PKIX Working Group
Internet Draft

R. Housley (SPYRUS)
W. Ford (VeriSign)
W. Polk (NIST)
D. Solo (Citigroup)

expires in six months

March 2001

Internet X.509 Public Key Infrastructure

Certificate and CRL Profile

<draft-ietf-pkix-new-part1-05.txt>

Status of this Memo

Abstract

This is the fifth draft of a specification based upon RFC 2459. When complete, this specification will obsolete RFC 2459. This specification includes minor edits and clarifications. The most notable departures from RFC 2459 are found in Section 6, Path Validation. In RFC 2459, the reader was expected to augment the path

validation algorithm, which concentrated upon policy processing, with information embedded in earlier sections. For example, parameter inheritance is discussed in Section 7, Algorithm Support, and can certainly affect the validity of a certification path. However, parameter inheritance was omitted from the path validation algorithm

in RFC 2459. In this draft, the path validation algorithm has a comprehensive and extremely detailed description. Details such as parameter inheritance are covered thoroughly. In addition, this draft anticipates certain corrections proposed in the X.509 standard for the policy processing aspects of path validation.

A new section 6.3, CRL validation, has been added as well. This section provides a supplement to the path validation algorithm that determines if a particular CRL may be used to verify the status of a particular certificate. (The basic path validation algorithm is, by design, independent of the type and format of status information.)

The most significant enhancement in draft five is a refinement of the processing rules for path length constraints when applied to CA certificates. This draft also completes the removal of processing rules for unique identifiers. This was generally performed in the fourth draft, but some details were overlooked. This draft also incorporates significant corrections to the ASN.1 modules in the appendices.

This memo profiles the X.509 v3 certificate and X.509 v2 CRL for use in the Internet. An overview of the approach and model are provided as an introduction. The X.509 v3 certificate format is described in detail, with additional information regarding the format and semantics of Internet name forms (e.g., IP addresses). Standard certificate extensions are described and one new Internet-specific extension is defined. A required set of certificate extensions is specified. The X.509 v2 CRL format is described and a required extension set is defined as well. An algorithm for X.509 certificate path validation is described. Supplemental information is provided describing the format of public keys and digital signatures in X.509 certificates for common Internet public key encryption algorithms (i.e., RSA, DSA, and Diffie-Hellman). ASN.1 modules and examples are provided in the appendices.

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 RFC 2119.

Please send comments on this document to the ietf-pkix@imc.org mail list.

Table of Contents

1 Introduction

This specification is one part of a family of standards for the X.509 Public Key Infrastructure (PKI) for the Internet. This specification is a standalone document; implementations of this standard may proceed independent from the other parts.

This specification profiles the format and semantics of certificates

and certificate revocation lists for the Internet PKI. Procedures are described for processing of certification paths in the Internet environment. Encoding rules are provided for popular cryptographic algorithms. Finally, ASN.1 modules are provided in the appendices for all data structures defined or referenced.

The specification describes the requirements which inspire the creation of this document and the assumptions which affect its scope in Section 2. Section 3 presents an architectural model and describes its relationship to previous IETF and ISO/IEC/ITU standards. In particular, this document's relationship with the IETF PEM specifications and the ISO/IEC/ITU X.509 documents are described.

The specification profiles the X.509 version 3 certificate in Section 4, and the X.509 version 2 certificate revocation list (CRL) in Section 5. The profiles include the identification of ISO/IEC/ITU and ANSI extensions which may be useful in the Internet PKI. The profiles are presented in the 1988 Abstract Syntax Notation One (ASN.1) rather than the 1994 syntax used in the ISO/IEC/ITU standards.

This specification also includes path validation procedures in Section 6. These procedures are based upon the ISO/IEC/ITU definition, but the presentation assumes one or more self-signed trusted CA certificates. Implementations are required to derive the same results but are not required to use the specified procedures.

Procedures for identification and encoding of public key materials and digital signatures are defined in [PKIX ALGS]. Implementations of this specification are not required to use any particular cryptographic algorithms. However, conforming implementations which use the algorithms identified in [PKIX ALGS] are required to identify and encode the public key materials and digital signatures as described in that specification.

Finally, three appendices are provided to aid implementers. Appendix A contains all ASN.1 structures defined or referenced within this specification. As above, the material is presented in the 1988 Abstract Syntax Notation One (ASN.1) rather than the 1994 syntax. Appendix B contains notes on less familiar features of the ASN.1

notation used within this specification. Appendix C contains

examples of a conforming certificate and a conforming CRL.

2 Requirements and Assumptions

The goal of this specification is to develop a profile to facilitate the use of X.509 certificates within Internet applications for those communities wishing to make use of X.509 technology. Such applications may include WWW, electronic mail, user authentication, and IPsec. In order to relieve some of the obstacles to using X.509 certificates, this document defines a profile to promote the development of certificate management systems; development of application tools; and interoperability determined by policy.

