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Textual Encodings of PKIX, PKCS, and CMS Structures

Abstract

This document describes and discusses the textual encodings of the Public-Key Infrastructure X.509 (PKIX), Public-Key Cryptography Standards (PKCS), and Cryptographic Message Syntax (CMS). The textual encodings are well-known, are implemented by several applications and libraries, and are widely deployed. This document articulates the de facto rules by which existing implementations operate and defines them so that future implementations can interoperate.

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1. Introduction

Several security-related standards used on the Internet define ASN.1 data formats that are normally encoded using the Basic Encoding Rules (BER) or Distinguished Encoding Rules (DER) [X.690], which are binary, octet-oriented encodings. This document is about the textual encodings of the following formats:

1. Certificates, Certificate Revocation Lists (CRLs), and Subject Public Key Info structures in the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile [RFC5280].

2. PKCS #10: Certification Request Syntax [RFC2986].

3. PKCS #7: Cryptographic Message Syntax [RFC2315].

4. Cryptographic Message Syntax [RFC5652].

5. PKCS #8: Private-Key Information Syntax [RFC5208], renamed to One Asymmetric Key in Asymmetric Key Package [RFC5958], and Encrypted Private-Key Information Syntax in the same documents.

6. Attribute Certificates in An Internet Attribute Certificate Profile for Authorization [RFC5755].

A disadvantage of a binary data format is that it cannot be interchanged in textual transports, such as email or text documents. One advantage with text-based encodings is that they are easy to modify using common text editors; for example, a user may concatenate several certificates to form a certificate chain with copy-and-paste operations.

The tradition within the RFC series can be traced back to Privacy-Enhanced Mail (PEM) [RFC1421], based on a proposal by Marshall Rose in Message Encapsulation [RFC934]. Originally called "PEM encapsulation mechanism", "encapsulated PEM message", or (arguably) "PEM printable encoding", today the format is sometimes referred to as "PEM encoding". Variations include OpenPGP ASCII armor [RFC4880] and OpenSSH key file format [RFC4716].

For reasons that basically boil down to non-coordination or inattention, many PKIX, PKCS, and CMS libraries implement a text-based encoding that is similar to -- but not identical with -- PEM encoding. This document specifies the _textual encoding_ format, articulates the de facto rules that most implementations operate by, and provides recommendations that will promote interoperability going forward. This document also provides common nomenclature for syntax elements, reflecting the evolution of this de facto standard format. Peter Gutmann's "X.509 Style Guide" [X.509SG] contains a section "base64 Encoding" that describes the formats and contains suggestions similar to what is in this document. All figures are real, functional examples, with key lengths and inner contents chosen to be as small as practicable.

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 RFC 2119 [RFC2119].

2. General Considerations

Textual encoding begins with a line comprising "-----BEGIN ", a label, and "-----", and ends with a line comprising "-----END ", a label, and "-----". Between these lines, or "encapsulation boundaries", are base64-encoded data according to Section 4 of [RFC4648]. (PEM [RFC1421] referred to this data as the "encapsulated text portion".) Data before the encapsulation boundaries are permitted, and parsers MUST NOT malfunction when processing such data. Furthermore, parsers SHOULD ignore whitespace and other non-base64 characters and MUST handle different newline conventions.

The type of data encoded is labeled depending on the type label in the "-----BEGIN " line (pre-encapsulation boundary). For example, the line may be "-----BEGIN CERTIFICATE-----" to indicate that the content is a PKIX certificate (see further below). Generators MUST put the same label on the "-----END " line (post-encapsulation boundary) as the corresponding "-----BEGIN " line. Labels are formally case-sensitive, uppercase, and comprised of zero or more characters; they do not contain consecutive spaces or hyphen-minuses, nor do they contain spaces or hyphen-minuses at either end. Parsers MAY disregard the label in the post-encapsulation boundary instead of signaling an error if there is a label mismatch: some extant implementations require the labels to match; others do not.

There is exactly one space character (SP) separating the "BEGIN" or "END" from the label. There are exactly five hyphen-minus (also known as dash) characters ("-") on both ends of the encapsulation boundaries, no more, no less.

The label type implies that the encoded data follows the specified syntax. Parsers MUST handle non-conforming data gracefully. However, not all parsers or generators prior to this document behave consistently. A conforming parser MAY interpret the contents as another label type but ought to be aware of the security implications discussed in the Security Considerations section. The labels described in this document identify container formats that are not specific to any particular cryptographic algorithm, a property consistent with algorithm agility. These formats use the ASN.1 AlgorithmIdentifier structure as described in Section 4.1.1.2 of [RFC5280].

