

Network Working Group
Request for Comments: 5272
Obsoletes: 2797
Category: Standards Track

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June 2008

Certificate Management over CMS (CMC)

Status of This Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

Abstract

This document defines the base syntax for CMC, a Certificate Management protocol using the Cryptographic Message Syntax (CMS). This protocol addresses two immediate needs within the Internet Public Key Infrastructure (PKI) community:

1. The need for an interface to public key certification products and services based on CMS and PKCS #10 (Public Key Cryptography Standard), and
2. The need for a PKI enrollment protocol for encryption only keys due to algorithm or hardware design.

CMC also requires the use of the transport document and the requirements usage document along with this document for a full definition.

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1. Introduction

This document defines the base syntax for CMC, a Certificate Management protocol using the Cryptographic Message Syntax (CMS). This protocol addresses two immediate needs within the Internet PKI community:

1. The need for an interface to public key certification products and services based on CMS and PKCS #10, and
2. The need for a PKI enrollment protocol for encryption only keys due to algorithm or hardware design.

A small number of additional services are defined to supplement the core certification request service.

1.1. Protocol Requirements

The protocol must be based as much as possible on the existing CMS, PKCS #10 [PKCS10] and CRMF (Certificate Request Message Format) [CRMF] specifications.

The protocol must support the current industry practice of a PKCS #10 certification request followed by a PKCS#7 "certs-only" response as a subset of the protocol.

The protocol must easily support the multi-key enrollment protocols required by S/MIME and other groups.

The protocol must supply a way of doing all enrollment operations in a single round-trip. When this is not possible the number of round-trips is to be minimized.

The protocol must be designed such that all key generation can occur on the client.

Support must exist for the mandatory algorithms used by S/MIME. Support should exist for all other algorithms cited by the S/MIME core documents.

The protocol must contain Proof-of-Possession (POP) methods. Optional provisions for multiple-round-trip POP will be made if necessary.

The protocol must support deferred and pending responses to enrollment requests for cases where external procedures are required to issue a certificate.

The protocol must support arbitrary chains of Registration Authorities (RAs) as intermediaries between certification requesters and Certification Authorities (CAs).

1.2. Requirements Terminology

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].

1.3. Changes since RFC 2797

We have done a major overhaul on the layout of the document. This included two different steps. Firstly we removed some sections from the document and moved them to two other documents. Information on how to transport our messages are now found in [CMC-TRANS]. Information on which controls and sections of this document must be implemented along with which algorithms are required can now be found in [CMC-COMPL].

A number of new controls have been added in this version:

Extended CMC Status Info Section 6.1.1

Publish Trust Anchors Section 6.15

Authenticate Data Section 6.16

Batch Request and Response Processing Section 6.17

Publication Information Section 6.18

Modify Certification Request Section 6.5.1

Control Processed Section 6.19

Identity Proof Section 6.2.2

Identity POP Link Witness V2 Section 6.3.1.1

2. Protocol Overview

A PKI enrollment transaction in this specification is generally composed of a single round-trip of messages. In the simplest case a PKI enrollment request, henceforth referred to as a PKI Request, is sent from the client to the server and a PKI enrollment response, henceforth referred to as a PKI Response, is then returned from the

server to the client. In more complicated cases, such as delayed certificate issuance, more than one round-trip is required.

This specification defines two PKI Request types and two PKI Response types.

PKI Requests are formed using either the PKCS #10 or CRMF structure. The two PKI Requests are:

Simple PKI Request: the bare PKCS #10 (in the event that no other services are needed), and

Full PKI Request: one or more PKCS #10, CRMF or Other Request Messages structures wrapped in a CMS encapsulation as part of a PKIData.

PKI Responses are based on SignedData or AuthenticatedData [CMS]. The two PKI Responses are

Simple PKI Response: a "certs-only" SignedData (in the event no other services are needed), or

Full PKI Response: a PKIResponse content type wrapped in a SignedData.

No special services are provided for either renewal (i.e., a new certificate with the same key) or rekey (i.e., a new certificate with a new key) of client certificates. Instead renewal and rekey requests look the same as any certification request, except that the identity proof is supplied by existing certificates from a trusted CA. (This is usually the same CA, but could be a different CA in the same organization where naming is shared.)

No special services are provided to distinguish between a rekey request and a new certification request (generally for a new purpose). A control to unpublish a certificate would normally be included in a rekey request, and be omitted in a new certification request. CAs or other publishing agents are also expected to have policies for removing certificates from publication either based on new certificates being added or the expiration or revocation of a certificate.

A provision exists for RAs to participate in the protocol by taking PKI Requests, wrapping them in a second layer of PKI Request with additional requirements or statements from the RA and then passing this new expanded PKI Request on to the CA.

This specification makes no assumptions about the underlying transport mechanism. The use of CMS does not imply an email-based transport. Several different possible transport methods are defined in [CMC-TRANS].

Optional services available through this specification are transaction management, replay detection (through nonces), deferred certificate issuance, certificate revocation requests and certificate/certificate revocation list (CRL) retrieval.

2.1. Terminology

There are several different terms, abbreviations, and acronyms used in this document. These are defined here, in no particular order, for convenience and consistency of usage:

End-Entity (EE) refers to the entity that owns a key pair and for whom a certificate is issued.

Registration Authority (RA) or Local RA (LRA) refers to an entity that acts as an intermediary between the EE and the CA. Multiple RAs can exist between the end-entity and the Certification Authority. RAs may perform additional services such as key generation or key archival. This document uses the term RA for both RA and LRA.

Certification Authority (CA) refers to the entity that issues certificates.

Client refers to an entity that creates a PKI Request. In this document, both RAs and EEs can be clients.

Server refers to the entities that process PKI Requests and create PKI Responses. In this document, both CAs and RAs can be servers.

PKCS #10 refers to the Public Key Cryptography Standard #10 [PKCS10], which defines a certification request syntax.

CRMF refers to the Certificate Request Message Format RFC [CRMF]. CMC uses this certification request syntax defined in this document as part of the protocol.

CMS refers to the Cryptographic Message Syntax RFC [CMS]. This document provides for basic cryptographic services including encryption and signing with and without key management.

PKI Request/Response refers to the requests/responses described in this document. PKI Requests include certification requests, revocation requests, etc. PKI Responses include certs-only messages, failure messages, etc.

Proof-of-Identity refers to the client proving they are who they say that they are to the server.

Enrollment or certification request refers to the process of a client requesting a certificate. A certification request is a subset of the PKI Requests.

Proof-of-Possession (POP) refers to a value that can be used to prove that the private key corresponding to a public key is in the possession and can be used by an end-entity. The different types of POP are:

Signature provides the required POP by a signature operation over some data.

Direct provides the required POP operation by an encrypted challenge/response mechanism.

Indirect provides the required POP operation by returning the issued certificate in an encrypted state. (This method is not used by CMC.)

Publish provides the required POP operation by providing the private key to the certificate issuer. (This method is not currently used by CMC. It would be used by Key Generation or Key Escrow extensions.)

Attested provides the required POP operation by allowing a trusted entity to assert that the POP has been proven by one of the above methods.

Object Identifier (OID) is a primitive type in Abstract Syntax Notation One (ASN.1).

2.2. Protocol Requests/Responses

Figure 1 shows the Simple PKI Requests and Responses. The contents of Simple PKI Request and Response are detailed in Sections 3.1 and 4.1.

Simple PKI Request

```

+-----+
| PKCS #10 |
+-----+-----+
| Certification Request
|
| Subject Name
| Subject Public Key Info
|   (K_PUB)
| Attributes
+-----+-----+
| signed with
| matching
| K_PRIV
+-----+-----+

```

Simple PKI Response

```

+-----+-----+
| CMS ContentInfo |
+-----+-----+
| CMS Signed Data,
|   no SignerInfo
|
| SignedData contains one
| or more certificates in
| the certificates field
| Relevant CA certs and
| CRLs can be included
| as well.
|
| encapsulatedContentInfo
| is absent.
+-----+-----+
| unsigned |
+-----+-----+

```

Figure 1: Simple PKI Requests and Responses

Figure 2 shows the Full PKI Requests and Responses. The contents of the Full PKI Request and Response are detailed in Sections 3.2 and 4.2.

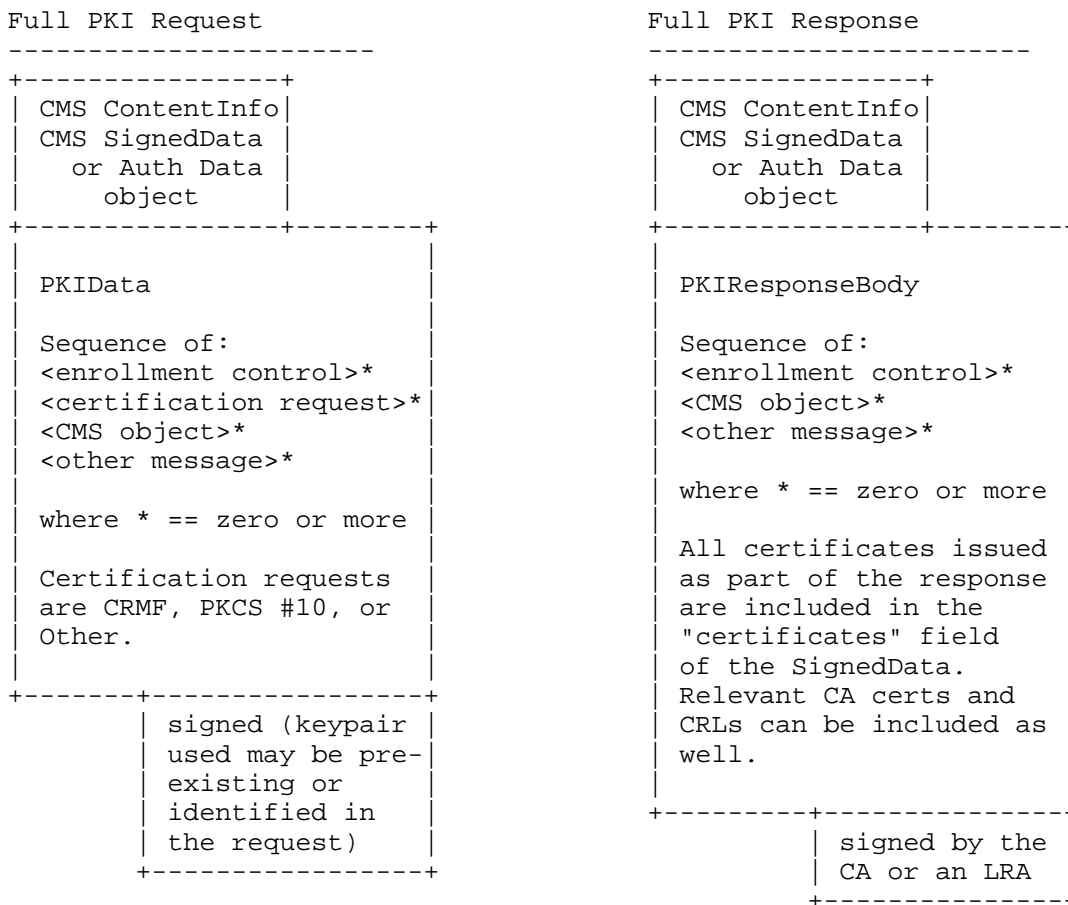


Figure 2: Full PKI Requests and Responses

3. PKI Requests

Two types of PKI Requests exist. This section gives the details for both types.

3.1. Simple PKI Request

A Simple PKI Request uses the PKCS #10 syntax CertificationRequest [PKCS10].

When a server processes a Simple PKI Request, the PKI Response returned is:

Simple PKI Response on success.

Full PKI Response on failure. The server MAY choose not to return a PKI Response in this case.

The Simple PKI Request MUST NOT be used if a proof-of-identity needs to be included.

The Simple PKI Request cannot be used if the private key is not capable of producing some type of signature (i.e., Diffie-Hellman (DH) keys can use the signature algorithms in [DH-POP] for production of the signature).

The Simple PKI Request cannot be used for any of the advanced services specified in this document.

The client MAY incorporate one or more X.509v3 extensions in any certification request based on PKCS #10 as an ExtensionReq attribute. The ExtensionReq attribute is defined as:

ExtensionReq ::= SEQUENCE SIZE (1..MAX) OF Extension

where Extension is imported from [PKIXCERT] and ExtensionReq is identified by:

id-ExtensionReq OBJECT IDENTIFIER ::= {iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1) pkcs-9(9) 14}

Servers MUST be able to process all extensions defined, but not prohibited, in [PKIXCERT]. Servers are not required to be able to process other X.509v3 extensions transmitted using this protocol, nor are they required to be able to process private extensions. Servers are not required to put all client-requested extensions into a certificate. Servers are permitted to modify client-requested extensions. Servers MUST NOT alter an extension so as to invalidate the original intent of a client-requested extension. (For example, changing key usage from keyAgreement to digitalSignature.) If a certification request is denied due to the inability to handle a requested extension and a PKI Response is returned, the server MUST return a PKI Response with a CMCFailInfo value with the value unsupportedExt.

3.2. Full PKI Request

The Full PKI Request provides the most functionality and flexibility.

The Full PKI Request is encapsulated in either a SignedData or an AuthenticatedData with an encapsulated content type of id-cct-PKIData (Section 3.2.1).

When a server processes a Full PKI Request, a PKI Response MUST be returned. The PKI Response returned is:

Simple PKI Response if the enrollment was successful and only certificates are returned. (A CMCStatusInfoV2 control with success is implied.)

Full PKI Response if the enrollment was successful and information is returned in addition to certificates, if the enrollment is pending, or if the enrollment failed.

If SignedData is used, the signature can be generated using either the private key material of an embedded signature certification request (i.e., included in the TaggedRequest tcr or crm fields) or a previously certified signature key. If the private key of a signature certification request is used, then:

- a. The certification request containing the corresponding public key MUST include a Subject Key Identifier extension.
- b. The subjectKeyIdentifier form of the signerIdentifier in SignerInfo MUST be used.
- c. The value of the subjectKeyIdentifier form of SignerInfo MUST be the Subject Key Identifier specified in the corresponding certification request. (The subjectKeyIdentifier form of SignerInfo is used here because no certificates have yet been issued for the signing key.) If the request key is used for signing, there MUST be only one SignerInfo in the SignedData.

If AuthenticatedData is used, then:

- a. The Password Recipient Info option of RecipientInfo MUST be used.
- b. A randomly generated key is used to compute the Message Authentication Code (MAC) value on the encapsulated content.
- c. The input for the key derivation algorithm is a concatenation of the identifier (encoded as UTF8) and the shared-secret.