Some communities will need to supplement, or possibly replace, this profile in order to meet the requirements of specialized application domains or environments with additional authorization, assurance, or operational requirements. However, for basic applications, common representations of frequently used attributes are defined so that application developers can obtain necessary information without regard to the issuer of a particular certificate or certificate revocation list (CRL).

A certificate user should review the certificate policy generated by the certification authority (CA) before relying on the authentication or non-repudiation services associated with the public key in a particular certificate. To this end, this standard does not prescribe legally binding rules or duties.

As supplemental authorization and attribute management tools emerge, such as attribute certificates, it may be appropriate to limit the authenticated attributes that are included in a certificate. These other management tools may provide more appropriate methods of conveying many authenticated attributes.

2.1 Communication and Topology

The users of certificates will operate in a wide range of environments with respect to their communication topology, especially users of secure electronic mail. This profile supports users without high bandwidth, real-time IP connectivity, or high connection availability. In addition, the profile allows for the presence of firewall or other filtered communication.

This profile does not assume the deployment of an X.500 Directory system. The profile does not prohibit the use of an X.500 Directory, but other means of distributing certificates and certificate revocation lists (CRLs) may be used.

2.2 Acceptability Criteria

The goal of the Internet Public Key Infrastructure (PKI) is to meet the needs of deterministic, automated identification, authentication, access control, and authorization functions. Support for these services determines the attributes contained in the certificate as well as the ancillary control information in the certificate such as policy data and certification path constraints.

2.3 User Expectations

Users of the Internet PKI are people and processes who use client software and are the subjects named in certificates. These uses include readers and writers of electronic mail, the clients for WWW browsers, WWW servers, and the key manager for IPsec within a router. This profile recognizes the limitations of the platforms these users employ and the limitations in sophistication and attentiveness of the users themselves. This manifests itself in minimal user configuration responsibility (e.g., trusted CA keys, rules), explicit platform usage constraints within the certificate, certification path constraints which shield the user from many malicious actions, and applications which sensibly automate validation functions.

2.4 Administrator Expectations

As with user expectations, the Internet PKI profile is structured to support the individuals who generally operate CAs. Providing administrators with unbounded choices increases the chances that a subtle CA administrator mistake will result in broad compromise. Also, unbounded choices greatly complicate the software that shall process and validate the certificates created by the CA.

3 Overview of Approach

Following is a simplified view of the architectural model assumed by the PKIX specifications.

