Text Encodings of PKIX and CMS Structures

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Abstract

This document describes and discusses the text encodings of the Public-Key Infrastructure X.509 (PKIX), Public-Key Cryptography Standards (PKCS), and Cryptographic Message Syntax (CMS). The text encodings are well-known, are implemented by several applications and libraries, and are widely deployed. This document is intended to articulate the de-facto rules that existing implementations operate by, and to give recommendations that will promote interoperability going forward.

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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 text encodings of these 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].
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 standards.

Although other formats exist that use the text encoding (or something like it) described in this document, the included formats share a common property: algorithm agility. “Algorithm agility” means that different algorithms to achieve the same purposes—such as content encryption or integrity protection—can be used in different instances of the same format because the instance data identifies the algorithms and associated parameters. Weakness in an algorithm does not destroy the utility of the format.

A disadvantage of a binary data format is that it cannot be interchanged in textual transports, such as e-mail or text documents. One advantage with text 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 PEM [RFC1421], based on a proposal by M. Rose in Message Encapsulation [RFC0934]. 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 [RFC2015] and OpenSSH Key File Format [RFC4716].

For reasons that basically boil down to non-coordination or inattention, many PKIX and CMS libraries implement a text encoding that is similar to—but not identical with—PEM encoding. This document specifies the "PKIX text 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.

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

PKIX text encoding begins with a line starting with ‐‐‐‐‐BEGIN and ends with a line starting with ‐‐‐‐‐END. Between these lines, or "encapsulation boundaries", are base64-encoded [RFC4648] data. Data before the ‐‐‐‐‐BEGIN and after the ‐‐‐‐‐END encapsulation boundaries are permitted and MUST NOT cause parsers to malfunction. Furthermore, parsers MUST 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. Parsers MAY disregard the label on the ‐‐‐‐‐END line instead of signaling an error if there is a label mismatch. There is exactly one space character (SP) separating the BEGIN or END from the label. There are exactly five hyphen-minus (or 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 Internet-Draft 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. Consistent with algorithm agility, the labels described in this document are not specific to any particular cryptographic algorithm.

Unlike legacy PEM encoding [RFC1421], OpenPGP ASCII armor, and the OpenSSH key file format, PKIX text encoding does not define or permit attributes to be encoded alongside the PKIX or CMS data. Whitespace MAY appear between the pre-encapsulation boundary and the base64, but generators SHOULD NOT emit such whitespace.

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

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). Parsers MAY handle other line sizes. These requirements are consistent with PEM [RFC1421].

3. ABNF

The ABNF of the PKIX text encoding is:

```
pkixmsg ::= preeb
```
This specification RECOMMENDS that new implementations emit the strict format [abnf-strict-fig] specified above.

4. Guide

For convenience, this table summarizes the structures, encodings, and references in the following sections:

<table>
<thead>
<tr>
<th>Sec.</th>
<th>Label</th>
<th>ASN.1 Type</th>
<th>Reference Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CERTIFICATE</td>
<td>Certificate</td>
<td>[RFC5280] id-pkix1-e</td>
</tr>
<tr>
<td>6</td>
<td>X.509 CRL</td>
<td>CertificateList</td>
<td>[RFC5280] id-pkix1-e</td>
</tr>
</tbody>
</table>
5. Text Encoding of Certificates

