

Network Working Group  
Request for Comments: 5349  
Category: Informational

L. Zhu  
K. Jaganathan  
K. Lauter  
Microsoft Corporation  
September 2008

## Elliptic Curve Cryptography (ECC) Support for Public Key Cryptography for Initial Authentication in Kerberos (PKINIT)

### Status of This Memo

This memo provides information for the Internet community. It does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

### Abstract

This document describes the use of Elliptic Curve certificates, Elliptic Curve signature schemes and Elliptic Curve Diffie-Hellman (ECDH) key agreement within the framework of PKINIT -- the Kerberos Version 5 extension that provides for the use of public key cryptography.

### Table of Contents

1. Introduction . . . . .	2
2. Conventions Used in This Document . . . . .	2
3. Using Elliptic Curve Certificates and Elliptic Curve Signature Schemes . . . . .	2
4. Using the ECDH Key Exchange . . . . .	3
5. Choosing the Domain Parameters and the Key Size . . . . .	4
6. Interoperability Requirements . . . . .	6
7. Security Considerations . . . . .	6
8. Acknowledgements . . . . .	7
9. References . . . . .	7
9.1. Normative References . . . . .	7
9.2. Informative References . . . . .	8

## 1. Introduction

Elliptic Curve Cryptography (ECC) is emerging as an attractive public-key cryptosystem that provides security equivalent to currently popular public-key mechanisms such as RSA and DSA with smaller key sizes [LENSTRA] [NISTSP80057].

Currently, [RFC4556] permits the use of ECC algorithms but it does not specify how ECC parameters are chosen or how to derive the shared key for key delivery using Elliptic Curve Diffie-Hellman (ECDH) [IEEE1363] [X9.63].

This document describes how to use Elliptic Curve certificates, Elliptic Curve signature schemes, and ECDH with [RFC4556]. However, it should be noted that there is no syntactic or semantic change to the existing [RFC4556] messages. Both the client and the Key Distribution Center (KDC) contribute one ECDH key pair using the key agreement protocol described in this document.

## 2. Conventions Used in This Document

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. Using Elliptic Curve Certificates and Elliptic Curve Signature Schemes

ECC certificates and signature schemes can be used in the Cryptographic Message Syntax (CMS) [RFC3852] [RFC3278] content type 'SignedData'.

X.509 certificates [RFC5280] that contain ECC public keys or are signed using ECC signature schemes MUST comply with [RFC3279].

The signatureAlgorithm field of the CMS data type 'SignerInfo' can contain one of the following ECC signature algorithm identifiers:

- ecdsa-with-Sha1 [RFC3279]
- ecdsa-with-Sha256 [X9.62]
- ecdsa-with-Sha384 [X9.62]
- ecdsa-with-Sha512 [X9.62]

The corresponding digestAlgorithm field contains one of the following hash algorithm identifiers respectively:

id-sha1	[RFC3279]
id-sha256	[X9.62]
id-sha384	[X9.62]
id-sha512	[X9.62]

Namely, id-sha1 MUST be used in conjunction with ecdsa-with-Sha1, id-sha256 MUST be used in conjunction with ecdsa-with-Sha256, id-sha384 MUST be used in conjunction with ecdsa-with-Sha384, and id-sha512 MUST be used in conjunction with ecdsa-with-Sha512.

Implementations of this specification MUST support ecdsa-with-Sha256 and SHOULD support ecdsa-with-Sha1.

#### 4. Using the ECDH Key Exchange

This section describes how ECDH can be used as the Authentication Service (AS) reply key delivery method [RFC4556]. Note that the protocol description here is similar to that of Modular Exponential Diffie-Hellman (MODP DH), as described in [RFC4556].

If the client wishes to use the ECDH key agreement method, it encodes its ECDH public key value and the key's domain parameters [IEEE1363] [X9.63] in clientPublicKeyValue of the PA-PK-AS-REQ message [RFC4556].

As described in [RFC4556], the ECDH domain parameters for the client's public key are specified in the algorithm field of the type SubjectPublicKeyInfo [RFC3279] and the client's ECDH public key value is mapped to a subjectPublicKey (a BIT STRING) according to [RFC3279].

The following algorithm identifier is used to identify the client's choice of the ECDH key agreement method for key delivery.

id-ecPublicKey (Elliptic Curve Diffie-Hellman [RFC3279])

If the domain parameters are not accepted by the KDC, the KDC sends back an error message [RFC4120] with the code KDC\_ERR\_DH\_KEY\_PARAMETERS\_NOT\_ACCEPTED [RFC4556]. This error message contains the list of domain parameters acceptable to the KDC. This list is encoded as TD-DH-PARAMETERS [RFC4556], and it is in the KDC's decreasing preference order. The client can then pick a set of domain parameters from the list and retry the authentication.