Unlike legacy PEM encoding [RFC1421], OpenPGP ASCII armor, and the OpenSSH key file format, textual encoding does *not* define or permit headers to be encoded alongside the data. Empty space can appear between the pre-encapsulation boundary and the base64, but generators SHOULD NOT emit such any such spacing. (The provision for this empty area is a throwback to PEM, which defined an "encapsulated header portion".)

Implementers need to be aware that extant parsers diverge considerably on the handling of whitespace. In this document, "whitespace" means any character or series of characters that represent horizontal or vertical space in typography. In US-ASCII, whitespace means HT (0x09), VT (0x0B), FF (0x0C), SP (0x20), CR

(0x0D), and LF (0x0A); "blank" means HT and SP; lines are divided with CRLF, CR, or LF. The common ABNF production WSP is congruent with "blank"; a new production W is used for "whitespace". The ABNF in Section 3 is specific to US-ASCII. As these textual encodings can be used on many different systems as well as on long-term archival storage media such as paper or engravings, an implementer ought to use the spirit rather than the letter of the rules when generating or parsing these formats in environments that are not strictly limited to US-ASCII.

Most extant parsers ignore blanks at the ends of lines; blanks at the beginnings of lines or in the middle of the base64-encoded data are far less compatible. These observations are codified in Figure 1. The most lax parser implementations are not line-oriented at all and will accept any mixture of whitespace outside of the encapsulation boundaries (see Figure 2). Such lax parsing may run the risk of accepting text that was not intended to be accepted in the first place (e.g., because the text was a snippet or sample).

Generators MUST wrap the base64-encoded lines so that each line consists of exactly 64 characters except for the final line, which will encode the remainder of the data (within the 64-character line boundary), and they MUST NOT emit extraneous whitespace. Parsers MAY handle other line sizes. These requirements are consistent with PEM [RFC1421].

Files MAY contain multiple textual encoding instances. This is used, for example, when a file contains several certificates. Whether the instances are ordered or unordered depends on the context.

3. ABNF

The ABNF [RFC5234] of the textual encoding is:

```
  textualmsg = preeb *WSP eol
               *eolWSP
               base64text
               posteb *WSP [eol]

  preeb      = "-----BEGIN " label "-----" ; unlike [RFC1421] (A)BNF,
                                           ; eol is not required (but
  posteb     = "-----END " label "-----"   ; see [RFC1421], Section 4.4)

  base64char = ALPHA / DIGIT / "+" / "/"

  base64pad  = "="

  base64line = 1*base64char *WSP eol
  base64finl = *base64char (base64pad *WSP eol base64pad /
                            *2base64pad) *WSP eol
                       ; ...AB= <EOL> = <EOL> is not good, but is valid

  base64text = *base64line base64finl
         ; we could also use <encbinbody> from RFC 1421, which requires
         ; 16 groups of 4 chars, which means exactly 64 chars per
         ; line, except the final line, but this is more accurate

  labelchar  = %x21-2C / %x2E-7E    ; any printable character,
                                    ; except hyphen-minus

  label      = [ labelchar *( ["-" / SP] labelchar ) ]       ; empty ok

  eol        = CRLF / CR / LF

  eolWSP     = WSP / CR / LF                        ; compare with LWSP
```

Figure 1: ABNF (Standard)

```
   laxtextualmsg    = *W preeb
                      laxbase64text
                      posteb *W

   W                = WSP / CR / LF / %x0B / %x0C           ; whitespace

   laxbase64text    = *(W / base64char) [base64pad *W [base64pad *W]]
```

Figure 2: ABNF (Lax)

```
   stricttextualmsg = preeb eol
                      strictbase64text
                      posteb eol

   strictbase64finl = *15(4base64char) (4base64char / 3base64char
                        base64pad / 2base64char 2base64pad) eol

   base64fullline   = 64base64char eol

   strictbase64text = *base64fullline strictbase64finl
```

Figure 3: ABNF (Strict)

New implementations SHOULD emit the strict format (Figure 3) specified above. The choice of parsing strategy depends on the context of use.

