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IKEv2-based Shared Secret Key for O/TWAMP
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Abstract

   The O/TWAMP security mechanism requires that both the client and
   server endpoints possess a shared secret. Since the currently-
   standardized O/TWAMP security mechanism only supports a pre-shared
   key mode, large scale deployment of O/TWAMP is hindered
   significantly. At the same time, recent trends point to wider IKEv2
   deployment which, in turn, calls for mechanisms and methods that
   enable tunnel end-users, as well as operators, to measure one-way and
   two-way network performance in a standardized manner. This document
   discusses the use of keys derived from an IKEv2 SA as the shared key
   in O/TWAMP. If the shared key can be derived from the IKEv2 SA, O/
   TWAMP can support certificate-based key exchange, which would allow
   for more operational flexibility and efficiency. The key derivation
   presented in this document can also facilitate automatic key
   management.

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1. Introduction

   The One-way Active Measurement Protocol (OWAMP) [RFC4656] and the
   Two-Way Active Measurement Protocol (TWAMP) [RFC5357] can be used to
   measure network performance parameters, such as latency, bandwidth,
   and packet loss by sending probe packets and monitoring their
   experience in the network. In order to guarantee the accuracy of
   network measurement results, security aspects must be considered.
   Otherwise, attacks may occur and the authenticity of the measurement
   results may be violated. For example, if no protection is provided,

an adversary in the middle may modify packet timestamps, thus
altering the measurement results.

The currently-standardized O/TWAMP security mechanism [RFC4656]
[RFC5357] requires that endpoints (i.e. both the client and the
server) possess a shared secret. In today's network deployments,
however, the use of pre-shared keys is far from optimal. For
example, in wireless infrastructure networks, certain network
elements, which can be seen as the two endpoints from an O/TWAMP
perspective, support certificate-based security. For instance,
consider the case in which one wants to measure IP performance
between an eNB and SeGW. Both eNB and SeGW are 3GPP LTE nodes and
support certificate mode and IKEv2. Since the currently standardized
O/TWAMP security mechanism only supports pre-shared key mode, large
scale deployment of O/TWAMP is hindered significantly. Furthermore,
deployment and management of "shared secrets" for massive equipment
installation consumes a tremendous amount of effort and is prone to
human error.

With IKEv2 widely used, employing keys derived from IKEv2 SA as
shared key can be considered as a viable alternative. In mobile
telecommunication networks, the deployment rate of IPsec exceeds 95%
with respect to the LTE serving network. In older-technology
cellular networks, such as UMTS and GSM, IPsec use penetration is
lower, but still quite significant. If the shared key can be derived
from the IKEv2 SA, O/TWAMP can support cert-based key exchange and
make it more flexible in practice and more efficient. The use of
IKEv2 also makes it easier to extend automatic key management. In
general, O/TWAMP measurement packets can be transmitted inside the
IPsec tunnel, as it occurs with typical user traffic, or transmitted
outside the IPsec tunnel. This may depend on the operator's policy
and is orthogonal to the mechanism described in this document.

When IPsec is deployed, protecting O/TWAMP traffic in unauthenticated
mode using IPsec is one option. Another option is to protect O/TWAMP
traffic using O/TWAMP layer security established using the PSK
derived from IKEv2 but bypassing the IPsec tunnel. Protecting
unauthenticated O/TWAMP control and/or test traffic via AH or ESP
cannot provide various security options, e.g. it cannot authenticate
part of a O/TWAMP packet as mentioned in [RFC4656]. For measuring
latency, timestamp is carried in O/TWAMP traffic. The sender has to
fetch the timestamp, encrypt it, and send it. In this case, the
middle step can be skipped, potentially improving accuracy as the
sequence number can be encrypted and authenticated before the
timestamp is fetched. It is the same case for the receiver since it
can obtain the timestamp by skipping the decryption step. In such
cases, protecting O/TWAMP traffic using O/TWAMP layer security but
bypassing IPsec tunnel has its advantages. This document describes

how to derive the shared secret key from the IKEv2 SA and employ the security service at the O/TWAMP layer. This method SHOULD be used when O/TWAMP traffic is bypassing IPsec protection and is running over an external network exactly between two IKEv2 systems.

