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     Problem Statement and Requirements for a TCP Authentication Option
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Abstract

   The TCP-MD5 option is commonly used to secure BGP sessions between
   routers, although it is known to have many serious deficiencies.
   This memo presents requirements for a TCP segment authentication
   mechanism that is intended to replace TCP-MD5. While TCP-MD5 was
   designed to protect TCP sessions whose payload is BGP, the
   applicability of the mechanism described herein is broader. This
   mechanism can be applied to any TCP connection, regardless of
   payload.

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This document resulted from the discussions of several IETF
participants, including significant input from a design team within
the TCPM working group who included (alphabetically):

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2. Introduction

Putting a security service into the transport layer has a long
history. SP4 [SP4] [SP4P] provided that service for the Secure Data
Network System (SDNS); OSI incorporated SP4 into its protocol suite
as the Transport Layer Security Protocol (TLSP) [TLSP].

TCP/IP has not had a full-fledged equivalent, though the TCP-MD5
option [RFC2385] has served for some purposes. TCP-MD5 is now known
to have several problems. In this memo, we analyze the need for a
TCP-based security service in Section 3 and discuss the requirements
that a solution should meet in Section 4,

Note that we have deliberately used the phrase "security service".
The in-use TCP-MD5 provides authentication-only and no TCP-based
confidentiality mechanism is deployed or yet defined by the IETF.
This document focuses on the requirements for an authentication-only
service to replace TCP-MD5. If a TCP-based confidentiality service
is also warranted, it could share many of these requirements, but
this is beyond the scope of the current work or expressed needs from
the community.

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

3. **Problem Statement**

   The TCP-MD5 mechanism described in [RFC2385], includes a Message
   Authentication Code (MAC) in each TCP header. The MAC value is
   computed by hashing over:

   o the TCP pseudo-header

   o the TCP header, excluding options, and assuming a checksum of zero

   o the TCP segment data

   o an independently-specified shared key or password

   To successfully spoof segments to a connection using the scheme
   described above, an attacker would not only have to guess TCP
   sequence numbers, but would also have to obtain the key that was used
   to calculate the MAC. This key never appears in the connection
   stream.

   [RFC3562] addresses key management considerations for TCP-MD5. Based
   upon the cryptographic strength of the MD5 hashing algorithm, RFC
   3562 recommends that keys be changed at least every 90 days.
   Unfortunately, TCP-MD5 only permits keys to be changed during the
   lifetime of a TCP connection if the change is synchronized at both
   ends. This limitation has proven to be a deterrent to the effective
   deployment of TCP-MD5, and necessitates a heuristic for key change
   [RFC4808].

   Also, TCP-MD5 is entirely dependent on the MD5 hash algorithm, for
   which there are now well-known collision-finding methods. In
   addition, the particular keyed-hash MAC construction used by TCP-MD5
   has serious cryptographic weaknesses. An attacker who can find a
   collision in the underlying hash function can forge a MAC using a
   simple chosen-message attack. It is quite clear that the existing
   TCP-MD5 mechanism is inadequate [I-D.manral-rpsec-existing-crypto].
   It is cryptographically unsound, requiring a process waiver to permit
   its continued use with BGP [RFC4278].

   TCP-MD5 has also been accused of not meeting operator requirements,
   even though it was originally intended for operators to protect TCP-
   based routing protocol sessions with (e.g. BGP, and now also LDP).
   TCP-MD5 is said to have high CPU utilization. The impact of MD5
   itself is known [RFC1810], but for specific TCP-MD5 implementations,
   hard data on the protocol's performance has not been made availble,
   nor have direct comparisons between TCP-MD5 and IPsec AH performance.

   The key management and key change synchronization difficulties

mentioned above have also been raised as operator concerns. It has
been admitted that many operators simply do not change keys on a
regular or systematic basis, but it is not clear whether this is a
symptom of TCP-MD5's lack of capabilities, or unrelated operational
culture. Based on the importance to the Internet of security for
routing protocol sessions, it is clear that TCP-MD5 should be
improved upon, and it seems likely that an improved version could
greatly increase the use of TCP-based authentication for routing
protocols and thus the robustness of routing sessions against the
known attacks targeting TCP connections [I-D.ietf-tcpm-tcp-antispoof]
[I-D.ietf-tcpm-tcpsecure].

It is less clear why authentication is needed at all within TCP
implementations. IPsec [RFC4301] can protect the entire TCP header
and payload, and TLS [RFC4346] can protect the payload data within a
TCP connection, when used by an application. However, these existing
solutions have their own deficiencies [I-D.ietf-tcpm-tcp-antispoof].