4. Guide

For convenience, these figures summarize the structures, encodings, and references in the following sections:

Sec.	Label	ASN.1 Type	Reference	Module
5	CERTIFICATE	Certificate	[RFC5280]	id-pkix1-e
6	X509 CRL	CertificateList	[RFC5280]	id-pkix1-e
7	CERTIFICATE REQUEST	CertificationRequest	[RFC2986]	id-pkcs10
8	PKCS7	ContentInfo	[RFC2315]	id-pkcs7*
9	CMS	ContentInfo	[RFC5652]	id-cms2004
10	PRIVATE KEY	PrivateKeyInfo ::=	[RFC5208]	id-pkcs8
		OneAsymmetricKey	[RFC5958]	id-aKPV1
11	ENCRYPTED PRIVATE KEY	EncryptedPrivateKeyInfo	[RFC5958]	id-aKPV1
12	ATTRIBUTE CERTIFICATE	AttributeCertificate	[RFC5755]	id-acv2
13	PUBLIC KEY	SubjectPublicKeyInfo	[RFC5280]	id-pkix1-e

Figure 4: Convenience Guide

```
 -----------------------------------------------------------------------
 id-pkixmod OBJECT IDENTIFIER ::= {iso(1) identified-organization(3)
            dod(6) internet(1) security(5) mechanisms(5) pkix(7) mod(0)}
 id-pkix1-e OBJECT IDENTIFIER ::= {id-pkixmod pkix1-explicit(18)}
 id-acv2    OBJECT IDENTIFIER ::= {id-pkixmod mod-attribute-cert-v2(61)}
 id-pkcs    OBJECT IDENTIFIER ::= {iso(1) member-body(2) us(840)
                                   rsadsi(113549) pkcs(1)}
 id-pkcs10  OBJECT IDENTIFIER ::= {id-pkcs 10 modules(1) pkcs-10(1)}
 id-pkcs7   OBJECT IDENTIFIER ::= {id-pkcs 7 modules(0) pkcs-7(1)}
 id-pkcs8   OBJECT IDENTIFIER ::= {id-pkcs 8 modules(1) pkcs-8(1)}
 id-sm-mod  OBJECT IDENTIFIER ::= {id-pkcs 9 smime(16) modules(0)}
 id-aKPV1   OBJECT IDENTIFIER ::= {id-sm-mod mod-asymmetricKeyPkgV1(50)}
 id-cms2004 OBJECT IDENTIFIER ::= {id-sm-mod cms-2004(24)}
```

* This OID does not actually appear in PKCS #7 v1.5 [RFC2315]. It was defined in the ASN.1 module to PKCS #7 v1.6 [P7v1.6], and has been carried forward through PKCS #12 [RFC7292].

Figure 5: ASN.1 Module Object Identifier Value Assignments

5. Textual Encoding of Certificates

5.1. Encoding

Public-key certificates are encoded using the "CERTIFICATE" label. The encoded data MUST be a BER (DER strongly preferred; see Appendix B) encoded ASN.1 Certificate structure as described in Section 4 of [RFC5280].

```
-----BEGIN CERTIFICATE-----
MIICLDCCAdKgAwIBAgIBADAKBggqhkjOPQQDAjB9MQswCQYDVQQGEwJCRTEPMA0G
A1UEChMGR251VExTMSUwIwYDVQQLExxHbnVUTFMgY2VydGlmaWNhdGUgYXV0aG9y
aXR5MQ8wDQYDVQQIEwZMZXV2ZW4xJTAjBgNVBAMTHEdudVRMUyBjZXJ0aWZpY2F0
ZSBhdXRob3JpdHkwHhcNMTEwNTIzMjAzODIxWhcNMTIxMjIyMDc0MTUxWjB9MQsw
CQYDVQQGEwJCRTEPMA0GA1UEChMGR251VExTMSUwIwYDVQQLExxHbnVUTFMgY2Vy
dGlmaWNhdGUgYXV0aG9yaXR5MQ8wDQYDVQQIEwZMZXV2ZW4xJTAjBgNVBAMTHEdu
dVRMUyBjZXJ0aWZpY2F0ZSBhdXRob3JpdHkwWTATBgcqhkjOPQIBBggqhkjOPQMB
BwNCAARS2I0jiuNn14Y2sSALCX3IybqiIJUvxUpj+oNfzngvj/Niyv2394BWnW4X
uQ4RTEiywK87WRcWMGgJB5kX/t2no0MwQTAPBgNVHRMBAf8EBTADAQH/MA8GA1Ud
DwEB/wQFAwMHBgAwHQYDVR0OBBYEFPC0gf6YEr+1KLlkQAPLzB9mTigDMAoGCCqG
SM49BAMCA0gAMEUCIDGuwD1KPyG+hRf88MeyMQcqOFZD0TbVleF+UsAGQ4enAiEA
l4wOuDwKQa+upc8GftXE2C//4mKANBC6It01gUaTIpo=
-----END CERTIFICATE-----
```

Figure 6: Certificate Example

Historically, the label "X509 CERTIFICATE" and also less commonly "X.509 CERTIFICATE" have been used. Generators conforming to this document MUST generate "CERTIFICATE" labels and MUST NOT generate "X509 CERTIFICATE" or "X.509 CERTIFICATE" labels. Parsers SHOULD NOT treat "X509 CERTIFICATE" or "X.509 CERTIFICATE" as equivalent to "CERTIFICATE", but a valid exception may be for backwards compatibility (potentially together with a warning).