When creating a PKI Request to renew or rekey a certificate:

- a. The Identification and Identity Proof controls are absent. The same information is provided by the use of an existing certificate from a CA when signing the PKI Request. In this case, the CA that issued the original certificate and the CA the request is made to will usually be the same, but could have a common operator.
- b. CAs and RAs can impose additional restrictions on the signing certificate used. They may require that the most recently issued signing certificate for a client be used.
- c. Some CAs may prevent renewal operations (i.e., reuse of the same keys). In this case the CA MUST return a PKI Response with noKeyReuse as the CMCFailInfo failure code.

3.2.1. PKIData Content Type

The PKIData content type is used for the Full PKI Request. A PKIData content type is identified by:

```
id-cct-PKIData ::= {id-pkix id-cct(12) 2 }
```

The ASN.1 structure corresponding to the PKIData content type is:

```
PKIData ::= SEQUENCE {
    controlSequence    SEQUENCE SIZE(0..MAX) OF TaggedAttribute,
    reqSequence        SEQUENCE SIZE(0..MAX) OF TaggedRequest,
    cmsSequence        SEQUENCE SIZE(0..MAX) OF TaggedContentInfo,
    otherMsgSequence   SEQUENCE SIZE(0..MAX) OF OtherMsg
}
```

The fields in PKIData have the following meaning:

controlSequence is a sequence of controls. The controls defined in this document are found in Section 6. Controls can be defined by other parties. Details on the TaggedAttribute structure can be found in Section 3.2.1.1.

reqSequence is a sequence of certification requests. The certification requests can be a CertificationRequest (PKCS #10), a CertReqMsg (CRMF), or an externally defined PKI request. Full details are found in Section 3.2.1.2. If an externally defined certification request is present, but the server does not understand the certification request (or will not process it), a CMCStatus of noSupport MUST be returned for the certification request item and no other certification requests are processed.

cmsSequence is a sequence of [CMS] message objects. See Section 3.2.1.3 for more details.

otherMsgSequence is a sequence of arbitrary data objects. Data objects placed here are referred to by one or more controls. This allows for controls to use large amounts of data without the data being embedded in the control. See Section 3.2.1.4 for more details.

All certification requests encoded into a single PKIData SHOULD be for the same identity. RAs that batch process (see Section 6.17) are expected to place the PKI Requests received into the cmsSequence of a PKIData.

Processing of the PKIData by a recipient is as follows:

1. All controls should be examined and processed in an appropriate manner. The appropriate processing is to complete processing at this time, to ignore the control, or to place the control on a to-do list for later processing. Controls can be processed in any order; the order in the sequence is not significant.
2. Items in the reqSequence are not referenced by a control. These items, which are certification requests, also need to be processed. As with controls, the appropriate processing can be either immediate processing or addition to a to-do list for later processing.
3. Finally, the to-do list is processed. In many cases, the to-do list will be ordered by grouping specific tasks together.

No processing is required for cmsSequence or otherMsgSequence members of PKIData if they are present and are not referenced by a control. In this case, the cmsSequence and otherMsgSequence members are ignored.

3.2.1.1. Control Syntax

The actions to be performed for a PKI Request/Response are based on the included controls. Each control consists of an object identifier and a value based on the object identifier.

The syntax of a control is:

```
TaggedAttribute ::= SEQUENCE {  
    bodyPartID      BodyPartID,  
    attrType        OBJECT IDENTIFIER,  
    attrValues      SET OF AttributeValue  
}
```

```
AttributeValue ::= ANY
```

The fields in TaggedAttribute have the following meaning:

bodyPartID is a unique integer that identifies this control.

attrType is the OID that identifies the control.

attrValues is the data values used in processing the control. The structure of the data is dependent on the specific control.

The final server MUST fail the processing of an entire PKIData if any included control is not recognized, that control is not already marked as processed by a Control Processed control (see Section 6.19) and no other error is generated. The PKI Response MUST include a CMCFailInfo value with the value badRequest and the bodyList MUST contain the bodyPartID of the invalid or unrecognized control(s). A server is the final server if and only if it is not passing the PKI Request on to another server. A server is not considered to be the final server if the server would have passed the PKI Request on, but instead it returned a processing error.

The controls defined by this document are found in Section 6.

3.2.1.2. Certification Request Formats

Certification Requests are based on PKCS #10, CRMF, or Other Request formats. Section 3.2.1.2.1 specifies the requirements for clients and servers dealing with PKCS #10. Section 3.2.1.2.2 specifies the requirements for clients and servers dealing with CRMF. Section 3.2.1.2.3 specifies the requirements for clients and servers dealing with Other Request.

```
TaggedRequest ::= CHOICE {
  tcr          [0] TaggedCertificationRequest,
  crm          [1] CertReqMsg,
  orm          [2] SEQUENCE {
    bodyPartID      BodyPartID,
    requestMessageType OBJECT IDENTIFIER,
    requestMessageValue ANY DEFINED BY requestMessageType
  }
}
```

The fields in TaggedRequest have the following meaning:

tcr is a certification request that uses the PKCS #10 syntax. Details on PKCS #10 are found in Section 3.2.1.2.1.

crm is a certification request that uses the CRMF syntax. Details on CRMF are found in Section 3.2.1.2.2.

orm is an externally defined certification request. One example is an attribute certification request. The fields of this structure are:

bodyPartID is the identifier number for this certification request. Details on body part identifiers are found in Section 3.2.2.

requestMessageType identifies the other request type. These values are defined outside of this document.

requestMessageValue is the data associated with the other request type.

3.2.1.2.1. PKCS #10 Certification Syntax

A certification request based on PKCS #10 uses the following ASN.1 structure:

```
TaggedCertificationRequest ::= SEQUENCE {
  bodyPartID      BodyPartID,
  certificationRequest CertificationRequest
}
```

The fields in TaggedCertificationRequest have the following meaning:

bodyPartID is the identifier number for this certification request. Details on body part identifiers are found in Section 3.2.2.

certificationRequest contains the PKCS-#10-based certification request. Its fields are described in [PKCS10].

When producing a certification request based on PKCS #10, clients MUST produce the certification request with a subject name and public key. Some PKI products are operated using a central repository of information to assign subject names upon receipt of a certification request. To accommodate this mode of operation, the subject field in a CertificationRequest MAY be NULL, but MUST be present. CAs that receive a CertificationRequest with a NULL subject field MAY reject such certification requests. If rejected and a PKI Response is returned, the CA MUST return a PKI Response with the CMCFailInfo value with the value badRequest.

3.2.1.2.2. CRMF Certification Syntax

A CRMF message uses the following ASN.1 structure (defined in [CRMF] and included here for convenience):

```
CertReqMsg ::= SEQUENCE {
    certReq    CertRequest,
    popo       ProofOfPossession OPTIONAL,
    -- content depends upon key type
    regInfo    SEQUENCE SIZE(1..MAX) OF AttributeTypeAndValue OPTIONAL }

CertRequest ::= SEQUENCE {
    certReqId    INTEGER,          -- ID for matching request and reply
    certTemplate CertTemplate,    -- Selected fields of cert to be issued
    controls     Controls OPTIONAL } -- Attributes affecting issuance

CertTemplate ::= SEQUENCE {
    version      [0] Version          OPTIONAL,
    serialNumber [1] INTEGER          OPTIONAL,
    signingAlg   [2] AlgorithmIdentifier OPTIONAL,
    issuer       [3] Name              OPTIONAL,
    validity     [4] OptionalValidity OPTIONAL,
    subject      [5] Name              OPTIONAL,
    publicKey    [6] SubjectPublicKeyInfo OPTIONAL,
    issuerUID    [7] UniqueIdentifier  OPTIONAL,
    subjectUID   [8] UniqueIdentifier  OPTIONAL,
    extensions   [9] Extensions       OPTIONAL }
```

The fields in CertReqMsg are explained in [CRMF].

This document imposes the following additional restrictions on the construction and processing of CRMF certification requests:

When a Full PKI Request includes a CRMF certification request, both the subject and publicKey fields in the CertTemplate MUST be defined. The subject field can be encoded as NULL, but MUST be present.

When both CRMF and CMC controls exist with equivalent functionality, the CMC control SHOULD be used. The CMC control MUST override the CRMF control.

The regInfo field MUST NOT be used on a CRMF certification request. Equivalent functionality is provided in the CMC regInfo control (Section 6.12).

The indirect method of proving POP is not supported in this protocol. One of the other methods (including the direct method described in this document) MUST be used. The value of encrCert in SubsequentMessage MUST NOT be used.

Since the subject and publicKeyValues are always present, the POPOSigningKeyInput MUST NOT be used when computing the value for POPSigningKey.

A server is not required to use all of the values suggested by the client in the CRMF certification request. Servers MUST be able to process all extensions defined, but not prohibited in [PKIXCERT]. Servers are not required to be able to process other X.509v3 extensions transmitted using this protocol, nor are they required to be able to process private extensions. Servers are permitted to modify client-requested extensions. Servers MUST NOT alter an extension so as to invalidate the original intent of a client-requested extension. (For example, change key usage from keyAgreement to digitalSignature.) If a certification request is denied due to the inability to handle a requested extension, the server MUST respond with a Full PKI Response with a CMCFailInfo value with the value of unsupportedExt.

3.2.1.2.3. Other Certification Request

This document allows for other certification request formats to be defined and used as well. An example of an other certification request format is one for Attribute Certificates. These other certification request formats are defined by specifying an OID for identification and the structure to contain the data to be passed.

3.2.1.3. Content Info Objects

The cmsSequence field of the PKIData and PKIResponse messages contains zero or more tagged content info objects. The syntax for this structure is:

```
TaggedContentInfo ::= SEQUENCE {
    bodyPartID          BodyPartID,
    contentInfo         ContentInfo
}
```

The fields in TaggedContentInfo have the following meaning:

bodyPartID is a unique integer that identifies this content info object.

contentInfo is a ContentInfo object (defined in [CMS]).

The four content types used in cmsSequence are AuthenticatedData, Data, EnvelopedData, and SignedData. All of these content types are defined in [CMS].

3.2.1.3.1. Authenticated Data

The AuthenticatedData content type provides a method of doing pre-shared-secret-based validation of data being sent between two parties. Unlike SignedData, it does not specify which party actually generated the information.

AuthenticatedData provides origination authentication in those circumstances where a shared-secret exists, but a PKI-based trust has not yet been established. No PKI-based trust may have been established because a trust anchor has not been installed on the client or no certificate exists for a signing key.

AuthenticatedData content type is used by this document for:

The id-cmc-authData control (Section 6.16), and

The top-level wrapper in environments where an encryption-only key is being certified.

This content type can include both PKIData and PKIResponse as the encapsulated content types. These embedded content types can contain additional controls that need to be processed.

3.2.1.3.2. Data

The Data content type allows for general transport of unstructured data.

The Data content type is used by this document for:

Holding the encrypted random value y for POP proof in the encrypted POP control (see Section 6.7).

3.2.1.3.3. Enveloped Data

The EnvelopedData content type provides for shrouding of data.

The EnvelopedData content type is the primary confidentiality method for sensitive information in this protocol. EnvelopedData can provide encryption of an entire PKI Request (see Section 5). EnvelopedData can also be used to wrap private key material for key archival. If the decryption on an EnvelopedData fails, a Full PKI Response is returned with a CMCFailInfo value of badMessageCheck and a bodyPartID of 0.

3.2.1.3.4. Signed Data

The SignedData content type provides for authentication and integrity.

The SignedData content type is used by this document for:

The outer wrapper for a PKI Request.

The outer wrapper for a PKI Response.

As part of processing a PKI Request/Response, the signature(s) MUST be verified. If the signature does not verify and the PKI Request/Response contains anything other than a CMC Status Info control, a Full PKI Response containing a CMC Status Info control MUST be returned using a CMCFailInfo with a value of badMessageCheck and a bodyPartID of 0.

For the PKI Response, SignedData allows the server to sign the returning data, if any exists, and to carry the certificates and CRLs corresponding to the PKI Request. If no data is being returned beyond the certificates and CRLs, the EncapsulatedInfo and SignerInfo fields are not populated.

3.2.1.4. Other Message Bodies

The otherMsgSequence field of the PKI Request/Response allows for arbitrary data objects to be carried as part of a PKI Request/Response. This is intended to contain a data object that is not already wrapped in a cmsSequence field (Section 3.2.1.3). The data object is ignored unless a control references the data object by bodyPartID.

```
OtherMsg ::= SEQUENCE {
    bodyPartID      BodyPartID,
    otherMsgType    OBJECT IDENTIFIER,
    otherMsgValue   ANY DEFINED BY otherMsgType }
```

The fields in OtherMsg have the following meaning:

bodyPartID is the unique id identifying this data object.

otherMsgType is the OID that defines the type of message body.

otherMsgValue is the data.

3.2.2. Body Part Identification

Each element of a PKIData or PKIResponse has an associated body part identifier. The body part identifier is a 4-octet integer using the ASN.1 of:

```
bodyIdMax INTEGER ::= 4294967295
```

```
BodyPartID ::= INTEGER(0..bodyIdMax)
```

Body part identifiers are encoded in the certReqIds field for CertReqMsg objects (in a TaggedRequest) or in the bodyPartID field of the other objects. The body part identifier MUST be unique within a single PKIData or PKIResponse. Body part identifiers can be duplicated in different layers (for example, a PKIData embedded within another).

The bodyPartID value of 0 is reserved for use as the reference to the current PKIData object.

Some controls, such as the Add Extensions control (Section 6.5.2), use the body part identifier in the pkiDataReference field to refer to a PKI Request in the current PKIData. Some controls, such as the Extended CMC Status Info control (Section 6.1.1), will also use body part identifiers to refer to elements in the previous PKI Request/

Response. This allows an error to be explicit about the control or PKI Request to which the error applies.

A BodyPartList contains a list of body parts in a PKI Request/Response (i.e., the Batch Request control in Section 6.17). The ASN.1 type BodyPartList is defined as:

```
BodyPartList ::= SEQUENCE SIZE (1..MAX) OF BodyPartID
```

A BodyPartPath contains a path of body part identifiers moving through nesting (i.e., the Modify Certification Request control in Section 6.5.1). The ASN.1 type BodyPartPath is defined as:

```
BodyPartPath ::= SEQUENCE SIZE (1..MAX) OF BodyPartID
```

3.2.3. CMC Unsigned Data Attribute

There is sometimes a need to include data in a PKI Request designed to be removed by an RA during processing. An example of this is the inclusion of an encrypted private key, where a Key Archive Agent removes the encrypted private key before sending it on to the CA. One side effect of this desire is that every RA that encapsulates this information needs to move the data so that it is not covered by that RA's signature. (A client PKI Request encapsulated by an RA cannot have a signed control removed by the Key Archive Agent without breaking the RA's signature.) The CMC Unsigned Data attribute addresses this problem.