After clarifying the terminology and scope in the subsequent sections, the remainder of this document is organized as follows. Section 4 summarizes O/TWAMP protocol operation with respect to security. Section 5 presents the method for binding TWAMP and IKEv2 for network measurements between the client and the server which both support IKEv2. Finally, Section 6 discusses the security considerations arising from the proposed mechanisms.

2. Terminology

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. Scope and Applicability

This document specifies a method for enabling network measurements between a TWAMP client and a TWAMP server which both support IPsec. In short, the shared key used for securing TWAMP traffic is derived using IKEv2 [RFC7296]. This document reserves from the TWAMP-Modes registry the Mode value IKEv2Derived which is equal to 128 (i.e. bit set in position 7) [NOTE to IANA: remove before allocation and final publication] and MUST be used by TWAMP implementations compatible with this specification.

Although the control procedures described in this document are applicable to OWAMP per se, the lack of an established IANA registry for OWAMP Mode values technically prevents us from extending OWAMP Mode values. Therefore, independent OWAMP implementations SHOULD be checked for full compatibility with respect to the use of this Mode value. Until an IANA registry for OWAMP Mode values is established, the use this feature in OWAMP implementations MUST be arranged privately among consenting OWAMP users.

4. O/TWAMP Security

Security for O/TWAMP-Control and O/TWAMP-Test are briefly reviewed in the following subsections.

4.1. O/TWAMP-Control Security

O/TWAMP uses a simple cryptographic protocol which relies on

o   AES in Cipher Block Chaining (AES-CBC) for confidentiality

o   HMAC-SHA1 truncated to 128 bits for message authentication

Three modes of operation are supported in the OWAMP-Control protocol:
unauthenticated, authenticated, and encrypted. In addition to these
modes, the TWAMP-Control protocol also supports a mixed mode, i.e.
the TWAMP-Control protocol operates in encrypted mode while TWAMP-
Test protocol operates in unauthenticated mode. The authenticated,
encrypted and mixed modes require that endpoints possess a shared
secret, typically a passphrase. The secret key is derived from the
passphrase using a password-based key derivation function PBKDF2
(PKCS#5) [RFC2898].

In the unauthenticated mode, the security parameters are left unused.
In the authenticated, encrypted and mixed modes, the security
parameters are negotiated during the control connection
establishment.

Figure 1 illustrates the initiation stage of the O/TWAMP-Control
protocol between a client and the server. In short, the client opens
a TCP connection to the server in order to be able to send O/TWAMP-
Control commands. The server responds with a Server Greeting, which
contains the Modes, Challenge, Salt, Count, and MBZ fields (see
Section 3.1 of [RFC4656]). If the client-preferred mode is
available, the client responds with a Set-Up- Response message,
wherein the selected Mode, as well as the KeyID, Token and Client IV
are included. The Token is the concatenation of a 16-octet
Challenge, a 16-octet AES Session-key used for encryption, and a
32-octet HMAC-SHA1 Session-key used for authentication. The Token is
encrypted using AES-CBC.

```
    +--------+                   +--------+
    | Client |                   | Server |
    +--------+                   +--------+
        |                            |
        |<---- TCP Connection ----->|
        |                            |
        |<---- Greeting message ----|
        |                            |
        |----- Set-Up-Response ---->|
        |                            |
        |<---- Server-Start --------|
        |                            |
```
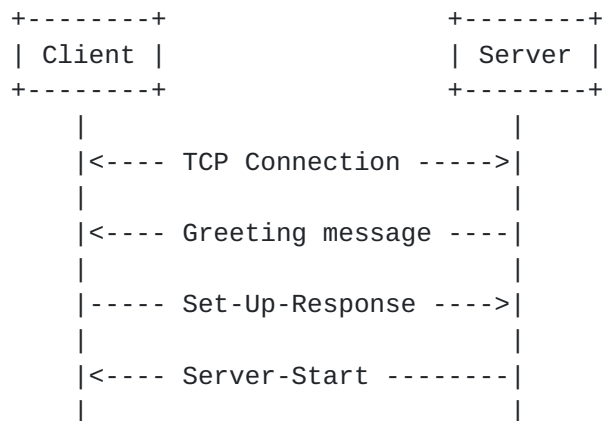
                Figure 1: Initiation of O/TWAMP-Control

   Encryption uses a key derived from the shared secret associated with
   KeyID. In the authenticated, encrypted and mixed modes, all further
   communication is encrypted using the AES Session-key and
   authenticated with the HMAC Session-key. After receiving Set-Up-
   Response the server responds with a Server-Start message containing
   Server-IV. The client encrypts everything it transmits through the
   just-established O/TWAMP-Control connection using stream encryption
   with Client- IV as the IV. Correspondingly, the server encrypts its
   side of the connection using Server-IV as the IV. The IVs themselves
   are transmitted in cleartext. Encryption starts with the block
   immediately following that containing the IV.