5.2. Explanatory Text

Many tools are known to emit explanatory text before the BEGIN and after the END lines for PKIX certificates, more than any other type. If emitted, such text SHOULD be related to the certificate, such as providing a textual representation of key data elements in the certificate.

```
Subject: CN=Atlantis
Issuer: CN=Atlantis
Validity: from 7/9/2012 3:10:38 AM UTC to 7/9/2013 3:10:37 AM UTC
-----BEGIN CERTIFICATE-----
MIIBmTCCAUegAwIBAgIBKjAJBgUrDgMCHQUAMBMxETAPBgNVBAMTCEF0bGFudGlz
MB4XDTEyMDcwOTAzMTAzOFoXDTEzMDcwOTAzMTAzN1owEzERMA8GA1UEAxMIQXRs
YW50aXMwXDANBgkqhkiG9w0BAQEFAANLADBIAkEAu+BXo+miabDIHHx+yquqzqNh
Ryn/XtkJIIHVcYtHvIX+S1x5ErgMoHehycpoxbErZmVR4GCq1S2diNmRFZCRtQID
AQABo4GJMIGGMAwGA1UdEwEB/wQCMAAwIAYDVR0EAQH/BBYwFDAOMAwGCisGAQQB
gjcCARUDAgeAMB0GA1UdJQQWMBQGCCsGAQUFBwMCBggrBgEFBQcDAzA1BgNVHQEE
LjAsgBA0jOnSSuIHYmnVryHAdywMoRUwEzERMA8GA1UEAxMIQXRsYW50aXOCASow
CQYFKw4DAh0FAANBAKi6HRBaNEL5R0n56nvfclQNaXiDT174uf+lojzA4lhVInc0
ILwpnZ1izL4MlI9eCSHhVQBHEp2uQdXJB+d5Byg=
-----END CERTIFICATE-----
```

Figure 7: Certificate Example with Explanatory Text

5.3. File Extension

Although textual encodings of PKIX structures can occur anywhere, many tools are known to offer an option to output this encoding when serializing PKIX structures. To promote interoperability and to separate DER encodings from textual encodings, the extension ".crt" SHOULD be used for the textual encoding of a certificate. Implementations should be aware that in spite of this recommendation, many tools still default to encode certificates in this textual encoding with the extension ".cer".

This section does not disturb the official application/pkix-cert registration [RFC2585] in any way (which states that "each '.cer' file contains exactly one certificate, encoded in DER format"), but merely articulates a widespread, de facto alternative.

6. Textual Encoding of Certificate Revocation Lists

Certificate Revocation Lists (CRLs) are encoded using the "X509 CRL" label. The encoded data MUST be a BER (DER strongly preferred; see Appendix B) encoded ASN.1 CertificateList structure as described in Section 5 of [RFC5280].

```
-----BEGIN X509 CRL-----
MIIB9DCCAV8CAQEwCwYJKoZIhvcNAQEFMIIBCDEXMBUGA1UEChMOVmVyaVNpZ24s
IEluYy4xHzAdBgNVBAsTFlZlcmlTaWduIFRydXN0IE5ldHdvcmsxRjBEBgNVBAsT
PXd3dy52ZXJpc2lnbi5jb20vcmVwb3NpdG9yeS9SUEEgSW5jb3JwLiBieSBSZWYu
LExJQUIuTFREKGMpOTgxHjAcBgNVBAsTFVBlcnNvbmEgTm90IFZhbGlkYXRlZDEm
MCQGA1UECxMdRGlnaXRhbCBJRCBDbGFzcyAxIC0gTmV0c2NhcGUxGDAWBgNVBAMU
D1NpbW9uIEpvc2Vmc3NvbjEiMCAGCSqGSIb3DQEJARYTc2ltb25Aam9zZWZzc29u
Lm9yZxcNMDYxMjI3MDgwMjM0WhcNMDcwMjA3MDgwMjM1WjAjMCECEC4QNwPfRoWd
elUNpllhhTgXDTA2MTIyNzA4MDIzNFowCwYJKoZIhvcNAQEFA4GBAD0zX+J2hkcc
Nbrq1Dn5IKL8nXLgPGcHv1I/le1MNo9t1ohGQxB5HnFUkRPAY82fR6Epor4aHgVy
b+5y+neKN9Kn2mPF4iiun+a4o26CjJ0pArojCL1p8T0yyi9Xxvyc/ezaZ98HiIyP
c3DGMNR+oUmSjKZ0jIhAYmeLxaPHfQwR
-----END X509 CRL-----
```