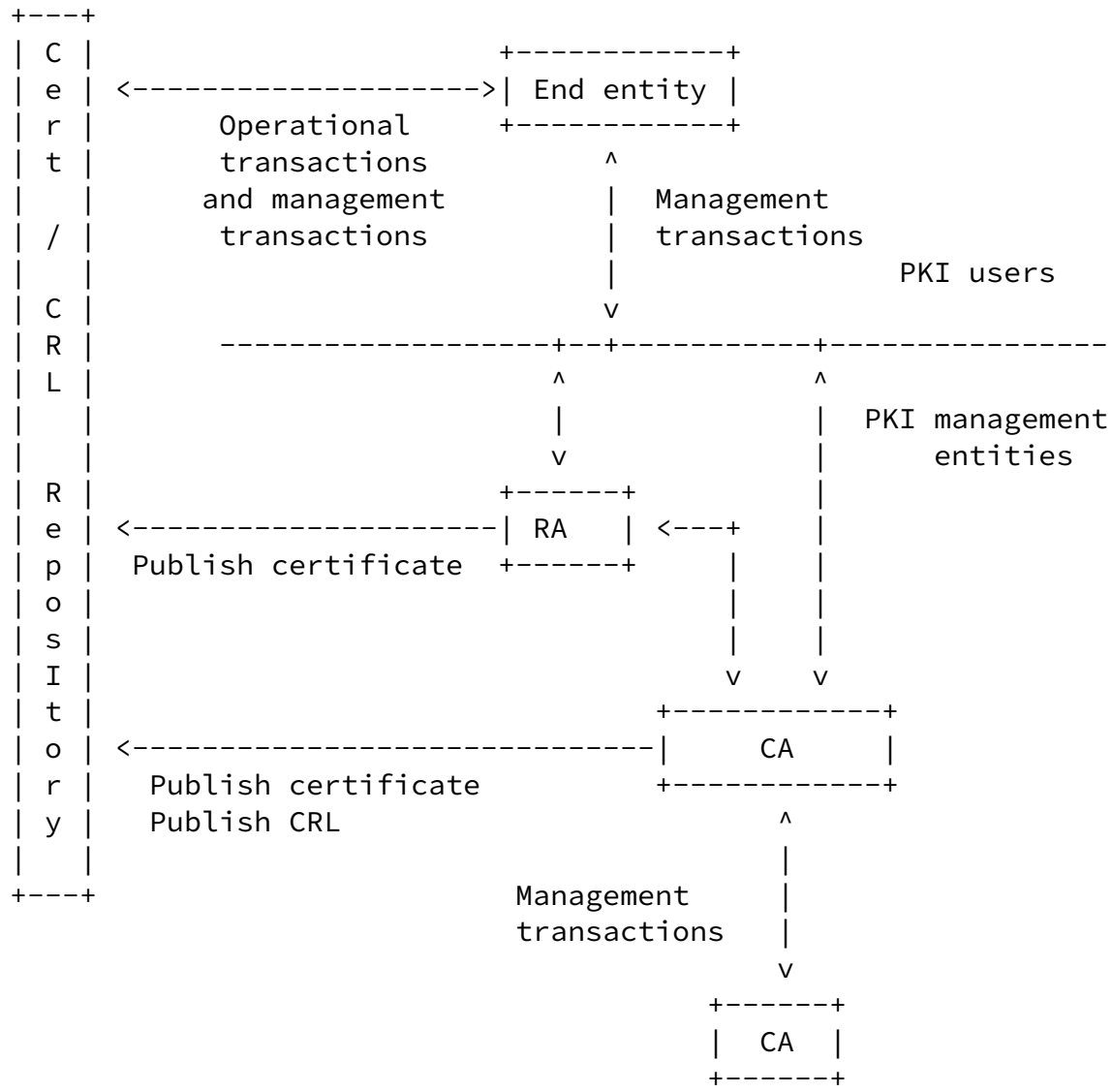


Figure 1 - PKI Entities

The components in this model are:

end entity: user of PKI certificates and/or end user system that is the subject of a certificate;
CA: certification authority;
RA: registration authority, i.e., an optional system to

which a CA delegates certain management functions;

repository: a system or collection of distributed systems that store certificates and CRLs and serves as a means of distributing these certificates and CRLs to end entities.

3.1 X.509 Version 3 Certificate

Users of a public key require confidence that the associated private key is owned by the correct remote subject (person or system) with which an encryption or digital signature mechanism will be used. This confidence is obtained through the use of public key certificates, which are data structures that bind public key values to subjects. The binding is asserted by having a trusted CA digitally sign each certificate. The CA may base this assertion upon technical means (a.k.a., proof of posession through a challenge-response protocol), presentation of the private key, or on an assertion by the subject. A certificate has a limited valid lifetime which is indicated in its signed contents. Because a certificate's signature and timeliness can be independently checked by a certificate-using client, certificates can be distributed via untrusted communications and server systems, and can be cached in unsecured storage in certificate-using systems.

ITU-T X.509 (formerly CCITT X.509) or ISO/IEC/ITU 9594-8, which was first published in 1988 as part of the X.500 Directory recommendations, defines a standard certificate format [X.509]. The certificate format in the 1988 standard is called the version 1 (v1) format. When X.500 was revised in 1993, two more fields were added, resulting in the version 2 (v2) format.

The Internet Privacy Enhanced Mail (PEM) RFCs, published in 1993, include specifications for a public key infrastructure based on X.509 v1 certificates [RFC 1422]. The experience gained in attempts to deploy RFC 1422 made it clear that the v1 and v2 certificate formats are deficient in several respects. Most importantly, more fields were needed to carry information which PEM design and implementation experience has proven necessary. In response to these new

requirements, ISO/IEC/ITU and ANSI X9 developed the X.509 version 3 (v3) certificate format. The v3 format extends the v2 format by adding provision for additional extension fields. Particular extension field types may be specified in standards or may be defined and registered by any organization or community. In June 1996, standardization of the basic v3 format was completed [X.509].

ISO/IEC/ITU and ANSI X9 have also developed standard extensions for use in the v3 extensions field [X.509][X9.55]. These extensions can convey such data as additional subject identification information, key attribute information, policy information, and certification path constraints.

However, the ISO/IEC/ITU and ANSI X9 standard extensions are very broad in their applicability. In order to develop interoperable implementations of X.509 v3 systems for Internet use, it is necessary

to specify a profile for use of the X.509 v3 extensions tailored for the Internet. It is one goal of this document to specify a profile for Internet WWW, electronic mail, and IPsec applications. Environments with additional requirements may build on this profile or may replace it.

3.2 Certification Paths and Trust

A user of a security service requiring knowledge of a public key generally needs to obtain and validate a certificate containing the required public key. If the public-key user does not already hold an assured copy of the public key of the CA that signed the certificate, the CA's name, and related information (such as the validity period or name constraints), then it might need an additional certificate to obtain that public key. In general, a chain of multiple certificates may be needed, comprising a certificate of the public key owner (the end entity) signed by one CA, and zero or more additional certificates of CAs signed by other CAs. Such chains, called certification paths, are required because a public key user is only initialized with a limited number of assured CA public keys.

There are different ways in which CAs might be configured in order for public key users to be able to find certification paths. For PEM, RFC 1422 defined a rigid hierarchical structure of CAs. There are three types of PEM certification authority:

(a) Internet Policy Registration Authority (IPRA): This authority, operated under the auspices of the Internet Society, acts as the root of the PEM certification hierarchy at level 1. It issues certificates only for the next level of authorities, PCAs. All certification paths start with the IPRA.

