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                  TLS Authentication using ITS certificate
                       draft-msahli-ise-ieee1609-06

Abstract

   The IEEE and ETSI have specified a type of end-entity certificates.
   This document defines an experimental change to TLS to support IEEE/
   ETSI certificate types to authenticate TLS entities.

Status of This Memo

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Table of Contents

1. Introduction

The TLS protocol [RFC8446] allows the use of X.509 certificates and
Raw Public Key to authenticate servers and clients. This document
describes an experimental extension following the procedures laid out
by [RFC7250] to support use of the certificate format specified by
the IEEE in [IEEE1609.2] and profiled by the European
Telecommunications Standards Institute (ETSI) in [TS103097]. In this
document, we call this certificates: ITS certificates. These
standards specify secure communications in vehicular environments.
These certificates are referred to in this document as Intelligent
Transportation Systems (ITS) Certificates.

The certificate types are optimized for bandwidth and processing time
to support delay-sensitive applications, and also to provide both
authentication and authorization information to enable fast access
control decisions in ad hoc networks such as are found in Intelligent

Transportation Systems (ITS). The standards specify different types of certificate to support a full Public Key Infrastructure (PKI) specification; the certificates to be used in this context are end-entity certificates, i.e. certificates that have the IEEE 1609.2 appPermissions field present.

Use of ITS certificates is becoming widespread in the ITS setting. ITS communications in practice make heavy use of 10 MHz channels with a typical throughput of 6 Mbps. (The 802.11OCB modulation that gives this throughput is not the one that gives the highest throughput, but it provides for a robust signal over a range up to 300-500 m, which is the "sweet spot" communications range for ITS operations like collision avoidance). The compact nature of ITS certificates as opposed to X.509 certificates makes them appropriate for this setting.

The ITS certificates are also suited to the M2M ad hoc network setting, because their direct encoding of permissions (see Security Considerations, section 7.4) allows a receiver to make an immediate accept/deny decision about an incoming message without having to refer to a remote identity and access management server. The EU has committed to the use of ITS certificates in Cooperative Intelligent Transportation Systems deployments. A multi-year project developed a certificate policy for the use of ITS certificates, including a specification of how different root certificates can be trusted across the system (hosted at https://ec.europa.eu/transport/themes/its/c-its_en, direct link at https://ec.europa.eu/transport/sites/transport/files/c-its_certificate_policy_release_1.pdf).

The EU has committed funding for the first five years of operation of the top-level Trust List Manager entity, enabling organizations such as motor vehicle OEMs and national road authorities to create root CAs and have them trusted. In the US, the US Department of Transportation (USDOT) published a proposed regulation, which as of late 2019, is active though not rapidly progressing, which would require all light vehicles in the US to implement V2X communications including the use of ITS certificates (available from https://www.federalregister.gov/documents/2017/01/12/2016-31059/federal-motor-vehicle-safety-standards-v2v-communications). As of 2019, ITS deployments across the US, Europe and Australia were using ITS certificates. Volkswagen have committed to deploying V2X using ITS certificates. New York, Tampa and Wyoming are deploying traffic management systems using ITS certificates. GM deployed V2X in their Cadillac CTSes using ITS certificates.

ITS certificates are also used in a number of standards that build on top of the foundational IEEE and ETSI standards, particularly the SAE

J2945/x series of standards for applications and ISO 21177, which builds a framework for exchanging multiple authentication tokens on top of the TLS variant specified in this document.

1.1. Experiment Overview

This document describes an experimental extension to the TLS security model. It uses a form of certificate that has not previously been used in the Internet. Systems using this Experimental approach are segregated from system using standard TLS by the use of a new Certificate Type value, reserved through IANA (see Section 9). An implementation of TLS that is not involved in the Experiment will not recognise this new Certificate Type and will not participate in the experiment: TLS sessions will either negotiate the use of existing X.509 certificates or fail to be established.

This extension has been encouraged by stakeholders in the Cooperative ITS community in order to support the ITS use cases deployment and it is anticipated that its use will be widespread.