Figure 8: CRL Example

Historically, the label "CRL" has rarely been used. Today, it is not common and many popular tools do not understand the label. Therefore, this document standardizes "X509 CRL" in order to promote interoperability and backwards-compatibility. Generators conforming to this document MUST generate "X509 CRL" labels and MUST NOT generate "CRL" labels. Parsers SHOULD NOT treat "CRL" as equivalent to "X509 CRL".

7. Textual Encoding of PKCS #10 Certification Request Syntax

PKCS #10 Certification Requests are encoded using the "CERTIFICATE REQUEST" label. The encoded data MUST be a BER (DER strongly preferred; see Appendix B) encoded ASN.1 CertificationRequest structure as described in [RFC2986].

```
-----BEGIN CERTIFICATE REQUEST-----
MIIBWDCCAQcCAQAwTjELMAkGA1UEBhMCU0UxJzAlBgNVBAoTHlNpbW9uIEpvc2Vm
c3NvbiBEYXRha29uc3VsdCBBQjEWMBQGA1UEAxMNam9zZWZzc29uLm9yZzBOMBAG
ByqGSM49AgEGBSuBBAAhAzoABLLPSkuXY0l66MbxVJ3Mot5FCFuqQfn6dTs+9/CM
EOlSwVej77tj56kj9R/j9Q+LfysX8FO9I5p3oGIwYAYJKoZIhvcNAQkOMVMwUTAY
BgNVHREEETAPgg1qb3NlZnNzb24ub3JnMAwGA1UdEwEB/wQCMAAwDwYDVR0PAQH/
BAUDAwegADAWBgNVHSUBAf8EDDAKBggrBgEFBQcDATAKBggqhkjOPQQDAgM/ADA8
AhxBvfhxPFfbBbsE1NoFmCUczOFApEuQVUw3ZP69AhwWXk3dgSUsKnuwL5g/ftAY
dEQc8B8jAcnuOrfU
-----END CERTIFICATE REQUEST-----
```

Figure 9: PKCS #10 Example

The label "NEW CERTIFICATE REQUEST" is also in wide use. Generators conforming to this document MUST generate "CERTIFICATE REQUEST" labels. Parsers MAY treat "NEW CERTIFICATE REQUEST" as equivalent to "CERTIFICATE REQUEST".

8. Textual Encoding of PKCS #7 Cryptographic Message Syntax

PKCS #7 Cryptographic Message Syntax structures are encoded using the "PKCS7" label. The encoded data MUST be a BER-encoded ASN.1 ContentInfo structure as described in [RFC2315].

```
-----BEGIN PKCS7-----
MIHjBgsqhkiG9w0BCRABF6CB0zCB0AIBADFho18CAQCgGwYJKoZIhvcNAQUMMA4E
CLfrI6dr0gUWAgITiDAjBgsqhkiG9w0BCRADCTAUBggqhkiG9w0DBwQIZpECRWtz
u5kEGDCjerXY8odQ7EEEromZJvAurk/j81IrozBSBgkqhkiG9w0BBwEwMwYLKoZI
hvcNAQkQAw8wJDAUBggqhkiG9w0DBwQI0tCBcU09nxEwDAYIKwYBBQUIAQIFAIAQ
OsYGYUFdAH0RNc1p4VbKEAQUM2Xo8PMHBoYdqEcsbTodlCFAZH4=
-----END PKCS7-----
```

Figure 10: PKCS #7 Example

The label "CERTIFICATE CHAIN" has been in use to denote a degenerate PKCS #7 structure that contains only a list of certificates (see Section 9 of [RFC2315]). Several modern tools do not support this label. Generators MUST NOT generate the "CERTIFICATE CHAIN" label. Parsers SHOULD NOT treat "CERTIFICATE CHAIN" as equivalent to "PKCS7".

PKCS #7 is an old specification that has long been superseded by CMS [RFC5652]. Implementations SHOULD NOT generate PKCS #7 when CMS is an alternative.

