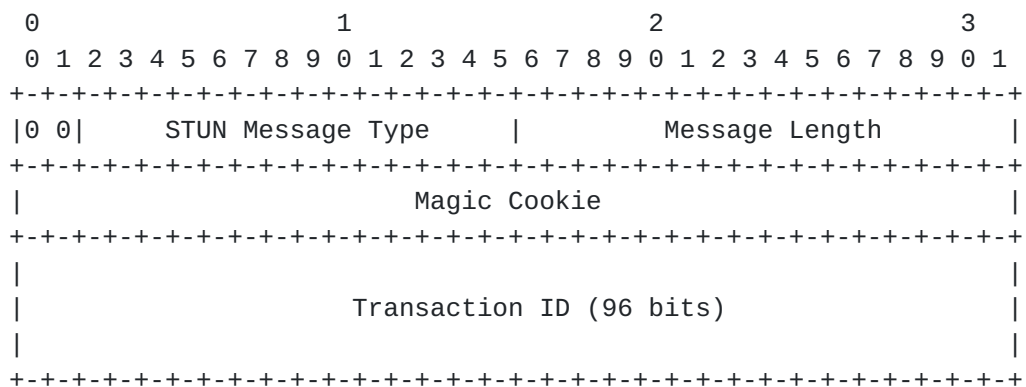


Figure 2: Format of STUN Message Header

The most significant 2 bits of every STUN message MUST be zeroes. This can be used to differentiate STUN packets from other protocols when STUN is multiplexed with other protocols on the same port.

The message type defines the message class (request, success response, failure response, or indication) and the message method (the primary function) of the STUN message. Although there are four message classes, there are only two types of transactions in STUN: request/response transactions (which consist of a request message and a response message) and indication transactions (which consist of a single indication message). Response classes are split into error and success responses to aid in quickly processing the STUN message.

The message type field is decomposed further into the following structure:



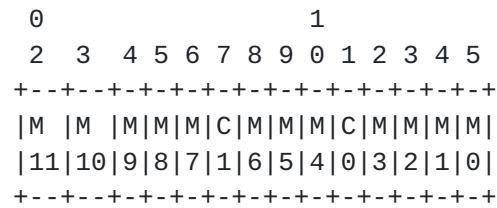


Figure 3: Format of STUN Message Type Field

Here the bits in the message type field are shown as most significant (M11) through least significant (M0). M11 through M0 represent a 12-bit encoding of the method. C1 and C0 represent a 2-bit encoding of the class. A class of 0b00 is a request, a class of 0b01 is an indication, a class of 0b10 is a success response, and a class of 0b11 is an error response. This specification defines a single method, Binding. The method and class are orthogonal, so that for each method, a request, success response, error response, and indication are possible for that method. Extensions defining new methods MUST indicate which classes are permitted for that method.

For example, a Binding request has class=0b00 (request) and method=0b00000000000001 (Binding) and is encoded into the first 16 bits as 0x0001. A Binding response has class=0b10 (success response) and method=0b00000000000001, and is encoded into the first 16 bits as 0x0101.

Note: This unfortunate encoding is due to assignment of values in [RFC3489] that did not consider encoding Indications, Success, and Errors using bit fields.

The magic cookie field MUST contain the fixed value 0x2112A442 in network byte order. In [RFC3489], this field was part of the transaction ID; placing the magic cookie in this location allows a server to detect if the client will understand certain attributes that were added in this revised specification. In addition, it aids in distinguishing STUN packets from packets of other protocols when STUN is multiplexed with those other protocols on the same port.

The transaction ID is a 96-bit identifier, used to uniquely identify STUN transactions. For request/response transactions, the transaction ID is chosen by the STUN client for the request and echoed by the server in the response. For indications, it is chosen by the agent sending the indication. It primarily serves to correlate requests with responses, though it also plays a small role in helping to prevent certain types of attacks. The server also uses the transaction ID as a key to identify each transaction uniquely across all clients. As such, the transaction ID MUST be uniformly and randomly chosen from the interval 0 .. 2\*\*96-1, and SHOULD be



cryptographically random. Resends of the same request reuse the same transaction ID, but the client MUST choose a new transaction ID for new transactions unless the new request is bit-wise identical to the previous request and sent from the same transport address to the same IP address. Success and error responses MUST carry the same transaction ID as their corresponding request. When an agent is acting as a STUN server and STUN client on the same port, the transaction IDs in requests sent by the agent have no relationship to the transaction IDs in requests received by the agent.

The message length MUST contain the size, in bytes, of the message not including the 20-byte STUN header. Since all STUN attributes are padded to a multiple of 4 bytes, the last 2 bits of this field are always zero. This provides another way to distinguish STUN packets from packets of other protocols.

Following the STUN fixed portion of the header are zero or more attributes. Each attribute is TLV (Type-Length-Value) encoded. The details of the encoding, and of the attributes themselves are given in [Section 14](#).

## **6. Base Protocol Procedures**

This section defines the base procedures of the STUN protocol. It describes how messages are formed, how they are sent, and how they are processed when they are received. It also defines the detailed processing of the Binding method. Other sections in this document describe optional procedures that a usage may elect to use in certain situations. Other documents may define other extensions to STUN, by adding new methods, new attributes, or new error response codes.

### **6.1. Forming a Request or an Indication**

When formulating a request or indication message, the agent MUST follow the rules in [Section 5](#) when creating the header. In addition, the message class MUST be either "Request" or "Indication" (as appropriate), and the method must be either Binding or some method defined in another document.

The agent then adds any attributes specified by the method or the usage. For example, some usages may specify that the agent use an authentication method ([Section 9](#)) or the FINGERPRINT attribute ([Section 7](#)).

If the agent is sending a request, it SHOULD add a SOFTWARE attribute to the request. Agents MAY include a SOFTWARE attribute in indications, depending on the method. Extensions to STUN should discuss whether SOFTWARE is useful in new indications.



For the Binding method with no authentication, no attributes are required unless the usage specifies otherwise.

All STUN messages sent over UDP or DTLS-over-UDP [[RFC6347](#)] SHOULD be less than the path MTU, if known.

If the path MTU is unknown for UDP, messages SHOULD be the smaller of 576 bytes and the first-hop MTU for IPv4 [[RFC1122](#)] and 1280 bytes for IPv6 [[RFC8200](#)]. This value corresponds to the overall size of the IP packet. Consequently, for IPv4, the actual STUN message would need to be less than 548 bytes (576 minus 20-byte IP header, minus 8-byte UDP header, assuming no IP options are used).

If the path MTU is unknown for DTLS-over-UDP, the rules described in the previous paragraph need to be adjusted to take into account the size of the (13-byte) DTLS Record header, the MAC size, and the padding size.

STUN provides no ability to handle the case where the request is under the MTU but the response would be larger than the MTU. It is not envisioned that this limitation will be an issue for STUN. The MTU limitation is a SHOULD, and not a MUST, to account for cases where STUN itself is being used to probe for MTU characteristics [[RFC5780](#)]. Outside of this or similar applications, the MTU constraint MUST be followed.

## **[6.2.](#) Sending the Request or Indication**

The agent then sends the request or indication. This document specifies how to send STUN messages over UDP, TCP, TLS-over-TCP, or DTLS-over-UDP; other transport protocols may be added in the future. The STUN usage must specify which transport protocol is used, and how the agent determines the IP address and port of the recipient. [Section 8](#) describes a DNS-based method of determining the IP address and port of a server that a usage may elect to use. STUN may be used with anycast addresses, but only with UDP and in usages where authentication is not used.

At any time, a client MAY have multiple outstanding STUN requests with the same STUN server (that is, multiple transactions in progress, with different transaction IDs). Absent other limits to the rate of new transactions (such as those specified by ICE for connectivity checks or when STUN is run over TCP), a client SHOULD limit itself to ten outstanding transactions to the same server.





### **6.2.1. Sending over UDP or DTLS-over-UDP**

When running STUN over UDP or STUN over DTLS-over-UDP [[RFC7350](#)], it is possible that the STUN message might be dropped by the network. Reliability of STUN request/response transactions is accomplished through retransmissions of the request message by the client application itself. STUN indications are not retransmitted; thus, indication transactions over UDP or DTLS-over-UDP are not reliable.

A client SHOULD retransmit a STUN request message starting with an interval of RTO ("Retransmission TimeOut"), doubling after each retransmission. The RTO is an estimate of the round-trip time (RTT), and is computed as described in [[RFC6298](#)], with two exceptions. First, the initial value for RTO SHOULD be greater than 500 ms. The exception cases for this "SHOULD" are when other mechanisms are used to derive congestion thresholds (such as the ones defined in ICE for fixed rate streams), or when STUN is used in non-Internet environments with known network capacities. In fixed-line access links, a value of 500 ms is RECOMMENDED. Second, the value of RTO SHOULD NOT be rounded up to the nearest second. Rather, a 1 ms accuracy SHOULD be maintained. As with TCP, the usage of Karn's algorithm is RECOMMENDED [[KARN87](#)]. When applied to STUN, it means that RTT estimates SHOULD NOT be computed from STUN transactions that result in the retransmission of a request.

The value for RTO SHOULD be cached by a client after the completion of the transaction, and used as the starting value for RTO for the next transaction to the same server (based on equality of IP address). The value SHOULD be considered stale and discarded after 10 minutes without any transactions to the same server.

Retransmissions continue until a response is received, or until a total of  $R_c$  requests have been sent.  $R_c$  SHOULD be configurable and SHOULD have a default of 7. If, after the last request, a duration equal to  $R_m$  times the RTO has passed without a response (providing ample time to get a response if only this final request actually succeeds), the client SHOULD consider the transaction to have failed.  $R_m$  SHOULD be configurable and SHOULD have a default of 16. A STUN transaction over UDP or DTLS-over-UDP is also considered failed if there has been a hard ICMP error [[RFC1122](#)]. For example, assuming an RTO of 500ms, requests would be sent at times 0 ms, 500 ms, 1500 ms, 3500 ms, 7500 ms, 15500 ms, and 31500 ms. If the client has not received a response after 39500 ms, the client will consider the transaction to have timed out.



### **6.2.2. Sending over TCP or TLS-over-TCP**

For TCP and TLS-over-TCP [[RFC5246](#)], the client opens a TCP connection to the server.

In some usages of STUN, STUN is sent as the only protocol over the TCP connection. In this case, it can be sent without the aid of any additional framing or demultiplexing. In other usages, or with other extensions, it may be multiplexed with other data over a TCP connection. In that case, STUN MUST be run on top of some kind of framing protocol, specified by the usage or extension, which allows for the agent to extract complete STUN messages and complete application layer messages. The STUN service running on the well-known port or ports discovered through the DNS procedures in [Section 8](#) is for STUN alone, and not for STUN multiplexed with other data. Consequently, no framing protocols are used in connections to those servers. When additional framing is utilized, the usage will specify how the client knows to apply it and what port to connect to. For example, in the case of ICE connectivity checks, this information is learned through out-of-band negotiation between client and server.

Reliability of STUN over TCP and TLS-over-TCP is handled by TCP itself, and there are no retransmissions at the STUN protocol level. However, for a request/response transaction, if the client has not received a response by  $T_i$  seconds after it sent the SYN to establish the connection, it considers the transaction to have timed out.  $T_i$  SHOULD be configurable and SHOULD have a default of 39.5s. This value has been chosen to equalize the TCP and UDP timeouts for the default initial RT0.

In addition, if the client is unable to establish the TCP connection, or the TCP connection is reset or fails before a response is received, any request/response transaction in progress is considered to have failed.

The client MAY send multiple transactions over a single TCP (or TLS-over-TCP) connection, and it MAY send another request before receiving a response to the previous. The client SHOULD keep the connection open until it:

- o has no further STUN requests or indications to send over that connection, and
- o has no plans to use any resources (such as a mapped address (MAPPED-ADDRESS or XOR-MAPPED-ADDRESS) or relayed address [[RFC5766](#)]) that were learned through STUN requests sent over that connection, and



- o if multiplexing other application protocols over that port, has finished using that other application, and
- o if using that learned port with a remote peer, has established communications with that remote peer, as is required by some TCP NAT traversal techniques (e.g., [[RFC6544](#)]).

At the server end, the server SHOULD keep the connection open, and let the client close it, unless the server has determined that the connection has timed out (for example, due to the client disconnecting from the network). Bindings learned by the client will remain valid in intervening NATs only while the connection remains open. Only the client knows how long it needs the binding. The server SHOULD NOT close a connection if a request was received over that connection for which a response was not sent. A server MUST NOT ever open a connection back towards the client in order to send a response. Servers SHOULD follow best practices regarding connection management in cases of overload.