Both the client and the KDC MUST have local policy that specifies which set of domain parameters are acceptable if they do not have a priori knowledge of the chosen domain parameters. The need for such local policy is explained in Section 7.

If the ECDH domain parameters are accepted by the KDC, the KDC sends back its ECDH public key value in the `subjectPublicKey` field of the PA-PK-AS-REP message [RFC4556].

As described in [RFC4556], the KDC's ECDH public key value is encoded as a BIT STRING according to [RFC3279].

Note that in the steps above, the client can indicate to the KDC that it wishes to reuse ECDH keys or it can allow the KDC to do so, by including the `clientDHNonce` field in the request [RFC4556]; the KDC can then reuse the ECDH keys and include the `serverDHNonce` field in the reply [RFC4556]. This logic is the same as that of the Modular Exponential Diffie-Hellman key agreement method [RFC4556].

If ECDH is negotiated as the key delivery method, then the PA-PK-AS-REP and AS reply key are generated as in Section 3.2.3.1 of [RFC4556] with the following difference: The ECDH shared secret value (an elliptic curve point) is calculated using operation ECSVDP-DH as described in Section 7.2.1 of [IEEE1363]. The x-coordinate of this point is converted to an octet string using operation FE2OSP as described in Section 5.5.4 of [IEEE1363]. This octet string is the `DHSharedSecret`.

Both the client and KDC then proceed as described in [RFC4556] and [RFC4120].

Lastly, it should be noted that ECDH can be used with any certificates and signature schemes. However, a significant advantage of using ECDH together with ECC certificates and signature schemes is that the ECC domain parameters in the client certificates or the KDC certificates can be used. This obviates the need of locally preconfigured domain parameters as described in Section 7.

## 5. Choosing the Domain Parameters and the Key Size

The domain parameters and the key size should be chosen so as to provide sufficient cryptographic security [RFC3766]. The following table, based on table 2 on page 63 of NIST SP800-57 part 1 [NISTSP80057], gives approximate comparable key sizes for symmetric- and asymmetric-key cryptosystems based on the best-known algorithms for attacking them.

Symmetric	ECC	RSA
80	160 - 223	1024
112	224 - 255	2048
128	256 - 383	3072
192	384 - 511	7680
256	512+	15360

Table 1: Comparable key sizes (in bits)

Thus, for example, when securing a 128-bit symmetric key, it is prudent to use 256-bit Elliptic Curve Cryptography (ECC), e.g., group P-256 (secp256r1) as described below.

A set of ECDH domain parameters is also known as a "curve". A curve is a "named curve" if the domain parameters are well known and can be identified by an Object Identifier; otherwise, it is called a "custom curve". [RFC4556] supports both named curves and custom curves, see Section 7 on the tradeoffs of choosing between named curves and custom curves.

The named curves recommended in this document are also recommended by the National Institute of Standards and Technology (NIST)[FIPS186-2]. These fifteen ECC curves are given in the following table [FIPS186-2] [SEC2].

Description		SEC 2 OID
-----		-----
ECPRGF192Random	group P-192	secp192r1
EC2NGF163Random	group B-163	sect163r2
EC2NGF163Koblitz	group K-163	sect163k1
ECPRGF224Random	group P-224	secp224r1
EC2NGF233Random	group B-233	sect233r1
EC2NGF233Koblitz	group K-233	sect233k1
ECPRGF256Random	group P-256	secp256r1
EC2NGF283Random	group B-283	sect283r1
EC2NGF283Koblitz	group K-283	sect283k1
ECPRGF384Random	group P-384	secp384r1
EC2NGF409Random	group B-409	sect409r1
EC2NGF409Koblitz	group K-409	sect409k1
ECPRGF521Random	group P-521	secp521r1
EC2NGF571Random	group B-571	sect571r1
EC2NGF571Koblitz	group K-571	sect571k1

## 6. Interoperability Requirements

Implementations conforming to this specification MUST support curve P-256 and P-384.

## 7. Security Considerations

When using ECDH key agreement, the recipient of an elliptic curve public key should perform the checks described in IEEE P1363, Section A16.10 [IEEE1363]. It is especially important, if the recipient is using a long-term ECDH private key, to check that the sender's public key is a valid point on the correct elliptic curve; otherwise, information may be leaked about the recipient's private key, and iterating the attack will eventually completely expose the recipient's private key.

Kerberos error messages are not integrity protected; as a result, the domain parameters sent by the KDC as TD-DH-PARAMETERS can be tampered with by an attacker so that the set of domain parameters selected could be either weaker or not mutually preferred. Local policy can configure sets of domain parameters that are acceptable locally or can disallow the negotiation of ECDH domain parameters.