The CMC Unsigned Data attribute contains information that is not directly signed by a client. When an RA encounters this attribute in the unsigned or unauthenticated attribute field of a request it is aggregating, the CMC Unsigned Data attribute is removed from the request prior to placing the request in a cmsSequence and placed in the unsigned or unauthenticated attributes of the RA's signed or authenticated data wrapper.

The CMC Unsigned Data attribute is identified by:

```
id-aa-cmc-unsignedData OBJECT IDENTIFIER ::= {id-aa 34}
```

The CMC Unsigned Data attribute has the ASN.1 definition:

```
CMCUnsignedData ::= SEQUENCE {
    bodyPartPath      BodyPartPath,
    identifier        OBJECT IDENTIFIER,
    content           ANY DEFINED BY identifier
}
```

The fields in CMCUnsignedData have the following meaning:

`bodyPartPath` is the path pointing to the control associated with this data. When an RA moves the control in an unsigned or unauthenticated attribute up one level as part of wrapping the data in a new SignedData or AuthenticatedData, the body part identifier of the embedded item in the PKIData is prepended to the `bodyPartPath` sequence.

`identifier` is the OID that defines the associated data.

`content` is the data.

There MUST be at most one CMC Unsigned Data attribute in the UnsignedAttribute sequence of a SignerInfo or in the UnauthenticatedAttribute sequence of an AuthenticatedData. UnsignedAttribute consists of a set of values; the attribute can have any number of values greater than zero in that set. If the CMC Unsigned Data attribute is in one SignerInfo or AuthenticatedData, it MUST appear with the same values(s) in all SignerInfo and AuthenticatedData items.

4. PKI Responses

Two types of PKI Responses exist. This section gives the details on both types.

4.1. Simple PKI Response

Clients MUST be able to process the Simple PKI Response. The Simple PKI Response consists of a SignedData with no EncapsulatedContentInfo and no SignerInfo. The certificates requested in the PKI Response are returned in the certificate field of the SignedData.

Clients MUST NOT assume the certificates are in any order. Servers SHOULD include all intermediate certificates needed to form complete certification paths to one or more trust anchors, not just the newly issued certificate(s). The server MAY additionally return CRLs in the CRL bag. Servers MAY include the self-signed certificates. Clients MUST NOT implicitly trust included self-signed certificate(s) merely due to its presence in the certificate bag. In the event clients receive a new self-signed certificate from the server, clients SHOULD provide a mechanism to enable the user to use the certificate as a trust anchor. (The Publish Trust Anchors control (Section 6.15) should be used in the event that the server intends the client to accept one or more certificates as trust anchors. This requires the use of the Full PKI Response message.)

4.2. Full PKI Response

Clients MUST be able to process a Full PKI Response.

The Full PKI Response consists of a SignedData or AuthenticatedData encapsulating a PKIResponse content type. The certificates issued in a PKI Response are returned in the certificates field of the immediately encapsulating SignedData.

Clients MUST NOT assume the certificates are in any order. Servers SHOULD include all intermediate certificates needed to form complete chains to one or more trust anchors, not just the newly issued certificate(s). The server MAY additionally return CRLs in the CRL bag. Servers MAY include self-signed certificates. Clients MUST NOT implicitly trust included self-signed certificate(s) merely due to its presence in the certificate bag. In the event clients receive a new self-signed certificate from the server, clients MAY provide a mechanism to enable the user to explicitly use the certificate as a trust anchor. (The Publish Trust Anchors control (Section 6.15) exists for the purpose of allowing for distribution of trust anchor certificates. If a trusted anchor publishes a new trusted anchor, this is one case where automated trust of the new trust anchor could be allowed.)

4.2.1. PKIResponse Content Type

The PKIResponse content type is used for the Full PKI Response. The PKIResponse content type is identified by:

```
id-cct-PKIResponse ::= {id-pkix id-cct(12) 3 }
```

The ASN.1 structure corresponding to the PKIResponse content type is:

```
PKIResponse ::= SEQUENCE {
    controlSequence SEQUENCE SIZE(0..MAX) OF TaggedAttribute,
    cmsSequence SEQUENCE SIZE(0..MAX) OF TaggedContentInfo,
    otherMsgSequence SEQUENCE SIZE(0..MAX) OF OtherMsg
}

ReponseBody ::= PKIResponse
```

Note: In [RFC2797], this ASN.1 type was named ResponseBody. It has been renamed to PKIResponse for clarity and the old name kept as a synonym.

The fields in PKIResponse have the following meaning:

controlSequence is a sequence of controls. The controls defined in this document are found in Section 6. Controls can be defined by other parties. Details on the TaggedAttribute structure are found in Section 3.2.1.1.

cmsSequence is a sequence of [CMS] message objects. See Section 3.2.1.3 for more details.

otherMsgSequence is a sequence of arbitrary data objects. Data objects placed here are referred to by one or more controls. This allows for controls to use large amounts of data without the data being embedded in the control. See Section 3.2.1.4 for more details.

Processing of PKIResponse by a recipient is as follows:

1. All controls should be examined and processed in an appropriate manner. The appropriate processing is to complete processing at this time, to ignore the control, or to place the control on a to-do list for later processing.
2. Additional processing of non-element items includes the saving of certificates and CRLs present in wrapping layers. This type of processing is based on the consumer of the element and should not be relied on by generators.

No processing is required for cmsSequence or otherMsgSequence members of the PKIResponse, if items are present and are not referenced by a control. In this case, the cmsSequence and otherMsgSequence members are to be ignored.

5. Application of Encryption to a PKI Request/Response

There are occasions when a PKI Request or Response must be encrypted in order to prevent disclosure of information in the PKI Request/Response from being accessible to unauthorized entities. This section describes the means to encrypt Full PKI Requests and Responses (Simple PKI Requests cannot be encrypted). Data portions of PKI Requests and Responses that are placed in the cmsSequence field can be encrypted separately.

Confidentiality is provided by wrapping the PKI Request/Response (a SignedData) in an EnvelopedData. The nested content type in the EnvelopedData is id-SignedData. Note that this is different from S/MIME where there is a MIME layer placed between the encrypted and signed data. It is recommended that if an EnvelopedData layer is

applied to a PKI Request/Response, a second signature layer be placed outside of the EnvelopedData layer. The following figure shows how this nesting would be done:

Normal	Option 1	Option 2
-----	-----	-----
SignedData	EnvelopedData	SignedData
PKIData	SignedData	EnvelopedData
	PKIData	SignedData
		PKIData

Note: PKIResponse can be substituted for PKIData in the above figure.

Options 1 and 2 prevent leakage of sensitive data by encrypting the Full PKI Request/Response. An RA that receives a PKI Request that it cannot decrypt MAY reject the PKI Request unless it can process the PKI Request without knowledge of the contents (i.e., all it does is amalgamate multiple PKI Requests and forward them to a server).

After the RA removes the envelope and completes processing, it may then apply a new EnvelopedData layer to protect PKI Requests for transmission to the next processing agent. Section 7 contains more information about RA processing.

Full PKI Requests/Responses can be encrypted or transmitted in the clear. Servers MUST provide support for all three options.

Alternatively, an authenticated, secure channel could exist between the parties that require confidentiality. Clients and servers MAY use such channels instead of the technique described above to provide secure, private communication of Simple and Full PKI Requests/Responses.

6. Controls

Controls are carried as part of both Full PKI Requests and Responses. Each control is encoded as a unique OID followed by the data for the control (see syntax in Section 3.2.1.1. The encoding of the data is based on the control. Processing systems would first detect the OID (TaggedAttribute attrType) and process the corresponding control value (TaggedAttribute attrValues) prior to processing the message body.

The OIDs are all defined under the following arc:

```
id-pkix OBJECT IDENTIFIER ::= { iso(1) identified-organization(3)
  dod(6) internet(1) security(5) mechanisms(5) pkix(7) }
```

```
id-cmc OBJECT IDENTIFIER ::= { id-pkix 7 }
```

The following table lists the names, OID, and syntactic structure for each of the controls described in this document.

Identifier	Description	OID	ASN.1 Structure	Section
id-cmc-statusInfo		id-cmc 1	CMCStatusInfo	6.1.2
id-cmc-identification		id-cmc 2	UTF8String	6.2.3
id-cmc-identityProof		id-cmc 3	OCTET STRING	6.2.2
id-cmc-dataReturn		id-cmc 4	OCTET STRING	6.4
id-cmc-transactionId		id-cmc 5	INTEGER	6.6
id-cmc-senderNonce		id-cmc 6	OCTET STRING	6.6
id-cmc-recipientNonce		id-cmc 7	OCTET STRING	6.6
id-cmc-addExtensions		id-cmc 8	AddExtensions	6.5.2
id-cmc-encryptedPOP		id-cmc 9	EncryptedPOP	6.7
id-cmc-decryptedPOP		id-cmc 10	DecryptedPOP	6.7
id-cmc-lraPOPWitness		id-cmc 11	LraPOPWitness	6.8
id-cmc-getCert		id-cmc 15	GetCert	6.9
id-cmc-getCRL		id-cmc 16	GetCRL	6.10
id-cmc-revokeRequest		id-cmc 17	RevokeRequest	6.11
id-cmc-regInfo		id-cmc 18	OCTET STRING	6.12
id-cmc-responseInfo		id-cmc 19	OCTET STRING	6.12
id-cmc-queryPending		id-cmc 21	OCTET STRING	6.13
id-cmc-popLinkRandom		id-cmc 22	OCTET STRING	6.3.1
id-cmc-popLinkWitness		id-cmc 23	OCTET STRING	6.3.1
id-cmc-popLinkWitnessV2		id-cmc 33	OCTET STRING	6.3.1.1
id-cmc-confirmCertAcceptance		id-cmc 24	CMCCertId	6.14
id-cmc-statusInfoV2		id-cmc 25	CMCStatusInfoV2	6.1.1
id-cmc-trustedAnchors		id-cmc 26	PublishTrustAnchors	6.15
id-cmc-authData		id-cmc 27	AuthPublish	6.16
id-cmc-batchRequests		id-cmc 28	BodyPartList	6.17
id-cmc-batchResponses		id-cmc 29	BodyPartList	6.17
id-cmc-publishCert		id-cmc 30	CMCPublicationInfo	6.18
id-cmc-modCertTemplate		id-cmc 31	ModCertTemplate	6.5.1
id-cmc-controlProcessed		id-cmc 32	ControlsProcessed	6.19
id-cmc-identityProofV2		id-cmc 34	IdentityProofV2	6.2.1

Table 1: CMC Control Attributes

6.1. CMC Status Info Controls

The CMC Status Info controls return information about the status of a client/server request/response. Two controls are described in this section. The Extended CMC Status Info control is the preferred control; the CMC Status Info control is included for backwards compatibility with RFC 2797.

Servers MAY emit multiple CMC status info controls referring to a single body part. Clients MUST be able to deal with multiple CMC status info controls in a PKI Response. Servers MUST use the Extended CMC Status Info control, but MAY additionally use the CMC Status Info control. Clients MUST be able to process the Extended

CMC Status Info control.

6.1.1. Extended CMC Status Info Control

The Extended CMC Status Info control is identified by the OID:

```
id-cmc-statusInfoV2 ::= { id-cmc 25 }
```

The Extended CMC Status Info control has the ASN.1 definition:

```
CMCStatusInfoV2 ::= SEQUENCE {
    cmcStatus          CMCStatus,
    bodyList           SEQUENCE SIZE (1..MAX) OF BodyPartReference,
    statusString       UTF8String OPTIONAL,
    otherInfo          OtherStatusInfo OPTIONAL
}

OtherStatusInfo ::= CHOICE {
    failInfo           CMCFailInfo,
    pendInfo           PendInfo,
    extendedFailInfo   ExtendedFailInfo
}

PendInfo ::= SEQUENCE {
    pendToken          OCTET STRING,
    pendTime           GeneralizedTime
}

ExtendedFailInfo ::= SEQUENCE {
    failInfoOID        OBJECT IDENTIFIER,
    failInfoValue      ANY DEFINED BY failInfoOID
}
```

```
BodyPartReference ::= CHOICE {  
    bodyPartID          BodyPartID,  
    bodyPartPath       BodyPartPath  
}
```

The fields in CMCStatusInfoV2 have the following meaning:

cmcStatus contains the returned status value. Details are in Section 6.1.3.

bodyList identifies the controls or other elements to which the status value applies. If an error is returned for a Simple PKI Request, this field is the bodyPartID choice of BodyPartReference with the single integer of value 1.

statusString contains additional description information. This string is human readable.

otherInfo contains additional information that expands on the CMC status code returned in the cmcStatus field.

The fields in OtherStatusInfo have the following meaning:

failInfo is described in Section 6.1.4. It provides an error code that details what failure occurred. This choice is present only if cmcStatus contains the value failed.

pendInfo contains information about when and how the client should request the result of this request. It is present when the cmcStatus is either pending or partial. pendInfo uses the structure PendInfo, which has the fields:

pendToken is the token used in the Query Pending control (Section 6.13).

pendTime contains the suggested time the server wants to be queried about the status of the certification request.

extendedFailInfo includes application-dependent detailed error information. This choice is present only if cmcStatus contains the value failed. Caution should be used when defining new values as they may not be correctly recognized by all clients and servers. The CMCFailInfo value of internalCAError may be assumed if the extended error is not recognized. This field uses the type ExtendedFailInfo. ExtendedFailInfo has the fields:

failInfoOID contains an OID that is associated with a set of extended error values.

failInfoValue contains an extended error code from the defined set of extended error codes.

If the cMCStatus field is success, the Extended CMC Status Info control MAY be omitted unless it is the only item in the response.

6.1.2. CMC Status Info Control

The CMC Status Info control is identified by the OID:

```
id-cmc-statusInfo ::= { id-cmc 1 }
```

The CMC Status Info control has the ASN.1 definition:

```
CMCStatusInfo ::= SEQUENCE {
    cMCStatus          CMCStatus,
    bodyList           BodyPartList,
    statusString       UTF8String OPTIONAL,
    otherInfo          CHOICE {
        failInfo       CMCFailInfo,
        pendInfo       PendInfo } OPTIONAL
}
```

The fields in CMCStatusInfo have the following meaning:

cMCStatus contains the returned status value. Details are in Section 6.1.3.

bodyList contains the list of controls or other elements to which the status value applies. If an error is being returned for a Simple PKI Request, this field contains a single integer of value 1.

statusString contains additional description information. This string is human readable.

otherInfo provides additional information that expands on the CMC status code returned in the cMCStatus field.

failInfo is described in Section 6.1.4. It provides an error code that details what failure occurred. This choice is present only if cMCStatus is failed.

pendInfo uses the PendInfo ASN.1 structure in Section 6.1.1. It contains information about when and how the client should request results of this request. The pendInfo field MUST be populated for a cMCStatus value of pending or partial. Further

details can be found in Section 6.1.1 (Extended CMC Status Info Control) and Section 6.13 (Query Pending Control).