The most serious problem with IPsec is that it is hard to protect an
individual TCP connection with it [I-D.bellovin-useipsec], due to the
lack of an API that an application can request IPsec protection for a
specific connection via. IPsec operates at the IP layer (with only a
sprinkling of transport layer concepts, such as port numbers used
within traffic selectors), and has no notion of individual transport
layer connections and their duration (only quintuples of IP
addresses, protocol, and port numbers), so "latching" a particular
TCP connection to an IPsec Security Association with a corresponding
lifetime is difficult [I-D.ietf-btns-connection-latching].

IPsec also has problems with NAT traversal [RFC2709] [RFC3715]
[RFC3947] [RFC3948]: NAT boxes can neither examine nor modify port
numbers on most IPsec-protected traffic, which causes very real
problems in many environments (though not, admittedly, when
protecting BGP). The net result is that IPsec usage is largely
limited to virtual private network scenarios; it is rarely used or
usable for individual applications over the Internet. At this point,
the primary use of the existing TCP-based security method is
protecting BGP sessions between routers. BGP speakers will rarely,
if ever, be behind NATs, so it would seem that IPsec could be
feasible in this use case. The existing TCP-MD5 is similarly
hindered by the presence of NATs. The improved TCP authentication
mechanism is intended for general use, not limited to BGP
connections. On a per-connection configurable basis, compatibility
with NATs is a goal of this work.

IPsec tunnels and ESP in transport or tunnel mode have often been
criticized for their interference with firewalls and with traffic
engineering, because they can hide port numbers and flags. A TCP

security option might choose to expose such fields for examination.

TLS does not suffer from any of these afflictions; however, it poses
issues of its own. The integrated key management in TLS works well
in many environments, but is too heavy-weight or otherwise
inappropriate for others. A more serious issue is the limited scope
of protection provided by TLS. It operates strictly above TCP, and
thus provides no protection at all against attacks against the TCP
header itself. Even if TLS is in use, it is possible for attackers
to reset connections (US-CERT Advisory TA04-111A) or perpetrate other
mischief that affects the TCP connection state before TLS processing
occurs [I-D.ietf-tcpm-tcp-antispoof].

Since TCP-MD5 is deeply flawed and neither IPsec nor TLS currently
provide the desired granularity of protection for some uses, it is
clear that an intermediate protection mechanism can be justfied.
There have been multiple proposals presented recently to fill this
void [I-D.bonica-tcp-auth] [I-D.weis-tcp-auth-auto-ks]
[I-D.touch-tcpm-tcp-simple-auth], but without an agreed-upon set of
requirements, evaluating these proposals has been postponed. In
Section 4 within this document, we provide a set of requirements that
has been agreed upon by authors of all of the currently known
proposed solutions.

4. Requirements

In this section, we present the distinguishing requirements for a
future TCP security option, based on a consensus within the TCPM
Authentication Option design team. These requirements are intended
to be used as a means of evaluating potential solutions. These
requirements partially have some basis in [RFC4808], and also have
some commonality with other requirement sets developed for BGP
session security [I-D.behringer-bgp-session-sec-req]. We also
include some expected constraints or behaviors of a solution in
Section 4.2, that are not expected to be useful in evaluating between
differing approaches, but are refinements that could be compatible
with any solution approach. Some suggested properties that the
design team was not able to obtain a consensus for or against are
listed in Appendix A.

4.1. Distinguishing Requirements

The requirements that a solution must fulfill are:

1. Protected Elements:

    A. TCP Pseudoheader

        The pseudoheader of specific IPv4 or IPv6 fields used in the
        computation of a segment's TCP checksum, from [RFC0793] and
        [RFC2460], is protected. By including source and destination
        IP addresses, this influences operation through NATs in a
        similar way to IPsec's Authentication Header, so although
        pseudoheader coverage MUST be possible in any viable
        solution, it MUST also be optional on a per-connection basis,

        For checksum purposes, the header of a TCP connection is the
        combination of its TCP Pseudoheader and its TCP Header. The
        IP addresses of the pseudoheader are included because they
        (together with the port numbers) define the connection; other
        fields are included to protect fields of the IP header that
        otherwise affect the TCP connection (in the latter case,
        largely by their inclusion in the TCP checksum).

    B. Base TCP Header

        The full base TCP header is protected, excluding any TCP
        options and the TCP checksum. By covering TCP port numbers,
        this influences operation through NATs in a similar way to
        IPsec's Authentication Header, so while port number coverage
        MUST be possible in any viable solution, it also MUST be
        optional on a per-connection basis.

The TCP Header is included by definition, since the purpose
of this security option is to protect the TCP header.

