Kerberos Cipher Suites in Transport Layer Security (TLS)

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1. **Abstract**

RFC 2712 [KERBTLS] introduced mechanisms for supporting Kerberos
[KERB] authentication within the TLS protocol [TLS]. This document
extends RFC 2712 to support delegation of Kerberos credentials. In
this way, a TLS server may obtain a Kerberos service ticket on behalf
of the TLS client. Thus, a single client identity may be used for
authentication within a multi-tier architecture. This draft also
proposes a mechanism for a TLS server to indicate Kerberos-specific
information to the client within the certificate request message in
the initial exchange.

2. **Introduction**

Flexibility is one of the main strengths of the TLS protocol. Clients

and servers can negotiate cipher suites to meet specific security and
administrative policies. RFC 2712 specified how TLS could be
extended to support organizations with heterogeneous security
deployments that include authentication systems based on symmetric
cryptography. Kerberos, originally developed at MIT, is based on an
open standard and is the most widely deployed symmetric key
authentication system. Just as other documents specify hybrid
asymmetric/symmetric key protocols [PKINIT] [PKCROSS] [PKTAPP], this
document specifies how TLS may incorporate both symmetric and
asymmetric key crypto systems.

This document describes the use of Kerberos authentication within
the TLS framework. This achieves mutual authentication and the
establishment of a master secret using Kerberos credentials.
Additionally, this document specifies support for delegation of
Kerberos credentials, which enables end to end authentication within
an n-tier architecture. The proposed changes are minimal and, in
fact, no different from adding a new public key algorithm to the TLS
framework.

3. **Kerberos Authentication Option In TLS**

   This section describes the addition of the Kerberos authentication
   option to the TLS protocol. Throughout this document, we refer to
   the basic SSL handshake shown in Figure 1. For a review of the TLS
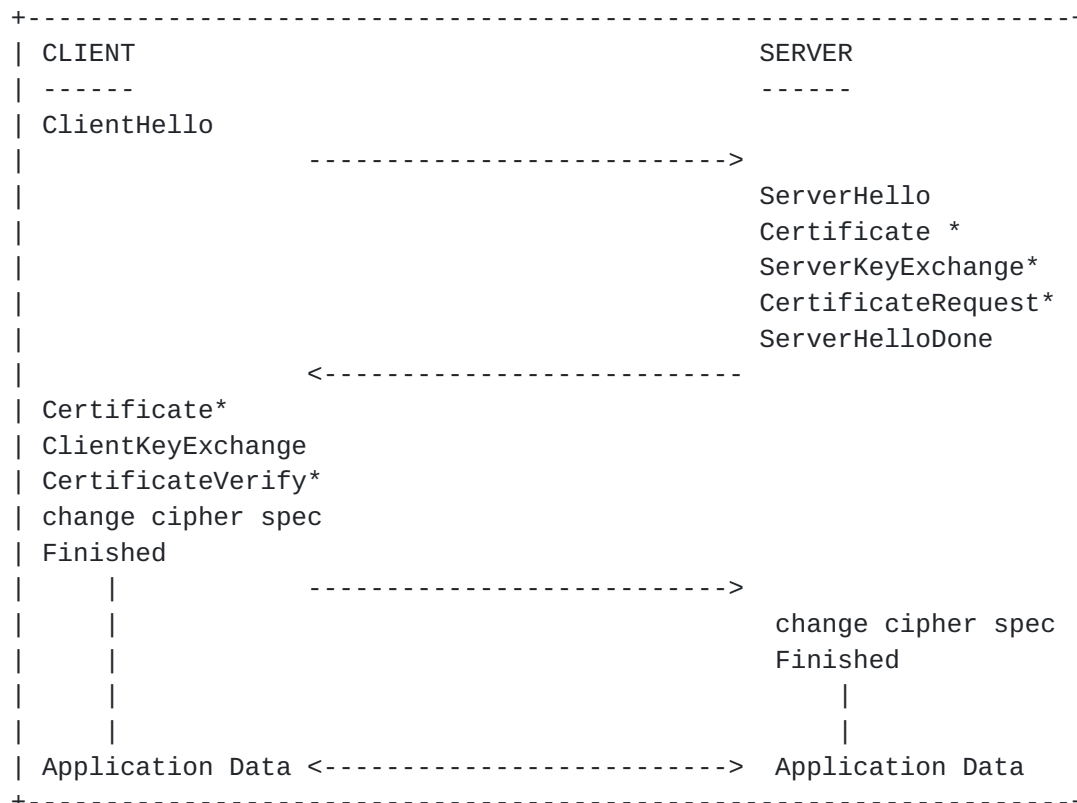   handshake see [TLS].

```
+----------------------------------------------------------------------+
| CLIENT                                          SERVER               |
| ------                                          ------               |
| ClientHello                                                          |
|                    -------------------------->                       |
|                                                 ServerHello          |
|                                                 Certificate *        |
|                                                 ServerKeyExchange*    |
|                                                 CertificateRequest*   |
|                                                 ServerHelloDone       |
|                    <--------------------------                        |
| Certificate*                                                         |
| ClientKeyExchange                                                    |
| CertificateVerify*                                                   |
| change cipher spec                                                   |
| Finished                                                             |
|       |            -------------------------->                       |
|       |                                         change cipher spec   |
|       |                                         Finished             |
|       |                                             |                |
|       |                                             |                |
| Application Data <--------------------------> Application Data       |
+----------------------------------------------------------------------+
```