If the `CMCStatus` field is `success`, the CMC Status Info control MAY be omitted unless it is the only item in the response. If no status exists for a Simple or Full PKI Request, then the value of `success` is assumed.

6.1.3. CMCStatus Values

`CMCStatus` is a field in the Extended CMC Status Info and CMC Status Info controls. This field contains a code representing the success or failure of a specific operation. `CMCStatus` has the ASN.1 structure:

```
CMCStatus ::= INTEGER {
    success          (0),
    -- reserved     (1),
    failed           (2),
    pending          (3),
    noSupport        (4),
    confirmRequired (5),
    popRequired      (6),
    partial          (7)
}
```

The values of `CMCStatus` have the following meaning:

`success` indicates the request was granted or the action was completed.

`failed` indicates the request was not granted or the action was not completed. More information is included elsewhere in the response.

`pending` indicates the PKI Request has yet to be processed. The requester is responsible to poll back on this Full PKI request. `pending` may only be returned for certification request operations.

`noSupport` indicates the requested operation is not supported.

`confirmRequired` indicates a Confirm Certificate Acceptance control (Section 6.14) must be returned before the certificate can be used.

`popRequired` indicates a direct POP operation is required (Section 6.3.1.3).

partial indicates a partial PKI Response is returned. The requester is responsible to poll back for the unfulfilled portions of the Full PKI Request.

6.1.4. CMCFailInfo

CMCFailInfo is a field in the Extended CMC Status Info and CMC Status Info controls. CMCFailInfo conveys more detailed information relevant to the interpretation of a failure condition. The CMCFailInfo has the following ASN.1 structure:

```
CMCFailInfo ::= INTEGER {
    badAlg          (0),
    badMessageCheck (1),
    badRequest      (2),
    badTime         (3),
    badCertId       (4),
    unsupportedExt   (5),
    mustArchiveKeys (6),
    badIdentity     (7),
    popRequired     (8),
    popFailed       (9),
    noKeyReuse      (10),
    internalCAError (11),
    tryLater        (12),
    authDataFail    (13)
}
```

The values of CMCFailInfo have the following meanings:

badAlg indicates unrecognized or unsupported algorithm.

badMessageCheck indicates integrity check failed.

badRequest indicates transaction was not permitted or supported.

badTime indicates message time field was not sufficiently close to the system time.

badCertId indicates no certificate could be identified matching the provided criteria.

unsupportedExt indicates a requested X.509 extension is not supported by the recipient CA.

mustArchiveKeys indicates private key material must be supplied.

badIdentity indicates identification control failed to verify.

popRequired indicates server requires a POP proof before issuing certificate.

popFailed indicates POP processing failed.

noKeyReuse indicates server policy does not allow key reuse.

internalCAError indicates that the CA had an unknown internal failure.

tryLater indicates that the server is not accepting requests at this time and the client should try at a later time.

authDataFail indicates failure occurred during processing of authenticated data.

If additional failure reasons are needed, they SHOULD use the ExtendedFailureInfo item in the Extended CMC Status Info control. However, for closed environments they can be defined using this type. Such codes MUST be in the range from 1000 to 1999.

6.2. Identification and Identity Proof Controls

Some CAs and RAs require that a proof-of-identity be included in a certification request. Many different ways of doing this exist with different degrees of security and reliability. Most are familiar with a bank's request to provide your mother's maiden name as a form of identity proof. The reasoning behind requiring a proof-of-identity can be found in Appendix C of [CRMF].

CMC provides a method to prove the client's identity based on a client/server shared-secret. If clients support the Full PKI Request, clients MUST implement this method of identity proof (Section 6.2.2). Servers MUST provide this method, but MAY additionally support bilateral methods of similar strength.

This document also provides an Identification control (Section 6.2.3). This control is a simple method to allow a client to state who they are to the server. Generally, a shared-secret AND an identifier of that shared-secret are passed from the server to the client. The identifier is placed in the Identification control, and the shared-secret is used to compute the Identity Proof control.

6.2.1. Identity Proof Version 2 Control

The Identity Proof Version 2 control is identified by the OID:

```
id-cmc-identityProofV2 ::= { id-cmc 34 }
```

The Identity Proof Version 2 control has the ASN.1 definition:

```
IdentifyProofV2 ::= SEQUENCE {
    hashAlgID      AlgorithmIdentifier,
    macAlgID       AlgorithmIdentifier,
    witness        OCTET STRING
}
```

The fields of IdentityProofV2 have the following meaning:

hashAlgID is the identifier and parameters for the hash algorithm used to convert the shared-secret into a key for the MAC algorithm.

macAlgID is the identifier and the parameters for the message authentication code algorithm used to compute the value of the witness field.

witness is the identity proof.

The required method starts with an out-of-band transfer of a token (the shared-secret). The shared-secret should be generated in a random manner. The distribution of this token is beyond the scope of this document. The client then uses this token for an identity proof as follows:

1. The PKIData reqSequence field (encoded exactly as it appears in the Full PKI Request including the sequence type and length) is the value to be validated.
2. A hash of the shared-secret as a UTF8 string is computed using hashAlgID.
3. A MAC is then computed using the value produced in Step 1 as the message and the value from Step 2 as the key.
4. The result from Step 3 is then encoded as the witness value in the Identity Proof Version 2 control.

When the server verifies the Identity Proof Version 2 control, it computes the MAC value in the same way and compares it to the witness value contained in the PKI Request.

If a server fails the verification of an Identity Proof Version 2 control, the CMCFailInfo value MUST be present in the Full PKI Response and MUST have a value of badIdentity.

Reuse of the shared-secret on certification request retries allows the client and server to maintain the same view of acceptable identity proof values. However, reuse of the shared-secret can potentially open the door for some types of attacks.

Implementations MUST be able to support tokens at least 16 characters long. Guidance on the amount of entropy actually obtained from a given length token based on character sets can be found in Appendix A of [PASSWORD].

6.2.2. Identity Proof Control

The Identity Proof control is identified by the OID:

```
id-cmc-identityProof ::= { id-cmc 3 }
```

The Identity Proof control has the ASN.1 definition:

```
IdentifyProof ::= OCTET STRING
```

This control is processed in the same way as the Identity Proof Version 2 control. In this case, the hash algorithm is fixed to SHA-1 and the MAC algorithm is fixed to HMAC-SHA1.

6.2.3. Identification Control

Optionally, servers MAY require the inclusion of the unprotected Identification control with an Identification Proof control. The Identification control is intended to contain a text string that assists the server in locating the shared-secret needed to validate the contents of the Identity Proof control. If the Identification control is included in the Full PKI Request, the derivation of the key in Step 2 (from Section 6.2.1) is altered so that the hash of the concatenation of the shared-secret and the UTF8 identity value (without the type and length bytes) are hashed rather than just the shared-secret.

The Identification control is identified by the OID:

```
id-cmc-identification ::= { id-cmc 2 }
```

The Identification control has the ASN.1 definition:

```
Identification ::= UTF8String
```

6.2.4. Hardware Shared-Secret Token Generation

The shared-secret between the EE and the server is sometimes computed using a hardware device that generates a series of tokens. The EE can therefore prove its identity by transferring this token in plain text along with a name string. The above protocol can be used with a hardware shared-secret token generation device by the following modifications:

1. The Identification control MUST be included and MUST contain the hardware-generated token.
2. The shared-secret value used above is the same hardware-generated token.
3. All certification requests MUST have a subject name, and the subject name MUST contain the fields required to identify the holder of the hardware token device.
4. The entire certification request MUST be shrouded in some fashion to prevent eavesdropping. Although the token is time critical, an active eavesdropper cannot be permitted to extract the token and submit a different certification request with the same token value.

6.3. Linking Identity and POP Information

In a Full PKI Request, identity information about the client is carried in the signature of the SignedData containing all of the certification requests. Proof-of-possession information for key pairs, however, is carried separately for each PKCS #10 or CRMF certification request. (For keys capable of generating a digital signature, the POP is provided by the signature on the PKCS #10 or CRMF request. For encryption-only keys, the controls described in Section 6.7 are used.) In order to prevent substitution-style attacks, the protocol must guarantee that the same entity generated both the POP and proof-of-identity information.

This section describes two mechanisms for linking identity and POP information: witness values cryptographically derived from the shared-secret (Section 6.3.1.3) and shared-secret/subject distinguished name (DN) matching (Section 6.3.2). Clients and servers MUST support the witness value technique. Clients and servers MAY support shared-secret/subject DN matching or other bilateral techniques of similar strength. The idea behind both mechanisms is to force the client to sign some data into each certification request that can be directly associated with the

shared-secret; this will defeat attempts to include certification requests from different entities in a single Full PKI Request.

6.3.1. Cryptographic Linkage

The first technique that links identity and POP information forces the client to include a piece of information cryptographically derived from the shared-secret as a signed extension within each certification request (PKCS #10 or CRMF).

6.3.1.1. POP Link Witness Version 2 Controls

The POP Link Witness Version 2 control is identified by the OID:

```
id-cmc-popLinkWitnessV2 ::= { id-cmc 33 }
```

The POP Link Witness Version 2 control has the ASN.1 definition:

```
PopLinkWitnessV2 ::= SEQUENCE {  
    keyGenAlgorithm  AlgorithmIdentifier,  
    macAlgorithm     AlgorithmIdentifier,  
    witness          OCTET STRING  
}
```

The fields of PopLinkWitnessV2 have the following meanings:

`keyGenAlgorithm` contains the algorithm used to generate the key for the MAC algorithm. This will generally be a hash algorithm, but could be a more complex algorithm.

`macAlgorithm` contains the algorithm used to create the witness value.

`witness` contains the computed witness value.

This technique is useful if null subject DNs are used (because, for example, the server can generate the subject DN for the certificate based only on the shared-secret). Processing begins when the client receives the shared-secret out-of-band from the server. The client then computes the following values:

1. The client generates a random byte-string, R, which SHOULD be at least 512 bits in length.
2. The key is computed from the shared-secret using the algorithm in `keyGenAlgorithm`.

3. A MAC is then computed over the random value produced in Step 1, using the key computed in Step 2.
4. The random value produced in Step 1 is encoded as the value of a POP Link Random control. This control MUST be included in the Full PKI Request.
5. The MAC value produced in Step 3 is placed in either the POP Link Witness control or the witness field of the POP Link Witness V2 control.
 - * For CRMF, the POP Link Witness/POP Link Witness V2 control is included in the controls field of the CertRequest structure.
 - * For PKCS #10, the POP Link Witness/POP Link Witness V2 control is included in the attributes field of the CertificationRequestInfo structure.

Upon receipt, servers MUST verify that each certification request contains a copy of the POP Link Witness/POP Link Witness V2 control and that its value was derived using the above method from the shared-secret and the random string included in the POP Link Random control.

The Identification control (see Section 6.2.3) or the subject DN of a certification request can be used to help identify which shared-secret was used.

6.3.1.2. POP Link Witness Control

The POP Link Witness control is identified by the OID:

```
id-cmc-popLinkWitness ::= { id-cmc 23 }
```

The POP Link Witness control has the ASN.1 definition:

```
PopLinkWitness ::= OCTET STRING
```

For this control, SHA-1 is used as the key generation algorithm. HMAC-SHA1 is used as the mac algorithm.

6.3.1.3. POP Link Random Control

The POP Link Random control is identified by the OID:

```
id-cmc-popLinkRandom ::= { id-cmc 22 }
```

The POP Link Random control has the ASN.1 definition:

```
PopLinkRandom ::= OCTET STRING
```

6.3.2. Shared-Secret/Subject DN Linking

The second technique to link identity and POP information is to link a particular subject distinguished name (subject DN) to the shared-secrets that are distributed out-of-band and to require that clients using the shared-secret to prove identity include that exact subject DN in every certification request. It is expected that many client-server connections that use shared-secret-based proof-of-identity will use this mechanism. (It is common not to omit the subject DN information from the certification request.)

When the shared-secret is generated and transferred out-of-band to initiate the registration process (Section 6.2), a particular subject DN is also associated with the shared-secret and communicated to the client. (The subject DN generated MUST be unique per entity in accordance with the CA policy; a null subject DN cannot be used. A common practice could be to place the identification value as part of the subject DN.) When the client generates the Full PKI Request, it MUST use these two pieces of information as follows:

1. The client MUST include the specific subject DN that it received along with the shared-secret as the subject name in every certification request (PKCS #10 and/or CRMF) in the Full PKI Request. The subject names in the certification requests MUST NOT be null.
2. The client MUST include an Identity Proof control (Section 6.2.2) or Identity Proof Version 2 control (Section 6.2.1), derived from the shared-secret, in the Full PKI Request.

The server receiving this message MUST (a) validate the Identity Proof control and then, (b) check that the subject DN included in each certification request matches that associated with the shared-secret. If either of these checks fails, the certification request MUST be rejected.

6.3.3. Renewal and Rekey Messages

When doing a renewal or rekey certification request, linking identity and POP information is simple. The client copies the subject DN for a current signing certificate into the subject name field of each certification request that is made. The POP for each certification request will now cover that information. The outermost signature layer is created using the current signing certificate, which allows

the original identity to be associated with the certification request. Since the name in the current signing certificate and the names in the certification requests match, the necessary linking has been achieved.

6.4. Data Return Control

The Data Return control allows clients to send arbitrary data (usually some type of internal state information) to the server and to have the data returned as part of the Full PKI Response. Data placed in a Data Return control is considered to be opaque to the server. The same control is used for both Full PKI Requests and Responses. If the Data Return control appears in a Full PKI Request, the server MUST return it as part of the PKI Response.

In the event that the information in the Data Return control needs to be confidential, it is expected that the client would apply some type of encryption to the contained data, but the details of this are outside the scope of this specification.

The Data Return control is identified by the OID:

```
id-cmc-dataReturn ::= { id-cmc 4 }
```

The Data Return control has the ASN.1 definition:

```
DataReturn ::= OCTET STRING
```

A client could use this control to place an identifier marking the exact source of the private key material. This might be the identifier of a hardware device containing the private key.

6.5. RA Certificate Modification Controls

These controls exist for RAs to be able to modify the contents of a certification request. Modifications might be necessary for various reasons. These include addition of certificate extensions or modification of subject and/or subject alternative names.

Two controls exist for this purpose. The first control, Modify Certification Request (Section 6.5.1), allows the RA to replace or remove any field in the certificate. The second control, Add Extensions (Section 6.5.2), only allows for the addition of extensions.