2. Requirements Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Extension Overview

The TLS extension "client_certificate_type" and "server_certificate_type" [RFC7250] are used to negotiate the type of Certificate messages used in TLS to authenticate the server and, optionally, the client. Using separate extension allows for mixed deployments where client and server can use certificates of different types. It is expected that ITS deployments will see both peers using ITS certificates due to the homogeneity of the ecosystem, but there is no barrier at a technical level that prevents mixed certificate usage. This document defines a new certificate type, 1609Dot2, for usage with TLS 1.3. The updated CertificateType enumeration and corresponding addition to the CertificateEntry structure are shown below. CertificateType values are sent in the "server_certificate_type" and "client_certificate_type" extension, and the CertificateEntry structures are included in the certificate chain sent in the Certificate message. In case of TLS 1.3, the "client_certificate_type " SHALL contain a list of supported certificate types proposed by the client as provided in the figure below:

```
   /* Managed by IANA */
    enum {
        X509(0),
        RawPublicKey(2),
        1609Dot2(3),
        (255)
    } CertificateType;

    struct {
        select (certificate_type) {

            /* certificate type defined in this document.*/
             case 1609Dot2:
             opaque cert_data<1..2^24-1>;

             /* RawPublicKey defined in RFC 7250*/
            case RawPublicKey:
            opaque ASN.1_subjectPublicKeyInfo<1..2^24-1>;

            /* X.509 certificate defined in RFC 5246*/
            case X.509:
            opaque cert_data<1..2^24-1>;

             };

            Extension extensions<0..2^16-1>;
        } CertificateEntry;
```

As per [RFC7250], the server processes the received
[endpoint]_certificate_type extension(s) and selects one of the
offered certificate types, returning the negotiated value in its
EncryptedExtensions (TLS 1.3) message. Note that there is no
requirement for the negotiated value to be the same in
client_certificate_type and server_certificate_type extensions sent
in the same message.

4. TLS Client and Server Handshake

Figure 1 shows the handshake message flow for a full TLS 1.3
handshake negotiating both certificate types.

```
     Client                                          Server

 Key  ^ ClientHello
 Exch | + server_certificate_type*
      | + client_certificate_type*
      | + key_share*
      v + signature_algorithms*        -------->
                                                ServerHello  ^ Key
                                               + key_share*  v Exch
                                          {EncryptedExtensions}  ^ Server
                                      {+ server_certificate_type*}| Params
                                      {+ client_certificate_type*}|
                                            {CertificateRequest*}  v
                                                   {Certificate*}  ^
                                             {CertificateVerify*}  | Auth
                                                     {Finished}  v
                                      <-------   [Application Data*]
      ^ {Certificate*}
 Auth | {CertificateVerify*}
      v {Finished}               -------->
        [Application Data]       <------->   [Application Data]
                 +   Indicates noteworthy extensions sent in the
                     previously noted message.

                 *   Indicates optional or situation-dependent
                     messages/extensions that are not always sent.

                 {} Indicates messages protected using keys
                     derived from a [sender]_handshake_traffic_secret.

                 [] Indicates messages protected using keys
                     derived from [sender]_application_traffic_secret_N.
```
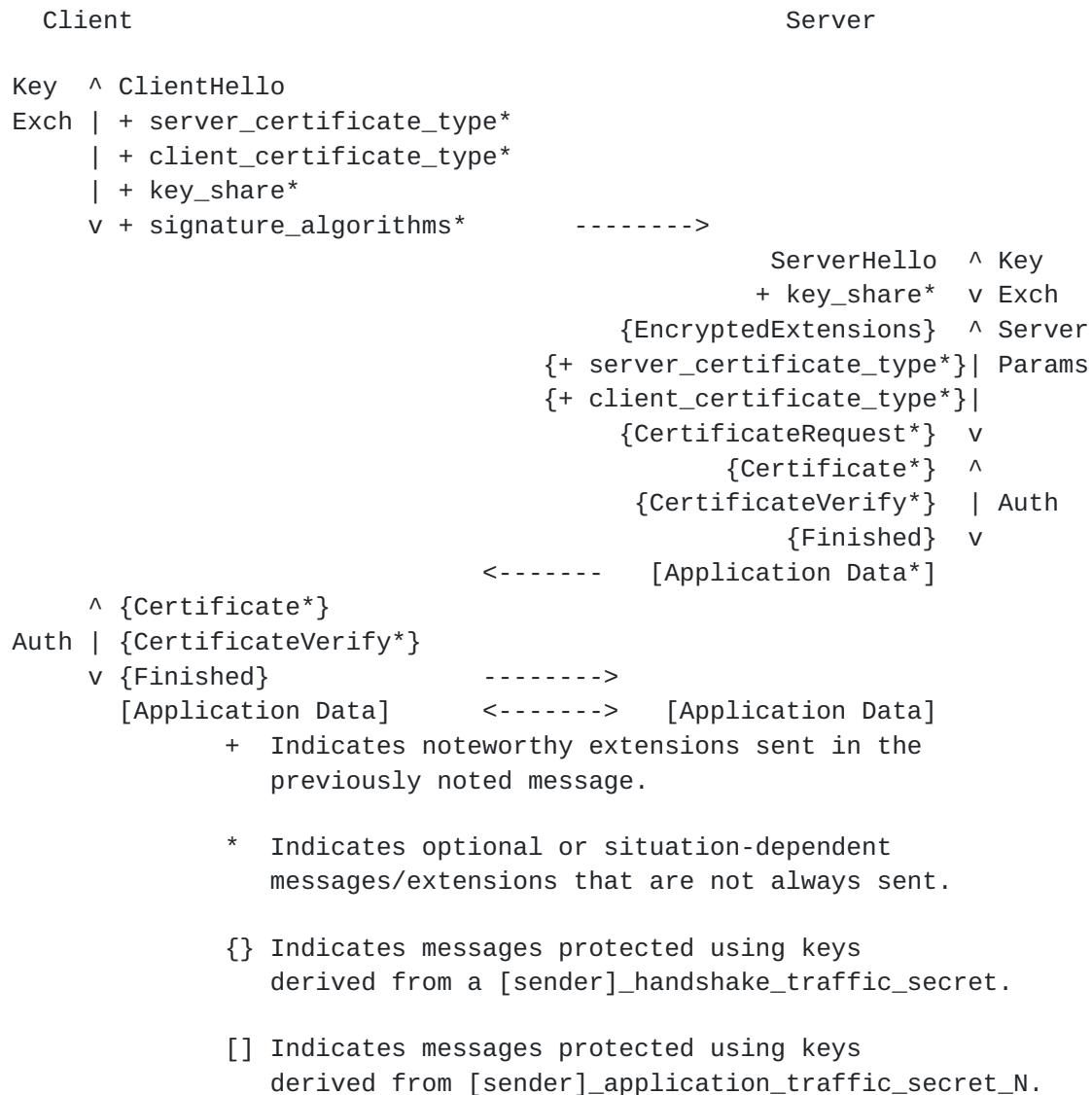
Figure 1: Message Flow with certificate type extension for Full TLS
1.3 Handshake