   The AES Session-key and HMAC Session-key are generated randomly by
   the client. The HMAC Session-key is communicated along with the AES
   Session-key during O/TWAMP-Control connection setup. The HMAC
   Session-key is derived independently of the AES Session-key.

4.2. O/TWAMP-Test Security

   The O/TWAMP-Test protocol runs over UDP, using the client and server
   IP and port numbers that were negotiated during the Request-Session
   exchange. O/TWAMP- Test has the same mode with O/TWAMP-Control and
   all O/TWAMP-Test sessions inherit the corresponding O/TWAMP-Control
   session mode except when operating in mixed mode.

   The O/TWAMP-Test packet format is the same in authenticated and
   encrypted modes. The encryption and authentication operations are,
   however, different. Similarly with the respective O/TWAMP-Control
   session, each O/TWAMP-Test session has two keys: an AES Session-key
   and an HMAC Session-key. However, there is a difference in how the
   keys are obtained:

O/TWAMP-Control: the keys are generated by the client and
        communicated to the server during the control connection
        establishment with the Set-Up-Response message (as part of
        the Token).

O/TWAMP-Test: the keys are derived from the O/TWAMP-Control keys and
        the session identifier (SID), which serve as inputs of the
        key derivation function (KDF). The O/TWAMP-Test AES Session-
        key is generated using the O/TWAMP- Control AES Session-key,
        with the 16-octet session identifier (SID), for encrypting
        and decrypting the packets of the particular O/TWAMP-Test
        session. The O/TWAMP-Test HMAC Session-key is generated
        using the O/TWAMP-Control HMAC Session-key, with the 16-octet
        session identifier (SID), for authenticating the packets of
        the particular O/TWAMP-Test session.

4.3. O/TWAMP Security Root

As discussed above, the AES Session-key and HMAC Session-key used by
the O/TWAMP-Test protocol are derived from the AES Session-key and
HMAC Session-key which are used in O/TWAMP-Control protocol. The AES
Session-key and HMAC Session-key used in the O/TWAMP-Control protocol
are generated randomly by the client, and encrypted with the shared
secret associated with KeyID. Therefore, the security root is the
shared secret key. Thus, for large deployments, key provision and
management may become overly complicated. Comparatively, a
certificate-based approach using IKEv2 can automatically manage the
security root and solve this problem, as we explain in Section 5.

5. O/TWAMP for IPsec Networks

This section presents a method of binding O/TWAMP and IKEv2 for
network measurements between a client and a server which both support
IPsec. In short, the shared key used for securing O/TWAMP traffic is
derived using IKEv2 [RFC7296].

5.1. Shared Key Derivation

In the authenticated, encrypted and mixed modes, the shared secret
key MUST be derived from the IKEv2 Security Association (SA). Note
that we explicitly opt to derive the shared secret key from the IKEv2
SA, rather than the child SA, since the use case whereby an IKEv2 SA
can be created without generating any child SA is possible [RFC6023].

When the shared secret key is derived from the IKEv2 SA, SK_d must be
generated first. SK_d MUST be computed as per [RFC7296].