6.5.1. Modify Certification Request Control

The Modify Certification Request control is used by RAs to change fields in a requested certificate.

The Modify Certification Request control is identified by the OID:

```
id-cmc-modCertTemplate ::= { id-cmc 31 }
```

The Modify Certification Request has the ASN.1 definition:

```
ModCertTemplate ::= SEQUENCE {  
    pkiDataReference      BodyPartPath,  
    certReferences        BodyPartList,  
    replace                BOOLEAN DEFAULT TRUE,  
    certTemplate          CertTemplate  
}
```

The fields in ModCertTemplate have the following meaning:

`pkiDataReference` is the path to the PKI Request containing certification request(s) to be modified.

`certReferences` refers to one or more certification requests in the PKI Request referenced by `pkiDataReference` to be modified. Each `BodyPartID` of the `certReferences` sequence MUST be equal to either the `bodyPartID` of a `TaggedCertificationRequest` (PKCS #10) or the `certReqId` of the `CertRequest` within a `CertReqMsg` (CRMF). By definition, the certificate extensions included in the `certTemplate` field are applied to every certification request referenced in the `certReferences` sequence. If a request corresponding to `bodyPartID` cannot be found, the `CMCFailInfo` with a value of `badRequest` is returned that references this control.

`replace` specifies if the target certification request is to be modified by replacing or deleting fields. If the value is `TRUE`, the data in this control replaces the data in the target certification request. If the value is `FALSE`, the data in the target certification request is deleted. The action is slightly different for the extensions field of `certTemplate`; each extension is treated individually rather than as a single unit.

`certTemplate` is a certificate template object [CRMF]. If a field is present and `replace` is `TRUE`, it replaces that field in the certification request. If the field is present and `replace` is `FALSE`, the field in the certification request is removed. If the field is absent, no action is performed. Each extension is treated as a single field.

Servers MUST be able to process all extensions defined, but not prohibited, in [PKIXCERT]. Servers are not required to be able to process every X.509v3 extension transmitted using this protocol, nor are they required to be able to process other, private extensions. Servers are not required to put all RA-requested extensions into a certificate. Servers are permitted to modify RA-requested extensions. Servers MUST NOT alter an extension so as to reverse the meaning of a client-requested extension. If a certification request is denied due to the inability to handle a requested extension and a Full PKI Response is returned, the server MUST return a CMCFailInfo value with the value of unsupportedExt.

If a certification request is the target of multiple Modify Certification Request controls, the behavior is:

- o If control A exists in a layer that contains the layer of control B, control A MUST override control B. In other words, controls should be applied from the innermost layer to the outermost layer.
- o If control A and control B are in the same PKIData (i.e., the same wrapping layer), the order of application is non-determinate.

The same order of application is used if a certification request is the target of both a Modify Certification Request control and an Add Extensions control.

6.5.2. Add Extensions Control

The Add Extensions control has been deprecated in favor of the Modify Certification Request control. It was replaced so that fields in the certification request other than extensions could be modified.

The Add Extensions control is used by RAs to specify additional extensions that are to be included in certificates.

The Add Extensions control is identified by the OID:

```
id-cmc-addExtensions ::= { id-cmc 8 }
```

The Add Extensions control has the ASN.1 definition:

```
AddExtensions ::= SEQUENCE {
    pkiDataReference      BodyPartID,
    certReferences        SEQUENCE OF BodyPartID,
    extensions            SEQUENCE OF Extension
}
```

The fields in AddExtensions have the following meaning:

`pkiDataReference` contains the body part identity of the embedded certification request.

`certReferences` is a list of references to one or more of the certification requests contained within a PKIData. Each body part identifier of the `certReferences` sequence MUST be equal to either the `bodyPartID` of a `TaggedCertificationRequest` (PKCS #10) or the `certReqId` of the `CertRequest` within a `CertReqMsg` (CRMF). By definition, the listed extensions are to be applied to every certification request referenced in the `certReferences` sequence. If a certification request corresponding to `bodyPartID` cannot be found, the `CMCFailInfo` with a value of `badRequest` is returned referencing this control.

`extensions` is a sequence of extensions to be applied to the referenced certification requests.

Servers MUST be able to process all extensions defined, but not prohibited, in [PKIXCERT]. Servers are not required to be able to process every X.509v3 extension transmitted using this protocol, nor are they required to be able to process other, private extensions. Servers are not required to put all RA-requested extensions into a certificate. Servers are permitted to modify RA-requested extensions. Servers MUST NOT alter an extension so as to reverse the meaning of a client-requested extension. If a certification request is denied due to the inability to handle a requested extension and a response is returned, the server MUST return a `CMCFailInfo` with the value of `unsupportedExt`.

If multiple Add Extensions controls exist in a Full PKI Request, the exact behavior is left up to the CA policy. However, it is recommended that the following policy be used. These rules would be applied to individual extensions within an Add Extensions control (as opposed to an "all or nothing" approach).

1. If the conflict is within a single PKIData, the certification request would be rejected with a `CMCFailInfo` value of `badRequest`.
2. If the conflict is between different PKIData, the outermost version of the extension would be used (allowing an RA to override the requested extension).

6.6. Transaction Identifier Control and Sender and Recipient Nonce Controls

Transactions are identified and tracked with a transaction identifier. If used, clients generate transaction identifiers and retain their value until the server responds with a Full PKI Response that completes the transaction. Servers correspondingly include received transaction identifiers in the Full PKI Response.

The Transaction Identifier control is identified by the OID:

```
id-cmc-transactionId ::= { id-cmc 5 }
```

The Transaction Identifier control has the ASN.1 definition:

```
TransactionId ::= INTEGER
```

The Transaction Identifier control identifies a given transaction. It is used by client and server to manage the state of an operation. Clients MAY include a Transaction Identifier control in a request. If the original request contains a Transaction Identifier control, all subsequent requests and responses MUST include the same Transaction Identifier control.

Replay protection is supported through the use of the Sender and Recipient Nonce controls. If nonces are used, in the first message of a transaction, a Recipient Nonce control is not transmitted; a Sender Nonce control is included by the transaction originator and retained for later reference. The recipient of a Sender Nonce control reflects this value back to the originator as a Recipient Nonce control and includes its own Sender Nonce control. Upon receipt by the transaction originator of this response, the transaction originator compares the value of Recipient Nonce control to its retained value. If the values match, the message can be accepted for further security processing. The received value for a Sender Nonce control is also retained for inclusion in the next message associated with the same transaction.

The Sender Nonce and Recipient Nonce controls are identified by the OIDs:

```
id-cmc-senderNonce ::= { id-cmc 6 }  
id-cmc-recipientNonce ::= { id-cmc 7 }
```

The Sender Nonce control has the ASN.1 definition:

```
SenderNonce ::= OCTET STRING
```

The Recipient Nonce control has the ASN.1 definition:

```
RecipientNonce ::= OCTET STRING
```

Clients MAY include a Sender Nonce control in the initial PKI Request. If a message includes a Sender Nonce control, the response MUST include the transmitted value of the previously received Sender Nonce control as a Recipient Nonce control and include a new value as its Sender Nonce control.

6.7. Encrypted and Decrypted POP Controls

Servers MAY require that this POP method be used only if another POP method is unavailable. Servers SHOULD reject all certification requests contained within a PKIData if any required POP is missing for any element within the PKIData.

Many servers require proof that the entity that generated the certification request actually possesses the corresponding private component of the key pair. For keys that can be used as signature keys, signing the certification request with the private key serves as a POP on that key pair. With keys that can only be used for encryption operations, POP MUST be performed by forcing the client to decrypt a value. See Section 5 of [CRMF] for a detailed discussion of POP.

By necessity, POP for encryption-only keys cannot be done in one round-trip, since there are four distinct steps:

1. Client tells the server about the public component of a new encryption key pair.
2. Server sends the client a POP challenge, encrypted with the presented public encryption key.
3. Client decrypts the POP challenge using the private key that corresponds to the presented public key and sends the plaintext back to the server.
4. Server validates the decrypted POP challenge and continues processing the certification request.

CMC defines two different controls. The first deals with the encrypted challenge sent from the server to the user in Step 2. The second deals with the decrypted challenge sent from the client to the server in Step 3.

The Encrypted POP control is used to send the encrypted challenge from the server to the client as part of the PKIResponse. (Note that it is assumed that the message sent in Step 1 above is a Full PKI Request and that the response in Step 2 is a Full PKI Response including a CMCFailInfo specifying that a POP is explicitly required, and providing the POP challenge in the encryptedPOP control.)

The Encrypted POP control is identified by the OID:

```
id-cmc-encryptedPOP ::= { id-cmc 9 }
```

The Encrypted POP control has the ASN.1 definition:

```
EncryptedPOP ::= SEQUENCE {
    request      TaggedRequest,
    cms          ContentInfo,
    thePOPAlgID  AlgorithmIdentifier,
    witnessAlgID AlgorithmIdentifier,
    witness      OCTET STRING
}
```

The Decrypted POP control is identified by the OID:

```
id-cmc-decryptedPOP ::= { id-cmc 10 }
```

The Decrypted POP control has the ASN.1 definition:

```
DecryptedPOP ::= SEQUENCE {
    bodyPartID  BodyPartID,
    thePOPAlgID AlgorithmIdentifier,
    thePOP      OCTET STRING
}
```

The encrypted POP algorithm works as follows:

1. The server randomly generates the POP Proof Value and associates it with the request.
2. The server returns the Encrypted POP control with the following fields set:

request is the original certification request (it is included here so the client need not keep a copy of the request).

cms is an EnvelopedData, the encapsulated content type being id-data and the content being the POP Proof Value; this value needs to be long enough that one cannot reverse the value from the witness hash. If the certification request contains a

Subject Key Identifier (SKI) extension, then the recipient identifier SHOULD be the SKI. If the issuerAndSerialNumber form is used, the IssuerName MUST be encoded as NULL and the SerialNumber as the bodyPartID of the certification request.

thePOPAlgID identifies the algorithm to be used in computing the return POP value.

witnessAlgID identifies the hash algorithm used on the POP Proof Value to create the field witness.

witness is the hashed value of the POP Proof Value.

3. The client decrypts the cms field to obtain the POP Proof Value. The client computes H(POP Proof Value) using the witnessAlgID and compares to the value of witness. If the values do not compare or the decryption is not successful, the client MUST abort the enrollment process. The client aborts the process by sending a request containing a CMC Status Info control with CMCFailInfo value of popFailed.
4. The client creates the Decrypted POP control as part of a new PKIData. The fields in the DecryptedPOP are:

bodyPartID refers to the certification request in the new PKI Request.

thePOPAlgID is copied from the encryptedPOP.

thePOP contains the possession proof. This value is computed by thePOPAlgID using the POP Proof Value and the request.

5. The server then re-computes the value of thePOP from its cached value and the request and compares to the value of thePOP. If the values do not match, the server MUST NOT issue the certificate. The server MAY re-issue a new challenge or MAY fail the request altogether.

When defining the algorithms for thePOPAlgID and witnessAlgID, care must be taken to ensure that the result of witnessAlgID is not a useful value to shortcut the computation with thePOPAlgID. The POP Proof Value is used as the secret value in the HMAC algorithm and the request is used as the data. If the POP Proof Value is greater than 64 bytes, only the first 64 bytes of the POP Proof Value is used as the secret.

One potential problem with the algorithm above is the amount of state that a CA needs to keep in order to verify the returned POP value. The following describes one of many possible ways of addressing the problem by reducing the amount of state kept on the CA to a single (or small set) of values.

1. Server generates random seed x , constant across all requests. (The value of x would normally be altered on a regular basis and kept for a short time afterwards.)
2. For certification request R , server computes $y = F(x,R)$. F can be, for example, $\text{HMAC-SHA1}(x,R)$. All that's important for statelessness is that y be consistently computable with only known state constant x and function F , other inputs coming from the certification request structure. y should not be predictable based on knowledge of R , thus the use of a one-way function like HMAC-SHA1 .

6.8. RA POP Witness Control

In a certification request scenario that involves an RA, the CA may allow (or require) that the RA perform the POP protocol with the entity that generated the certification request. In this case, the RA needs a way to inform the CA that it has done the POP. The RA POP Witness control addresses this issue.

The RA POP Witness control is identified by the OID:

```
id-cmc-lraPOPWitness ::= { id-cmc 11 }
```

The RA POP Witness control has the ASN.1 definition:

```
LraPopWitness ::= SEQUENCE {
    pkiDataBodyid  BodyPartID,
    bodyIds        SEQUENCE of BodyPartID
}
```

The fields in LraPOPWitness have the following meaning:

`pkiDataBodyid` contains the body part identifier of the nested `TaggedContentInfo` containing the client's Full PKI Request. `pkiDataBodyid` is set to 0 if the request is in the current `PKIData`.

`bodyIds` is a list of certification requests for which the RA has performed an out-of-band authentication. The method of authentication could be archival of private key material, challenge-response, or other means.

If a certification server does not allow an RA to do the POP verification, it returns a CMCFailInfo with the value of popFailed. The CA MUST NOT start a challenge-response to re-verify the POP itself.

6.9. Get Certificate Control

Everything described in this section is optional to implement.

The Get Certificate control is used to retrieve a previously issued certificate from a certificate repository. A CA, an RA, or an independent service may provide this repository. The clients expected to use this facility are those where a fully deployed directory is either infeasible or undesirable.

The Get Certificate control is identified by the OID:

```
id-cmc-getCert ::= { id-cmc 15 }
```

The Get Certificate control has the ASN.1 definition:

```
GetCert ::= SEQUENCE {  
    issuerName      GeneralName,  
    serialNumber    INTEGER }
```

The fields in GetCert have the following meaning:

issuerName is the name of the certificate issuer.

serialNumber identifies the certificate to be retrieved.

The server that responds to this request places the requested certificate in the certificates field of a SignedData. If the Get Certificate control is the only control in a Full PKI Request, the response should be a Simple PKI Response.

6.10. Get CRL Control

Everything described in this section is optional to implement.

The Get CRL control is used to retrieve CRLs from a repository of CRLs. A CA, an RA, or an independent service may provide this repository. The clients expected to use this facility are those where a fully deployed directory is either infeasible or undesirable.

The Get CRL control is identified by the OID:

```
id-cmc-getCRL ::= { id-cmc 16 }
```

The Get CRL control has the ASN.1 definition:

```
GetCRL ::= SEQUENCE {
    issuerName      Name,
    cRLName         GeneralName OPTIONAL,
    time            GeneralizedTime OPTIONAL,
    reasons         ReasonFlags OPTIONAL }
```

The fields in a GetCRL have the following meanings:

issuerName is the name of the CRL issuer.

cRLName may be the value of CRLDistributionPoints in the subject certificate or equivalent value in the event the certificate does not contain such a value.

time is used by the client to specify from among potentially several issues of CRL that one whose thisUpdate value is less than but nearest to the specified time. In the absence of a time component, the CA always returns with the most recent CRL.

reasons is used to specify from among CRLs partitioned by revocation reason. Implementers should bear in mind that while a specific revocation request has a single CRLReason code -- and consequently entries in the CRL would have a single CRLReason code value -- a single CRL can aggregate information for one or more reasonFlags.