### **6.2.3. Sending over TLS-over-TCP or DTLS-over-UDP**

When STUN is run by itself over TLS-over-TCP or DTLS-over-UDP, the TLS\_DHE\_RSA\_WITH\_AES\_128\_GCM\_SHA256 and TLS\_ECDHE\_RSA\_WITH\_AES\_128\_GCM\_SHA256 cipher suites MUST be implemented and other cipher suites MAY be implemented. Perfect Forward Secrecy (PFS) cipher suites MUST be preferred over non-PFS cipher suites. Cipher suites with known weaknesses, such as those based on (single) DES and RC4, MUST NOT be used. Implementations MUST disable TLS-level compression.

When it receives the TLS Certificate message, the client SHOULD verify the certificate and inspect the site identified by the certificate. If the certificate is invalid or revoked, or if it does not identify the appropriate party, the client MUST NOT send the STUN message or otherwise proceed with the STUN transaction. The client MUST verify the identity of the server. To do that, it follows the identification procedures defined in [[RFC6125](#)]. Alternatively, a client MAY be configured with a set of IP addresses that are trusted; if a certificate is received that identifies one of those IP addresses, the client considers the identity of the server to be verified.

When STUN is run multiplexed with other protocols over a TLS-over-TCP connection or a DTLS-over-UDP association, the mandatory ciphersuites and TLS handling procedures operate as defined by those protocols.



### **6.3. Receiving a STUN Message**

This section specifies the processing of a STUN message. The processing specified here is for STUN messages as defined in this specification; additional rules for backwards compatibility are defined in [Section 11](#). Those additional procedures are optional, and usages can elect to utilize them. First, a set of processing operations is applied that is independent of the class. This is followed by class-specific processing, described in the subsections that follow.

When a STUN agent receives a STUN message, it first checks that the message obeys the rules of [Section 5](#). It checks that the first two bits are 0, that the magic cookie field has the correct value, that the message length is sensible, and that the method value is a supported method. It checks that the message class is allowed for the particular method. If the message class is "Success Response" or "Error Response", the agent checks that the transaction ID matches a transaction that is still in progress. If the FINGERPRINT extension is being used, the agent checks that the FINGERPRINT attribute is present and contains the correct value. If any errors are detected, the message is silently discarded. In the case when STUN is being multiplexed with another protocol, an error may indicate that this is not really a STUN message; in this case, the agent should try to parse the message as a different protocol.

The STUN agent then does any checks that are required by a authentication mechanism that the usage has specified (see [Section 9](#)).

Once the authentication checks are done, the STUN agent checks for unknown attributes and known-but-unexpected attributes in the message. Unknown comprehension-optional attributes MUST be ignored by the agent. Known-but-unexpected attributes SHOULD be ignored by the agent. Unknown comprehension-required attributes cause processing that depends on the message class and is described below.

At this point, further processing depends on the message class of the request.

#### **6.3.1. Processing a Request**

If the request contains one or more unknown comprehension-required attributes, the server replies with an error response with an error code of 420 (Unknown Attribute), and includes an UNKNOWN-ATTRIBUTES attribute in the response that lists the unknown comprehension-required attributes.





The server then does any additional checking that the method or the specific usage requires. If all the checks succeed, the server formulates a success response as described below.

When run over UDP or DTLS-over-UDP, a request received by the server could be the first request of a transaction, or a retransmission. The server MUST respond to retransmissions such that the following property is preserved: if the client receives the response to the retransmission and not the response that was sent to the original request, the overall state on the client and server is identical to the case where only the response to the original retransmission is received, or where both responses are received (in which case the client will use the first). The easiest way to meet this requirement is for the server to remember all transaction IDs received over UDP or DTLS-over-UDP and their corresponding responses in the last 40 seconds. However, this requires the server to hold state, and will be inappropriate for any requests which are not authenticated. Another way is to reprocess the request and recompute the response. The latter technique MUST only be applied to requests that are idempotent (a request is considered idempotent when the same request can be safely repeated without impacting the overall state of the system) and result in the same success response for the same request. The Binding method is considered to be idempotent. Note that there are certain rare network events that could cause the reflexive transport address value to change, resulting in a different mapped address in different success responses. Extensions to STUN MUST discuss the implications of request retransmissions on servers that do not store transaction state.

#### **6.3.1.1. Forming a Success or Error Response**

When forming the response (success or error), the server follows the rules of [Section 6](#). The method of the response is the same as that of the request, and the message class is either "Success Response" or "Error Response".

For an error response, the server MUST add an ERROR-CODE attribute containing the error code specified in the processing above. The reason phrase is not fixed, but SHOULD be something suitable for the error code. For certain errors, additional attributes are added to the message. These attributes are spelled out in the description where the error code is specified. For example, for an error code of 420 (Unknown Attribute), the server MUST include an UNKNOWN-ATTRIBUTES attribute. Certain authentication errors also cause attributes to be added (see [Section 9](#)). Extensions may define other errors and/or additional attributes to add in error cases.



If the server authenticated the request using an authentication mechanism, then the server SHOULD add the appropriate authentication attributes to the response (see [Section 9](#)).

The server also adds any attributes required by the specific method or usage. In addition, the server SHOULD add a SOFTWARE attribute to the message.

For the Binding method, no additional checking is required unless the usage specifies otherwise. When forming the success response, the server adds a XOR-MAPPED-ADDRESS attribute to the response, where the contents of the attribute are the source transport address of the request message. For UDP or DTLS-over-UDP this is the source IP address and source UDP port of the request message. For TCP and TLS-over-TCP, this is the source IP address and source TCP port of the TCP connection as seen by the server.

#### **[6.3.1.2](#). Sending the Success or Error Response**

The response (success or error) is sent over the same transport as the request was received on. If the request was received over UDP or DTLS-over-UDP the destination IP address and port of the response are the source IP address and port of the received request message, and the source IP address and port of the response are equal to the destination IP address and port of the received request message. If the request was received over TCP or TLS-over-TCP, the response is sent back on the same TCP connection as the request was received on.

#### **[6.3.2](#). Processing an Indication**

If the indication contains unknown comprehension-required attributes, the indication is discarded and processing ceases.

The agent then does any additional checking that the method or the specific usage requires. If all the checks succeed, the agent then processes the indication. No response is generated for an indication.

For the Binding method, no additional checking or processing is required, unless the usage specifies otherwise. The mere receipt of the message by the agent has refreshed the "bindings" in the intervening NATs.

Since indications are not re-transmitted over UDP or DTLS-over-UDP (unlike requests), there is no need to handle re-transmissions of indications at the sending agent.



### **6.3.3. Processing a Success Response**

If the success response contains unknown comprehension-required attributes, the response is discarded and the transaction is considered to have failed.

The client then does any additional checking that the method or the specific usage requires. If all the checks succeed, the client then processes the success response.

For the Binding method, the client checks that the XOR-MAPPED-ADDRESS attribute is present in the response. The client checks the address family specified. If it is an unsupported address family, the attribute SHOULD be ignored. If it is an unexpected but supported address family (for example, the Binding transaction was sent over IPv4, but the address family specified is IPv6), then the client MAY accept and use the value.

### **6.3.4. Processing an Error Response**

If the error response contains unknown comprehension-required attributes, or if the error response does not contain an ERROR-CODE attribute, then the transaction is simply considered to have failed.

The client then does any processing specified by the authentication mechanism (see [Section 9](#)). This may result in a new transaction attempt.

The processing at this point depends on the error code, the method, and the usage; the following are the default rules:

- o If the error code is 300 through 399, the client SHOULD consider the transaction as failed unless the ALTERNATE-SERVER extension is being used. See [Section 10](#).
- o If the error code is 400 through 499, the client declares the transaction failed; in the case of 420 (Unknown Attribute), the response should contain a UNKNOWN-ATTRIBUTES attribute that gives additional information.
- o If the error code is 500 through 599, the client MAY resend the request; clients that do so MUST limit the number of times they do this.

Any other error code causes the client to consider the transaction failed.



## **7. FINGERPRINT Mechanism**

This section describes an optional mechanism for STUN that aids in distinguishing STUN messages from packets of other protocols when the two are multiplexed on the same transport address. This mechanism is optional, and a STUN usage must describe if and when it is used. The FINGERPRINT mechanism is not backwards compatible with [RFC3489](#), and cannot be used in environments where such compatibility is required.

In some usages, STUN messages are multiplexed on the same transport address as other protocols, such as the Real Time Transport Protocol (RTP). In order to apply the processing described in [Section 6](#), STUN messages must first be separated from the application packets.

[Section 5](#) describes three fixed fields in the STUN header that can be used for this purpose. However, in some cases, these three fixed fields may not be sufficient.

When the FINGERPRINT extension is used, an agent includes the FINGERPRINT attribute in messages it sends to another agent. [Section 14.7](#) describes the placement and value of this attribute.

When the agent receives what it believes is a STUN message, then, in addition to other basic checks, the agent also checks that the message contains a FINGERPRINT attribute and that the attribute contains the correct value. [Section 6.3](#) describes when in the overall processing of a STUN message the FINGERPRINT check is performed. This additional check helps the agent detect messages of other protocols that might otherwise seem to be STUN messages.

## **8. DNS Discovery of a Server**

This section describes an optional procedure for STUN that allows a client to use DNS to determine the IP address and port of a server. A STUN usage must describe if and when this extension is used. To use this procedure, the client must know a STUN URI [[RFC7064](#)]; the usage must also describe how the client obtains this URI. Hard-coding a STUN URI into software is NOT RECOMMENDED in case the domain name is lost or needs to change for legal or other reasons.

When a client wishes to locate a STUN server on the public Internet that accepts Binding request/response transactions, the STUN URI scheme is "stun". When it wishes to locate a STUN server that accepts Binding request/response transactions over a TLS, or DTLS session, the URI scheme is "stuns".

The syntax of the "stun" and "stuns" URIs are defined in [Section 3.1 of \[RFC7064\]](#). STUN usages MAY define additional URI schemes.





### **8.1. STUN URI Scheme Semantics**

If the <host> part of a "stun" URI contains an IP address, then this IP address is used directly to contact the server. A "stuns" URI containing an IP address MUST be rejected, unless the domain name is provided by the same mechanism that provided the STUN URI, and that domain name can be passed to the verification code.

If the URI does not contain an IP address, the domain name contained in the <host> part is resolved to a transport address using the SRV procedures specified in [[RFC2782](#)]. The DNS SRV service name is the content of the <scheme> part. The protocol in the SRV lookup is the transport protocol the client will run STUN over: "udp" for UDP and "tcp" for TCP.

The procedures of [RFC 2782](#) are followed to determine the server to contact. [RFC 2782](#) spells out the details of how a set of SRV records is sorted and then tried. However, [RFC 2782](#) only states that the client should "try to connect to the (protocol, address, service)" without giving any details on what happens in the event of failure. When following these procedures, if the STUN transaction times out without receipt of a response, the client SHOULD retry the request to the next server in the ordered defined by [RFC 2782](#). Such a retry is only possible for request/response transmissions, since indication transactions generate no response or timeout.

In addition, instead of querying either the A or the AAAA resource records for a domain name, the client MUST query both and try the requests with all the IP addresses received, as specified in [[RFC6555](#)].

The default port for STUN requests is 3478, for both TCP and UDP. The default port for STUN over TLS and STUN over DTLS requests is 5349. Servers can run STUN over DTLS on the same port as STUN over UDP if the server software supports determining whether the initial message is a DTLS or STUN message. Servers can run STUN over TLS on the same port as STUN over TCP if the server software supports determining whether the initial message is a TLS or STUN message.

Administrators of STUN servers SHOULD use these ports in their SRV records for UDP and TCP. In all cases, the port in DNS MUST reflect the one on which the server is listening.

If no SRV records were found, the client performs both an A and AAAA record lookup of the domain name, as described in [[RFC6555](#)]. The result will be a list of IP addresses, each of which can be simultaneously contacted at the default port using UDP or TCP, independent of the STUN usage. For usages that require TLS, the



client connects to the IP addresses using the default STUN over TLS port. For usages that require DTLS, the client connects to the IP addresses using the default STUN over DTLS port.

## **9. Authentication and Message-Integrity Mechanisms**

This section defines two mechanisms for STUN that a client and server can use to provide authentication and message integrity; these two mechanisms are known as the short-term credential mechanism and the long-term credential mechanism. These two mechanisms are optional, and each usage must specify if and when these mechanisms are used. Consequently, both clients and servers will know which mechanism (if any) to follow based on knowledge of which usage applies. For example, a STUN server on the public Internet supporting ICE would have no authentication, whereas the STUN server functionality in an agent supporting connectivity checks would utilize short-term credentials. An overview of these two mechanisms is given in [Section 2](#).