The shared secret key MUST be generated as follows:

      Shared secret key = PRF(SK_d, "IPPM")

   Wherein the string "IPPM" comprises four ASCII characters and prf is
   a pseudorandom function. It is recommended that the shared secret
   key is derived in the IPsec layer. This way, the IPsec keying
   material is not exposed to the O/TWAMP client. Note, however, that
   the interaction between the O/TWAMP and IPsec layers is host-internal
   and implementation-specific. Therefore, this is clearly outside the
   scope of this document, which focuses on the interaction between the
   O/TWAMP client and server. That said, one possible way could be the
   following: at the client side, the IPSec layer can perform a lookup
   in the Security Association Database (SAD) using the IP address of
   the server and thus match the corresponding IKEv2 SA. At the server
   side, the IPSec layer can look up the corresponding IKEv2 SA by using
   the SPIs sent by the client, and therefore extract the shared secret
   key. In case that both client and server do support IKEv2 but there
   is no current IKEv2 SA, two alternative ways could be considered.
   First, the O/TWAMP client initiates the establishment of the IKEv2
   SA, logs this operation, and selects the mode which supports IKEv2.
   Alternatively, the O/TWAMP client does not initiate the establishment
   of the IKEv2 SA, logs an error for operational management purposes,
   and proceeds with the modes defined in [RFC4656][RFC5357][RFC5618].
   Again, although both alternatives are feasible, they are in fact
   implementation-specific.

   If rekeying for the IKEv2 SA or deletion of the IKEv2 SA occurs, the
   corresponding shared secret key generated from the SA can continue to
   be used until the O/TWAMP session terminates.

5.2. Server Greeting Message Update

   To achieve a binding association between the key generated from IKEv2
   and the O/TWAMP shared secret key, Server Greeting Message should be
   updated as in Figure 2.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                    Unused (12 octets)                         |
|                                                               |
|+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-++-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Modes                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                    Challenge (16 octets)                      |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                     Salt (16 octets)                          |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Count (4 octets)                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                     MBZ (12 octets)                           |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Server Greeting format

The Modes field in Figure 2 will need to allow for support of key
derivation as discussed in Section 5.1. As such, the Modes value
extension MUST be supported by implementations compatible with this
document, indicating support for deriving the shared key from the
IKEv2 SA. The new Modes value indicating support for this
specification is IKEv2Derived and is equal to 128 (i.e. bit set in
position 7) [NOTE to IANA: remove before allocation and final
publication]. Clearly, an implementation compatible with this
specification MUST support the authenticated, encrypted and mixed
modes as per [RFC4656][RFC5357][RFC5618].

The choice of this set of Modes values poses no backwards
compatibility problems to existing O/TWAMP clients. Robust legacy
client implementations would disregard the fact that the IKEv2Derived
Modes bit in the Server Greeting is set. On the other hand, a client
compatible with this specification can easily identify that the O/
TWAMP server contacted does not support this specification. If the
server supports other Modes, as one could assume, the client would
then decide which Mode to use and indicate such accordingly as per
[RFC4656][RFC5357]. A client compatible with this specification

which decides not to employ IKEv2 derivation, can simply behave as a
purely [RFC4656]/[RFC5357] compatible client.

5.3. Set-Up-Response Update

The Set-Up-Response Message should be updated as in Figure 3. When a
O/TWAMP client compatible with this specification receives a Server
Greeting indicating support for Mode IKEv2Derived it SHOULD reply to
the O/TWAMP server with a Set-Up response that indicates so. For
example, a compatible O/TWAMP client choosing the authenticated mode
with IKEv2 shared secret key derivation should set Mode to 130, i.e.
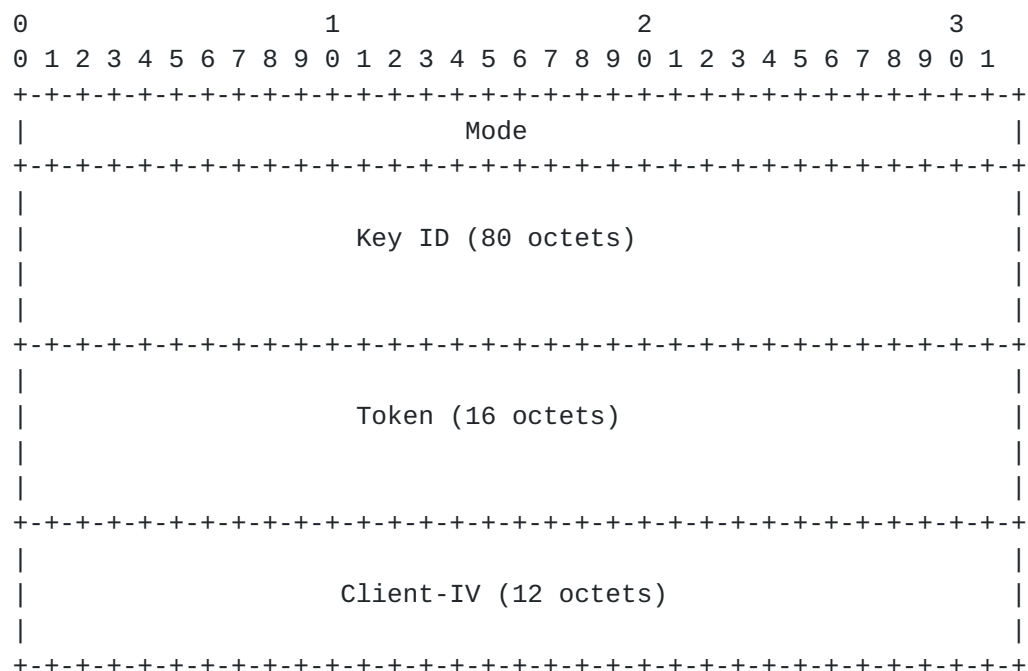set the bits in positions 1 and 7 (TBD IANA) to one.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             Mode                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                      Key ID (80 octets)                       |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                      Token (16 octets)                        |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                    Client-IV (12 octets)                      |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: Set-Up-Response Message