FIGURE 1: The TLS protocol. All messages followed by a star are
          optional. Note: This figure was taken from RFC 2246.

The TLS security context is negotiated in the client and server hello
messages. For example: TLS_RSA_WITH_RC4_128_MD5 means the initial
authentication will be done using the RSA public key algorithm, RC4
will be used with a 128 bit session key, and MACs will be based on
the MD5 algorithm. Thus, to facilitate the Kerberos authentication
option, we must start by defining Kerberos cipher suites including
(but not limited to):

```
CipherSuite      TLS_KRB5_WITH_3DES_EDE_CBC_SHA      = { 0x00,0x70 };
CipherSuite      TLS_KRB5_WITH_3DES_EDE_CBC_MD5      = { 0x00,0x71 };
CipherSuite      TLS_KRB5_WITH_RC4_128_SHA           = { 0x00,0x72 };
CipherSuite      TLS_KRB5_WITH_RC4_128_MD5           = { 0x00,0x73 };
CipherSuite      TLS_KRB5_WITH_DES_CBC_SHA           = { 0x00,0x74 };
CipherSuite      TLS_KRB5_WITH_DES_CBC_MD5           = { 0x00,0x75 };
CipherSuite      TLS_KRB5_WITH_AES_128_CBC_SHA       = { 0x00,0x76 };
CipherSuite      TLS_KRB5_WITH_AES_256_CBC_SHA       = { 0x00,0x77 };
CipherSuite      TLS_KRB5_WITH_NULL_SHA              = { 0x00,0x78 };
CipherSuite      TLS_KRB5_WITH_NULL_MD5              = { 0x00,0x79 };
```

To establish a Kerberos-based security context, one or more of the
above cipher suites must be specified in the client hello message. If
the TLS server supports the Kerberos authentication option, the
server hello message, sent to the client, will confirm the Kerberos
cipher suite selected by the server. The server's certificate and
the ServerKeyExchange shown in Figure 1 will be omitted since
authentication and the establishment of a master secret will be done
using the client's Kerberos credentials for the TLS server. Note
that these messages are specified as optional in the TLS protocol;
therefore, omitting them is permissible.

The Kerberos option affects three of the TLS messages: the
CertificateRequest, the client Certificate, and the
ClientKeyExchange. However, only the client Certificate and the
ClientKeyExchange are required.

3.1. Usage of the CertificateRequest Message

If the server accepts a Kerberos-based ciphersuite, then it MUST send
the CertificateRequest message to the client. This message conveys
Kerberos-specific characteristics such as realm name or attributes
such as forwarded ticket.