Beyond elliptic curve size, the main issue is elliptic curve structure. As a general principle, it is more conservative to use elliptic curves with as little algebraic structure as possible. Thus, random curves are more conservative than special curves (such as Koblitz curves), and curves over  $F_p$  with  $p$  random are more conservative than curves over  $F_p$  with  $p$  of a special form. (Also, curves over  $F_p$  with  $p$  random might be considered more conservative than curves over  $F_{2^m}$ , as there is no choice between multiple fields of similar size for characteristic 2.) Note, however, that algebraic structure can also lead to implementation efficiencies, and implementors and users may, therefore, need to balance conservatism against a need for efficiency. Concrete attacks are known against only very few special classes of curves, such as supersingular curves, and these classes are excluded from the ECC standards such as [IEEE1363] and [X9.62].

Another issue is the potential for catastrophic failures when a single elliptic curve is widely used. In this case, an attack on the elliptic curve might result in the compromise of a large number of keys. Again, this concern may need to be balanced against efficiency and interoperability improvements associated with widely used curves. Substantial additional information on elliptic curve choice can be found in [IEEE1363], [X9.62], and [FIPS186-2].

## 8. Acknowledgements

The following people have made significant contributions to this document: Paul Leach, Dan Simon, Kelvin Yiu, David Cross, Sam Hartman, Tolga Acar, and Stefan Santesson.

## 9. References

### 9.1. Normative References

- [FIPS186-2] NIST, "Digital Signature Standard", FIPS 186-2, 2000.
- [IEEE1363] IEEE, "Standard Specifications for Public Key Cryptography", IEEE 1363, 2000.
- [NISTSP80057] NIST, "Recommendation on Key Management", SP 800-57, August 2005,  
<<http://csrc.nist.gov/publications/nistpubs/>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC3278] Blake-Wilson, S., Brown, D., and P. Lambert, "Use of Elliptic Curve Cryptography (ECC) Algorithms in Cryptographic Message Syntax (CMS)", RFC 3278, April 2002.
- [RFC3279] Bassham, L., Polk, W., and R. Housley, "Algorithms and Identifiers for the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 3279, April 2002.
- [RFC3766] Orman, H. and P. Hoffman, "Determining Strengths For Public Keys Used For Exchanging Symmetric Keys", BCP 86, RFC 3766, April 2004.
- [RFC3852] Housley, R., "Cryptographic Message Syntax (CMS)", RFC 3852, July 2004.
- [RFC4120] Neuman, C., Yu, T., Hartman, S., and K. Raeburn, "The Kerberos Network Authentication Service (V5)", RFC 4120, July 2005.
- [RFC4556] Zhu, L. and B. Tung, "Public Key Cryptography for Initial Authentication in Kerberos (PKINIT)", RFC 4556, June 2006.

- [RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 5280, May 2008.
- [X9.62] ANSI, "Public Key Cryptography For The Financial Services Industry: The Elliptic Curve Digital Signature Algorithm (ECDSA)", ANSI X9.62, 2005.
- [X9.63] ANSI, "Public Key Cryptography for the Financial Services Industry: Key Agreement and Key Transport using Elliptic Curve Cryptography", ANSI X9.63, 2001.

## 9.2. Informative References

- [LENSTRA] Lenstra, A. and E. Verheul, "Selecting Cryptographic Key Sizes", Journal of Cryptography 14, 255-293, 2001.
- [SEC2] Standards for Efficient Cryptography Group, "SEC 2 - Recommended Elliptic Curve Domain Parameters", Ver. 1.0, 2000, <<http://www.secg.org>>.



## Authors' Addresses

Larry Zhu  
Microsoft Corporation  
One Microsoft Way  
Redmond, WA 98052  
US

EMail: lzhu@microsoft.com

Karthik Jaganathan  
Microsoft Corporation  
One Microsoft Way  
Redmond, WA 98052  
US

EMail: karthikj@microsoft.com

Kristin Lauter  
Microsoft Corporation  
One Microsoft Way  
Redmond, WA 98052  
US

EMail: klauter@microsoft.com

## Full Copyright Statement

Copyright (C) The IETF Trust (2008).

This document is subject to the rights, licenses and restrictions contained in BCP 78, and except as set forth therein, the authors retain all their rights.

This document and the information contained herein are provided on an "AS IS" basis and THE CONTRIBUTOR, THE ORGANIZATION HE/SHE REPRESENTS OR IS SPONSORED BY (IF ANY), THE INTERNET SOCIETY, THE IETF TRUST AND THE INTERNET ENGINEERING TASK FORCE DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

## Intellectual Property

The IETF takes no position regarding the validity or scope of any Intellectual Property Rights or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; nor does it represent that it has made any independent effort to identify any such rights. Information on the procedures with respect to rights in RFC documents can be found in BCP 78 and BCP 79.

Copies of IPR disclosures made to the IETF Secretariat and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementers or users of this specification can be obtained from the IETF on-line IPR repository at <http://www.ietf.org/ipr>.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights that may cover technology that may be required to implement this standard. Please address the information to the IETF at [ietf-ipr@ietf.org](mailto:ietf-ipr@ietf.org).