The Security Parameter Index (SPI)(see [RFC4301] [RFC7296]) can
uniquely identify the Security Association (SA). If the client
supports the derivation of shared secret key from IKEv2 SA, it will
choose the corresponding mode value and carry SPIi and SPIr in the
Key ID field. SPIi and SPIr MUST be included in the Key ID field of
Set-Up-Response Message to indicate the IKEv2 SA from which the O/
TWAMP shared secret key derived from. The length of SPI is 4 octets.
Therefore, the first 4 octets of Key ID field MUST carry SPIi and the
second 4 octets MUST carry SPIr. The remaining bits of the Key ID
field MUST set to zero.

A O/TWAMP server which supports the specification of this document,
MUST obtain the SPIi and SPIr from the first 8 octets and ignore the

remaining octets of the Key ID field. Then, the client and the
server can derive the shared secret key based on the mode value and
SPI. If the O/TWAMP server cannot find the IKEv2 SA corresponding to
the SPIi and SPIr received, it MUST log the event for operational
management purposes. In addition, the O/TWAMP server SHOULD set the
Accept field of the Server-Start message to the value 6 to indicate
that server is not willing to conduct further transactions in this O/
TWAMP-Control session since it can not find the corresponding IKEv2
SA.

5.4. O/TWAMP over an IPsec tunnel

IPsec AH [RFC4302] and ESP [RFC4303] provide confidentiality and
data integrity to IP datagrams. Thus an IPsec tunnel can be used to
provide the protection needed for O/TWAMP Control and Test packets,
even if the peers choose the unauthenticated mode of operation. If
the two endpoints are already connected through an IPSec tunnel it is
RECOMMENDED that the O/TWAMP measurement packets are forwarded over
the IPSec tunnel if the peers choose the unauthenticated mode in
order to ensure authenticity and security.

6. Security Considerations

As the shared secret key is derived from the IKEv2 SA, the key
derivation algorithm strength and limitations are as per [RFC7296].
The strength of a key derived from a Diffie-Hellman exchange using
any of the groups defined here depends on the inherent strength of
the group, the size of the exponent used, and the entropy provided by
the random number generator employed. The strength of all keys and
implementation vulnerabilities, particularly Denial of Service (DoS)
attacks are as defined in [RFC7296].

As a more general note, the IPPM community may want to revisit the
arguments listed in [RFC4656], Sec. 6.6. Other widely-used Internet
security mechanisms, such as TLS and DTLS, may also be considered for
future use over and above of what is already specified in [RFC4656]
[RFC5357].

7. IANA Considerations

IANA is requested to allocate the IKEv2Derived Mode bit that is equal
to 128 (i.e. bit set in position 7) in the TWAMP-Modes registry. The
TWAMP-Modes registry should be augmented as follows:

```
Value   Description              Semantics Definition
------------------------------------------------------------
128     IKEv2 Derived            This memo, Section 5.2
        Mode Capability          new bit position 7
```

Figure 4: IKEv2 Modes Capability

8. Acknowledgments

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