RFC 2246 defines the CertificateRequest message as follows:
```
+----------------------------------------------------------------+
|                                                                |
|    enum {                                                       |
|        rsa_sign(1), dss_sign(2), rsa_fixed_dh(3), dss_fixed_dh(4), |
```

```
|        (255)                                                    |
|    } ClientCertificateType;                                     |
|                                                                 |
|    opaque DistinguishedName<1..2^16-1>;                         |
|                                                                 |
|    struct { ClientCertificateType certificate_types<1..2^8-1>;  |
|            DistinguishedName certificate_authorities<3..2^16-1>; |
|    } CertificateRequest;                                        |
|                                                                 |
+-----------------------------------------------------------------+
```
FIGURE 2: CertificateRequest message from RFC 2246

This specification defines a new ClientCertificateType for a Kerberos
certificate. This enables a client to respond to the
CertificateRequest message when using Kerberos ciphersuites. The
Kerberos ClientCertificateType MUST NOT be included in
certificate_types for non-Kerberos ciphersuites. Thus the following
change for ClientCertificateType is required (Figure 3).

```
+-----------------------------------------------------------------+
|                                                                 |
|    enum {                                                       |
|        rsa_sign(1), dss_sign(2), rsa_fixed_dh(3), dss_fixed_dh(4), |
|        kerberos(5), (255)                                       |
|    } ClientCertificateType;                                     |
|                                                                 |
+-----------------------------------------------------------------+
```
FIGURE 3: New Kerberos ClientCertificateType

In the case of a public key based authentication algorithm, the
opaque DistinguishedName field is derived from [X509], and it
contains the name of an acceptable certification authority (This is
as specified in [TLS]). In the case of a Kerberos
ClientCertificateType, the DistinguishedName field is defined to
represent Kerberos information (KerbInfo) as shown in Figure 4. The
srv_tgt attribute type is used by the server to send a TGT that the
client presents to the KDC in the case of user-to-user
authentication. The KDC uses the session key from this ticket to
encrypt a service ticket for the server. In this case the attr_data
must be of non-zero length and contain the server's TGT.

```
+-----------------------------------------------------------------+
|                                                                 |
|    enum                                                         |
|    {                                                            |
|       srv_tkt(1), fwd_tgt(2), (255)                             |
|    } KerbInfoType;                                              |
|                                                                 |
|    enum                                                         |
|    {                                                            |
|       initial_tkt_required(1), srv_tgt(2), (255)                |
```

```
    |    } AttrType; /* This may be extended to include attributes    */ |
    |                /*  such as forwardable or renewable for example */ |
    |                                                                     |
    |    struct                                                           |
    |    {                                                                |
    |       AttrType        attr_type;                                    |
    |       opaque          attr_data <0..2^16-1>;                        |
    |    } AttrInfoType                                                   |
    |                                                                     |
    |    struct                                                           |
    |    {                                                                |
    |       uint32          length; /* length of this struct */          |
    |       KerbInfoType    type;                                         |
    |       opaque          sname <0..2^16-1>;                            |
    |       opaque          srealm <0..2^16-1>;                           |
    |       opaque          cname <0..2^16-1>;                            |
    |       opaque          crealm <0..2^16-1>;                           |
    |       AttrInfoType    attr_info <0..2^16-1>; /* sequence of    */   |
    |                                              /* attributes     */   |
    |       uint32          etypes <0..2^16-1>; /* list of supported */   |
    |                                           /* Kerberos etypes   */   |
    |                                           /* for authentication */  |
    |    } TktInfo;                                                       |
    |                                                                     |
    |    struct                                                           |
    |    {                                                                |
    |       TktInfo         tkt_info <1..2^20-1>; /* MUST have at least */ |
    |                                             /* 1 TktInfo structs */  |
    |    } KerbInfo                                                       |
    |                                                                     |
    +---------------------------------------------------------------------+
    FIGURE 4: Kerberos Information for CertificateRequest Message
```

3.2. Usage of the Client Certificate Message

As specified by [TLS], when the client receives the
CertificateRequest message, it MUST respond with the client
Certificate message. As stated above, this specification defines a
Kerberos certificate type. The format for the Kerberos certificate
is specified in figure 5 below. This structure consists of a
Kerberos AP-REQ message that is used for authenticating the client to
he server. It optionally contains a series of Kerberos KRB-CRED
messages to convey delegated credentials.