In the case of TLS 1.3, in order to negotiate the support of ITS
certificate-based authentication, clients and servers include the
extension of type "client_certificate_type" and
"server_certificate_type" in the extended Client Hello and
"EncryptedExtensions".

4.1. Client Hello

   In order to indicate the support of ITS certificates, a client MUST
   include an extension of type "client_certificate_type" or
   "server_certificate_type" in the extended Client Hello message as
   described in Section 4.1.2 of TLS 1.3 [RFC8446].

   For both TLS 1.3, the rules for when the Client Certificate and
   CertificateVerify messages appear are as follows:

      - The client's Certificate message is present if and only if the
      server sent a CertificateRequest message.

      - The client's CertificateVerify message is present if and only if
      the client's Certificate message is present and contains a non-
      empty certificate_list.

   For maximum compatibility, all implementations SHOULD be prepared to
   handle "potentially" extraneous certificates and arbitrary orderings
   from any TLS version, with the exception of the end-entity
   certificate which MUST be first.

4.2. Server Hello

   When the server receives the Client Hello containing the
   client_certificate_type extension and/or the server_certificate_type
   extension, the following scenarios are possible:

      - If both client and server indicate support for the ITS
      certificate type, the server MAY select the first (most preferred)
      certificate type from the client's list that is supported by both
      peers

      - The server does not support any of the proposed certificate
      types and terminates the session with a fatal alert of type
      "unsupported_certificate".

      - The server supports the certificate types specified in this
      document. In this case, it MAY respond with a certificate of this
      type. It MAY also include the client_certificate_type extension
      in Encrypted Extension. Then, the server requests a certificate
      from the client (via the CertificateRequest message)

   The certificates in the TLS client or server certificate chain MAY be
   sent as part of the handshake, or MAY be sent obtained from an online
   repository, or might already be known to and cached at the endpoint.
   If the handshake does not contain all the certificates in the chain,
   and the endpoint cannot access the repository, and the endpoint does

not already know the certificates from the chain, then it SHALL
reject the other endpoint's certificate and close the connection.
Protocols to support retrieving certificates from a repository are
specified in ETSI[ETSI102941].