5.1. Encoding

Certificates are encoded using the **CERTIFICATE** label. The encoded data MUST be a BER (DER strongly preferred) encoded ASN.1 Certificate structure as described in section 4 of [RFC5280].

```
-----BEGIN CERTIFICATE-----
MIICLDCCAdKgAwIBAgIBADAKBggqhkjOPQQDAjB9MQswCQYDVQQGEwJCRTEPMA0G
A1UEChMGR251VExTMSUwIwYDVQQLEExHbmnVUTFMgY2Vydml2aXNpZ2UgY3Jj
MQ8wDQYDVQQIEwZMZXV2ZW4xJTAjBgNVBAMTHEdudVRMUyBjZXJ0aWZpY2F0
ZSBhcmzdXRob3IjZSk7cTBzaWJvdW5kZXIudXMwGgYDVR0PAQH/BAQDAgEG
MIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEALHr5cZGh+G0mZlf
ki5B9G1qmLBM5/lc9zj9BcY6eP1Zv9y90p2bB9bZ0eMg2yZzF5IM6Kv3jD
QvLQ9oS5QmM5cS06+H67sMlCD+rNLJpy8a9eo/kGBnQYWSshI71Nv9Loe
oT0XStW5S9/9DMSaTjYR99p36Fklo083O39y9GzY9OLdJYFU0wDQYDVQQIEwZMZXV2ZW4xJTAj
BgNVBAMTHEdudVRMUyBjZXJ0aWZpY2F0ZSBhcmzdXRob3IjZSk7cTBzaWJvdW5k
ZXIudXMwGgYDVR0PAQH/BAQDAgEGMIIBCgKCAQEANnNpmP2f8vkogojBq/5Wc
q+D2bTbGl5Gju5Kiu5mLQjD1ZwZ5CqH4qk7k1YIFYtVoy6qX4Q+sX2T7O
q7m5/152DQyKJy793+5F+jGQk1K1aMO0OKlG1sBz3HbG0tjOQ2Gjk+i27
jCvVp4QVD18ae29z3/5c3wKIP9nTcYXm997oPeXHJlu1u1J6xkF9Sb2h8
T7Xo5kZ4Pn0mr9a30tNtP9E6F6Lw2O19V+2g6+3f3435I85H/p7dUj+b
xX12J5N6a/2Oz5RQz+6FfUq9s9saS19357InXfjY0k5dW+K+K+aNnU
-----END CERTIFICATE-----
```

Figure 3: Convenience Guide

Figure 4: 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 are NOT RECOMMENDED to treat...
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-----
MIIBmTCCAuEgAwIBAgIBKjAJBgUrDgMCHQUAMBMxETAPBgNVBAMTCEF0bGFudGlzMB4XDTEyMDcwOTAzMTAzOFoXDTEzMDcwOTAzMTAzN1owEzERMA8GA1UEAxMIQXRsYW50aXMwXDANBkqkhki9g6s8iERMA8GA1UEAxMIQXRsYW50aXMwXzAMBgNVBAMTCEF0bGFudGlzMB4XDTEyMDcwOTAzMTAzOFoXDTEzMDcwOTAzMTAzN1owEzERMA8GA1UEAxMIQXRsYW50aXMwXzAMBgNVBAMTCEF0bGFudGlzMB4XDTEyMDcwOTAzMTAzOFoXDTEzMDcwOTAzMTAzN1owEzERMA8GA1UEAxMIQXRsYW50aXMwXzAMBgNVBAMTCEF0bGFudGlz

---END CERTIFICATE-----

Figure 5: Certificate Example with Explanatory Text

5.3. File Extension

Although text encodings of PKIX structures can occur anywhere, many tools are known to offer an option to encode PKIX structures in this text encoding. To promote interoperability and to separate DER encodings from text encodings, this Internet-Draft RECOMMENDS that the extension .crt be used for this text encoding. Implementations should be aware that in spite of this recommendation, many tools still default to encode certificates in this text encoding with the extension .cer.

6. Text 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) encoded ASN.1 CertificateList structure as described in Section 5 of [RFC5280].

---BEGIN X509 CRL-----

---END X509 CRL-----

Figure 6: 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 are NOT RECOMMENDED to treat CRL as equivalent to X509 CRL.

7. Text 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) encoded ASN.1 |CertificateRequest| structure as described in [RFC2986].

```
-----BEGIN CERTIFICATE REQUEST-----
MIIBDCAQCAQAwfjeLMaegAMBMU0xJzAlBnvBAoTH1NpbW9uIEpvc2Vm
c3NhbyBEYXRhYXNzQ29uc3VsbCBQcDAtWBMQGA1UEAxMnam9zZWzc29u
Lm9yZzBOMBAG
BygGA1UdEwEB/wQMAwIBAgIBADAEAwgDMS0wJDAUBggqhkiG9w0BAQf
-----END CERTIFICATE REQUEST-----
```