Note that the client may determine the type of credentials to send to
the server, based on local policy. Part of the input to a client's
decision may come from the Kerberos KDC. For example, The client may
convey a delegated ticket based on the ok-as-delegate ticket flag set
in the service ticket. Also, the session key used to protect a
forwarded credential, MUST be of equal or greater strength than the

key used to protect the ticket when originally sent to the client
(typically, this key is the client principal key, shared with the
Kerberos KDC).

```
+-----------------------------------------------------------------------+
|                                                                       |
|   opaque KrbCred <1..2^16-1>; /* Kerberos-defined KRB-CRED */         |
|                                                                       |
|   struct                                                              |
|   {                                                                   |
|       opaque     ap_req <1..2^16-1>;                                  |
|       KrbCred    krb_cred <0..2^20-1>;                                |
|   } KerberosCert;                                                     |
|                                                                       |
+-----------------------------------------------------------------------+
```
FIGURE 5: Kerberos Certificate Type

[3.3](). Usage of the ClientKeyExchange Message

The Kerberos option must be added to the ClientKeyExchange message as
shown in Figure 6.

```
+-----------------------------------------------------------------------+
|                                                                       |
|   struct                                                              |
|   {                                                                   |
|       select (KeyExchangeAlgorithm)                                   |
|       {                                                               |
|           case krb:              KerbEncryptedPreMasterSecret;        |
|           case rsa:              EncryptedPreMasterSecret;            |
|           case diffie_hellman:   ClientDiffieHellmanPublic;           |
|       } Exchange_keys;                                                |
|   } ClientKeyExchange;                                                |
|                                                                       |
| KerbEncryptedPreMasterSecret contains the PreMasterSecret             |
| encrypted within a Kerberos-defined EncryptedData structure.         |
| The encryption key is sealed in the ticket sent in the Client        |
| Certificate message.                                                  |
|                                                                       |
+-----------------------------------------------------------------------+
```
FIGURE 6: The Kerberos option in the ClientKeyExchange.

To use the Kerberos authentication option, the TLS client must obtain
a service ticket for the TLS server. In TLS, the ClientKeyExchange
message is used to pass a random 48-byte pre-master secret to the
server.

The client and server then use the pre-master secret to independently
derive the master secret, which in turn is used for generating

session keys and for MAC computations. Thus, if the Kerberos option
is selected, the pre-master secret structure is the same as that used
in the RSA case; it is encrypted under the Kerberos session key and
sent to the TLS server along with the Kerberos credentials (see
Figure 2). The ticket and authenticator are encoded per RFC 1510
(ASN.1 encoding). Once the ClientKeyExchange message is received,
the server's secret key is used to unwrap the credentials and extract
the pre-master secret.

Lastly, the client and server exchange the finished messages to
complete the handshake. At this point we have achieved the
following:

1) A master secret, used to protect all subsequent communication, is
   securely established.

2) Mutual client-server authentication is achieved, since the TLS
   server proves knowledge of the master secret in the finished
   message.

Kerberos fits seamlessly into TLS, without adding any new messages.

4. **Naming Conventions:**

To obtain an appropriate service ticket, the TLS client must
determine the principal name of the TLS server. The Kerberos service
naming convention is as follows:

     host/MachineName@Realm
      where:
        - The literal, "host", follows the Kerberos convention when not
          concerned about the protection domain on a particular machine.
        - "MachineName" is the particular instance of the service.
        - The Kerberos "Realm" is the domain name of the machine.

As specified above, in the CertificateRequest message, the server may
indicate the appropriate principal name and realm.

5. **Summary**

The proposed Kerberos authentication option is added in exactly the
same manner as a new public key algorithm would be added to TLS.
Furthermore, it establishes the master secret in exactly the same
manner.

6. **Security Considerations**

Kerberos ciphersuites are subject to the same security considerations
as the TLS protocol. In addition, just as a public key implementation

must take care to protect the private key (for example the PIN for a smartcard), a Kerberos implementation must take care to protect the long lived secret that is shared between the principal and the KDC. In particular, a weak password may be subject to a dictionary attack. In order to strengthen the initial authentication to a KDC, an implementor may choose to utilize secondary authentication via a token card, or one may utilize initial authentication to the KDC based on public key cryptography (commonly known as PKINIT - a product of the Kerberos working group of the IETF).