Each mechanism specifies the additional processing required to use that mechanism, extending the processing specified in [Section 6](#). The additional processing occurs in three different places: when forming a message, when receiving a message immediately after the basic checks have been performed, and when doing the detailed processing of error responses.

### **9.1. Short-Term Credential Mechanism**

The short-term credential mechanism assumes that, prior to the STUN transaction, the client and server have used some other protocol to exchange a credential in the form of a username and password. This credential is time-limited. The time limit is defined by the usage. As an example, in the ICE usage [[I-D.ietf-ice-rfc5245bis](#)], the two endpoints use out-of-band signaling to agree on a username and password, and this username and password are applicable for the duration of the media session.

This credential is used to form a message-integrity check in each request and in many responses. There is no challenge and response as in the long-term mechanism; consequently, replay is prevented by virtue of the time-limited nature of the credential.

#### **9.1.1. HMAC Key**

For short-term credentials the HMAC key is defined as follow:

```
key = OpaqueString(password)
```



where the OpaqueString profile is defined in [[RFC7613](#)].

### **9.1.2. Forming a Request or Indication**

For a request or indication message, the agent MUST include the USERNAME, MESSAGE-INTEGRITY-SHA256, and MESSAGE-INTEGRITY attributes in the message unless the agent knows from an external indication which message integrity algorithm is supported by both agents. In this case either MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 MUST be included in addition to USERNAME. The HMAC for the MESSAGE-INTEGRITY attribute is computed as described in [Section 14.5](#) and the HMAC for the MESSAGE-INTEGRITY-SHA256 attributes is computed as described in [Section 14.6](#). Note that the password is never included in the request or indication.

### **9.1.3. Receiving a Request or Indication**

After the agent has done the basic processing of a message, the agent performs the checks listed below in order specified:

- o If the message does not contain 1) a MESSAGE-INTEGRITY or a MESSAGE-INTEGRITY-SHA256 attribute and 2) a USERNAME attribute:
  - \* If the message is a request, the server MUST reject the request with an error response. This response MUST use an error code of 400 (Bad Request).
  - \* If the message is an indication, the agent MUST silently discard the indication.
- o If the USERNAME does not contain a username value currently valid within the server:
  - \* If the message is a request, the server MUST reject the request with an error response. This response MUST use an error code of 401 (Unauthenticated).
  - \* If the message is an indication, the agent MUST silently discard the indication.
- o If the MESSAGE-INTEGRITY-SHA256 attribute is present compute the value for the message integrity as described in [Section 14.6](#), using the password associated with the username. If the MESSAGE-INTEGRITY-SHA256 attribute is not present, and using the same password, compute the value for the message integrity as described in [Section 14.5](#). If the resulting value does not match the contents of the corresponding attribute (MESSAGE-INTEGRITY-SHA256 or MESSAGE-INTEGRITY):



- \* If the message is a request, the server MUST reject the request with an error response. This response MUST use an error code of 401 (Unauthenticated).
- \* If the message is an indication, the agent MUST silently discard the indication.

If these checks pass, the agent continues to process the request or indication. Any response generated by a server to a request that contains a MESSAGE-INTEGRITY-SHA256 attribute MUST include the MESSAGE-INTEGRITY-SHA256 attribute, computed using the password utilized to authenticate the request. Any response generated by a server to a request that contains only a MESSAGE-INTEGRITY attribute MUST include the MESSAGE-INTEGRITY attribute, computed using the password utilized to authenticate the request. This means that only one of these attributes can appear in a response. The response MUST NOT contain the USERNAME attribute.

If any of the checks fail, a server MUST NOT include a MESSAGE-INTEGRITY-SHA256, MESSAGE-INTEGRITY, or USERNAME attribute in the error response. This is because, in these failure cases, the server cannot determine the shared secret necessary to compute the MESSAGE-INTEGRITY-SHA256 or MESSAGE-INTEGRITY attributes.

#### **9.1.4. Receiving a Response**

The client looks for the MESSAGE-INTEGRITY or the MESSAGE-INTEGRITY-SHA256 attribute in the response. If present and if the client only sent only one of MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attributes in the request (because of the external indication in [Section 9.2.3](#), or this being a subsequent request as defined in [Section 9.1.5](#)) the algorithm in the response has to match otherwise the response MUST be discarded.

The client then computes the message integrity over the response as defined in [Section 14.5](#) or [Section 14.6](#), respectively, using the same password it utilized for the request. If the resulting value matches the contents of the MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, respectively, the response is considered authenticated. If the value does not match, or if both MESSAGE-INTEGRITY and MESSAGE-INTEGRITY-SHA256 were absent, the processing depends on the request been sent over a reliable or an unreliable transport.

If the request was sent over an unreliable transport, the response MUST be discarded, as if it was never received. This means that retransmits, if applicable, will continue. If all the responses received are discarded then instead of signalling a timeout after





ending the transaction the layer MUST signal that an attack took place.

If the request was sent over a reliable transport, the response MUST be discarded and the layer MUST immediately end the transaction and signal that an attack took place.

#### **9.1.5. Sending Subsequent Requests**

A client sending subsequent requests to the same server MUST send only the MESSAGE-INTEGRITY-SHA256 or the MESSAGE-INTEGRITY attribute that matches the attribute that was received in the response to the initial request. Here same server means same IP address and port number, not just the same URI or SRV lookup result.

#### **9.2. Long-Term Credential Mechanism**

The long-term credential mechanism relies on a long-term credential, in the form of a username and password that are shared between client and server. The credential is considered long-term since it is assumed that it is provisioned for a user, and remains in effect until the user is no longer a subscriber of the system, or is changed. This is basically a traditional "log-in" username and password given to users.

Because these usernames and passwords are expected to be valid for extended periods of time, replay prevention is provided in the form of a digest challenge. In this mechanism, the client initially sends a request, without offering any credentials or any integrity checks. The server rejects this request, providing the user a realm (used to guide the user or agent in selection of a username and password) and a nonce. The nonce provides the replay protection. It is a cookie, selected by the server, and encoded in such a way as to indicate a duration of validity or client identity from which it is valid. The client retries the request, this time including its username and the realm, and echoing the nonce provided by the server. The client also includes a message-integrity, which provides an HMAC over the entire request, including the nonce. The server validates the nonce and checks the message integrity. If they match, the request is authenticated. If the nonce is no longer valid, it is considered "stale", and the server rejects the request, providing a new nonce.

In subsequent requests to the same server, the client reuses the nonce, username, realm, and password it used previously. In this way, subsequent requests are not rejected until the nonce becomes invalid by the server, in which case the rejection provides a new nonce to the client.



Note that the long-term credential mechanism cannot be used to protect indications, since indications cannot be challenged. Usages utilizing indications must either use a short-term credential or omit authentication and message integrity for them.

To indicate that it supports this specification, a server MUST prepend the NONCE attribute value with the character string composed of "obMatJos2" concatenated with the Base64 [\[RFC4648\]](#) encoding of the 24 bit STUN Security Features as defined in [Section 17.1](#). The 24 bit Security Feature set is encoded as a 24 bit integer in network order. If no security features are used, then the value 0 MUST be encoded instead. For the remainder of this document the term "nonce cookie" will refer to the complete 13 character string prepended to the NONCE attribute value.

Since the long-term credential mechanism is susceptible to offline dictionary attacks, deployments SHOULD utilize passwords that are difficult to guess. In cases where the credentials are not entered by the user, but are rather placed on a client device during device provisioning, the password SHOULD have at least 128 bits of randomness. In cases where the credentials are entered by the user, they should follow best current practices around password structure.

#### **[9.2.1](#). Bid Down Attack Prevention**

This document introduces two new security features that provide the ability to choose the algorithm used for password protection as well as the ability to use an anonymous username. Both of these capabilities are optional in order to remain backwards compatible with previous versions of the STUN protocol.

These new capabilities are subject to bid down attacks whereby an attacker in the message path can remove these capabilities and force weaker security properties. To prevent these kinds of attacks from going undetected, the nonce is enhanced with additional information.

The value of the "nonce cookie" will vary based on the specific STUN Security Features bit values selected. When this document makes reference to the "nonce cookie" in a section discussing a specific STUN Security Feature it is understood that the corresponding STUN Security Feature bit in the "nonce cookie" is set to 1.

For example, in [Section 9.2.4](#) discussing the PASSWORD-ALGORITHMS security feature, it is implied that the "Password algorithms" bit, as defined in [Section 17.1](#), is set to 1 in the "nonce cookie".



### **9.2.2. HMAC Key**

For long-term credentials that do not use a different algorithm, as specified by the PASSWORD-ALGORITHM attribute, the key is 16 bytes:

```
key = MD5(username ":" OpaqueString(realm) ":" OpaqueString(password))
```

Where MD5 is defined in [[RFC1321](#)] and the OpaqueString profile is defined in [[RFC7613](#)].

The 16-byte key is formed by taking the MD5 hash of the result of concatenating the following five fields: (1) the username, with any quotes and trailing nulls removed, as taken from the USERNAME attribute (in which case OpaqueString has already been applied); (2) a single colon; (3) the realm, with any quotes and trailing nulls removed and after processing using OpaqueString; (4) a single colon; and (5) the password, with any trailing nulls removed and after processing using OpaqueString. For example, if the username was 'user', the realm was 'realm', and the password was 'pass', then the 16-byte HMAC key would be the result of performing an MD5 hash on the string 'user:realm:pass', the resulting hash being 0x8493fbc53ba582fb4c044c456bdc40eb.

The structure of the key when used with long-term credentials facilitates deployment in systems that also utilize SIP. Typically, SIP systems utilizing SIP's digest authentication mechanism do not actually store the password in the database. Rather, they store a value called H(A1), which is equal to the key defined above.

When a PASSWORD-ALGORITHM is used, the key length and algorithm to use are described in [Section 17.5.1](#).

### **9.2.3. Forming a Request**

There are two cases when forming a request. In the first case, this is the first request from the client to the server (as identified by its IP address and port). In the second case, the client is submitting a subsequent request once a previous request/response transaction has completed successfully. Forming a request as a consequence of a 401 or 438 error response is covered in [Section 9.2.5](#) and is not considered a "subsequent request" and thus does not utilize the rules described in [Section 9.2.3.2](#).

The difference between a first request and a subsequent request is the presence or absence of some attributes, so omitting or including them is a MUST.



#### **9.2.3.1. First Request**

If the client has not completed a successful request/response transaction with the server (as identified by hostname, if the DNS procedures of [Section 8](#) are used, else IP address if not), it MUST omit the USERNAME, USERHASH, MESSAGE-INTEGRITY, MESSAGE-INTEGRITY-SHA256, REALM, NONCE, PASSWORD-ALGORITHMS, and PASSWORD-ALGORITHM attributes. In other words, the very first request is sent as if there were no authentication or message integrity applied.

#### **9.2.3.2. Subsequent Requests**

Once a request/response transaction has completed successfully, the client will have been presented a realm and nonce by the server, and selected a username and password with which it authenticated. The client SHOULD cache the username, password, realm, and nonce for subsequent communications with the server. When the client sends a subsequent request, it MUST include either the USERNAME or USERHASH, REALM, NONCE, and PASSWORD-ALGORITHM attributes with these cached values. It MUST include a MESSAGE-INTEGRITY attribute or a MESSAGE-INTEGRITY-SHA256 attribute, computed as described in [Section 14.5](#) and [Section 14.6](#) using the cached password. The choice between the two attributes depends on the attribute received in the response to the first request.

#### **9.2.4. Receiving a Request**

After the server has done the basic processing of a request, it performs the checks listed below in the order specified:

- o If the message does not contain a MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, the server MUST generate an error response with an error code of 401 (Unauthenticated). This response MUST include a REALM value. It is RECOMMENDED that the REALM value be the domain name of the provider of the STUN server. The response MUST include a NONCE, selected by the server. The server MUST ensure that the same NONCE cannot be selected for clients that use different source IP addresses, different source ports, or both different source IP addresses and source ports. The server MAY support alternate password algorithms, in which case it can list them in preferential order in a PASSWORD-ALGORITHMS attribute. If the server adds a PASSWORD-ALGORITHMS attribute it MUST set the STUN Security Feature "Password algorithms" bit set to 1. The server MAY support anonymous username, in which case it MUST set the STUN Security Feature "Anonymous username" bit set to 1. The response SHOULD NOT contain a USERNAME, USERHASH, MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute.