5. **Certificate Verification**

Verification of an ITS certificates or certificate chain is described
in section 5.1 of [IEEE1609.2]. In the case of TLS 1.3 and when the
certificate_type is 1609.2, the CertificateVerify contents and
processing are different than for the CertificateVerify message
specified for other values of certificate_type in [RFC8446]. In this
case, the CertificateVerify message contains a Canonical Octet
Encoding Rules [ITU-TX.696] -encoded IEEE1609Dot2Data of type signed
as specified in [IEEE1609.2], [IEEE1609.2b], where:

   Payload contains an extDataHash containing the SHA-256 hash of the
   data the signature is calculated over. This is identical to the
   data that the signature is calculated over it in standard TLS,
   which is reproduced below for clarity.

   Provider Service Identifier (Psid) indicates the application
   activity that the certificate is authorizing.

   generationTime is the time at which the data structure was
   generated.

   PduFunctionalType (as specified in [IEEE1609.2b]) is present and
   is set equal to tlsHandshake (1).

All other fields in the headerInfo are omitted. The certificate
appPermissions field SHALL be present and SHALL permit (as defined in
[IEEE1609.2]) signing of PDUs with the PSID indicated in the
HeaderInfo of the SignedData. If the application specification for
that PSID requires Service Specific Permissions (SSP) for signing a
pduFunctionalType of tlsHandshake, this SSP SHALL also be present.
For more details on the use of PSID and SSP, see [IEEE1609.2] clauses
5.1.1 and 5.2.3.3.3. All other fields in the headerInfo are omitted.

The certificate appPermissions field SHALL be present and SHALL
permit (as defined in IEEE 1609.2) signing of PDUs with the PSID
indicated in the HeaderInfo of the SignedData. If the application
specification for that PSID requires Service Specific Permissions
(SSP) for signing a pduFunctionalType of tlsHandshake, this SSP SHALL
also be present.

The signature and verification are carried out as specified in
[IEEE1609.2].

The input to the hash process is identical to the message input for
TLS 1.3, as specified in [RFC8446] section 4.4.3, consisting of pad,
context string, separator and content, where content is Transcript-
Hash(Handshake Context, Certificate).

6. Examples

Some of message-exchange examples are illustrated in Figures 2 and 3.

6.1. TLS Server and TLS Client use the ITS Certificate

This section shows an example where the TLS client as well as the TLS
server use ITS certificates. In consequence, both the server and the
client populate the client_certificate_type and
server_certificate_type extension with the IEEE 1609 Dot 2 type as
mentioned in figure 2.

```
        Client                                         Server

   ClientHello,
   client_certificate_type=1609Dot2,
   server_certificate_type=1609Dot2,   -------->     ServerHello,
                                               {EncryptedExtensions}
                                   {client_certificate_type=1609Dot2}
                                   {server_certificate_type=1609Dot2}
                                                  {CertificateRequest}
                                                         {Certificate}
                                                   {CertificateVerify}
                                                            {Finished}
      {Certificate}              <-------         [Application Data]
      {CertificateVerify}
      {Finished}                 -------->
      [Application Data]         <------->         [Application Data]


        Figure 2: TLS Client and TLS Server use the ITS certificate
```

6.2. TLS Client uses the ITS certificate and TLS Server uses the X.509 certificate

This example shows the TLS authentication, where the TLS Client
populates the server_certificate_type extension with the X.509
certificate and Raw Public Key type as presented in figure 3. The
client indicates its ability to receive and to validate an X.509
certificate from the server. The server chooses the X.509
certificate to make its authentication with the Client. This is
applicable in case of Raw Public Key supported by the server.

```
   Client                                        Server
   ClientHello,
   client_certificate_type=(1609Dot2),
   server_certificate_type=(1609Dot2,
   X509,RawPublicKey),           ----------->        ServerHello,
                                              {EncryptedExtensions}
                             {client_certificate_type=1609Dot2}
                                 {server_certificate_type=X509}
                                             {CertificateRequest}
                                                    {Certificate}
                                              {CertificateVerify}
                                                       {Finished}
                             <---------      [Application Data]
   {Finished}                --------->
   [Application Data]        <-------->      [Application Data]
```

                 Figure 3: TLS Client uses the ITS certificate and TLS Server uses the
                              X.509 certificate

7. Security Considerations

   This section provides an overview of the basic security
   considerations which need to be taken into account before
   implementing the necessary security mechanisms. The security
   considerations described throughout [RFC8446] apply here as well.