9. Textual Encoding of Cryptographic Message Syntax

Cryptographic Message Syntax structures are encoded using the "CMS" label. The encoded data MUST be a BER-encoded ASN.1 ContentInfo structure as described in [RFC5652].

```
-----BEGIN CMS-----
MIGDBgsqhkiG9w0BCRABCaB0MHICAQAwDQYLKoZIhvcNAQkQAwgwXgYJKoZIhvcN
AQcBoFEET3icc87PK0nNK9ENqSxItVIoSa0o0S/ISczMs1ZIzkgsKk4tsQ0N1nUM
dvb05OXi5XLPLEtViMwvLVLwSE0sKlFIVHAqSk3MBkkBAJv0Fx0=
-----END CMS-----
```

Figure 11: CMS Example

CMS is the IETF successor to PKCS #7. Section 1.1.1 of [RFC5652] describes the changes since PKCS #7 v1.5. Implementations SHOULD generate CMS when it is an alternative, promoting interoperability and forwards-compatibility.

10. One Asymmetric Key and the Textual Encoding of PKCS #8 Private Key Info

Unencrypted PKCS #8 Private Key Information Syntax structures (PrivateKeyInfo), renamed to Asymmetric Key Packages (OneAsymmetricKey), are encoded using the "PRIVATE KEY" label. The encoded data MUST be a BER (DER preferred; see Appendix B) encoded ASN.1 PrivateKeyInfo structure as described in PKCS #8 [RFC5208], or a OneAsymmetricKey structure as described in [RFC5958]. The two are semantically identical and can be distinguished by version number.

```
-----BEGIN PRIVATE KEY-----
MIGEAgEAMBAGByqGSM49AgEGBSuBBAAKBG0wawIBAQQgVcB/UNPxalR9zDYAjQIf
jojUDiQuGnSJrFEEzZPT/92hRANCAASc7UJtgnF/abqWM60T3XNJEzBv5ez9TdwK
H0M6xpM2q+53wmsN/eYLdgtjgBd3DBmHtPilCkiFICXyaA8z9LkJ
-----END PRIVATE KEY-----
```

Figure 12: PKCS #8 PrivateKeyInfo (OneAsymmetricKey) Example

11. Textual Encoding of PKCS #8 Encrypted Private Key Info

Encrypted PKCS #8 Private Key Information Syntax structures (EncryptedPrivateKeyInfo), called the same in [RFC5958], are encoded using the "ENCRYPTED PRIVATE KEY" label. The encoded data MUST be a BER (DER preferred; see Appendix B) encoded ASN.1 EncryptedPrivateKeyInfo structure as described in PKCS #8 [RFC5208] and [RFC5958].

```
-----BEGIN ENCRYPTED PRIVATE KEY-----
MIHNMEAGCSqGSIb3DQEFDTAzMBsGCSqGSIb3DQEFDDAOBAghhICA6T/51QICCAAw
FAYIKoZIhvcNAwcECBCxDgvI59i9BIGIY3CAqlMNBgaSI5QiiWVNJ3IpfLnEiEsW
Z0JIoHyRmKK/+cr9QPLnzxImm0TR9s4JrG3CilzTWvb0jIvbG3hu0zyFPraoMkap
8eRzWsIvC5SVel+CSjoS2mVS87cyjlD+txrmrXOVYDE+eTgMLbrLmsWh3QkCTRtF
QC7k0NNzUHTV9yGDwfqMbw==
-----END ENCRYPTED PRIVATE KEY-----
```

Figure 13: PKCS #8 EncryptedPrivateKeyInfo Example

12. Textual Encoding of Attribute Certificates

Attribute certificates are encoded using the "ATTRIBUTE CERTIFICATE" label. The encoded data MUST be a BER (DER strongly preferred; see Appendix B) encoded ASN.1 AttributeCertificate structure as described in [RFC5755].

```
-----BEGIN ATTRIBUTE CERTIFICATE-----
MIICKzCCAZQCAQEwgZeggZQwgYmkgYYwgYMxCzAJBgNVBAYTAlVTMREwDwYDVQQI
DAhOZXcgWW9yazEUMBIGA1UEBwwLU3RvbnkgQnJvb2sxDzANBgNVBAoMBkNTRTU5
MjE6MDgGA1UEAwwxU2NvdHQgU3RhbGxlci9lbWFpbEFkZHJlc3M9c3N0YWxsZXJA
aWMuc3VueXNiLmVkdQIGARWrgUUSoIGMMIGJpIGGMIGDMQswCQYDVQQGEwJVUzER
MA8GA1UECAwITmV3IFlvcmsxFDASBgNVBAcMC1N0b255IEJyb29rMQ8wDQYDVQQK
DAZDU0U1OTIxOjA4BgNVBAMMMVNjb3R0IFN0YWxsZXIvZW1haWxBZGRyZXNzPXNz
dGFsbGVyQGljLnN1bnlzYi5lZHUwDQYJKoZIhvcNAQEFBQACBgEVq4FFSjAiGA8z
OTA3MDIwMTA1MDAwMFoYDzM5MTEwMTMxMDUwMDAwWjArMCkGA1UYSDEiMCCGHmh0
dHA6Ly9pZGVyYXNobi5vcmcvaW5kZXguaHRtbDANBgkqhkiG9w0BAQUFAAOBgQAV
M9axFPXXozEFcer06bj9MCBBCQLtAM7ZXcZjcxyva7xCBDmtZXPYUluHf5OcWPJz
5XPus/xS9wBgtlM3fldIKNyNO8RsMp6Ocx+PGlICc7zpZiGmCYLl64lAEGPO/bsw
Smluak1aZIttePeTAHeJJs8izNJ5aR3Wcd3A5gLztQ==
-----END ATTRIBUTE CERTIFICATE-----
```