(b) Policy Certification Authorities (PCAs): PCAs are at level 2 of the hierarchy, each PCA being certified by the IPRA. A PCA shall establish and publish a statement of its policy with respect to certifying users or subordinate certification authorities. Distinct PCAs aim to satisfy different user needs. For example, one PCA (an organizational PCA) might support the general electronic mail needs of commercial organizations, and another PCA (a high-assurance PCA) might have a more stringent policy designed for satisfying legally binding digital signature requirements.

(c) Certification Authorities (CAs): CAs are at level 3 of the hierarchy and can also be at lower levels. Those at level 3 are certified by PCAs. CAs represent, for example, particular organizations, particular organizational units (e.g., departments, groups, sections), or particular geographical areas.

RFC 1422 furthermore has a name subordination rule which requires that a CA can only issue certificates for entities whose names are subordinate (in the X.500 naming tree) to the name of the CA itself. The trust associated with a PEM certification path is implied by the PCA name. The name subordination rule ensures that CAs below the PCA are sensibly constrained as to the set of subordinate entities they can certify (e.g., a CA for an organization can only certify entities in that organization's name tree). Certificate user systems are able to mechanically check that the name subordination rule has been followed.

The RFC 1422 uses the X.509 v1 certificate formats. The limitations of X.509 v1 required imposition of several structural restrictions to clearly associate policy information or restrict the utility of certificates. These restrictions included:

(a) a pure top-down hierarchy, with all certification paths starting from IPRA;

(b) a naming subordination rule restricting the names of a CA's subjects; and

(c) use of the PCA concept, which requires knowledge of individual PCAs to be built into certificate chain verification logic. Knowledge of individual PCAs was required to determine if a chain could be accepted.

With X.509 v3, most of the requirements addressed by RFC 1422 can be addressed using certificate extensions, without a need to restrict the CA structures used. In particular, the certificate extensions relating to certificate policies obviate the need for PCAs and the constraint extensions obviate the need for the name subordination rule. As a result, this document supports a more flexible architecture, including:

(a) Certification paths may start with a public key of a CA in a user's own domain, or with the public key of the top of a hierarchy. Starting with the public key of a CA in a user's own domain has certain advantages. In some environments, the local domain is the most trusted.

(b) Name constraints may be imposed through explicit inclusion of a name constraints extension in a certificate, but are not required.

(c) Policy extensions and policy mappings replace the PCA concept, which permits a greater degree of automation. The application can determine if the certification path is acceptable

based on the contents of the certificates instead of a priori knowledge of PCAs. This permits automation of certificate chain processing.

3.3 Revocation

When a certificate is issued, it is expected to be in use for its entire validity period. However, various circumstances may cause a certificate to become invalid prior to the expiration of the validity period. Such circumstances include change of name, change of association between subject and CA (e.g., an employee terminates

employment with an organization), and compromise or suspected compromise of the corresponding private key. Under such circumstances, the CA needs to revoke the certificate.

X.509 defines one method of certificate revocation. This method involves each CA periodically issuing a signed data structure called a certificate revocation list (CRL). A CRL is a time stamped list identifying revoked certificates which is signed by a CA and made freely available in a public repository. Each revoked certificate is identified in a CRL by its certificate serial number. When a certificate-using system uses a certificate (e.g., for verifying a remote user's digital signature), that system not only checks the certificate signature and validity but also acquires a suitably-recent CRL and checks that the certificate serial number is not on that CRL. The meaning of "suitably-recent" may vary with local policy, but it usually means the most recently-issued CRL. A CA issues a new CRL on a regular periodic basis (e.g., hourly, daily, or weekly). An entry is added to the CRL as part of the next update following notification of revocation. An entry may be removed from the CRL after appearing on one regularly scheduled CRL issued beyond the revoked certificate's validity period.

An advantage of this revocation method is that CRLs may be distributed by exactly the same means as certificates themselves, namely, via untrusted communications and server systems.

One limitation of the CRL revocation method, using untrusted communications and servers, is that the time granularity of revocation is limited to the CRL issue period. For example, if a revocation is reported now, that revocation will not be reliably notified to certificate-using systems until all currently issued CRLs are updated -- this may be up to one hour, one day, or one week depending on the frequency that the CA issues CRLs.

As with the X.509 v3 certificate format, in order to facilitate interoperable implementations from multiple vendors, the X.509 v2 CRL format needs to be profiled for Internet use. It is one goal of this

document to specify that profile. However, this profile does not require CAs to issue CRLs. Message formats and protocols supporting on-line revocation notification may be defined in other PKIX specifications. On-line methods of revocation notification may be

applicable in some environments as an alternative to the X.509 CRL. On-line revocation checking may significantly reduce the latency between a revocation report and the distribution of the information to relying parties. Once the CA accepts the report as authentic and valid, any query to the on-line service will correctly reflect the certificate validation impacts of the revocation. However, these methods impose new security requirements: the certificate validator needs to trust the on-line validation service while the repository does not need to be trusted.