The unauthenticated CertificateRequest message, specified above, enables the server to request a particular client principal name as well as a particular service principal name. In the event that a service principal name is specified, there is a risk that the client may be tricked into requesting a ticket for a rogue server. Furthermore, if delegation is requested, the client may be tricked into forwarding its TGT to a rogue server. In order to assure that a service ticket is obtained for the correct server, the client should rely on a combination of its own local policy, local configuration information, and information supplied by the KDC. The client may choose to use only the naming convention specified in section 4. The client may rely on the KDC performing name cannonicalization (this is a matter that is adressed in revisions to RFC 1510).

The client must apply its local policy to determine whether or not to forward its credentials. As previously stated, the client should incorporate information from the KDC, in particular the ok-as-delegate ticket flag, in making such a policy decision.

The forwarded credential MUST be protected in a key that is at least the same strength as the principal key that originally protected the TGT.

A forwarded TGT presents more vulnerabilities in the event of a rogue server or the compromise of the session key. An attacker would be able to impersonate the client to obtain new service tickets. Such an attack may be mitigated by the use of restrictions, such as those described in [Neuman].

It has been shown that 56-bit DES keys are relatively easy to compromise [DESCRACK]; therefore, use of 56-bit DES is discouraged.

7. Acknowledgements

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 Clifford Neuma - ISI
 John Brezak and David Mowers - Microsoft

8. References

[KERBTLS]   A. Medvinsky and M. Hur, "Addition of Kerberos Cipher
            Suites to Transport Layer Security (TLS)", RFC 2712,
            October 1999.

[KERB]   J. Kohl and C. Neuman, "The Kerberos Network
            Authentication Service (V5)", RFC 1510, September 1993.

[TLS]   T. Dierks and C. Allen, "The TLS Protocol, Version 1.0",
            RFC 2246, January 1999.

[PKINIT]   B. Tung, C. Neuman, M. Hur, A. Medvinsky, S. Medvinsky,
            J. Wray, J. Trostle. Public Key Cryptography for Initial
            Authentication in Kerberos.
            draft-ietf-cat-kerberos-pk-init-14.txt

[PKTAPP]   A. Medvinsky, M. Hur, S. Medvinsky, C. Neuman.
            Public Key Utilizing Tickets for Application
            Servers (PKTAPP). draft-ietf-cat-kerberos-pk-tapp-03.txt

[PKCROSS]   M. Hur, B. Tung, T. Ryutov, C. Neuman, G. Tsudik,
            A. Medvinsky, B. Sommerfeld. Public Key Cryptography for
            Cross-Realm Authentication in Kerberos.
            draft-ietf-cat-kerberos-pk-cross-07.txt

[X509]   ITU-T (formerly CCITT) Information technology - Open
            Systems Interconnection - The Directory: Authentication
            Framework Recommendation X.509 ISO/IEC 9594-8

[NEUMAN]   B.C. Neuman, "Proxy-Based Authorization and Accounting for
            Distributed Systems". Proceedings of the 13th
            International Conference on Distributed Computing Systems,
            May 1993

[DESCRACK] Electronic Frontier Foundation, "Cracking DES: Secrets of
            Encryption Research, Wiretap Politics, and Chip Design".
            May 1998, Electronic Frontier Foundation.

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10. Full Copyright Statement

11. Appendix

Changes from RFC 2712

    Added new cipher suites with NULL confidentiality:
        TLS_KRB5_WITH_NULL_SHA
        TLS_KRB5_WITH_NULL_MD5

Added new cipher suites to support AES:

     TLS_KRB5_WITH_AES_128_CBC_SHA
     TLS_KRB5_WITH_AES_256_CBC_SHA

40 bit ciphers have been removed, and AES ciphers have been added.

All of the ciphersuites have been renumbered to avoid conflicts with exisiting implementations of RFC 2712.

RFC 2712 utilized only the ClientKeyExchange message for conveying the Kerberos credentials and encrypted premaster-secret. This specification moves the Kerberos credentials to the client certificate message, and it allows the client to pass delegated credentials as well. Additionally, this specification allows the server to specify Kerberos-specific information (realm, delegation required, etc.) in the CertificateRequest message.