Note: Reusing a NONCE for different source IP addresses or ports was not explicitly forbidden in [\[RFC5389\]](#).

- o If the message contains a MESSAGE-INTEGRITY or a MESSAGE-INTEGRITY-SHA256 attribute, but is missing either the USERNAME or USERHASH, REALM, or NONCE attribute, the server MUST generate an error response with an error code of 400 (Bad Request). This response SHOULD NOT include a USERNAME, USERHASH, NONCE, or REALM. The response cannot contain a MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, as the attributes required to generate them are missing.
- o If the NONCE attribute starts with the "nonce cookie" with the STUN Security Feature "Password algorithm" bit set to 1 but PASSWORD-ALGORITHMS does not match the value sent in the response that sent this NONCE, then the server MUST generate an error response with an error code of 400 (Bad Request).
- o If the NONCE attribute starts with the "nonce cookie" with the STUN Security Feature "Password algorithm" bit set to 1 but the request contains neither PASSWORD-ALGORITHMS nor PASSWORD-ALGORITHM, then the request is processed as though PASSWORD-ALGORITHM were MD5 (Note that if the original PASSWORD-ALGORITHMS attribute did not contain MD5, this will result in a 400 Bad Request in a later step below).
- o If the NONCE attribute starts with the "nonce cookie" with the STUN Security Feature "Password algorithm" bit set to 1 but only one of PASSWORD-ALGORITHM or PASSWORD-ALGORITHMS is present, then the server MUST generate an error response with an error code of 400 (Bad Request).
- o If the NONCE attribute starts with the "nonce cookie" with the STUN Security Feature "Password algorithm" bit set to 1 but PASSWORD-ALGORITHM does not match one of the entries in PASSWORD-ALGORITHMS, then the server MUST generate an error response with an error code of 400 (Bad Request).
- o If the NONCE is no longer valid and at the same time the MESSAGE-INTEGRITY or a MESSAGE-INTEGRITY-SHA256 attribute is invalid, the server MUST generate an error response with an error code of 401. This response MUST include NONCE, REALM, and PASSWORD-ALGORITHMS attributes and SHOULD NOT include the USERNAME or USERHASH attribute. The response MAY include a MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, using the previous NONCE to calculate it.



- o If the NONCE is no longer valid, the server MUST generate an error response with an error code of 438 (Stale Nonce). This response MUST include NONCE, REALM, and PASSWORD-ALGORITHMS attributes and SHOULD NOT include the USERNAME, USERHASH attribute. The response MAY include a MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, using the previous NONCE to calculate it. Servers can invalidate nonces in order to provide additional security. See [Section 4.3 of \[RFC7616\]](#) for guidelines.
- o If the value of the USERNAME or USERHASH attribute is not valid, the server MUST generate an error response with an error code of 401 (Unauthenticated). This response MUST include a REALM value. It is RECOMMENDED that the REALM value be the domain name of the provider of the STUN server. The response MUST include a NONCE, selected by the server. The response MUST include a PASSWORD-ALGORITHMS attribute. The response SHOULD NOT contain a USERNAME, USERHASH attribute. The response MAY include a MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, using the previous password to calculate it.
- o If the MESSAGE-INTEGRITY-SHA256 attribute is present compute the value for the message integrity as described in [Section 14.6](#), using the password associated with the username. Else, using the same password, compute the value for the message integrity as described in [Section 14.5](#). If the resulting value does not match the contents of the MESSAGE-INTEGRITY attribute or the MESSAGE-INTEGRITY-SHA256 attribute, the server MUST reject the request with an error response. This response MUST use an error code of 401 (Unauthenticated). It MUST include REALM and NONCE attributes and SHOULD NOT include the USERNAME, USERHASH, MESSAGE-INTEGRITY, or MESSAGE-INTEGRITY-SHA256 attribute.

If these checks pass, the server continues to process the request. Any response generated by the server MUST include MESSAGE-INTEGRITY-SHA256 attribute, computed using the username and password utilized to authenticate the request, unless the request was processed as though PASSWORD-ALGORITHM was MD5 (because the request contained neither PASSWORD-ALGORITHMS nor PASSWORD-ALGORITHM). In that case the MESSAGE-INTEGRITY attribute MUST be used instead of the MESSAGE-INTEGRITY-SHA256 attribute. The REALM, NONCE, USERNAME and USERHASH attributes SHOULD NOT be included.

#### **9.2.5. Receiving a Response**

If the response is an error response with an error code of 401 (Unauthenticated) or 438 (Stale Nonce), the client MUST test if the NONCE attribute value starts with the "nonce cookie". If the test succeeds and the "nonce cookie" has the STUN Security Feature



"Password algorithm" bit set to 1 but no PASSWORD-ALGORITHMS attribute is present, then the client MUST NOT retry the request with a new transaction. If the test succeeds and the "nonce cookie" has the STUN Security Feature "Username anonymity" bit set to 1 but no USERHASH attribute is present, then the client MUST NOT retry the request with a new transaction.

If the response is an error response with an error code of 401 (Unauthenticated), the client SHOULD retry the request with a new transaction. This request MUST contain a USERNAME or a USERHASH, determined by the client as the appropriate username for the REALM from the error response. If the "nonce cookie" was present and had the STUN Security Feature "Username anonymity" bit set to 1 then the USERHASH attribute MUST be used, else the USERNAME attribute MUST be used. The request MUST contain the REALM, copied from the error response. The request MUST contain the NONCE, copied from the error response. If the response contains a PASSWORD-ALGORITHMS attribute, the request MUST contain the PASSWORD-ALGORITHMS attribute with the same content. If the response contains a PASSWORD-ALGORITHMS attribute, and this attribute contains at least one algorithm that is supported by the client then the request MUST contain a PASSWORD-ALGORITHM attribute with the first algorithm supported on the list. If the response contains a PASSWORD-ALGORITHMS attribute, and this attribute does not contain any algorithm that is supported by the client, then the client MUST NOT retry the request with a new transaction. The client MUST NOT perform this retry if it is not changing the USERNAME or USERHASH or REALM or its associated password, from the previous attempt.

If the response is an error response with an error code of 438 (Stale Nonce), the client MUST retry the request, using the new NONCE attribute supplied in the 438 (Stale Nonce) response. This retry MUST also include either the USERNAME or USERHASH, REALM and either the MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attributes.

For all other responses, if the NONCE attribute starts with the "nonce cookie" with the STUN Security Feature "Password algorithm" bit set to 1 but PASSWORD-ALGORITHMS is not present, the response MUST be ignored. For all other responses, if the NONCE attribute starts with the "nonce cookie" with the STUN Security Feature "User anonymity" bit set to 1 but USERHASH is not present, the response MUST be ignored.

If the response is an error response with an error code of 400, and does not contain either MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute then the response MUST be discarded, as if it was never received. This means that retransmits, if applicable, will continue.



The client looks for the MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute in the response (either success or failure). If present, the client computes the message integrity over the response as defined in [Section 14.5](#) or [Section 14.6](#), using the same password it utilized for the request. If the resulting value matches the contents of the MESSAGE-INTEGRITY or MESSAGE-INTEGRITY-SHA256 attribute, the response is considered authenticated. If the value does not match, or if both MESSAGE-INTEGRITY and MESSAGE-INTEGRITY-SHA256 were absent, the processing depends on the request been sent over a reliable or an unreliable transport.

If the request was sent over an unreliable transport, the response MUST be discarded, as if it was never received. This means that retransmits, if applicable, will continue. If all the responses received are discarded then instead of signalling a timeout after ending the transaction the layer MUST signal that an attack took place.

If the request was sent over a reliable transport, the response MUST be discarded and the layer MUST immediately end the transaction and signal that an attack took place.

If the response contains a PASSWORD-ALGORITHMS attribute, the subsequent request MUST be authenticated using MESSAGE-INTEGRITY-SHA256 only.

## **10. ALTERNATE-SERVER Mechanism**

This section describes a mechanism in STUN that allows a server to redirect a client to another server. This extension is optional, and a usage must define if and when this extension is used.

A server using this extension redirects a client to another server by replying to a request message with an error response message with an error code of 300 (Try Alternate). The server MUST include an ALTERNATE-SERVER attribute in the error response. The error response message MAY be authenticated; however, there are use cases for ALTERNATE-SERVER where authentication of the response is not possible or practical. If the transaction uses TLS or DTLS and if the transaction is authenticated by a MESSAGE-INTEGRITY-SHA256 attribute and if the server wants to redirect to a server that uses a different certificate, then it MUST include an ALTERNATE-DOMAIN attribute containing the subjectAltName of that certificate.

A client using this extension handles a 300 (Try Alternate) error code as follows. The client looks for an ALTERNATE-SERVER attribute in the error response. If one is found, then the client considers the current transaction as failed, and reattempts the request with





the server specified in the attribute, using the same transport protocol used for the previous request. That request, if authenticated, MUST utilize the same credentials that the client would have used in the request to the server that performed the redirection. If the transport protocol uses TLS or DTLS, then the client looks for an ALTERNATE-DOMAIN attribute. If the attribute is found, the domain MUST be used to validate the certificate using the recommendations in [\[RFC6125\]](#). If the attribute is not found, the same domain that was used for the original request MUST be used to validate the certificate. If the client has been redirected to a server on which it has already tried this request within the last five minutes, it MUST ignore the redirection and consider the transaction to have failed. This prevents infinite ping-ponging between servers in case of redirection loops.

## **11. Backwards Compatibility with [RFC 3489](#)**

In addition to the backward compatibility already described in [Section 12 of \[RFC5389\]](#), DTLS MUST NOT be used with [\[RFC3489\]](#) (also referred to as "classic STUN"). Any STUN request or indication without the magic cookie (see [Section 6 of \[RFC5389\]](#)) over DTLS MUST always result in an error.

## **12. Basic Server Behavior**

This section defines the behavior of a basic, stand-alone STUN server.

Historically, "classic STUN [\[RFC3489\]](#)" only defined the behavior of a server that was providing clients with server reflexive transport addresses by receiving and replying to STUN Binding requests. [\[RFC5389\]](#) redefined the protocol as an extensible framework and the server functionality became the sole STUN Usage defined in that document. This STUN Usage is also known as Basic STUN Server.

The STUN server MUST support the Binding method. It SHOULD NOT utilize the short-term or long-term credential mechanism. This is because the work involved in authenticating the request is more than the work in simply processing it. It SHOULD NOT utilize the ALTERNATE-SERVER mechanism for the same reason. It MUST support UDP and TCP. It MAY support STUN over TCP/TLS or STUN over UDP/DTLS; however, DTLS and TLS provide minimal security benefits in this basic mode of operation. It MAY utilize the FINGERPRINT mechanism but MUST NOT require it. Since the stand-alone server only runs STUN, FINGERPRINT provides no benefit. Requiring it would break compatibility with [RFC 3489](#), and such compatibility is desirable in a stand-alone server. Stand-alone STUN servers SHOULD support



backwards compatibility with [[RFC3489](#)] clients, as described in [Section 11](#).

It is RECOMMENDED that administrators of STUN servers provide DNS entries for those servers as described in [Section 8](#). If both A and AAAA Resource Records are returned then the client can simultaneously send STUN Binding requests to the IPv4 and IPv6 addresses (as specified in [[RFC6555](#)]), as the Binding request is idempotent. Note that the MAPPED-ADDRESS or XOR-MAPPED-ADDRESS attributes that are returned will not necessarily match the address family of the server address used.

A basic STUN server is not a solution for NAT traversal by itself. However, it can be utilized as part of a solution through STUN usages. This is discussed further in [Section 13](#).

### **[13](#). STUN Usages**

STUN by itself is not a solution to the NAT traversal problem. Rather, STUN defines a tool that can be used inside a larger solution. The term "STUN usage" is used for any solution that uses STUN as a component.

A STUN usage defines how STUN is actually utilized -- when to send requests, what to do with the responses, and which optional procedures defined here (or in an extension to STUN) are to be used. A usage would also define:

- o Which STUN methods are used.
- o What transports are used. If DTLS-over-UDP is used then implementing the denial-of-service countermeasure described in [Section 4.2.1 of \[RFC6347\]](#) is mandatory.
- o What authentication and message-integrity mechanisms are used.
- o The considerations around manual vs. automatic key derivation for the integrity mechanism, as discussed in [[RFC4107](#)].
- o What mechanisms are used to distinguish STUN messages from other messages. When STUN is run over TCP, a framing mechanism may be required.
- o How a STUN client determines the IP address and port of the STUN server.