C. TCP Options

Additionally, each defined TCP option type may be either
selected for or excluded from protection. This is configured
on a per-option type, per-connection basis, and is static for
the lifetime of a TCP connection.

Other TCP options may or may not be protected by this
security option, as desired. The primary reason for
excluding options is efficiency, and because this level of
protection can be relaxed in a way that impacts only an
individual connection, this is a user choice.

Note that the authentication option itself MUST be included,
with the authentication hash zeroed out.

D. TCP Data

The payload of each TCP segment containing the data given to
applications MUST also be protected.

2. Option Structure Requirements:

A. Privacy

The authentication option MUST NOT directly expose sensitive
security parameters, so that a third party's ability to view
packets does not also permit them to inject authenticable
packets or to otherwise determine information that could be
used to compromise a particular connection, or other
connections, between a pair of hosts.

B. Allow Optional

A host capable of parsing the authentication option MUST be
able to requrie or ignore the option on received segments on
a per-connection basis.

The purposed of the option is to authenticate connections;
hosts must be able to discard segments sent to connections
intended to be authenticated (i.e. they MUST be able to
require the option's use). Authentication determines the ID
of the source of a packet; some hosts may not be interested
in verifying the ID. Presumably, use of the option would be
determined a-priori, before a connection is established by a

separate key and/or policy management system, but it still
may be useful to offload or otherwise ignore an expensive
authentication calculation, especially if the resulting ID
confirmation is not desired.

C. Require Non-Optional

A host capable of sending the authentication option MUST be
able to coordinate in-band whether the option should be
required or might be ignored for a particular connection with
a capable receiver.

This requirement supports senders who prefer to use the
option, but who are also willing to support hosts not
implementing the option. Such coordination would typically
happen in the key management system, but since that system
could be manual, an in-band mechanism to confirm use of this
option and backoff if not supported is required. This
mechanism would also prevent backoff if the sender does not
desire that behavior.

D. Standard Parsing

The authentication option MUST be trivially parseable by
those TCP implementations that do not support it. This means
that it must follow the [RFC0793] format of including a type
and length field, so that it can be skipped over when it is
not supported by an implementation. TCP already specifies
that hosts not supporting an option ignore that option in
received segments; stating this requirement here simply
ensures that TCP authentication solutions do not alter the
format of the base TCP header or radically depart from the
typical options encoding.

E. Compatible with Large Windows

The authentication option MUST allow the concurrent use of
timestamps and window-scaling within protected connections,
as excluding these could limit its range of performance.

These options are in common use, and are needed for
performance over high-speed or high-delay paths. Use of the
authentication option thus needs to permit the use of these
options, or its practical deployability will be severely
limited.

F. Compatible with SACK

If the use of Selective Acknowledgements (SACK) is negotiated
on a connection, the authentication option MUST allow room
for at least one SACK block to be included in the TCP
options, and preferably more.

This option, like (E), is in common use, and is needed for
performance in large-window, lossy connections. Use of the
authentication option thus needs to permit the use of SACK.

3. Cryptography Requirements

   A. Baseline Defaults

   There MUST be at least one set of particular cryptography
   algorithms or constructions whose use is supported by all
   implementations and can be safely assumed to be supported by
   any implementation of the authentication option.

   This requirement is intended to support interoperability of
   this option, by having a single default.

   B. Good Algorithms and Constructions

   The authentication option MUST support default cryptography
   algorithms and constructions that are accepted by the
   community. This means it MUST NOT rely on non-standard or
   ad-hoc hash functions, keyed-hash constructions, signature
   schemes, or other functions, and MUST use published and
   standard schemes (i.e. it should use a construction like HMAC
   versus the form of keyed-hash used in TCP-MD5).

   This requirement is intended to correct the flaws in the
   strength of authentication provided by the keyed hash used in
   TCP-MD5.

   C. Algorithm Agility

   The authentication option MUST be capable of supporting
   algorithms other than its defaults, in order to adapt to
   future discoveries. An implementation that supports multiple
   algorithms MUST permit concurrent connections to use
   different algorithms.

   The existing TCP-MD5 requires substantial revision or
   retirement because its algorithms cannot be replaced. This
   requirement allows the authentication option to be agile to
   algorithmic attacks, where additional algorithms can be added
   as needed.

D. Order-Independent Processing

    Authentication MUST be performed on individual, unordered TCP
    segments, so that it is not severely influenced by reasonable
    amounts of packet loss or reordering.

    TCP headers are processed in the order received, although the
    data is reordered based on header information. As a result,
    header fields must be authenticated in the order received; to
    reorder them first would alter TCP semantics, and would
    potentially require data in unauthenticated segments to be
    quarantined (i.e. copied again) until authenticated later.