Figure 7: 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. Text 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-----
MIHjBgsqkhIGw0BCaRBF6C0bZCB0AIBAqDfho1BDAQCGwYJKoZIhvcNAQUUMA4E
CjLfrI6dr8UWAgITD1DajBgsqkhIGw0BCrADCTAUbgghk169w0DBwQIZpECRwtwz
u5kEgDcjerXy8odQ7EErOMzJvAurk/j81IrozBSbgkhIGw0BBwEwMwYLkoZI
hvcNAQkQAo8wJDAUBgghk1IGw0DBwQ10tCbcU09nxEwDABIYkwyBBgqQIAQFAIAQ
0sGUYUFdAH0RNC1p4VbKEAOUMZxo8PMHBoYdqEcSbTodCFAZI4=
-----END PKCS7-----
```

Figure 8: PKCS #7 Example

The label CERTIFICATE_CHAIN has been in use to denote a degenerative PKCS #7 structure that contains only a list of certificates. Several modern tools do not support this label. Generators MUST NOT generate the CERTIFICATE_CHAIN label. Parsers are NOT RECOMMENDED to treat CERTIFICATE_CHAIN as equivalent to PKCS7.

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

9. Text 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-----
```
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. Text Encoding of PKCS #8 Private Key Info, and One Asymmetric Key

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) 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/UNPxalR9zDYAjQIfjojUdIq6n5JzFEEzZPT/92hRANCAAc7UJtgf/abqWM68T3XNZez5ez97dwKHz063pZ2q53umsN/eYLdtjg8dB3DBHtPlIlK5fICXyaA8z9LJK
-----END PRIVATE KEY-----

Figure 10: PKCS #8 PrivateKeyInfo Example

11. Text 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) encoded ASN.1 EncryptedPrivateKeyInfo structure as described in PKCS #8 [RFC5208] and [RFC5958].

----BEGIN ENCRYPTED PRIVATE KEY-----
MIHNMEAGCSqGSIb3DQEFDTAzMBsGCSqGSIb3DQEFDADA0BAGhhICA6T/51QICCAAwFAYKoIHNCawECCBcxGvI5919BIGIY3CAq1MBgaISiDzWV3JipfLE1sWZ03iOHymKk/c+9q9Lzix1mz0MT9s43G3c1IzTWlb9j1vb3hub0zyYFPraomkap8erZwsLc55veL5+s0z3m9s87cyjJdt+txzmROVYDE+eTgLbrLmsgWh3QkCTRfQC7k0NNzUHTV9yDgwfbMbez
-----END ENCRYPTED PRIVATE KEY-----

Figure 11: PKCS #8 EncryptedPrivateKeyInfo Example

12. Text Encoding of Attribute Certificates

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

----BEGIN ATTRIBUTE CERTIFICATE-----
MIICKzCCAZQCAQEggZQwYmggYyqGMXzA1BgvNvBAYTA1VTMREwDwYDVQQI
DAA0ZxgW9yazEUMB1A1UEBwnLU3RvbnkgQnJv8b2sxxZANBgNVBAAtMBkNTRtUS
Mje6MDqGAiU9AwmxU2NvdHug1c199lbfjbfEFkZHZl3M9c3N00xwS2ZX3A
awMuc3VuemNlMvdkOQArW5USoIgWMMgIgJiGGM1DQswqCVVDVQGwEwJUZuER
MABGAIUECwAtM3F1fmsxCfDASgBvBacMC1N0b255IEjyb29rMQ8wDQVYDQOK
D4ZDUKU10I5i0j4A4BgvBAMMVMJb3R8IF00YxwS2ZX1Zw1haMwUBZGRYzXNzPXNZ
-----END ATTRIBUTE CERTIFICATE-----
13. Text Encoding of Subject Public Key Info

Public keys are encoded using the `PUBLIC KEY` label. The encoded data MUST be a BER (DER preferred) encoded `SubjectPublicKeyInfo` structure as described in Section 4.1.2.7 of [RFC5280].

```
-----BEGIN PUBLIC KEY-----
MHYwEAYHkoZlzd0CAQYFK4EACIDYgAEn1lwLN/KBYQRVH6HfIMTzFeqOVztle
kLchp2hi78cCaMY81FBlYs8397krc+M4aBeCGYFjba+hiXttJWPL7yd1E+5UG4U
Nkn3Eos8EiZYs1DVsyfy9eejJ+8AXgp
-----END PUBLIC KEY-----
```

Figure 13: 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 Internet-Draft 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. IANA Considerations

This document implies no IANA Considerations.