- o How simultaneous use of IPv4 and IPv6 addresses (Happy Eyeballs [[RFC6555](#)]) works with non-idempotent transactions when both address families are found for the STUN server.
- o Whether backwards compatibility to [RFC 3489](#) is required.
- o What optional attributes defined here (such as FINGERPRINT and ALTERNATE-SERVER) or in other extensions are required.
- o If MESSAGE-INTEGRITY-256 truncation is permitted, and the limits permitted for truncation.

In addition, any STUN usage must consider the security implications of using STUN in that usage. A number of attacks against STUN are known (see the Security Considerations section in this document), and any usage must consider how these attacks can be thwarted or mitigated.

Finally, a usage must consider whether its usage of STUN is an example of the Unilateral Self-Address Fixing approach to NAT traversal, and if so, address the questions raised in [RFC 3424](#) [[RFC3424](#)].

#### **[14.](#) STUN Attributes**

After the STUN header are zero or more attributes. Each attribute MUST be TLV encoded, with a 16-bit type, 16-bit length, and value. Each STUN attribute MUST end on a 32-bit boundary. As mentioned above, all fields in an attribute are transmitted most significant bit first.

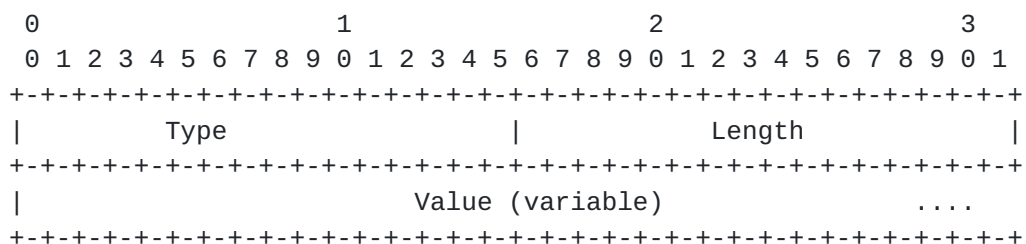


Figure 4: Format of STUN Attributes

The value in the length field MUST contain the length of the Value part of the attribute, prior to padding, measured in bytes. Since STUN aligns attributes on 32-bit boundaries, attributes whose content is not a multiple of 4 bytes are padded with 1, 2, or 3 bytes of padding so that its value contains a multiple of 4 bytes. The padding bits are ignored, and may be any value.



Any attribute type MAY appear more than once in a STUN message. Unless specified otherwise, the order of appearance is significant: only the first occurrence needs to be processed by a receiver, and any duplicates MAY be ignored by a receiver.

To allow future revisions of this specification to add new attributes if needed, the attribute space is divided into two ranges. Attributes with type values between 0x0000 and 0x7FFF are comprehension-required attributes, which means that the STUN agent cannot successfully process the message unless it understands the attribute. Attributes with type values between 0x8000 and 0xFFFF are comprehension-optional attributes, which means that those attributes can be ignored by the STUN agent if it does not understand them.

The set of STUN attribute types is maintained by IANA. The initial set defined by this specification is found in [Section 17.3](#).

The rest of this section describes the format of the various attributes defined in this specification.

#### [14.1](#). MAPPED-ADDRESS

The MAPPED-ADDRESS attribute indicates a reflexive transport address of the client. It consists of an 8-bit address family and a 16-bit port, followed by a fixed-length value representing the IP address. If the address family is IPv4, the address MUST be 32 bits. If the address family is IPv6, the address MUST be 128 bits. All fields must be in network byte order.

The format of the MAPPED-ADDRESS attribute is:

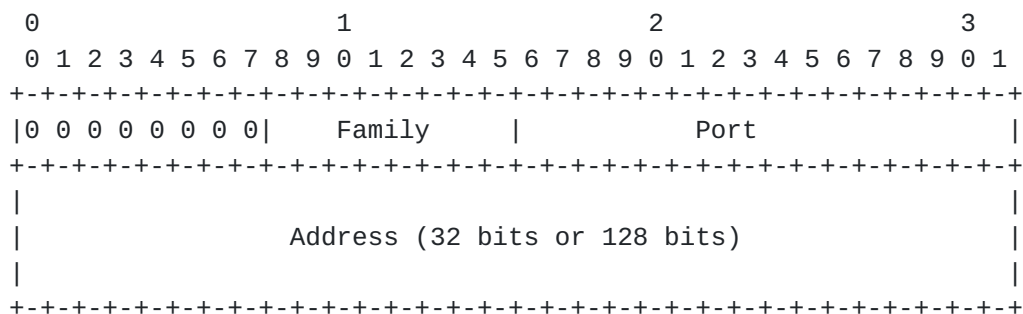


Figure 5: Format of MAPPED-ADDRESS Attribute

The address family can take on the following values:

0x01:IPv4  
0x02:IPv6





The first 8 bits of the MAPPED-ADDRESS MUST be set to 0 and MUST be ignored by receivers. These bits are present for aligning parameters on natural 32-bit boundaries.

This attribute is used only by servers for achieving backwards compatibility with [\[RFC3489\]](#) clients.

#### 14.2. XOR-MAPPED-ADDRESS

The XOR-MAPPED-ADDRESS attribute is identical to the MAPPED-ADDRESS attribute, except that the reflexive transport address is obfuscated through the XOR function.

The format of the XOR-MAPPED-ADDRESS is:

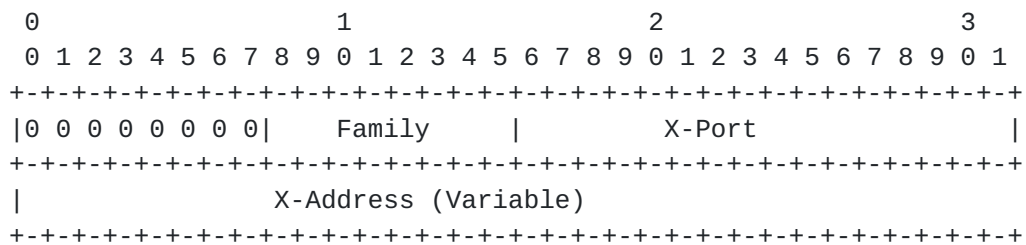


Figure 6: Format of XOR-MAPPED-ADDRESS Attribute

The Family represents the IP address family, and is encoded identically to the Family in MAPPED-ADDRESS.

X-Port is computed by taking the mapped port in host byte order, XOR'ing it with the most significant 16 bits of the magic cookie, and then the converting the result to network byte order. If the IP address family is IPv4, X-Address is computed by taking the mapped IP address in host byte order, XOR'ing it with the magic cookie, and converting the result to network byte order. If the IP address family is IPv6, X-Address is computed by taking the mapped IP address in host byte order, XOR'ing it with the concatenation of the magic cookie and the 96-bit transaction ID, and converting the result to network byte order.

The rules for encoding and processing the first 8 bits of the attribute's value, the rules for handling multiple occurrences of the attribute, and the rules for processing address families are the same as for MAPPED-ADDRESS.

Note: XOR-MAPPED-ADDRESS and MAPPED-ADDRESS differ only in their encoding of the transport address. The former encodes the transport address by exclusive-or'ing it with the magic cookie. The latter encodes it directly in binary. [RFC 3489](#) originally specified only



MAPPED-ADDRESS. However, deployment experience found that some NATs rewrite the 32-bit binary payloads containing the NAT's public IP address, such as STUN's MAPPED-ADDRESS attribute, in the well-meaning but misguided attempt at providing a generic ALG function. Such behavior interferes with the operation of STUN and also causes failure of STUN's message-integrity checking.

#### **14.3. USERNAME**

The USERNAME attribute is used for message integrity. It identifies the username and password combination used in the message-integrity check.

The value of USERNAME is a variable-length value. It MUST contain a UTF-8 [[RFC3629](#)] encoded sequence of less than 513 bytes, and MUST have been processed using the OpaqueString profile [[RFC7613](#)].

#### **14.4. USERHASH**

The USERHASH attribute is used as a replacement for the USERNAME attribute when username anonymity is supported.

The value of USERHASH has a fixed length of 32 bytes. The username MUST have been processed using the OpaqueString profile [[RFC7613](#)] before hashing.

The following is the operation that the client will perform to hash the username:

```
userhash = SHA256(username ":" realm)
```

#### **14.5. MESSAGE-INTEGRITY**

The MESSAGE-INTEGRITY attribute contains an HMAC-SHA1 [[RFC2104](#)] of the STUN message. The MESSAGE-INTEGRITY attribute can be present in any STUN message type. Since it uses the SHA1 hash, the HMAC will be at 20 bytes.

The text used as input to HMAC is the STUN message, including the header, up to and including the attribute preceding the MESSAGE-INTEGRITY attribute. With the exception of the MESSAGE-INTEGRITY-SHA256 and FINGERPRINT attributes, which appear after MESSAGE-INTEGRITY, agents MUST ignore all other attributes that follow MESSAGE-INTEGRITY.

The key for the HMAC depends on which credential mechanism is in use. [Section 9.1.1](#) defines the key for the short-term credential mechanism and [Section 9.2.2](#) defines the key for the long-term credential



mechanism. Other credential mechanisms MUST define the key that is used for the HMAC.

Based on the rules above, the hash used to construct MESSAGE-INTEGRITY includes the length field from the STUN message header. Prior to performing the hash, the MESSAGE-INTEGRITY attribute MUST be inserted into the message (with dummy content). The length MUST then be set to point to the length of the message up to, and including, the MESSAGE-INTEGRITY attribute itself, but excluding any attributes after it. Once the computation is performed, the value of the MESSAGE-INTEGRITY attribute can be filled in, and the value of the length in the STUN header can be set to its correct value -- the length of the entire message. Similarly, when validating the MESSAGE-INTEGRITY, the length field should be adjusted to point to the end of the MESSAGE-INTEGRITY attribute prior to calculating the HMAC. Such adjustment is necessary when attributes, such as FINGERPRINT, appear after MESSAGE-INTEGRITY.

#### **14.6. MESSAGE-INTEGRITY-SHA256**

The MESSAGE-INTEGRITY-SHA256 attribute contains an HMAC-SHA-256 [[RFC2104](#)] of the STUN message. The MESSAGE-INTEGRITY-SHA256 attribute can be present in any STUN message type. Since it uses the SHA256 hash, the HMAC will be at most 32 bytes. The HMAC MUST NOT be truncated below a minimum size of 16 bytes. If truncation is employed then the HMAC size MUST be a multiple of 4. Truncation MUST be done by stripping off the final bytes. STUN Usages can define their own truncation limits, as long as they adhere to the guidelines specified above. STUN Usages that do not define truncation limits MUST NOT use truncation at all.

The text used as input to HMAC is the STUN message, including the header, up to and including the attribute preceding the MESSAGE-INTEGRITY-SHA256 attribute. With the exception of the FINGERPRINT attribute, which appears after MESSAGE-INTEGRITY-SHA256, agents MUST ignore all other attributes that follow MESSAGE-INTEGRITY-SHA256.

The key for the HMAC depends on which credential mechanism is in use. [Section 9.1.1](#) defines the key for the short-term credential mechanism and [Section 9.2.2](#) defines the key for the long-term credential mechanism. Other credential mechanism MUST define the key that is used for the HMAC.

Based on the rules above, the hash used to construct MESSAGE-INTEGRITY-SHA256 includes the length field from the STUN message header. Prior to performing the hash, the MESSAGE-INTEGRITY-SHA256 attribute MUST be inserted into the message (with dummy content). The length MUST then be set to point to the length of the message up



to, and including, the MESSAGE-INTEGRITY-SHA256 attribute itself, but excluding any attributes after it. Once the computation is performed, the value of the MESSAGE-INTEGRITY-SHA256 attribute can be filled in, and the value of the length in the STUN header can be set to its correct value -- the length of the entire message. Similarly, when validating the MESSAGE-INTEGRITY-SHA256, the length field should be adjusted to point to the end of the MESSAGE-INTEGRITY-SHA256 attribute prior to calculating the HMAC. Such adjustment is necessary when attributes, such as FINGERPRINT, appear after MESSAGE-INTEGRITY-SHA256.

#### **14.7. FINGERPRINT**

The FINGERPRINT attribute MAY be present in all STUN messages. The value of the attribute is computed as the CRC-32 of the STUN message up to (but excluding) the FINGERPRINT attribute itself, XOR'ed with the 32-bit value 0x5354554e (the XOR helps in cases where an application packet is also using CRC-32 in it). The 32-bit CRC is the one defined in ITU V.42 [[ITU.V42.1994](#)], which has a generator polynomial of  $x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x+1$ . See the sample code for the CRC-32 in [Section 8 of \[RFC1952\]](#).