3.4 Operational Protocols

Operational protocols are required to deliver certificates and CRLs (or status information) to certificate using client systems. Provision is needed for a variety of different means of certificate and CRL delivery, including distribution procedures based on LDAP, HTTP, FTP, and X.500. Operational protocols supporting these functions are defined in other PKIX specifications. These specifications may include definitions of message formats and procedures for supporting all of the above operational environments, including definitions of or references to appropriate MIME content types.

3.5 Management Protocols

Management protocols are required to support on-line interactions between PKI user and management entities. For example, a management protocol might be used between a CA and a client system with which a key pair is associated, or between two CAs which cross-certify each other. The set of functions which potentially need to be supported by management protocols include:

(a) registration: This is the process whereby a user first makes itself known to a CA (directly, or through an RA), prior to that CA issuing a certificate or certificates for that user.

(b) initialization: Before a client system can operate securely it is necessary to install key materials which have the appropriate relationship with keys stored elsewhere in the infrastructure. For example, the client needs to be securely initialized with the public key and other assured information of the trusted CA(s), to be used in validating certificate paths. Furthermore, a client typically needs to be initialized with its own key pair(s).

(c) certification: This is the process in which a CA issues a certificate for a user's public key, and returns that certificate to the user's client system and/or posts that certificate in a repository.

(d) key pair recovery: As an option, user client key materials (e.g., a user's private key used for encryption purposes) may be backed up by a CA or a key backup system. If a user needs to recover these backed up key materials (e.g., as a result of a forgotten password or a lost key chain file), an on-line protocol exchange may be needed to support such recovery.

(e) key pair update: All key pairs need to be updated regularly, i.e., replaced with a new key pair, and new certificates issued.

(f) revocation request: An authorized person advises a CA of an abnormal situation requiring certificate revocation.

(g) cross-certification: Two CAs exchange information used in establishing a cross-certificate. A cross-certificate is a certificate issued by one CA to another CA which contains a CA signature key used for issuing certificates.

Note that on-line protocols are not the only way of implementing the above functions. For all functions there are off-line methods of achieving the same result, and this specification does not mandate use of on-line protocols. For example, when hardware tokens are used, many of the functions may be achieved as part of the physical token delivery. Furthermore, some of the above functions may be combined into one protocol exchange. In particular, two or more of the registration, initialization, and certification functions can be combined into one protocol exchange.

The PKIX series of specifications may define a set of standard message formats supporting the above functions in future specifications. In that case, the protocols for conveying these messages in different environments (e.g., on-line, file transfer, e-mail, and WWW) will also be described in those specifications.

4 Certificate and Certificate Extensions Profile

This section presents a profile for public key certificates that will foster interoperability and a reusable PKI. This section is based upon the X.509 v3 certificate format and the standard certificate extensions defined in [X.509]. The ISO/IEC/ITU documents use the 1993 version of ASN.1; while this document uses the 1988 ASN.1 syntax, the encoded certificate and standard extensions are

equivalent. This section also defines private extensions required to

support a PKI for the Internet community.

Certificates may be used in a wide range of applications and environments covering a broad spectrum of interoperability goals and a broader spectrum of operational and assurance requirements. The goal of this document is to establish a common baseline for generic applications requiring broad interoperability and limited special purpose requirements. In particular, the emphasis will be on supporting the use of X.509 v3 certificates for informal Internet electronic mail, IPsec, and WWW applications.

4.1 Basic Certificate Fields

The X.509 v3 certificate basic syntax is as follows. For signature calculation, the certificate is encoded using the ASN.1 distinguished encoding rules (DER) [X.208]. ASN.1 DER encoding is a tag, length, value encoding system for each element.

```
Certificate  ::=  SEQUENCE  {
     tbsCertificate       TBSCertificate,
     signatureAlgorithm   AlgorithmIdentifier,
     signatureValue       BIT STRING  }

TBSCertificate  ::=  SEQUENCE  {
     version         [0]  EXPLICIT Version DEFAULT v1,
     serialNumber         CertificateSerialNumber,
     signature            AlgorithmIdentifier,
     issuer               Name,
     validity             Validity,
     subject              Name,
     subjectPublicKeyInfo SubjectPublicKeyInfo,
     issuerUniqueID  [1]  IMPLICIT UniqueIdentifier OPTIONAL,
                          -- If present, version shall be v2 or v3
     subjectUniqueID [2]  IMPLICIT UniqueIdentifier OPTIONAL,
                          -- If present, version shall be v2 or v3
     extensions      [3]  EXPLICIT Extensions OPTIONAL
                          -- If present, version shall be v3
     }

Version  ::=  INTEGER  {  v1(0), v2(1), v3(2)  }
```

```
   CertificateSerialNumber  ::=  INTEGER

   Validity ::= SEQUENCE {
        notBefore      Time,
        notAfter       Time }

   Time ::= CHOICE {
```



```
        utcTime        UTCTime,
        generalTime    GeneralizedTime }

   UniqueIdentifier  ::=  BIT STRING

   SubjectPublicKeyInfo  ::=  SEQUENCE  {
        algorithm            AlgorithmIdentifier,
        subjectPublicKey     BIT STRING  }

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

   Extension  ::=  SEQUENCE  {
        extnID      OBJECT IDENTIFIER,
        critical    BOOLEAN DEFAULT FALSE,
        extnValue   OCTET STRING  }
```

The following items describe the X.509 v3 certificate for use in the Internet.