7.1. Securely Obtaining Certificates from an Online Repository

   In particular, the certificates used to establish a secure connection
   MAY be obtained from an online repository. An online repository may
   be used to obtain the CA certificates in the chain of either
   participant in the secure session. ETSI TS 102 941 [ETSI102941]
   provides a mechanism that can be used to securely obtain ITS
   certificates.

7.2. Expiry of Certificates

   Conventions around certificate lifetime differ between ITS
   certificates and X.509 certificates, and in particular ITS
   certificates may be relatively short-lived compared with typical
   X.509 certificates. A party to a TLS session that accepts ITS
   certificates MUST check the expiry time in the received ITS
   certificate and SHOULD terminate a session when the certificate
   received in the handshake expires.

7.3. Algorithms and Cryptographic Strength

All ITS certificates use public-key cryptographic algorithms with an estimated strength on the order of 128 bits or more, specifically, Elliptic Curve Cryptography (ECC) based on curves with keys of length 256 bits or longer. An implementation of the techniques specified in this document SHOULD require that if X.509 certificates are used by one of the parties to the session, those certificates are associated with cryptographic algorithms with (pre-quantum-computer) strength of at least 128 bits.

7.4. Interpreting ITS Certificate Permissions

ITS certificates in TLS express the certificate holders permissions using two fields: a PSID, also known as an ITS Application Identifier (ITS-AID), which identifies a broad set of application activities which provide a context for the certificate holder's permissions, and a Service Specific Permissions (SSP) field associated with that PSID, which identifies which specific application activities the certificate holder is entitled to carry out within the broad set of activities identified by that PSID. For example, SAE [SAEJ29453] uses PSID 0204099 to indicate activities around reporting weather and managing weather response activities, and an SSP that states whether the certificate holder is a Weather Data Management System (WDMS, i.e. a central road manager), an ordinary vehicle, or a vehicle belonging to a managed road maintenance fleet. For more information about PSIDs, see [IEEE16092] and for more information about the development of SSPs, see [SAEJ29455]

7.5. Psid and Pdufunctionaltype in CertificateVerify

The CertificateVerify message for TLS 1.3 is an Ieee1609Dot2Data of type signed, signed using an ITS certificate. This certificate may include multiple PSIDs. When a CertificateVerify message of this form is used, the HeaderInfo within the Ieee1609Dot2Data MUST have the pduFunctionalType field present and set to tlsHandshake. The background to this requirement is as follows. A ITS certificate may (depending on the definition of the application associated with its PSID(s)) be used to directly sign messages, or to sign TLS CertificateVerify messages, or both. To prevent the possibility that a signature generated in one context could be replayed in a different context i.e., that a message signature could be replayed as a CertificateVerify, or vice versa, the pduFunctionalType field provides a statement of intent by the signer as to the intended use of the signed message. If the pduFunctionalType field is absent, the message is a directly signed message for the application and MUST NOT be interpreted as a CertificateVerify.

   Note that each PSID is owned by an owning organization that has sole
   rights to define activities associated with that PSID. If an
   application specifier wishes to expand activities associated with an
   existing PSID (for example, to include activities over a secure
   session such as specified in this document), that application
   specifier must negotiate with the PSID owner to have that
   functionality added to the official specification of activities
   associated with that PSID.

8. Privacy Considerations

   For privacy considerations in a vehicular environment the ITS
   certificate is used for many reasons:

      In order to address the risk of a personal data leakage, messages
      exchanged for V2V communications are signed using ITS pseudonym
      certificates

      The purpose of these certificates is to provide privacy and
      minimize the exchange of private data

9. IANA Considerations

   IANA maintains the "Transport Layer Security (TLS) Extensions"
   registry with a subregistry called "TLS Certificate Types".

   IANA has previously assigned an entry (value 3) for "1609Dot2" with
   reference set to draft-tls-certieee1609. IANA is requested to update
   that entry to reference the RFC number of this document when it is
   published.

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   support of the draft.

11. Normative References

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