When present, the FINGERPRINT attribute MUST be the last attribute in the message, and thus will appear after MESSAGE-INTEGRITY.

The FINGERPRINT attribute can aid in distinguishing STUN packets from packets of other protocols. See [Section 7](#).

As with MESSAGE-INTEGRITY, the CRC used in the FINGERPRINT attribute covers the length field from the STUN message header. Therefore, this value must be correct and include the CRC attribute as part of the message length, prior to computation of the CRC. When using the FINGERPRINT attribute in a message, the attribute is first placed into the message with a dummy value, then the CRC is computed, and then the value of the attribute is updated. If the MESSAGE-INTEGRITY attribute is also present, then it must be present with the correct message-integrity value before the CRC is computed, since the CRC is done over the value of the MESSAGE-INTEGRITY attribute as well.

#### **14.8. ERROR-CODE**

The ERROR-CODE attribute is used in error response messages. It contains a numeric error code value in the range of 300 to 699 plus a textual reason phrase encoded in UTF-8 [[RFC3629](#)], and is consistent in its code assignments and semantics with SIP [[RFC3261](#)] and HTTP [[RFC7231](#)]. The reason phrase is meant for user consumption, and can be anything appropriate for the error code. Recommended reason phrases for the defined error codes are included in the IANA registry





for error codes. The reason phrase MUST be a UTF-8 [RFC3629] encoded sequence of less than 128 characters (which can be as long as 763 bytes).

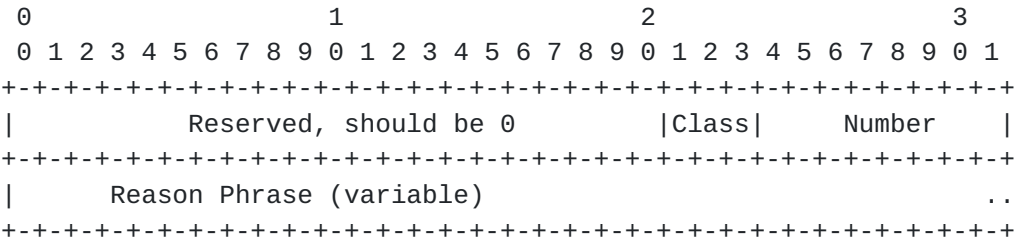


Figure 7: ERROR-CODE Attribute

To facilitate processing, the class of the error code (the hundreds digit) is encoded separately from the rest of the code, as shown in Figure 7.

The Reserved bits SHOULD be 0, and are for alignment on 32-bit boundaries. Receivers MUST ignore these bits. The Class represents the hundreds digit of the error code. The value MUST be between 3 and 6. The Number represents the error code modulo 100, and its value MUST be between 0 and 99.

The following error codes, along with their recommended reason phrases, are defined:

300 Try Alternate: The client should contact an alternate server for this request. This error response MUST only be sent if the request included either a USERNAME or USERHASH attribute and a valid MESSAGE-INTEGRITY attribute; otherwise, it MUST NOT be sent and error code 400 (Bad Request) is suggested. This error response MUST be protected with the MESSAGE-INTEGRITY attribute, and receivers MUST validate the MESSAGE-INTEGRITY of this response before redirecting themselves to an alternate server.

Note: Failure to generate and validate message integrity for a 300 response allows an on-path attacker to falsify a 300 response thus causing subsequent STUN messages to be sent to a victim.

400 Bad Request: The request was malformed. The client SHOULD NOT retry the request without modification from the previous attempt. The server may not be able to generate a valid MESSAGE-INTEGRITY for this error, so the client MUST NOT expect a valid MESSAGE-INTEGRITY attribute on this response.



401 Unauthenticated: The request did not contain the correct credentials to proceed. The client should retry the request with proper credentials.

420 Unknown Attribute: The server received a STUN packet containing a comprehension-required attribute that it did not understand. The server MUST put this unknown attribute in the UNKNOWN-ATTRIBUTE attribute of its error response.

438 Stale Nonce: The NONCE used by the client was no longer valid. The client should retry, using the NONCE provided in the response.

500 Server Error: The server has suffered a temporary error. The client should try again.

#### **14.9. REALM**

The REALM attribute may be present in requests and responses. It contains text that meets the grammar for "realm-value" as described in [\[RFC3261\]](#) but without the double quotes and their surrounding whitespace. That is, it is an unquoted realm-value (and is therefore a sequence of qdtext or quoted-pair). It MUST be a UTF-8 [\[RFC3629\]](#) encoded sequence of less than 128 characters (which can be as long as 763 bytes), and MUST have been processed using the OpaqueString profile [\[RFC7613\]](#).

Presence of the REALM attribute in a request indicates that long-term credentials are being used for authentication. Presence in certain error responses indicates that the server wishes the client to use a long-term credential for authentication.

#### **14.10. NONCE**

The NONCE attribute may be present in requests and responses. It contains a sequence of qdtext or quoted-pair, which are defined in [RFC 3261](#) [\[RFC3261\]](#). Note that this means that the NONCE attribute will not contain actual quote characters. See [\[RFC7616\]](#), [Section 5.4](#), for guidance on selection of nonce values in a server. It MUST be less than 128 characters (which can be as long as 763 bytes).

#### **14.11. PASSWORD-ALGORITHMS**

The PASSWORD-ALGORITHMS attribute may be present in requests and responses. It contains the list of algorithms that the server can use to derive the long-term password.



The set of known algorithms is maintained by IANA. The initial set defined by this specification is found in [Section 17.5](#).

The attribute contains a list of algorithm numbers and variable length parameters. The algorithm number is a 16-bit value as defined in [Section 17.5](#). The parameters start with the actual length of the parameters as a 16-bit value, followed by the parameters that are specific to each algorithm. The parameters are padded to a 32-bit boundary, in the same manner as an attribute.

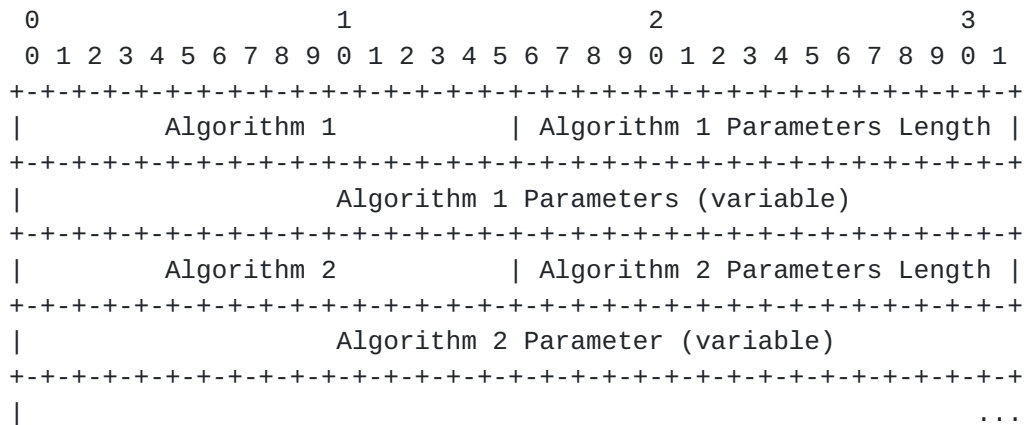


Figure 8: Format of PASSWORD-ALGORITHMS Attribute

#### **[14.12.](#) PASSWORD-ALGORITHM**

The PASSWORD-ALGORITHM attribute is present only in requests. It contains the algorithms that the server must use to derive the long-term password.

The set of known algorithms is maintained by IANA. The initial set defined by this specification is found in [Section 17.5](#).

The attribute contains an algorithm number and variable length parameters. The algorithm number is a 16-bit value as defined in [Section 17.5](#). The parameters starts with the actual length of the parameters as a 16-bit value, followed by the parameters that are specific to the algorithm. The parameters are padded to a 32-bit boundary, in the same manner as an attribute.



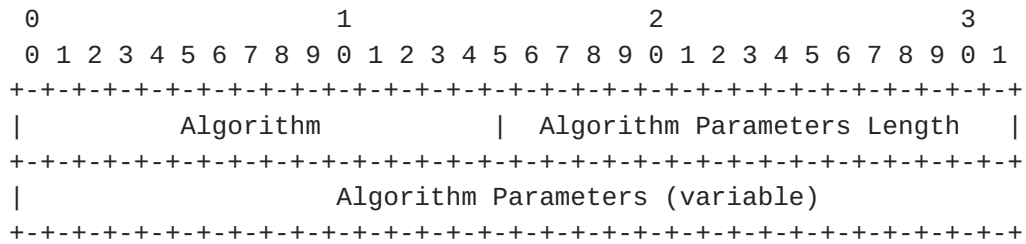


Figure 9: Format of PASSWORD-ALGORITHM Attribute

**14.13. UNKNOWN-ATTRIBUTES**

The UNKNOWN-ATTRIBUTES attribute is present only in an error response when the response code in the ERROR-CODE attribute is 420.

The attribute contains a list of 16-bit values, each of which represents an attribute type that was not understood by the server.

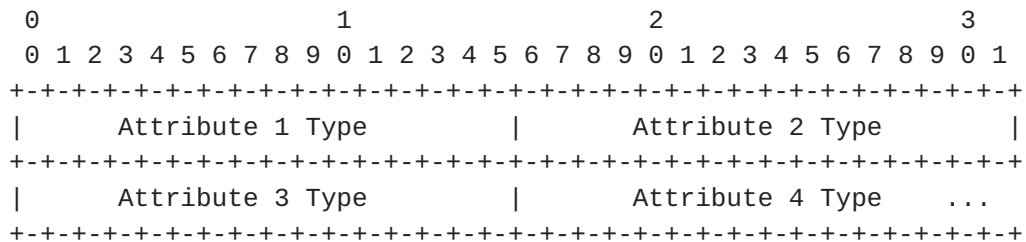


Figure 10: Format of UNKNOWN-ATTRIBUTES Attribute

Note: In [RFC3489], this field was padded to 32 by duplicating the last attribute. In this version of the specification, the normal padding rules for attributes are used instead.

**14.14. SOFTWARE**

The SOFTWARE attribute contains a textual description of the software being used by the agent sending the message. It is used by clients and servers. Its value SHOULD include manufacturer and version number. The attribute has no impact on operation of the protocol, and serves only as a tool for diagnostic and debugging purposes. The value of SOFTWARE is variable length. It MUST be a UTF-8 [RFC3629] encoded sequence of less than 128 characters (which can be as long as 763 bytes).

**14.15. ALTERNATE-SERVER**

The alternate server represents an alternate transport address identifying a different STUN server that the STUN client should try.





It is encoded in the same way as MAPPED-ADDRESS, and thus refers to a single server by IP address. The IP address family MUST be identical to that of the source IP address of the request.

#### **14.16. ALTERNATE-DOMAIN**

The alternate domain represents the domain name that is used to verify the IP address in the ALTERNATE-SERVER attribute when the transport protocol uses TLS or DTLS.

The value of ALTERNATE-DOMAIN is variable length. It MUST be a UTF-8 [[RFC3629](#)] encoded sequence of less than 128 characters (which can be as long as 763 bytes).

### **15. Security Considerations**

#### **15.1. Attacks against the Protocol**

##### **15.1.1. Outside Attacks**

An attacker can try to modify STUN messages in transit, in order to cause a failure in STUN operation. These attacks are detected for both requests and responses through the message-integrity mechanism, using either a short-term or long-term credential. Of course, once detected, the manipulated packets will be dropped, causing the STUN transaction to effectively fail. This attack is possible only by an on-path attacker.

An attacker that can observe, but not modify, STUN messages in-transit (for example, an attacker present on a shared access medium, such as Wi-Fi), can see a STUN request, and then immediately send a STUN response, typically an error response, in order to disrupt STUN processing. This attack is also prevented for messages that utilize MESSAGE-INTEGRITY. However, some error responses, those related to authentication in particular, cannot be protected by MESSAGE-INTEGRITY. When STUN itself is run over a secure transport protocol (e.g., TLS), these attacks are completely mitigated.

Depending on the STUN usage, these attacks may be of minimal consequence and thus do not require message integrity to mitigate. For example, when STUN is used to a basic STUN server to discover a server reflexive candidate for usage with ICE, authentication and message integrity are not required since these attacks are detected during the connectivity check phase. The connectivity checks themselves, however, require protection for proper operation of ICE overall. As described in [Section 13](#), STUN usages describe when authentication and message integrity are needed.