4.1.1 Certificate Fields

The Certificate is a SEQUENCE of three required fields. The fields are described in detail in the following subsections.

4.1.1.1 tbsCertificate

The field contains the names of the subject and issuer, a public key associated with the subject, a validity period, and other associated information. The fields are described in detail in section 4.1.2; the tbscertificate may also include extensions which are described in section 4.2.

4.1.1.2 signatureAlgorithm

The signatureAlgorithm field contains the identifier for the cryptographic algorithm used by the CA to sign this certificate. [PKIX ALGS] lists the supported signature algorithms.

An algorithm identifier is defined by the following ASN.1 structure:

```
AlgorithmIdentifier  ::=  SEQUENCE  {
     algorithm               OBJECT IDENTIFIER,
     parameters              ANY DEFINED BY algorithm OPTIONAL  }
```

The algorithm identifier is used to identify a cryptographic algorithm. The OBJECT IDENTIFIER component identifies the algorithm (such as DSA with SHA-1). The contents of the optional parameters field will vary according to the algorithm identified. [PKIX ALGS]

lists the supported algorithms for this specification.

This field MUST contain the same algorithm identifier as the signature field in the sequence tbsCertificate (see sec. 4.1.2.3).

4.1.1.3 signatureValue

The signatureValue field contains a digital signature computed upon the ASN.1 DER encoded tbsCertificate. The ASN.1 DER encoded tbsCertificate is used as the input to the signature function. This signature value is then ASN.1 encoded as a BIT STRING and included in the Certificate's signature field. The details of this process are specified for each of the supported algorithms in [PKIX ALGS].

By generating this signature, a CA certifies the validity of the information in the tbsCertificate field. In particular, the CA certifies the binding between the public key material and the subject of the certificate.

4.1.2 TBSCertificate

The sequence TBSCertificate contains information associated with the subject of the certificate and the CA who issued it. Every TBSCertificate contains the names of the subject and issuer, a public key associated with the subject, a validity period, a version number, and a serial number; some may contain optional unique identifier

fields. The remainder of this section describes the syntax and semantics of these fields. A TBSCertificate may also include extensions. Extensions for the Internet PKI are described in Section 4.2.

4.1.2.1 Version

This field describes the version of the encoded certificate. When extensions are used, as expected in this profile, use X.509 version 3 (value is 2). If no extensions are present, but a UniqueIdentifier is present, use version 2 (value is 1). If only basic fields are present, use version 1 (the value is omitted from the certificate as the default value).

Implementations SHOULD be prepared to accept any version certificate. At a minimum, conforming implementations MUST recognize version 3 certificates.

Generation of version 2 certificates is not expected by implementations based on this profile.

4.1.2.2 Serial number

The serial number MUST be a positive integer assigned by the CA to each certificate. It MUST be unique for each certificate issued by a given CA (i.e., the issuer name and serial number identify a unique certificate). CAs MUST force the serialNumber to be a non-negative integer.

Given the uniqueness requirements above serial numbers can be expected to contain long integers. Certificate users MUST be able to handle serialNumber values up to 20 octets. Conformant CAs MUST NOT use serialNumber values longer than 20 octets.

Note: Non-conforming CAs may issue certificates with serial numbers that are negative, or zero. Certificate users SHOULD be prepared to handle such certificates.

4.1.2.3 Signature

This field contains the algorithm identifier for the algorithm used by the CA to sign the certificate.

This field MUST contain the same algorithm identifier as the signatureAlgorithm field in the sequence Certificate (see sec. 4.1.1.2). The contents of the optional parameters field will vary according to the algorithm identified. [PKIX ALGS] lists the supported signature algorithms.

4.1.2.4 Issuer

The issuer field identifies the entity who has signed and issued the certificate. The issuer field MUST contain a non-empty distinguished name (DN). The issuer field is defined as the X.501 type Name. [X.501] Name is defined by the following ASN.1 structures:

```
Name ::= CHOICE {
  RDNSequence }

RDNSequence ::= SEQUENCE OF RelativeDistinguishedName

RelativeDistinguishedName ::=
  SET OF AttributeTypeAndValue

AttributeTypeAndValue ::= SEQUENCE {
  type     AttributeType,
  value    AttributeValue }

AttributeType ::= OBJECT IDENTIFIER
```



```
AttributeValue ::= ANY DEFINED BY AttributeType

DirectoryString ::= CHOICE {
      teletexString           TeletexString (SIZE (1..MAX)),
      printableString         PrintableString (SIZE (1..MAX)),
      universalString         UniversalString (SIZE (1..MAX)),
      utf8String              UTF8String (SIZE (1.. MAX)),
      bmpString               BMPString (SIZE (1..MAX)) }
```

The Name describes a hierarchical name composed of attributes, such as country name, and corresponding values, such as US. The type of

the component AttributeValue is determined by the AttributeType; in general it will be a DirectoryString.