Figure 14: Attribute Certificate Example

13. Textual Encoding of Subject Public Key Info

Public keys are encoded using the "PUBLIC KEY" label. The encoded data MUST be a BER (DER preferred; see Appendix B) encoded ASN.1 SubjectPublicKeyInfo structure as described in Section 4.1.2.7 of [RFC5280].

```
-----BEGIN PUBLIC KEY-----
MHYwEAYHKoZIzj0CAQYFK4EEACIDYgAEn1LlwLN/KBYQRVH6HfIMTzfEqJOVztLe
kLchp2hi78cCaMY81FBlYs8J9l7krc+M4aBeCGYFjba+hiXttJWPL7ydlE+5UG4U
Nkn3Eos8EiZByi9DVsyfy9eejh+8AXgp
-----END PUBLIC KEY-----
```

Figure 15: Subject Public Key Info Example

14. Security Considerations

Data in this format often originates from untrusted sources, thus parsers must be prepared to handle unexpected data without causing security vulnerabilities.

Implementers building implementations that rely on canonical representation or the ability to fingerprint a particular data object need to understand that this document does not define canonical encodings. The first ambiguity is introduced by permitting the text-encoded representation instead of the binary BER or DER encodings, but further ambiguities arise when multiple labels are treated as similar. Variations of whitespace and non-base64 alphabetic characters can create further ambiguities. Data encoding ambiguities also create opportunities for side channels. If canonical encodings are desired, the encoded structure must be decoded and processed into a canonical form (namely, DER encoding).

15. References

15.1. Normative References

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15.2. Informative References

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Appendix A. Non-conforming Examples

This appendix contains examples for the non-recommended label variants described earlier in this document. As discussed earlier, supporting these is not required and is sometimes discouraged. Still, they can be useful for interoperability testing and for easy reference.

```
-----BEGIN X509 CERTIFICATE-----
MIIBHDCBxaADAgECAgIcxzAJBgcqhkjOPQQBMBAxDjAMBgNVBAMUBVBLSVghMB4X
DTE0MDkxNDA2MTU1MFoXDTI0MDkxNDA2MTU1MFowEDEOMAwGA1UEAxQFUEtJWCEw
WTATBgcqhkjOPQIBBggqhkjOPQMBBwNCAATwoQSr863QrR0PoRIYQ96H7WykDePH
Wa0eVAE24bth43wCNc+U5aZ761dhGhSSJkVWRgVH5+prLIr+nzfIq+X4oxAwDjAM
BgNVHRMBAf8EAjAAMAkGByqGSM49BAEDRwAwRAIfMdKS5F63lMnWVhi7uaKJzKCs
NnY/OKgBex6MIEAv2AIhAI2GdvfL+mGvhyPZE+JxRxWChmggb5/9eHdUcmW/jkOH
-----END X509 CERTIFICATE-----
```

Figure 16: Non-standard 'X509' Certificate Example

```
-----BEGIN X.509 CERTIFICATE-----
MIIBHDCBxaADAgECAgIcxzAJBgcqhkjOPQQBMBAxDjAMBgNVBAMUBVBLSVghMB4X
DTE0MDkxNDA2MTU1MFoXDTI0MDkxNDA2MTU1MFowEDEOMAwGA1UEAxQFUEtJWCEw
WTATBgcqhkjOPQIBBggqhkjOPQMBBwNCAATwoQSr863QrR0PoRIYQ96H7WykDePH
Wa0eVAE24bth43wCNc+U5aZ761dhGhSSJkVWRgVH5+prLIr+nzfIq+X4oxAwDjAM
BgNVHRMBAf8EAjAAMAkGByqGSM49BAEDRwAwRAIfMdKS5F63lMnWVhi7uaKJzKCs
NnY/OKgBex6MIEAv2AIhAI2GdvfL+mGvhyPZE+JxRxWChmggb5/9eHdUcmW/jkOH
-----END X.509 CERTIFICATE-----
```