Since STUN uses the HMAC of a shared secret for authentication and integrity protection, it is subject to offline dictionary attacks. When authentication is utilized, it SHOULD be with a strong password that is not readily subject to offline dictionary attacks. Protection of the channel itself, using TLS or DTLS, mitigates these attacks.

STUN supports both MESSAGE-INTEGRITY and MESSAGE-INTEGRITY-SHA256, which is subject to bid down attacks by an on-path attacker. Protection of the channel itself, using TLS or DTLS, mitigates these attacks. Timely removal of the support of MESSAGE-INTEGRITY in a future version of STUN is necessary.

#### **15.1.2. Inside Attacks**

A rogue client may try to launch a DoS attack against a server by sending it a large number of STUN requests. Fortunately, STUN requests can be processed statelessly by a server, making such attacks hard to launch.

A rogue client may use a STUN server as a reflector, sending it requests with a falsified source IP address and port. In such a case, the response would be delivered to that source IP and port. There is no amplification of the number of packets with this attack (the STUN server sends one packet for each packet sent by the client), though there is a small increase in the amount of data, since STUN responses are typically larger than requests. This attack is mitigated by ingress source address filtering.

Revealing the specific software version of the agent through the SOFTWARE attribute might allow them to become more vulnerable to attacks against software that is known to contain security holes. Implementers SHOULD make usage of the SOFTWARE attribute a configurable option.

#### **15.2. Attacks Affecting the Usage**

This section lists attacks that might be launched against a usage of STUN. Each STUN usage must consider whether these attacks are applicable to it, and if so, discuss counter-measures.

Most of the attacks in this section revolve around an attacker modifying the reflexive address learned by a STUN client through a Binding request/response transaction. Since the usage of the reflexive address is a function of the usage, the applicability and remediation of these attacks are usage-specific. In common situations, modification of the reflexive address by an on-path attacker is easy to do. Consider, for example, the common situation



where STUN is run directly over UDP. In this case, an on-path attacker can modify the source IP address of the Binding request before it arrives at the STUN server. The STUN server will then return this IP address in the XOR-MAPPED-ADDRESS attribute to the client, and send the response back to that (falsified) IP address and port. If the attacker can also intercept this response, it can direct it back towards the client. Protecting against this attack by using a message-integrity check is impossible, since a message-integrity value cannot cover the source IP address, since the intervening NAT must be able to modify this value. Instead, one solution to preventing the attacks listed below is for the client to verify the reflexive address learned, as is done in ICE [[I-D.ietf-ice-rfc5245bis](#)]. Other usages may use other means to prevent these attacks.

#### **15.2.1. Attack I: Distributed DoS (DDoS) against a Target**

In this attack, the attacker provides one or more clients with the same faked reflexive address that points to the intended target. This will trick the STUN clients into thinking that their reflexive addresses are equal to that of the target. If the clients hand out that reflexive address in order to receive traffic on it (for example, in SIP messages), the traffic will instead be sent to the target. This attack can provide substantial amplification, especially when used with clients that are using STUN to enable multimedia applications. However, it can only be launched against targets for which packets from the STUN server to the target pass through the attacker, limiting the cases in which it is possible.

#### **15.2.2. Attack II: Silencing a Client**

In this attack, the attacker provides a STUN client with a faked reflexive address. The reflexive address it provides is a transport address that routes to nowhere. As a result, the client won't receive any of the packets it expects to receive when it hands out the reflexive address. This exploitation is not very interesting for the attacker. It impacts a single client, which is frequently not the desired target. Moreover, any attacker that can mount the attack could also deny service to the client by other means, such as preventing the client from receiving any response from the STUN server, or even a DHCP server. As with the attack in [Section 15.2.1](#), this attack is only possible when the attacker is on path for packets sent from the STUN server towards this unused IP address.



### **15.2.3. Attack III: Assuming the Identity of a Client**

This attack is similar to attack II. However, the faked reflexive address points to the attacker itself. This allows the attacker to receive traffic that was destined for the client.

### **15.2.4. Attack IV: Eavesdropping**

In this attack, the attacker forces the client to use a reflexive address that routes to itself. It then forwards any packets it receives to the client. This attack would allow the attacker to observe all packets sent to the client. However, in order to launch the attack, the attacker must have already been able to observe packets from the client to the STUN server. In most cases (such as when the attack is launched from an access network), this means that the attacker could already observe packets sent to the client. This attack is, as a result, only useful for observing traffic by attackers on the path from the client to the STUN server, but not generally on the path of packets being routed towards the client.

## **15.3. Hash Agility Plan**

This specification uses both HMAC-SHA-1 and HMAC-SHA-256 for computation of the message integrity. If, at a later time, HMAC-SHA-256 is found to be compromised, the following is the remedy that will be applied:

- o Both a new message-integrity attribute and a new STUN Security Feature bit will be allocated in a Standard Track document. The new message-integrity attribute will have its value computed using a new hash. The STUN Security Feature bit will be used to simultaneously signal to a STUN client using the Long Term Credential Mechanism that this server supports this new hash algorithm, and will prevent bid down attacks on the new message-integrity attribute.
- o STUN Client and Server using the Short Term Credential Mechanism will need to get an updated external mechanism that they can use to signal what message-integrity attributes are in use.

The bid down protection mechanism described in this document is new, and thus cannot currently protect against a bid down attack that lowers the strength of the hash algorithm to HMAC-SHA-1. This is why, after a transition period, a new document updating this document will assign a new STUN Security Feature bit for deprecating HMAC-SHA-1. When used, this bit will signal that HMAC-SHA-1 is deprecated and should no longer be used.





## **16. IAB Considerations**

The IAB has studied the problem of Unilateral Self-Address Fixing (UNSAF), which is the general process by which a client attempts to determine its address in another realm on the other side of a NAT through a collaborative protocol reflection mechanism ([\[RFC3424\]](#)). STUN can be used to perform this function using a Binding request/response transaction if one agent is behind a NAT and the other is on the public side of the NAT.

The IAB has suggested that protocols developed for this purpose document a specific set of considerations. Because some STUN usages provide UNSAF functions (such as ICE [\[I-D.ietf-ice-rfc5245bis\]](#) ), and others do not (such as SIP Outbound [\[RFC5626\]](#)), answers to these considerations need to be addressed by the usages themselves.

## **17. IANA Considerations**

### **17.1. STUN Security Features Registry**

A STUN Security Feature set is a 24 bit value.

IANA is requested to create a new registry containing the STUN Security Features that are protected by the bid down attack prevention mechanism described in [section 9.2.1](#).

The initial STUN Security Features are:

0x000001: Password algorithms  
0x000002: Username anonymity

New Security Features are assigned by a Standard Action [\[RFC8126\]](#).

### **17.2. STUN Methods Registry**

IANA is requested to update the name for method 0x002 and the reference from [RFC 5389](#) to RFC-to-be for the following STUN methods:

0x000: (Reserved)  
0x001: Binding  
0x002: (Reserved; prior to [\[RFC5389\]](#) this was SharedSecret)

### **17.3. STUN Attribute Registry**



### **17.3.1. Updated Attributes**

IANA is requested to update the names for attributes 0x0002, 0x0003, 0x0004, 0x0005, 0x0007, and 0x000B, and the reference from [RFC 5389](#) to RFC-to-be for the following STUN methods:

Comprehension-required range (0x0000-0x7FFF):

0x0000: (Reserved)

0x0001: MAPPED-ADDRESS

0x0002: (Reserved; prior to [[RFC5389](#)] this was RESPONSE-ADDRESS)

0x0003: (Reserved; prior to [[RFC5389](#)] this was CHANGE-REQUEST)

0x0004: (Reserved; prior to [[RFC5389](#)] this was SOURCE-ADDRESS)

0x0005: (Reserved; prior to [[RFC5389](#)] this was CHANGED-ADDRESS)

0x0006: USERNAME

0x0007: (Reserved; prior to [[RFC5389](#)] this was PASSWORD)

0x0008: MESSAGE-INTEGRITY

0x0009: ERROR-CODE

0x000A: UNKNOWN-ATTRIBUTES

0x000B: (Reserved; prior to [[RFC5389](#)] this was REFLECTED-FROM)

0x0014: REALM

0x0015: NONCE

0x0020: XOR-MAPPED-ADDRESS

Comprehension-optional range (0x8000-0xFFFF)

0x8022: SOFTWARE

0x8023: ALTERNATE-SERVER

0x8028: FINGERPRINT

### **17.3.2. New Attributes**

IANA is requested to add the following attribute to the STUN Attribute Registry:

Comprehension-required range (0x0000-0x7FFF):

0xFFFF: MESSAGE-INTEGRITY-SHA256

0xFFFF: PASSWORD-ALGORITHM

0xFFFF: USERHASH

Comprehension-optional range (0x8000-0xFFFF)

0xFFFF: PASSWORD-ALGORITHMS

0xFFFF: ALTERNATE-DOMAIN

### **17.4. STUN Error Code Registry**

IANA is requested to update the reference from [RFC 5389](#) to RFC-to-be for the Error Codes given in [Section 14.8](#).



## **17.5. Password Algorithm Registry**

IANA is requested to create a new registry for Password Algorithm.

A Password Algorithm is a hex number in the range 0x0000 - 0xFFFF.

The initial Password Algorithms are:

0x0001: MD5

0x0002: SHA256

Password Algorithms in the first half of the range (0x0000 - 0x7FFF) are assigned by IETF Review [[RFC8126](#)]. Password Algorithms in the second half of the range (0x8000 - 0xFFFF) are assigned by Designated Expert [[RFC8126](#)].

### **17.5.1. Password Algorithms**

#### **17.5.1.1. MD5**

This password algorithm is taken from [[RFC1321](#)].

The key length is 20 bytes and the parameters value is empty.

Note: This algorithm MUST only be used for compatibility with legacy systems.

```
key = MD5(username ":" realm ":" OpaqueString(password))
```

#### **17.5.1.2. SHA256**

This password algorithm is taken from [[RFC7616](#)].

The key length is 32 bytes and the parameters value is empty.

```
key = SHA256(username ":" realm ":" OpaqueString(password))
```

## **17.6. STUN UDP and TCP Port Numbers**

IANA is requested to update the reference from [RFC 5389](#) to RFC-to-be for the following ports:

stun	3478/tcp	Session Traversal Utilities for NAT (STUN) port
stun	3478/udp	Session Traversal Utilities for NAT (STUN) port
stuns	5349/tcp	Session Traversal Utilities for NAT (STUN) port



## **18. Changes since [RFC 5389](#)**

This specification obsoletes [[RFC5389](#)]. This specification differs from [RFC 5389](#) in the following ways:

- o Added support for DTLS-over-UDP ([RFC 6347](#)).
- o Made clear that the RT0 is considered stale if there is no transactions with the server.
- o Aligned the RT0 calculation with [RFC 6298](#).
- o Updated the cipher suites for TLS.
- o Added support for STUN URI ([RFC 7064](#)).
- o Added support for SHA256 message integrity.
- o Updated the PRECIS support to [RFC 7613](#).
- o Added protocol and registry to choose the password encryption algorithm.
- o Added support for anonymous username.
- o Added protocol and registry for preventing biddown attacks.
- o Sharing a NONCE is no longer permitted.
- o Added the possibility of using a domain name in the alternate server mechanism.
- o Added more C snippets.
- o Added test vector.

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#### [Appendix A](#). C Snippet to Determine STUN Message Types

Given a 16-bit STUN message type value in host byte order in `msg_type` parameter, below are C macros to determine the STUN message types:

```
<CODE BEGINS>
#define IS_REQUEST(msg_type)      (((msg_type) & 0x0110) == 0x0000)
#define IS_INDICATION(msg_type)  (((msg_type) & 0x0110) == 0x0010)
#define IS_SUCCESS_RESP(msg_type) (((msg_type) & 0x0110) == 0x0100)
#define IS_ERR_RESP(msg_type)    (((msg_type) & 0x0110) == 0x0110)
<CODE ENDS>
```

A function to convert method and class into a message type:

```
<CODE BEGINS>
int type(int method, int cls) {
    return (method & 0x0F80) << 9 | (method & 0x0070) << 5
        | (method & 0x000F) | (cls & 0x0002) << 8
        | (cls & 0x0001) << 4;
}
<CODE ENDS>
```

A function to extract the method from the message type:





```
<CODE BEGINS>
int method(int type) {
    return (type & 0x3E00) >> 2 | (type & 0x00E0) >> 1
        | (type & 0x000F);
}
<CODE ENDS>
```

A function to extract the class from the message type:

```
<CODE BEGINS>
int cls(int type) {
    return (type & 0x0100) >> 7 | (type & 0x0010) >> 4;
}
<CODE ENDS>
```

## **Appendix B. Test Vectors**

This section augments the list of test vectors defined in [\[RFC5769\]](#) with MESSAGE-INTEGRITY-SHA256. All the formats and definitions listed in [Section 2 of \[RFC5769\]](#) apply here.