A server responding to this request places the requested CRL in the crls field of a SignedData. If the Get CRL control is the only control in a Full PKI Request, the response should be a Simple PKI Response.

6.11. Revocation Request Control

The Revocation Request control is used to request that a certificate be revoked.

The Revocation Request control is identified by the OID:

```
id-cmc-revokeRequest ::= { id-cmc 17 }
```

The Revocation Request control has the ASN.1 definition:

```
RevokeRequest ::= SEQUENCE {
    issuerName      Name,
    serialNumber    INTEGER,
    reason          CRLReason,
    invalidityDate  GeneralizedTime OPTIONAL,
    sharedSecret    OCTET STRING OPTIONAL,
    comment         UTF8string OPTIONAL }
```

The fields of RevokeRequest have the following meaning:

issuerName is the issuerName of the certificate to be revoked.

serialNumber is the serial number of the certificate to be revoked.

reason is the suggested CRLReason code for why the certificate is being revoked. The CA can use this value at its discretion in building the CRL.

invalidityDate is the suggested value for the Invalidity Date CRL Extension. The CA can use this value at its discretion in building the CRL.

sharedSecret is a secret value registered by the EE when the certificate was obtained to allow for revocation of a certificate in the event of key loss.

comment is a human-readable comment.

For a revocation request to be reliable in the event of a dispute, a strong proof-of-origin is required. However, in the instance when an EE has lost use of its signature private key, it is impossible for the EE to produce a digital signature (prior to the certification of a new signature key pair). The Revoke Request control allows the EE to send the CA a shared-secret that may be used as an alternative authenticator in the instance of loss of use of the EE's signature private key. The acceptability of this practice is a matter of local security policy.

It is possible to sign the revocation for the lost certificate with a different certificate in some circumstances. A client can sign a revocation for an encryption key with a signing certificate if the name information matches. Similarly, an administrator or RA can be assigned the ability to revoke the certificate of a third party. Acceptance of the revocation by the server depends on local policy in these cases.

Clients MUST provide the capability to produce a digitally signed Revocation Request control. Clients SHOULD be capable of producing an unsigned Revocation Request control containing the EE shared-secret (the unsigned message consisting of a SignedData with no signatures). If a client provides shared-secret-based self-revocation, the client MUST be capable of producing a Revocation Request control containing the shared-secret. Servers MUST be capable of accepting both forms of revocation requests.

The structure of an unsigned, shared-secret-based revocation request is a matter of local implementation. The shared-secret does not need to be encrypted when sent in a Revocation Request control. The shared-secret has a one-time use (i.e., it is used to request revocation of the certificate), and public knowledge of the shared-secret after the certificate has been revoked is not a problem. Clients need to inform users that the same shared-secret SHOULD NOT be used for multiple certificates.

A Full PKI Response MUST be returned for a revocation request.

6.12. Registration and Response Information Controls

The Registration Information control allows for clients to pass additional information as part of a Full PKI Request.

The Registration Information control is identified by the OID:

```
id-cmc-regInfo ::= { id-cmc 18 }
```

The Registration Information control has the ASN.1 definition:

```
RegInfo ::= OCTET STRING
```

The content of this data is based on bilateral agreement between the client and server.

The Response Information control allows a server to return additional information as part of a Full PKI Response.

The Response Information control is identified by the OID:

```
id-cmc-responseInfo ::= { id-cmc 19 }
```

The Response Information control has the ASN.1 definition:

```
ResponseInfo ::= OCTET STRING
```

The content of this data is based on bilateral agreement between the client and server.

6.13. Query Pending Control

In some environments, process requirements for manual intervention or other identity checks can delay the return of the certificate. The Query Pending control allows clients to query a server about the state of a pending certification request. The server returns a `pendToken` as part of the Extended CMC Status Info and the CMC Status Info controls (in the `otherInfo` field). The client copies the `pendToken` into the Query Pending control to identify the correct certification request to the server. The server returns a suggested time for the client to query for the state of a pending certification request.

The Query Pending control is identified by the OID:

```
id-cmc-queryPending ::= { id-cmc 21 }
```

The Query Pending control has the ASN.1 definition:

```
QueryPending ::= OCTET STRING
```

If a server returns a pending or partial `CMCStatusInfo` (the transaction is still pending), the `otherInfo` MAY be omitted. If the `otherInfo` is not omitted, the value of `'pendInfo'` MUST be the same as the original `pendInfo` value.

6.14. Confirm Certificate Acceptance Control

Some CAs require that clients give a positive confirmation that the certificates issued to the EE are acceptable. The Confirm Certificate Acceptance control is used for that purpose. If the CMC Status Info on a PKI Response is `confirmRequired`, then the client MUST return a Confirm Certificate Acceptance control contained in a Full PKI Request.

Clients SHOULD wait for the PKI Response from the server that the confirmation has been received before using the certificate for any purpose.

The Confirm Certificate Acceptance control is identified by the OID:

```
id-cmc-confirmCertAcceptance ::= { id-cmc 24 }
```

The Confirm Certificate Acceptance control has the ASN.1 definition:

```
CMCCertId ::= IssuerAndSerialNumber
```

CMCCertId contains the issuer and serial number of the certificate being accepted.

Servers MUST return a Full PKI Response for a Confirm Certificate Acceptance control.

Note that if the CA includes this control, there will be two full round-trips of messages.

1. The client sends the certification request to the CA.
2. The CA returns a Full PKI Response with the certificate and this control.
3. The client sends a Full PKI Request to the CA with an Extended CMC Status Info control accepting and a Confirm Certificate Acceptance control or an Extended CMC Status Info control rejecting the certificate.
4. The CA sends a Full PKI Response to the client with an Extended CMC Status Info of success.

6.15. Publish Trust Anchors Control

The Publish Trust Anchors control allows for the distribution of set trust anchors from a central authority to an EE. The same control is also used to update the set of trust anchors. Trust anchors are distributed in the form of certificates. These are expected, but not required, to be self-signed certificates. Information is extracted from these certificates to set the inputs to the certificates validation algorithm in Section 6.1.1 of [PKIXCERT].

The Publish Trust Anchors control is identified by the OID:

```
id-cmc-trustedAnchors ::= { id-cmc 26 }
```

The Publish Trust Anchors control has the ASN.1 definition:

```
PublishTrustAnchors ::= SEQUENCE {  
    seqNumber      INTEGER,  
    hashAlgorithm  AlgorithmIdentifier,  
    anchorHashes   SEQUENCE OF OCTET STRING  
}
```

The fields in PublishTrustAnchors have the following meaning:

seqNumber is an integer indicating the location within a sequence of updates.

hashAlgorithm is the identifier and parameters for the hash algorithm that is used in computing the values of the anchorHashes field. All implementations MUST implement SHA-1 for this field.

anchorHashes are the hashes for the certificates that are to be treated as trust anchors by the client. The actual certificates are transported in the certificate bag of the containing SignedData structure.

While it is recommended that the sender place the certificates that are to be trusted in the PKI Response, it is not required as the certificates should be obtainable using normal discovery techniques.

Prior to accepting the trust anchors changes, a client MUST at least do the following: validate the signature on the PKI Response to a current trusted anchor, check with policy to ensure that the signer is permitted to use the control, validate that the authenticated publish time in the signature is near to the current time, and validate that the sequence number is greater than the previously used one.

In the event that multiple agents publish a set of trust anchors, it is up to local policy to determine how the different trust anchors should be combined. Clients SHOULD be able to handle the update of multiple trust anchors independently.

Note: Clients that handle this control must use extreme care in validating that the operation is permissible. Incorrect handling of this control allows for an attacker to change the set of trust anchors on the client.

6.16. Authenticated Data Control

The Authenticated Data control allows a server to provide data back to the client in an authenticated manner. This control uses the Authenticated Data structure to allow for validation of the data. This control is used where the client has a shared-secret and a secret identifier with the server, but where a trust anchor has not yet been downloaded onto the client so that a signing certificate for the server cannot be validated. The specific case that this control was created for use with is the Publish Trust Anchors control (Section 6.15), but it may be used in other cases as well.

The Authenticated Data control is identified by the OID:

```
id-cmc-authData ::= { id-cmc 27 }
```

The Authenticated Data control has the ASN.1 definition:

```
AuthPublish ::= BodyPartID
```

AuthPublish is a body part identifier that refers to a member of the cmsSequence element for the current PKI Response or PKI Data. The cmsSequence element is AuthenticatedData. The encapsulated content is an id-cct-PKIData. The controls in the controlSequence need to be processed if the authentication succeeds. (One example is the Publish Trust Anchors control in Section 6.15.)

If the authentication operation fails, the CMCFailInfo authDataFail is returned.

6.17. Batch Request and Response Controls

These controls allow for an RA to collect multiple requests together into a single Full PKI Request and forward it to a CA. The server would then process the requests and return the results in a Full PKI Response.

The Batch Request control is identified by the OID:

```
id-cmc-batchRequests ::= {id-cmc 28}
```

The Batch Response control is identified by the OID:

```
id-cmc-batchResponses ::= {id-cmc 29}
```

Both the Batch Request and Batch Response controls have the ASN.1 definition:

```
BodyPartList ::= SEQUENCE of BodyPartID
```

The data associated with these controls is a set of body part identifiers. Each request/response is placed as an individual entry in the cmsSequence of the new PKIData/PKIResponse. The body part identifiers of these entries are then placed in the body part list associated with the control.

When a server processes a Batch Request control, it MAY return the responses in one or more PKI Responses. A CMCStatus value of partial is returned on all but the last PKI Response. The CMCStatus would be success if the Batch Requests control was processed; the responses

are created with their own CMCStatus code. Errors on individual requests are not propagated up to the top level.

When a PKI Response with a CMCStatus value of partial is returned, the Query Pending control (Section 6.13) is used to retrieve additional results. The returned status includes a suggested time after which the client should ask for the additional results.

6.18. Publication Information Control

The Publication Information control allows for modifying publication of already issued certificates, both for publishing and removal from publication. A common usage for this control is to remove an existing certificate from publication during a rekey operation. This control should always be processed after the issuance of new certificates and revocation requests. This control should not be processed if a certificate failed to be issued.

The Publication Information control is identified by the OID:

```
id-cmc-publishCert ::= { id-cmc 30 }
```

The Publication Information control has the ASN.1 definition:

```
CMCPublicationInfo ::= SEQUENCE {
    hashAlg      AlgorithmIdentifier,
    certHashes   SEQUENCE of OCTET STRING,
    pubInfo      PKIPublicationInfo

PKIPublicationInfo ::= SEQUENCE {
    action       INTEGER {
        dontPublish (0),
        pleasePublish (1) },
    pubInfos     SEQUENCE SIZE (1..MAX) OF SinglePubInfo OPTIONAL }

    -- pubInfos MUST NOT be present if action is "dontPublish"
    -- (if action is "pleasePublish" and pubInfos is omitted,
    -- "dontCare" is assumed)

SinglePubInfo ::= SEQUENCE {
    pubMethod    INTEGER {
        dontCare (0),
        x500 (1),
        web (2),
        ldap (3) },
    pubLocation  GeneralName OPTIONAL }
}
```

The fields in CMCPublicationInfo have the following meaning:

hashAlg is the algorithm identifier of the hash algorithm used to compute the values in certHashes.

certHashes are the hashes of the certificates for which publication is to change.

pubInfo is the information where and how the certificates should be published. The fields in pubInfo (taken from [CRMF]) have the following meanings:

action indicates the action the service should take. It has two values:

dontPublish indicates that the PKI should not publish the certificate (this may indicate that the requester intends to publish the certificate him/herself). dontPublish has the added connotation of removing from publication the certificate if it is already published.

pleasePublish indicates that the PKI MAY publish the certificate using whatever means it chooses unless pubInfos is present. Omission of the CMC Publication Info control results in the same behavior.

pubInfos pubInfos indicates how (e.g., X500, Web, IP Address) the PKI SHOULD publish the certificate.

A single certificate SHOULD NOT appear in more than one Publication Information control. The behavior is undefined in the event that it does.

6.19. Control Processed Control

The Control Processed control allows an RA to indicate to subsequent control processors that a specific control has already been processed. This permits an RA in the middle of a processing stream to process a control defined either in a local context or in a subsequent document.

The Control Processed control is identified by the OID:

```
id-cmc-controlProcessed ::= { id-cmc 32 }
```

The Control Processed control has the ASN.1 definition:

```
ControllList ::= SEQUENCE {
    bodyList      SEQUENCE SIZE (1..MAX) OF BodyPartReference
}
```

bodyList is a series of body part identifiers that form a path to each of the controls that were processed by the RA. This control is only needed for those controls that are not part of this standard and thus would cause an error condition of a server attempting to deal with a control not defined in this document. No error status is needed since an error causes the RA to return the request to the client with the error rather than passing the request on to the next server in the processing list.

7. Registration Authorities

This specification permits the use of RAs. An RA sits between the EE and the CA. From the EE's perspective, the RA appears to be the CA, and from the server, the RA appears to be a client. RAs receive the PKI Requests, perform local processing and then forward them onto CAs. Some of the types of local processing that an RA can perform include:

- o Batching multiple PKI Requests together,
- o Performing challenge/response POP proofs,
- o Adding private or standardized certificate extensions to all certification requests,
- o Archiving private key material,
- o Routing requests to different CAs.

When an RA receives a PKI Request, it has three options: it may forward the PKI Request without modification, it may add a new wrapping layer to the PKI Request, or it may remove one or more existing layers and add a new wrapping layer.

When an RA adds a new wrapping layer to a PKI Request, it creates a new PKIData. The new layer contains any controls required (for example, if the RA does the POP proof for an encryption key or the Add Extension control to modify a PKI Request) and the client PKI Request. The client PKI Request is placed in the cmsSequence if it is a Full PKI Request and in the reqSequence if it is a Simple PKI Request. If an RA is batching multiple client PKI Requests together,

then each client PKI Request is placed into the appropriate location in the RA's PKIData object along with all relevant controls.

If multiple RAs are in the path between the EE and the CA, this will lead to multiple wrapping layers on the request.

In processing a PKI Request, an RA MUST NOT alter any certification requests (PKCS #10 or CRMF) as any alteration would invalidate the signature on the certification request and thus the POP for the private key.