E. Parameter Changes Require Key Changes

    A change in the keys used MUST accompany any change in the
    other parameters the cryptography functions for the
    authentication option are configured with.

    This requirement allows the design of a compact option. It
    allows the key ID and key itself to indicate the parameters,
    rather than requiring header fields for them. It also avoids
    interpreting those parameters from in-band information,
    further avoiding exposing them to parties on the path.

4. Keying Requirements

A. Intraconnection Rekeying

    Within the course of a single connection, the authentication
    option MUST accomodate rekeying.

    TCP spoofing attacks, which this option is intended to
    defeat, are often targeted at relatively long-lived
    connections. Use of a single key over a long connection is a
    known security problem, so it would be preferable to either
    limit the length of a connection or require in-band keying
    support.

    Unfortunately, not all applications are easy to restart.
    BGP, for which this option is intended, is being augmented
    for graceful restart [RFC4724] [RFC4781], but this extension
    is under recent scrutiny. TCP itself has no limit on the
    length of a connection, and it would be preferable to avoid
    modifying this semantic.

B. Efficient Rekeying

A rekeying event MUST NOT significantly affect performance of
the TCP connection. Most segments should be validated by a
single pass of the construction of cryptography algorithms
used for authentication, and no validations should require
more than a small, fixed number of passes.

Any aspect of this option which is inefficient is likely to
inhibit its deployment. When using this option, segments may
arrive out of order, and it would be inefficient to determine
which key is appropriate via a large number of trials. Such
trials would present a DoS vulnerability during rekeying.
This issue is discussed in [RFC4808].

C. Automated and Manual Keying

The authentication option MUST support both manual
configuration of preshared keys and automated key management.
This allows for different modes of operation depending on the
user's particular deployment environment.

D. Key-Mananagement Agnostic

The per-segment authentication is performed without regards
to the manner in which keying material is obtained. This
requirement decouples the option mechanism itself from the
key management system used, so that either multiple protocols
can be integrated, or any flawed methods can be easily
replaced in the future.

4.2. Expected Constraints

In addition to having a wire format that supports the Distinguishing
Requirements, a solution should include the following caveats in its
internal operation.

1. Silent Failure

On failure (due to incorrect or missing authentication data),
segments MUST be silently discarded, with no reply generated.
Shuch events SHOULD be logged periodically. Failed segments MUST
NOT alter the protocol state of the TCP connection itself.

Silence and the use of only periodic logging prevents the
creation of a new DoS opportunity.

2. Maximum of One Option per Segment

At most, one authentication option MUST be allowed per segment.

The presence of multiple options MUST be treated as a failure.

Use of multiple options would present another DoS opportunity, and provides no additional protection vs. a single option with appropriate connection latching to other mechanisms, if desired.

3.   Outgoing All-or-None Operation

Within a connection, once the authentication option is enabled, all segments MUST carry the option.

This prevents headers and/or data from being injected into a protected connection.

4.   Incoming All-Checked Operation

An implementation capable of using the authentication option MUST check every incoming segment's connection state to decide whether the option's presence is required.

This requirement allows a host to determine which connections require the option, vs. which allow it as optional. Checking connection state for every incoming segment enforces required use for indicated connections.

5.   Non-Interaction with TCP-MD5

An implementation MUST NOT allow a connection to simultaneously use the new authentication option and TCP-MD5. An implementation MAY support the use of either exclusively the new authentication option or exclusively TCP-MD5 for each individual connection.

This option is intended to supercede TCP-MD5, and in the spirit of (2) above, only one such option is useful per connection. Support for existing TCP-MD5 would support legacy interoperation.

6.   Optional ICMP Discard

An implementation MUST be configurable to allow a protected connection to ignore incoming ICMP Type 3 messages with Codes 2-4. This SHOULD be the default configuration.

This requirement prevents an ICMP attack on protected connections via unprotected/unauthenticable (ICMP) packets.

5. Security Considerations

This document does not specify any protocol; it discusses known security problems with a currently deployed protocol, and the requirements for fixing those problems in a new protocol. This document is itself a set of security considerations, and its publication raises no new security considerations.

6. IANA Considerations

This document does not update or create any IANA registries.

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Appendix A. **Un-Agreed Properties**

There were some items that were suggested as requirements but which were not ratified by all participants in the design team. These are listed here.

1. Saves Work When Optional

    A host sending TCP segments should be able to detect on a per-connection basis whether the authentication option is required or is being ignored by a receiver who supports the option.

2. Single-Pass Rekeying

    The authentication option should support rekeying where incoming segments are validated using a single pass of the cryptographic construction used for authentication.

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