The DirectoryString type is defined as a choice of PrintableString, TeletexString, BMPString, UTF8String, and UniversalString. The UTF8String encoding is the preferred encoding, and all certificates issued after December 31, 2003 MUST use the UTF8String encoding of DirectoryString (except as noted below). Until that date, conforming CAs MUST choose from the following options when creating a distinguished name, including their own:

(a) if the character set is sufficient, the string MAY be represented as a PrintableString;

(b) failing (a), if the BMPString character set is sufficient the string MAY be represented as a BMPString; and

(c) failing (a) and (b), the string MUST be represented as a UTF8String. If (a) or (b) is satisfied, the CA MAY still choose to represent the string as a UTF8String.

Exceptions to the December 31, 2003 UTF8 encoding requirements are as follows:

(a) CAs MAY issue "name rollover" certificates to support an orderly migration to UTF8String encoding. Such certificates would include the CA's UTF8String encoded name as issuer and and the old name encoding as subject, or vice-versa.

(b) As stated in section 4.1.2.6, the subject field MUST be populated with a non-empty distinguished name matching the contents of the issuer field in all certificates issued by the subject CA regardless of encoding.

The TeletexString and UniversalString are included for backward compatibility, and should not be used for certificates for new

subjects. However, these types may be used in certificates where the name was previously established. Certificate users SHOULD be prepared to receive certificates with these types.

In addition, many legacy implementations support names encoded in the

ISO 8859-1 character set (Latin1String) but tag them as TeletexString. The Latin1String includes characters used in Western European countries which are not part of the TeletexString charcter set. Implementations that process TeletexString SHOULD be prepared to handle the entire ISO 8859-1 character set.[ISO 8859-1]

As noted above, distinguished names are composed of attributes. This specification does not restrict the set of attribute types that may appear in names. However, conforming implementations MUST be prepared to receive certificates with issuer names containing the set of attribute types defined below. This specification also recommends support for additional attribute types.

Standard sets of attributes have been defined in the X.500 series of specifications.[X.520] Implementations of this specification MUST be prepared to receive the following standard attribute types in issuer and subject (see 4.1.2.6) names:

* country,
* organization,
* organizational-unit,
* distinguished name qualifier,
* state or province name,
* common name (e.g., "Susan Housley"), and
* serial number.

In addition, implementations of this specification SHOULD be prepared to receive the following standard attribute types in issuer and subject names:

* locality,
* title,
* surname,
* given name,
* initials,
* pseudonym, and
* generation qualifier (e.g., "Jr.", "3rd", or "IV").

The syntax and associated object identifiers (OIDs) for these attribute types are provided in the ASN.1 modules in Appendices A and B.

In addition, implementations of this specification MUST be prepared

to receive the domainComponent attribute, as defined in [RFC 2247]. The Domain (Nameserver) System (DNS) provides a hierarchical resource labeling system. This attribute provides is a convenient mechanism for organizations that wish to use DNs that parallel their DNS names. This is not a replacement for the dNSName component of the alternative name field. Implementations are not required to convert such names into DNS names. The syntax and associated OID for this attribute type is provided in the ASN.1 modules in Appendices A and B.

Certificate users MUST be prepared to process the issuer distinguished name and subject distinguished name (see sec. 4.1.2.6) fields to perform name chaining for certification path validation (see section 6). Name chaining is performed by matching the issuer distinguished name in one certificate with the subject name in a CA certificate.

This specification requires only a subset of the name comparison functionality specified in the X.500 series of specifications. The requirements for conforming implementations are as follows:

(a) attribute values encoded in different types (e.g., PrintableString and BMPString) may be assumed to represent different strings;

(b) attribute values in types other than PrintableString are case sensitive (this permits matching of attribute values as binary objects);

(c) attribute values in PrintableString are not case sensitive (e.g., "Marianne Swanson" is the same as "MARIANNE SWANSON"); and

(d) attribute values in PrintableString are compared after removing leading and trailing white space and converting internal substrings of one or more consecutive white space characters to a single space.

These name comparison rules permit a certificate user to validate certificates issued using languages or encodings unfamiliar to the certificate user.

In addition, implementations of this specification MAY use these comparison rules to process unfamiliar attribute types for name chaining. This allows implementations to process certificates with unfamiliar attributes in the issuer name.