An example of how this would look is illustrated by the following figure:

```

SignedData (by RA)
  PKIData
    controlSequence
      RA added control statements
    reqSequence
      Zero or more Simple PKI Requests from clients
    cmsSequence
      Zero or more Full PKI Requests from clients
        SignedData (signed by client)
          PKIData

```

Under some circumstances, an RA is required to remove wrapping layers. The following sections look at the processing required if encryption layers and signing layers need to be removed.

7.1. Encryption Removal

There are two cases that require an RA to remove or change encryption in a PKI Request. In the first case, the encryption was applied for the purposes of protecting the entire PKI Request from unauthorized entities. If the CA does not have a Recipient Info entry in the encryption layer, the RA MUST remove the encryption layer. The RA MAY add a new encryption layer with or without adding a new signing layer.

The second change of encryption that may be required is to change the encryption inside of a signing layer. In this case, the RA MUST remove all signing layers containing the encryption. All control statements MUST be merged according to local policy rules as each signing layer is removed and the resulting merged controls MUST be placed in a new signing layer provided by the RA. If the signing layer provided by the EE needs to also be removed, the RA can also remove this layer.

7.2. Signature Layer Removal

Only two instances exist where an RA should remove a signature layer on a Full PKI Request: if an encryption layer needs to be modified within the request, or if a CA will not accept secondary delegation (i.e., multiple RA signatures). In all other situations, RAs SHOULD NOT remove a signing layer from a PKI Request.

If an RA removes a signing layer from a PKI Request, all control statements MUST be merged according to local policy rules. The resulting merged control statements MUST be placed in a new signing layer provided by the RA.

8. Security Considerations

Mechanisms for thwarting replay attacks may be required in particular implementations of this protocol depending on the operational environment. In cases where the CA maintains significant state information, replay attacks may be detectable without the inclusion of the optional nonce mechanisms. Implementers of this protocol need to carefully consider environmental conditions before choosing whether or not to implement the senderNonce and recipientNonce controls described in Section 6.6. Developers of state-constrained PKI clients are strongly encouraged to incorporate the use of these controls.

Extreme care needs to be taken when archiving a signing key. The holder of the archived key may have the ability to use the key to generate forged signatures. There are however reasons why a signing key should be archived. An archived CA signing key can be recovered in the event of failure to continue to produce CRLs following a disaster.

Due care must be taken prior to archiving keys. Once a key is given to an archiving entity, the archiving entity could use the keys in a way not conducive to the archiving entity. Users should be made especially aware that proper verification is made of the certificate used to encrypt the private key material.

Clients and servers need to do some checks on cryptographic parameters prior to issuing certificates to make sure that weak parameters are not used. A description of the small subgroup attack is provided in [X942]. Methods of avoiding the small subgroup attack can be found in [SMALL-GROUP]. CMC implementations ought to be aware of this attack when doing parameter validations.

When using a shared-secret for authentication purposes, the shared-secret should be generated using good random number techniques [RANDOM]. User selection of the secret allows for dictionary attacks to be mounted.

Extreme care must be used when processing the Publish Trust Anchors control. Incorrect processing can lead to the practice of slamming where an attacker changes the set of trusted anchors in order to weaken security.

One method of controlling the use of the Publish Trust Anchors control is as follows. The client needs to associate with each trust anchor accepted by the client the source of the trust anchor. Additionally, the client should associate with each trust anchor the types of messages for which the trust anchor is valid (i.e., is the trust anchor used for validating S/MIME messages, TLS, or CMC enrollment messages?).

When a new message is received with a Publish Trust Anchors control, the client would accept the set of new trust anchors for specific applications only if the signature validates, the signer of the message has the required policy approval for updating the trust anchors, and local policy also would allow updating the trust anchors.

The CMS AuthenticatedData structure provides message integrity, it does not provide message authentication in all cases. When using MACs in this document the following restrictions need to be observed. All messages should be for a single entity. If two entities are placed in a single message, the entities can generate new messages that have a valid MAC and might be assumed to be from the original message sender. All entities that have access to the shared-secret can generate messages that will have a successful MAC validation. This means that care must be taken to keep this value secret. Whenever possible, the SignedData structure should be used in preference to the AuthenticatedData structure.

9. IANA Considerations

This document defines a number of control objects. These are identified by Object Identifiers (OIDs). The objects are defined from an arc delegated by IANA to the PKIX Working Group. No further action by IANA is necessary for this document or any anticipated updates.

10. Acknowledgments

The authors and the PKIX Working Group are grateful for the participation of Xiaoyi Liu and Jeff Weinstein in helping to author the original versions of this document.

The authors would like to thank Brian LaMacchia for his work in developing and writing up many of the concepts presented in this document. The authors would also like to thank Alex Deacon and Barb Fox for their contributions.

11. References

11.1. Normative References

- [CMS] Housley, R., "Cryptographic Message Syntax (CMS)", RFC 3852, July 2004.
- [CRMF] Schaad, J., "Internet X.509 Certification Request Message Format", RFC 4211, January 2005.
- [DH-POP] Prafullchandra, H. and J. Schaad, "Diffie-Hellman Proof-of-Possession Algorithms", RFC 2875, June 2000.
- [PKCS10] Kaliski, B., "PKCS #10: Certification Request Syntax v1.5", RFC 2314, October 1997.
- Note that this version of PKCS #10 is used for compatibility with the use of 1988 ASN.1 syntax. An effort is currently underway in the PKIX working group to update to use 2003 ASN.1 syntax.
- [PKIXCERT] Housley, R., Ford, W., Polk, W., and D. Solo, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 3280, April 2002.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", RFC 2119, BCP 14, March 1997.

11.2. Informative References

- [CMC-TRANS] Schaad, J. and M. Myers, "Certificate Management over CMS (CMC): Transport Protocols", RFC 5273, June 2008.
- [CMC-COMPL] Schaad, J. and M. Myers, "Certificate Management Messages over CMS (CMC): Compliance Requirements", RFC 5274, June 2008.

- [PASSWORD] Burr, W., Dodson, D., and W. Polk, "Electronic Authentication Guideline", NIST SP 800-63, April 2006.
- [RANDOM] Eastlake, 3rd, D., Schiller, J., and S. Crocker, "Randomness Requirements for Security", BCP 106, RFC 4086, June 2005.
- [SMALL-GROUP] Zuccherato, R., "Methods for Avoiding the "Small-Subgroup" Attacks on the Diffie-Hellman Key Agreement Method for S/MIME", RFC 2785, March 2000.
- [X942] Rescorla, E., "Diffie-Hellman Key Agreement Method", RFC 2631, June 1999.
- [RFC2797] Myers, M., Liu, X., Schaad, J., and J. Weinstein, "Certificate Management Messages over CMS", RFC 2797, April 2000.

Appendix A. ASN.1 Module

```
EnrollmentMessageSyntax
{ iso(1) identified-organization(3) dod(4) internet(1)
  security(5) mechanisms(5) pkix(7) id-mod(0) id-mod-cmc2002(23) }

DEFINITIONS IMPLICIT TAGS ::=
BEGIN

-- EXPORTS All --
-- The types and values defined in this module are exported for use
-- in the other ASN.1 modules. Other applications may use them for
-- their own purposes.

IMPORTS

-- PKIX Part 1 - Implicit      From [PKIXCERT]
  GeneralName, CRLReason, ReasonFlags
  FROM PKIX1Implicit88 {iso(1) identified-organization(3) dod(6)
    internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
    id-pkix1-implicit(19)}

-- PKIX Part 1 - Explicit      From [PKIXCERT]
  AlgorithmIdentifier, Extension, Name, CertificateSerialNumber
  FROM PKIX1Explicit88 {iso(1) identified-organization(3) dod(6)
    internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
    id-pkix1-explicit(18)}

-- Cryptographic Message Syntax FROM [CMS]
  ContentInfo, Attribute, IssuerAndSerialNumber
  FROM CryptographicMessageSyntax2004 { iso(1) member-body(2)
    us(840) rsadsi(113549) pkcs(1) pkcs-9(9) smime(16)
    modules(0) cms-2004(24)}

-- CRMF                        FROM [CRMF]
  CertReqMsg, PKIPublicationInfo, CertTemplate
  FROM PKIXCRMF-2005 {iso(1) identified-organization(3) dod(6)
    internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
    id-mod-crmf2005(36)};

-- Global Types
  UTF8String ::= [UNIVERSAL 12] IMPLICIT OCTET STRING
  -- The content of this type conforms to RFC 2279.
```

```
id-pkix OBJECT IDENTIFIER ::= { iso(1) identified-organization(3)
  dod(6) internet(1) security(5) mechanisms(5) pkix(7) }

id-cmc OBJECT IDENTIFIER ::= {id-pkix 7} -- CMC controls
id-cct OBJECT IDENTIFIER ::= {id-pkix 12} -- CMC content types

-- The following controls have the type OCTET STRING

id-cmc-identityProof OBJECT IDENTIFIER ::= {id-cmc 3}
id-cmc-dataReturn OBJECT IDENTIFIER ::= {id-cmc 4}
id-cmc-regInfo OBJECT IDENTIFIER ::= {id-cmc 18}
id-cmc-responseInfo OBJECT IDENTIFIER ::= {id-cmc 19}
id-cmc-queryPending OBJECT IDENTIFIER ::= {id-cmc 21}
id-cmc-popLinkRandom OBJECT IDENTIFIER ::= {id-cmc 22}
id-cmc-popLinkWitness OBJECT IDENTIFIER ::= {id-cmc 23}

-- The following controls have the type UTF8String

id-cmc-identification OBJECT IDENTIFIER ::= {id-cmc 2}

-- The following controls have the type INTEGER

id-cmc-transactionId OBJECT IDENTIFIER ::= {id-cmc 5}

-- The following controls have the type OCTET STRING

id-cmc-senderNonce OBJECT IDENTIFIER ::= {id-cmc 6}
id-cmc-recipientNonce OBJECT IDENTIFIER ::= {id-cmc 7}

-- This is the content type used for a request message in the protocol

id-cct-PKIData OBJECT IDENTIFIER ::= { id-cct 2 }

PKIData ::= SEQUENCE {
  controlSequence SEQUENCE SIZE(0..MAX) OF TaggedAttribute,
  reqSequence SEQUENCE SIZE(0..MAX) OF TaggedRequest,
  cmsSequence SEQUENCE SIZE(0..MAX) OF TaggedContentInfo,
  otherMsgSequence SEQUENCE SIZE(0..MAX) OF OtherMsg
}

bodyIdMax INTEGER ::= 4294967295

BodyPartID ::= INTEGER(0..bodyIdMax)
```

```
TaggedAttribute ::= SEQUENCE {
    bodyPartID      BodyPartID,
    attrType        OBJECT IDENTIFIER,
    attrValues      SET OF AttributeValue
}

AttributeValue ::= ANY

TaggedRequest ::= CHOICE {
    tcr              [0] TaggedCertificationRequest,
    crm              [1] CertReqMsg,
    orm              [2] SEQUENCE {
        bodyPartID      BodyPartID,
        requestMessageType OBJECT IDENTIFIER,
        requestMessageValue ANY DEFINED BY requestMessageType
    }
}

TaggedCertificationRequest ::= SEQUENCE {
    bodyPartID      BodyPartID,
    certificationRequest CertificationRequest
}

CertificationRequest ::= SEQUENCE {
    certificationRequestInfo SEQUENCE {
        version          INTEGER,
        subject          Name,
        subjectPublicKeyInfo SEQUENCE {
            algorithm      AlgorithmIdentifier,
            subjectPublicKey BIT STRING },
        attributes        [0] IMPLICIT SET OF Attribute },
    signatureAlgorithm    AlgorithmIdentifier,
    signature              BIT STRING
}

TaggedContentInfo ::= SEQUENCE {
    bodyPartID      BodyPartID,
    contentInfo      ContentInfo
}

OtherMsg ::= SEQUENCE {
    bodyPartID      BodyPartID,
    otherMsgType    OBJECT IDENTIFIER,
    otherMsgValue    ANY DEFINED BY otherMsgType }