16. Acknowledgements

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 are appropriate or necessary.

17. References

17.1. Normative References

17.2. Informative References


Appendix A. Non-Conforming Examples

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

-----BEGIN X509 CERTIFICATE-----
MIIBHDCBxaADAgECAgIcxzAJBgcqhkjOPQBBMBAxDjAMBgNVBAMVBVBLVghMB4X
DTE0MDkxNDA2MTU1MFoXDTI0MDkxNDA2MTU1MFowEDEOMAwGAIUEAxQFUEtJWCeW
WTATBgcqhkjOPQIBggqhkjOPQMBBwNCAAtwoQ5rB63QrR0P0R1YQ96H7WykDePH
Wa0eVAE24bth4wCNc+U5aZ761dhGHS3kVWwV5HR+prLI+nznfIqX4oxAwDjAM
BqNVHRMBAf8EajAAMAkGBqQgSM49BAEDRwAwRAIwMdK55F631MnWhi7uakJzkKCs
NnY/OKgBex6MIEAv2AIhAI2GdvFw+mgvhyPZE+JxR+wChmgb/g5/9eHdUcmw/jkOH
-----END X509 CERTIFICATE-----

Figure 14: Non-standard 'X509' Certificate Example

-----BEGIN X.509 CERTIFICATE-----
MIIBHDCBxaADAgECAgIcxzAJBgcqhkjOPQBBMBAxDjAMBgNVBAMVBVBLVghMB4X
DTE0MDkxNDA2MTU1MFoXDTI0MDkxNDA2MTU1MFowEDEOMAwGAIUEAxQFUEtJWCeW
WTATBgcqhkjOPQIBggqhkjOPQMBBwNCAAtwoQ5rB63QrR0P0R1YQ96H7WykDePH
Wa0eVAE24bth4wCNc+U5aZ761dhGHS3kVWwV5HR+prLI+nznfIqX4oxAwDjAM
BqNVHRMBAf8EajAAMAkGBqQgSM49BAEDRwAwRAIwMdK55F631MnWhi7uakJzkKCs
NnY/OKgBex6MIEAv2AIhAI2GdvFw+mgvhyPZE+JxR+wChmgb/g5/9eHdUcmw/jkOH
-----END X.509 CERTIFICATE-----

Figure 15: Non-standard 'X.509' Certificate Example
-----BEGIN NEW CERTIFICATE REQUEST-----
MIIBDCCAQcCAQAwTjELEMgGA1UEBhMCU0Ux3d1jBiBQ5EgBLBBkUgY29tcG9uZS5ld3Mw
OJ85IioSbTlJMGV66EPGxvY3NHQ transitioning to a new certificate request.

-----BEGIN CERTIFICATE CHAIN-----
MIHjBgsqhkiG9w0BCRABF6CB0zCB0AIBADHo18CAQCAgYWJyKoZiHvcNAQJMA4E

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 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 do 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.

<table>
<thead>
<tr>
<th>Sec.</th>
<th>Label</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CERTIFICATE</td>
<td>1 2 ~3</td>
</tr>
<tr>
<td>6</td>
<td>.509 CRL</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>CERTIFICATE REQUEST</td>
<td>1 ~3</td>
</tr>
<tr>
<td>8</td>
<td>PKCS7</td>
<td>*</td>
</tr>
<tr>
<td>9</td>
<td>CMS</td>
<td>*</td>
</tr>
<tr>
<td>10</td>
<td>PRIVATE KEY</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>ENCRYPTED PRIVATE KEY</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>ATTRIBUTE CERTIFICATE</td>
<td>1 ~3</td>
</tr>
<tr>
<td>13</td>
<td>PUBLIC KEY</td>
<td>2 3</td>
</tr>
</tbody>
</table>

Figure 18 matches the structures in this document with the particular reasons 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, which is yet another reason to DER encode these things in the first place.

**Figure 18: Guide for DER Encoding**

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