### **B.1. Sample Request with Long-Term Authentication with MESSAGE-INTEGRITY-SHA256 and USERHASH**

This request uses the following parameters:

Username: "<U+30DE><U+30C8><U+30EA><U+30C3><U+30AF><U+30B9>" (without quotes) unaffected by OpaqueString [\[RFC7613\]](#) processing

Password: "The<U+00AD>M<U+00AA>tr<U+2168>" and "TheMatrIX" (without quotes) respectively before and after OpaqueString processing

Nonce: "obMatJos2AAACf//499k954d60L34oL9FSTvy64sA" (without quotes)

Realm: "example.org" (without quotes)



00 01 00 9c	Request type and message length
21 12 a4 42	Magic cookie
78 ad 34 33 }	
c6 ad 72 c0 }	Transaction ID
29 da 41 2e }	
XX XX 00 20	USERHASH attribute header
4a 3c f3 8f }	
ef 69 92 bd }	
a9 52 c6 78 }	
04 17 da 0f }	Userhash value (32 bytes)
24 81 94 15 }	
56 9e 60 b2 }	
05 c4 6e 41 }	
40 7f 17 04 }	
00 15 00 29	NONCE attribute header
6f 62 4d 61 }	
74 4a 6f 73 }	
32 41 41 41 }	
43 66 2f 2f }	
34 39 39 6b }	Nonce value and padding (3 bytes)
39 35 34 64 }	
36 4f 4c 33 }	
34 6f 4c 39 }	
46 53 54 76 }	
79 36 34 73 }	
41 00 00 00 }	
00 14 00 0b	REALM attribute header
65 78 61 6d }	
70 6c 65 2e }	Realm value (11 bytes) and padding (1 byte)
6f 72 67 00 }	
XX XX 00 20	MESSAGE-INTEGRITY-SHA256 attribute header
c4 ec a2 b6 }	
24 6f 26 be }	
bc 2f 77 49 }	
07 c2 00 a3 }	HMAC-SHA256 value
76 c7 c2 8e }	
b4 d1 26 60 }	
bb fe 9f 28 }	
0e 85 71 f2 }	

Note: Before publication, the XX XX placeholder must be replaced by the value assigned to MESSAGE-INTEGRITY-SHA256 and USERHASH by IANA. The MESSAGE-INTEGRITY-SHA256 attribute value will need to be updated after this.



## **Appendix C. Release notes**

This section must be removed before publication as an RFC.

### **C.1. Modifications between [draft-ietf-tram-stunbis-14](#) and [draft-ietf-tram-stunbis-13](#)**

- o Reorder the paragraphs in [section 9.1.4](#).
- o The realm is now processed through Opaque in [section 9.2.2](#).
- o Make clear in [section 9.2.4](#) that it is an exclusive-xor.
- o Removed text that implied that nonce sharing was explicitly permitted in [RFC 5389](#).
- o In same section, s/username/value/ for USERCASH.
- o Modify the IANA requests to explicitly say that the reserved codepoints were prior to [RFC 5389](#).

### **C.2. Modifications between [draft-ietf-tram-stunbis-13](#) and [draft-ietf-tram-stunbis-12](#)**

- o Update references.
- o Fixes some text following Shepherd review.
- o Update co-author info.

### **C.3. Modifications between [draft-ietf-tram-stunbis-12](#) and [draft-ietf-tram-stunbis-11](#)**

- o Clarifies the procedure to define a new hash algorithm for message-integrity.
- o Explain the procedure to deprecate SHA1 as message-integrity.
- o Added procedure for Happy Eyeballs ([RFC 6555](#)).
- o Added verification that Happy Eyeballs works in the STUN Usage checklist.
- o Add reference to Base64 RFC.
- o Changed co-author affiliation.



**C.4. Modifications between [draft-ietf-tram-stunbis-11](#) and [draft-ietf-tram-stunbis-10](#)**

- o Made clear that the same HMAC than received in response of short term credential must be used for subsequent transactions.
- o s/URL/URI/
- o The "nonce cookie" is now mandatory to signal that SHA256 must be used in the next transaction.
- o s/SHA1/SHA256/
- o Changed co-author affiliation.

**C.5. Modifications between [draft-ietf-tram-stunbis-10](#) and [draft-ietf-tram-stunbis-09](#)**

- o Removed the reserved value in the security registry, as it does not make sense in a bitset.
- o Updated change list.
- o Updated the minimum truncation size for M-I-256 to 16 bytes.
- o Changed the truncation order to match [RFC 7518](#).
- o Fixed bugs in truncation boundary text.
- o Stated that STUN Usages have to explicitly state that they can use truncation.
- o Removed truncation from the MESSAGE-INTEGRITY attribute.
- o Add reference to C code in [RFC 1952](#).
- o Replaced [RFC 2818](#) reference to [RFC 6125](#).

**C.6. Modifications between [draft-ietf-tram-stunbis-09](#) and [draft-ietf-tram-stunbis-08](#)**

- o Removed the reserved value in the security registry, as it does not make sense in a bitset.
- o Updated change list.
- o Updated the minimum truncation size for M-I-256 to 16 bytes.





- o Changed the truncation order to match [RFC 7518](#).
- o Fixed bugs in truncation boundary text.
- o Stated that STUN Usages have to explicitly state that they can use truncation.
- o Removed truncation from the MESSAGE-INTEGRITY attribute.
- o Add reference to C code in [RFC 1952](#).
- o Replaced [RFC 2818](#) reference to [RFC 6125](#).

**C.7. Modifications between [draft-ietf-tram-stunbis-09](#) and [draft-ietf-tram-stunbis-08](#)**

- o Packets discarded in a reliable or unreliable transaction triggers an attack error instead of a timeout error. An attack error on a reliable transport is signaled immediately instead of waiting for the timeout.
- o Explicitly state that a received 400 response without authentication will be dropped until timeout.
- o Clarify the SHOULD omit/include rules in LTCM.
- o If the nonce and the hmac are both invalid, then a 401 is sent instead of a 438.
- o The 401 and 438 error response to subsequent requests may use the previous NONCE/password to authenticate, if they are still available.
- o Change "401 Unauthorized" to "401 Unauthenticated"
- o Make clear that in some cases it is impossible to add a MI or MI2 even if the text says SHOULD NOT.

**C.8. Modifications between [draft-ietf-tram-stunbis-08](#) and [draft-ietf-tram-stunbis-07](#)**

- o Updated list of changes since [RFC 5389](#).
- o More examples are automatically generated.
- o Message integrity truncation is fixed at a multiple of 4 bytes, because the padding will not decrease by more than this.



- o USERHASH contains the 32 bytes of the hash, not a character string.
- o Updated the example to use the USERHASH attribute and the modified NONCE attribute.
- o Updated ICEbis reference.

**C.9. Modifications between [draft-ietf-tram-stunbis-07](#) and [draft-ietf-tram-stunbis-06](#)**

- o Add USERHASH attribute to carry the hashed version of the username.
- o Add IANA registry and nonce encoding for Security Features that need to be protected from bid down attacks.
- o Modified MESSAGE-INTEGRITY and MESSAGE-INTEGRITY-SHA256 to support truncation limits (pending cryptographic review),

**C.10. Modifications between [draft-ietf-tram-stunbis-06](#) and [draft-ietf-tram-stunbis-05](#)**

- o Changed I-D references to RFC references.
- o Changed CHANGE-ADDRESS to CHANGE-REQUEST (Errata #4233).
- o Added test vector for MESSAGE-INTEGRITY-SHA256.
- o Address additional review comments from Jonathan Lennox and Brandon Williams.

**C.11. Modifications between [draft-ietf-tram-stunbis-05](#) and [draft-ietf-tram-stunbis-04](#)**

- o Address review comments from Jonathan Lennox and Brandon Williams.

**C.12. Modifications between [draft-ietf-tram-stunbis-04](#) and [draft-ietf-tram-stunbis-03](#)**

- o Remove SCTP.
- o Remove DANE.
- o s/MESSAGE-INTEGRITY2/MESSAGE-INTEGRITY-SHA256/
- o Remove Salted SHA256 password hash.



- o The RTO delay between transactions is removed.
- o Make clear that reusing NONCE will trigger a wasted round trip.

**C.13. Modifications between [draft-ietf-tram-stunbis-03](#) and [draft-ietf-tram-stunbis-02](#)**

- o SCTP prefix is now 0b00000101 instead of 0x11.
- o Add SCTP at various places it was needed.
- o Update the hash agility plan to take in account HMAC-SHA-256.
- o Adds the bid down attack on message-integrity in the security section.

**C.14. Modifications between [draft-ietf-tram-stunbis-02](#) and [draft-ietf-tram-stunbis-01](#)**

- o STUN hash algorithm agility (currently only SHA-1 is allowed).
- o Clarify terminology, text and guidance for STUN fragmentation.
- o Clarify whether it's valid to share nonces across TURN allocations.
- o Prevent the server to allocate the same NONCE to clients with different IP address and/or different port. This prevent sharing the nonce between TURN allocations in TURN.
- o Add reference to [draft-ietf-uta-tls-bcp](#)
- o Add a new attribute ALTERNATE-DOMAIN to verify the certificate of the ALTERNATE-SERVER after a 300 over (D)TLS.
- o The RTP delay between transactions applies only to parallel transactions, not to serial transactions. That prevents a 3RTT delay between the first transaction and the second transaction with long term authentication.
- o Add text saying ORIGIN can increase a request size beyond the MTU and so require an SCTPoUDP transport.
- o Move the Acknowledgments and Contributor sections to the end of the document, in accordance with [RFC 7322 section 4](#).



**C.15.** Modifications between [draft-ietf-tram-stunbis-01](#) and [draft-ietf-tram-stunbis-00](#)

- o Add negotiation mechanism for new password algorithms.
- o Describe the MESSAGE-INTEGRITY/MESSAGE-INTEGRITY2 protocol.
- o Add support for SCTP to solve the fragmentation problem.
- o Merge [RFC 7350](#):
  - \* Split the "Sending over..." sections in 3.
  - \* Add DTLS-over-UDP as transport.
  - \* Update the cipher suites and cipher/compression restrictions.
  - \* A stuns uri with an IP address is rejected.
  - \* Replace most of the [RFC 3489](#) compatibility by a reference to the section in [RFC 5389](#).
  - \* Update the STUN Usages list with transport applicability.
- o Merge [RFC 7064](#):
  - \* DNS discovery is done from the URI.
  - \* Reorganized the text about default ports.
- o Add more C snippets.
- o Make clear that the cached RTO is discarded only if there is no new transations for 10 minutes.

**C.16.** Modifications between [draft-salgueiro-tram-stunbis-02](#) and [draft-ietf-tram-stunbis-00](#)

- o Draft adopted as WG item.

**C.17.** Modifications between [draft-salgueiro-tram-stunbis-02](#) and [draft-salgueiro-tram-stunbis-01](#)

- o Add definition of MESSAGE-INTEGRITY2.
- o Update text and reference from [RFC 2988](#) to [RFC 6298](#).
- o s/The IAB has mandated/The IAB has suggested/ (Errata #3737).





- o Fix the figure for the UNKNOWN-ATTRIBUTES (Errata #2972).
- o Fix section number and make clear that the original domain name is used for the server certificate verification. This is consistent with what [RFC 5922](#) ([section 4](#)) is doing. (Errata #2010)
- o Remove text transitioning from [RFC 3489](#).
- o Add definition of MESSAGE-INTEGRITY2.
- o Update text and reference from [RFC 2988](#) to [RFC 6298](#).
- o s/The IAB has mandated/The IAB has suggested/ (Errata #3737).
- o Fix the figure for the UNKNOWN-ATTRIBUTES (Errata #2972).
- o Fix section number and make clear that the original domain name is used for the server certificate verification. This is consistent with what [RFC 5922](#) ([section 4](#)) is doing. (Errata #2010)

**C.18. Modifications between [draft-salgueiro-tram-stunbis-01](#) and [draft-salgueiro-tram-stunbis-00](#)**

- o Restore the [RFC 5389](#) text.
- o Add list of open issues.

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