```

```
-- This defines the response message in the protocol
id-cct-PKIResponse OBJECT IDENTIFIER ::= { id-cct 3 }

ResponseBody ::= PKIResponse

PKIResponse ::= SEQUENCE {
    controlSequence SEQUENCE SIZE(0..MAX) OF TaggedAttribute,
    cmsSequence     SEQUENCE SIZE(0..MAX) OF TaggedContentInfo,
    otherMsgSequence SEQUENCE SIZE(0..MAX) OF OtherMsg
}

-- Used to return status state in a response

id-cmc-statusInfo OBJECT IDENTIFIER ::= {id-cmc 1}

CMCStatusInfo ::= SEQUENCE {
    cmcStatus      CMCStatus,
    bodyList       SEQUENCE SIZE (1..MAX) OF BodyPartID,
    statusString   UTF8String OPTIONAL,
    otherInfo      CHOICE {
        failInfo      CMCFailInfo,
        pendInfo      PendInfo } OPTIONAL
}

PendInfo ::= SEQUENCE {
    pendToken      OCTET STRING,
    pendTime       GeneralizedTime
}

CMCStatus ::= INTEGER {
    success        (0),
    failed         (2),
    pending        (3),
    noSupport      (4),
    confirmRequired (5),
    popRequired    (6),
    partial        (7)
}

-- Note:
-- The spelling of unsupportedExt is corrected in this version.
-- In RFC 2797, it was unsupportedExt.
```

```
CMCFailInfo ::= INTEGER {
    badAlg          (0),
    badMessageCheck (1),
    badRequest      (2),
    badTime         (3),
    badCertId       (4),
    unsupportedExt  (5),
    mustArchiveKeys (6),
    badIdentity     (7),
    popRequired     (8),
    popFailed       (9),
    noKeyReuse      (10),
    internalCAError (11),
    tryLater        (12),
    authDataFail    (13)
}

-- Used for RAs to add extensions to certification requests
id-cmc-addExtensions OBJECT IDENTIFIER ::= {id-cmc 8}

AddExtensions ::= SEQUENCE {
    pkiDataReference    BodyPartID,
    certReferences      SEQUENCE OF BodyPartID,
    extensions          SEQUENCE OF Extension
}

id-cmc-encryptedPOP OBJECT IDENTIFIER ::= {id-cmc 9}
id-cmc-decryptedPOP OBJECT IDENTIFIER ::= {id-cmc 10}

EncryptedPOP ::= SEQUENCE {
    request    TaggedRequest,
    cms        ContentInfo,
    thePOPAlgID AlgorithmIdentifier,
    witnessAlgID AlgorithmIdentifier,
    witness    OCTET STRING
}

DecryptedPOP ::= SEQUENCE {
    bodyPartID    BodyPartID,
    thePOPAlgID  AlgorithmIdentifier,
    thePOP        OCTET STRING
}

id-cmc-lraPOPWitness OBJECT IDENTIFIER ::= {id-cmc 11}
```

```
LraPopWitness ::= SEQUENCE {
    pkiDataBodyid  BodyPartID,
    bodyIds        SEQUENCE OF BodyPartID
}

--
id-cmc-getCert OBJECT IDENTIFIER ::= {id-cmc 15}

GetCert ::= SEQUENCE {
    issuerName      GeneralName,
    serialNumber    INTEGER }

id-cmc-getCRL OBJECT IDENTIFIER ::= {id-cmc 16}

GetCRL ::= SEQUENCE {
    issuerName      Name,
    cRLName        GeneralName OPTIONAL,
    time           GeneralizedTime OPTIONAL,
    reasons        ReasonFlags OPTIONAL }

id-cmc-revokeRequest OBJECT IDENTIFIER ::= {id-cmc 17}

RevokeRequest ::= SEQUENCE {
    issuerName      Name,
    serialNumber    INTEGER,
    reason          CRLReason,
    invalidityDate  GeneralizedTime OPTIONAL,
    passphrase     OCTET STRING OPTIONAL,
    comment         UTF8String OPTIONAL }

id-cmc-confirmCertAcceptance OBJECT IDENTIFIER ::= {id-cmc 24}

CMCCertId ::= IssuerAndSerialNumber

-- The following is used to request V3 extensions be added to a
-- certificate

id-ExtensionReq OBJECT IDENTIFIER ::= {iso(1) member-body(2) us(840)
    rsadsi(113549) pkcs(1) pkcs-9(9) 14}

ExtensionReq ::= SEQUENCE SIZE (1..MAX) OF Extension

-- The following exists to allow Diffie-Hellman Certification Requests
-- Messages to be well-formed

id-alg-noSignature OBJECT IDENTIFIER ::= {id-pkix id-alg(6) 2}

NoSignatureValue ::= OCTET STRING
```

```
-- Unauthenticated attribute to carry removable data.
-- This could be used in an update of "CMC Extensions: Server Side
-- Key Generation and Key Escrow" (February 2005) and in other
-- documents.

id-aa OBJECT IDENTIFIER ::= { iso(1) member-body(2) us(840)
    rsadsi(113549) pkcs(1) pkcs-9(9) smime(16) id-aa(2)}
id-aa-cmc-unsignedData OBJECT IDENTIFIER ::= {id-aa 34}

CMCUnsignedData ::= SEQUENCE {
    bodyPartPath      BodyPartPath,
    identifier         OBJECT IDENTIFIER,
    content            ANY DEFINED BY identifier
}

-- Replaces CMC Status Info
--

id-cmc-statusInfoV2 OBJECT IDENTIFIER ::= {id-cmc 25}

CMCStatusInfoV2 ::= SEQUENCE {
    cMCStatus          CMCStatus,
    bodyList           SEQUENCE SIZE (1..MAX) OF
                        BodyPartReference,
    statusString       UTF8String OPTIONAL,
    otherInfo          CHOICE {
        failInfo        CMCFailInfo,
        pendInfo        PendInfo,
        extendedFailInfo SEQUENCE {
            failInfoOID  OBJECT IDENTIFIER,
            failInfoValue AttributeValue
        }
    } OPTIONAL
}

BodyPartReference ::= CHOICE {
    bodyPartID      BodyPartID,
    bodyPartPath    BodyPartPath
}

BodyPartPath ::= SEQUENCE SIZE (1..MAX) OF BodyPartID
```

```
-- Allow for distribution of trust anchors
--

id-cmc-trustedAnchors OBJECT IDENTIFIER ::= {id-cmc 26}

PublishTrustAnchors ::= SEQUENCE {
    seqNumber      INTEGER,
    hashAlgorithm  AlgorithmIdentifier,
    anchorHashes   SEQUENCE OF OCTET STRING
}

id-cmc-authData OBJECT IDENTIFIER ::= {id-cmc 27}

AuthPublish ::= BodyPartID

-- These two items use BodyPartList
id-cmc-batchRequests OBJECT IDENTIFIER ::= {id-cmc 28}
id-cmc-batchResponses OBJECT IDENTIFIER ::= {id-cmc 29}

BodyPartList ::= SEQUENCE SIZE (1..MAX) OF BodyPartID

--
id-cmc-publishCert OBJECT IDENTIFIER ::= {id-cmc 30}

CMCPublicationInfo ::= SEQUENCE {
    hashAlg          AlgorithmIdentifier,
    certHashes       SEQUENCE OF OCTET STRING,
    pubInfo          PKIPublicationInfo
}

id-cmc-modCertTemplate OBJECT IDENTIFIER ::= {id-cmc 31}

ModCertTemplate ::= SEQUENCE {
    pkiDataReference  BodyPartPath,
    certReferences    BodyPartList,
    replace           BOOLEAN DEFAULT TRUE,
    certTemplate       CertTemplate
}

-- Inform follow on servers that one or more controls have already been
-- processed

id-cmc-controlProcessed OBJECT IDENTIFIER ::= {id-cmc 32}

ControlsProcessed ::= SEQUENCE {
    bodyList          SEQUENCE SIZE(1..MAX) OF BodyPartReference
}


```



```
-- Identity Proof control w/ algorithm agility

id-cmc-identityProofV2 OBJECT IDENTIFIER ::= { id-cmc 34 }

IdentifyProofV2 ::= SEQUENCE {
    proofAlgID      AlgorithmIdentifier,
    macAlgId        AlgorithmIdentifier,
    witness         OCTET STRING
}

id-cmc-popLinkWitnessV2 OBJECT IDENTIFIER ::= { id-cmc 33 }
PopLinkWitnessV2 ::= SEQUENCE {
    keyGenAlgorithm AlgorithmIdentifier,
    macAlgorithm     AlgorithmIdentifier,
    witness          OCTET STRING
}

END
```

Appendix B. Enrollment Message Flows

This section is informational. The purpose of this section is to present, in an abstracted version, the messages that would flow between the client and server for several different common cases.

B.1. Request of a Signing Certificate

This section looks at the messages that would flow in the event that an enrollment is occurring for a signing-only key. If the certificate was designed for both signing and encryption, the only difference would be the key usage extension in the certification request.

Message #2 from client to server:

```
ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIData
    eContent
      controlSequence
        {102, id-cmc-identityProof, computed value}
        {103, id-cmc-senderNonce, 10001}
      reqSequence
        certRequest
          certReqId = 201
          certTemplate
            subject = My Proposed DN
            publicKey = My Public Key
            extensions
              {id-ce-subjectPublicKeyIdentifier, 1000}
              {id-ce-keyUsage, digitalSignature}
        SignedData.SignerInfos
          SignerInfo
            sid.subjectKeyIdentifier = 1000
```

Response from server to client:

```

ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIResponse
    eContent
      controlSequence
        {102, id-cmc-statusInfoV2, {success, 201}}
        {103, id-cmc-senderNonce, 10005}
        {104, id-cmc-recipientNonce, 10001}
      certificates
        Newly issued certificate
        Other certificates
    SignedData.SignerInfos
      Signed by CA

```

B.2. Single Certification Request, But Modified by RA

This section looks at the messages that would flow in the event that an enrollment has one RA in the middle of the data flow. That RA will modify the certification request before passing it on to the CA.

Message from client to RA:

```

ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIData
    eContent
      controlSequence
        {102, id-cmc-identityProof, computed value}
        {103, id-cmc-senderNonce, 10001}
      reqSequence
        certRequest
          certReqId = 201
          certTemplate
            subject = My Proposed DN
            publicKey = My Public Key
            extensions
              {id-ce-subjectPublicKeyIdentifier, 1000}
              {id-ce-keyUsage, digitalSignature}
    SignedData.SignerInfos
      SignerInfo
        sid.subjectKeyIdentifier = 1000

```

Message from RA to CA:

```
ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIData
    eContent
      controlSequence
        { 102, id-cmc-batchRequests, { 1, 2 } }
        { 103, id-cmc-addExtensions,
          { {1, 201, {id-ce-certificatePolicies, anyPolicy}}
            {1, 201, {id-ce-subjectAltName, {extension data}}
            {2, XXX, {id-ce-subjectAltName, {extension data}}}}
          The Value XXX is not known here; it would
          reference into the second client request,
          which is not displayed above.
        cmsSequence
          { 1, <Message from client to RA #1> }
          { 2, <Message from client to RA #2> }
      SignedData.SignerInfos
        SignerInfo
          sid = RA key.
```

Response from CA to RA:

```

ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIResponse
    eContent
      controlSequence
        {102, id-cmc-BatchResponse, {999, 998}}

        {103, id-cmc-statusInfoV2, {failed, 2, badIdentity}}
      cmsSequence
        { bodyPartID = 999
          contentInfo
            ContentInfo.contentType = id-signedData
            ContentInfo.content
              SignedData.encapContentInfo
                eContentType = id-ct-PKIResponse
                eContent
                  controlSequence
                    {102, id-cmc-statusInfoV2, {success, 201}}
                  certificates
                    Newly issued certificate
                    Other certificates
                  SignedData.SignerInfos
                    Signed by CA
                }
            { bodyPartID = 998,
              contentInfo
                ContentInfo.contentType = id-signedData
                ContentInfo.content
                  SignedData.encapContentInfo
                    eContentType = id-ct-PKIResponse
                    eContent
                      controlSequence
                        {102, id-cmc-statusInfoV2, {failure, badAlg}}
                      certificates
                        Newly issued certificate
                        Other certificates
                      SignedData.SignerInfos
                        Signed by CA
                    }
            SignedData.SignerInfos
              Signed by CA
          }
        }
    }
  }

```

Response from RA to client:

```
ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIResponse
    eContent
      controlSequence
        {102, id-cmc-statusInfoV2, {success, 201}}
certificates
  Newly issued certificate
  Other certificates
SignedData.SignerInfos
  Signed by CA
```

B.3. Direct POP for an RSA Certificate

This section looks at the messages that would flow in the event that an enrollment is done for an encryption only certificate using an direct POP method. For simplicity, it is assumed that the certification requester already has a signing-only certificate.

The fact that a second round-trip is required is implicit rather than explicit. The server determines this based on the fact that no other POP exists for the certification request.

Message #1 from client to server:

```

ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIData
    eContent
      controlSequence
        {102, id-cmc-transactionId, 10132985123483401}
        {103, id-cmc-senderNonce, 10001}
        {104, id-cmc-dataReturn, <packet of binary data identifying
                                where the key in question is.>}
      reqSequence
        certRequest
          certReqId = 201
          certTemplate
            subject = <My DN from my signing cert>
            publicKey = My Public Key
            extensions
              {id-ce-keyUsage, keyEncipherment}
          popo
            keyEncipherment
              subsequentMessage
        SignedData.SignerInfos
          SignerInfo
            Signed by requester's signing cert

```

Response #1 from server to client:

```

ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIResponse
    eContent
      controlSequence
        {101, id-cmc-statusInfoV2, {failed, 201, popRequired}}
        {102, id-cmc-transactionId, 10132985123483401}
        {103, id-cmc-senderNonce, 10005}
        {104, id-cmc-recipientNonce, 10001}
        {105, id-cmc-encryptedPOP, {
          request {
            certRequest
              certReqId = 201
              certTemplate
                subject = <My DN from my signing cert>
                publicKey = My Public Key
                extensions
                  {id-ce-keyUsage, keyEncipherment}

```

```

        popo
            keyEncipherment
            subsequentMessage
        }
    cms
        contentType = id-envelopedData
        content
            recipientInfos.riid.issuerSerialNumber = <NULL, 201>
            encryptedContentInfo
                eContentType = id-data
                eContent = <Encrypted value of 'y'>
            thePOPAlgID = HMAC-SHA1
            witnessAlgID = SHA-1
            witness <hashed value of 'y'>}}
        {106, id-cmc-dataReturn, <packet of binary data identifying
            where the key in question is.>}
certificates
    Other certificates (optional)
SignedData.SignerInfos
    Signed by CA

ContentInfo.contentType = id-signedData
ContentInfo.content
    SignedData.encapContentInfo
        eContentType = id-ct-PKIData
        eContent
            controlSequence
                {102, id-cmc-transactionId, 10132985123483401}
                {103, id-cmc-senderNonce, 100101}
                {104, id-cmc-dataReturn, <packet of binary data identifying
                    where the key in question is.>}
                {105, id-cmc-recipientNonce, 10005}
                {107, id-cmc-decryptedPOP, {
                    bodyPartID 201,
                    thePOPAlgID HMAC-SHA1,
                    thePOP <HMAC computed value goes here>}}
    reqSequence
        certRequest
            certReqId = 201
            certTemplate
                subject = <My DN from my signing cert>
                publicKey = My Public Key
                extensions
                    {id-ce-keyUsage, keyEncipherment}
        popo
            keyEncipherment
            subsequentMessage

```



```
SignedData.SignerInfos
  SignerInfo
    Signed by requester's signing cert
```

Response #2 from server to client:

```
ContentInfo.contentType = id-signedData
ContentInfo.content
  SignedData.encapContentInfo
    eContentType = id-ct-PKIResponse
    eContent
      controlSequence
        {101, id-cmc-transactionId, 10132985123483401}
        {102, id-cmc-statusInfoV2, {success, 201}}
        {103, id-cmc-senderNonce, 10019}
        {104, id-cmc-recipientNonce, 100101}
        {105, id-cmc-dataReturn, <packet of binary data identifying
          where the key in question is.>}
  certificates
    Newly issued certificate
    Other certificates
  SignedData.SignerInfos
    Signed by CA
```

Appendix C. Production of Diffie-Hellman Public Key Certification Requests

Part of a certification request is a signature over the request; Diffie-Hellman is a key agreement algorithm and cannot be used to directly produce the required signature object. [DH-POP] provides two ways to produce the necessary signature value. This document also defines a signature algorithm that does not provide a POP value, but can be used to produce the necessary signature value.

C.1. No-Signature Signature Mechanism

Key management (encryption/decryption) private keys cannot always be used to produce some type of signature value as they can be in a decrypt-only device. Certification requests require that the signature field be populated. This section provides a signature algorithm specifically for that purposes. The following object identifier and signature value are used to identify this signature type:

```
id-alg-noSignature OBJECT IDENTIFIER ::= {id-pkix id-alg(6) 2}

NoSignatureValue ::= OCTET STRING
```

The parameters for id-alg-noSignature MUST be present and MUST be encoded as NULL. NoSignatureValue contains the hash of the certification request. It is important to realize that there is no security associated with this signature type. If this signature type is on a certification request and the Certification Authority policy requires proof-of-possession of the private key, the POP mechanism defined in Section 6.7 MUST be used.

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