Figure 17: Non-standard 'X.509' Certificate Example

```
-----BEGIN NEW CERTIFICATE REQUEST-----
MIIBWDCCAQcCAQAwTjELMAkGA1UEBhMCU0UxJzAlBgNVBAoTHlNpbW9uIEpvc2Vm
c3NvbiBEYXRha29uc3VsdCBBQjEWMBQGA1UEAxMNam9zZWZzc29uLm9yZzBOMBAG
ByqGSM49AgEGBSuBBAAhAzoABLLPSkuXY0l66MbxVJ3Mot5FCFuqQfn6dTs+9/CM
EOlSwVej77tj56kj9R/j9Q+LfysX8FO9I5p3oGIwYAYJKoZIhvcNAQkOMVMwUTAY
BgNVHREEETAPgg1qb3NlZnNzb24ub3JnMAwGA1UdEwEB/wQCMAAwDwYDVR0PAQH/
BAUDAwegADAWBgNVHSUBAf8EDDAKBggrBgEFBQcDATAKBggqhkjOPQQDAgM/ADA8
AhxBvfhxPFfbBbsE1NoFmCUczOFApEuQVUw3ZP69AhwWXk3dgSUsKnuwL5g/ftAY
dEQc8B8jAcnuOrfU
-----END NEW CERTIFICATE REQUEST-----
```

Figure 18: Non-standard 'NEW' PKCS #10 Example

```
-----BEGIN CERTIFICATE CHAIN-----
MIHjBgsqhkiG9w0BCRABF6CB0zCB0AIBADFho18CAQCgGwYJKoZIhvcNAQUMMA4E
CLfrI6dr0gUWAgITiDAjBgsqhkiG9w0BCRADCTAUBggqhkiG9w0DBwQIZpECRWtz
u5kEGDCjerXY8odQ7EEEromZJvAurk/j81IrozBSBgkqhkiG9w0BBwEwMwYLKoZI
hvcNAQkQAw8wJDAUBggqhkiG9w0DBwQI0tCBcU09nxEwDAYIKwYBBQUIAQIFAIAQ
OsYGYUFdAH0RNc1p4VbKEAQUM2Xo8PMHBoYdqEcsbTodlCFAZH4=
-----END CERTIFICATE CHAIN-----
```

Figure 19: Non-standard 'CERTIFICATE CHAIN' Example

Appendix B. DER Expectations

This appendix is informative. Consult the respective standards for the normative rules.

DER is a restricted profile of BER [X.690]; thus, all DER encodings of data values are BER encodings, but just one of the BER encodings is the DER encoding for a data value. Canonical encoding matters when performing cryptographic operations; additionally, canonical encoding has certain efficiency advantages for parsers. There are three principal reasons to encode with DER:

1. A digital signature is (supposed to be) computed over the DER encoding of the semantic content, so providing anything other than the DER encoding is senseless. (In practice, an implementer might choose to have an implementation parse and digest the data as is, but this practice amounts to guesswork.)

2. In practice, cryptographic hashes are computed over the DER encoding for identification.

3. In practice, the content is small. DER always encodes data values in definite-length form (where the length is stated at the beginning of the encoding); thus, a parser can anticipate memory or resource usage up front.

Figure 20 matches the structures in this document with the particular reasons for DER encoding:

Sec.	Label	Reasons
5	CERTIFICATE	1 2 ~3
6	X509 CRL	1
7	CERTIFICATE REQUEST	1 ~3
8	PKCS7	*
9	CMS	*
10	PRIVATE KEY	3
11	ENCRYPTED PRIVATE KEY	3
12	ATTRIBUTE CERTIFICATE	1 ~3
13	PUBLIC KEY	2 3

Figure 20: Guide for DER Encoding

* Cryptographic Message Syntax is designed for content of any length; indefinite-length encoding enables one-pass processing (streaming) when generating the encoding. Only certain parts -- namely, signed and authenticated attributes -- need to be DER encoded.

~ Although not always "small", these encoded structures should not be particularly "large" (e.g., more than 16 kilobytes). The parser ought to be informed of large things up front in any event; this is yet another reason to DER encode these things in the first place.

Figure 20: Guide for DER Encoding

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Peter Gutmann suggested to document labels for Attribute Certificates and PKCS #7 messages, and to add examples for the non-standard variants. Dr. Stephen Henson suggested distinguishing when BER versus DER is appropriate or necessary.

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