Note that the comparison rules defined in the X.500 series of specifications indicate that the character sets used to encode data

in distinguished names are irrelevant. The characters themselves are compared without regard to encoding. Implementations of the profile are permitted to use the comparison algorithm defined in the X.500 series. Such an implementation will recognize a superset of name matches recognized by the algorithm specified above.

4.1.2.5 Validity

The certificate validity period is the time interval during which the CA warrants that it will maintain information about the status of the certificate. The field is represented as a SEQUENCE of two dates: the date on which the certificate validity period begins (notBefore) and the date on which the certificate validity period ends (notAfter). Both notBefore and notAfter may be encoded as UTCTime or GeneralizedTime.

CAs conforming to this profile MUST always encode certificate validity dates through the year 2049 as UTCTime; certificate validity dates in 2050 or later MUST be encoded as GeneralizedTime.

The validity period for a certificate is the period of time from notBefore through notAfter, inclusive.

4.1.2.5.1 UTCTime

The universal time type, UTCTime, is a standard ASN.1 type intended for representation of dates and time. UTCTime specifies the year through the two low order digits and time is specified to the precision of one minute or one second. UTCTime includes either Z (for Zulu, or Greenwich Mean Time) or a time differential.

For the purposes of this profile, UTCTime values MUST be expressed Greenwich Mean Time (Zulu) and MUST include seconds (i.e., times are YYMMDDHHMMSSZ), even where the number of seconds is zero. Conforming systems MUST interpret the year field (YY) as follows:

> Where YY is greater than or equal to 50, the year shall be interpreted as 19YY; and
>
> Where YY is less than 50, the year shall be interpreted as 20YY.

4.1.2.5.2 GeneralizedTime

The generalized time type, GeneralizedTime, is a standard ASN.1 type for variable precision representation of time. Optionally, the GeneralizedTime field can include a representation of the time differential between local and Greenwich Mean Time.

For the purposes of this profile, GeneralizedTime values MUST be expressed Greenwich Mean Time (Zulu) and MUST include seconds (i.e., times are YYYYMMDDHHMMSSZ), even where the number of seconds is zero. GeneralizedTime values MUST NOT include fractional seconds.

4.1.2.6 Subject

The subject field identifies the entity associated with the public key stored in the subject public key field. The subject name may be carried in the subject field and/or the subjectAltName extension. If the subject is a CA (e.g., the basic constraints extension, as discussed in 4.2.1.10, is present and the value of cA is TRUE,) then the subject field MUST be populated with a non-empty distinguished name matching the contents of the issuer field (see sec. 4.1.2.4) in all certificates issued by the subject CA. If subject naming information is present only in the subjectAltName extension (e.g., a key bound only to an email address or URI), then the subject name MUST be an empty sequence and the subjectAltName extension MUST be critical.

Where it is non-empty, the subject field MUST contain an X.500 distinguished name (DN). The DN MUST be unique for each subject entity certified by the one CA as defined by the issuer name field. A CA may issue more than one certificate with the same DN to the same subject entity.

The subject name field is defined as the X.501 type Name. Implementation requirements for this field are those defined for the issuer field (see sec. 4.1.2.4). When encoding attribute values of type DirectoryString, the encoding rules for the issuer field MUST be implemented. Implementations of this specification MUST be prepared to receive subject names containing the attribute types required for the issuer field. Implementations of this specification SHOULD be prepared to receive subject names containing the recommended attribute types for the issuer field. The syntax and associated

object identifiers (OIDs) for these attribute types are provided in the ASN.1 modules in Appendices A and B. Implementations of this specification MAY use these comparison rules to process unfamiliar attribute types (i.e., for name chaining). This allows implementations to process certificates with unfamiliar attributes in the subject name.

In addition, legacy implementations exist where an RFC 822 name is embedded in the subject distinguished name as an EmailAddress attribute. The attribute value for EmailAddress is of type IA5String to permit inclusion of the character '@', which is not part of the PrintableString character set. EmailAddress attribute values are not case sensitive (e.g., "fanfeedback@redsox.com" is the same as

"FANFEEDBACK@REDSOX.COM").

Conforming implementations generating new certificates with electronic mail addresses MUST use the rfc822Name in the subject alternative name field (see sec. 4.2.1.7) to describe such identities. Simultaneous inclusion of the EmailAddress attribute in the subject distinguished name to support legacy implementations is deprecated but permitted.

4.1.2.7 Subject Public Key Info

This field is used to carry the public key and identify the algorithm with which the key is used. The algorithm is identified using the AlgorithmIdentifier structure specified in section 4.1.1.2. The object identifiers for the supported algorithms and the methods for encoding the public key materials (public key and parameters) are specified in [PKIX ALGS].

4.1.2.8 Unique Identifiers

These fields may only appear if the version is 2 or 3 (see sec. 4.1.2.1). The subject and issuer unique identifiers are present in the certificate to handle the possibility of reuse of subject and/or issuer names over time. This profile recommends that names not be reused for different entities and that Internet certificates not make use of unique identifiers. CAs conforming to this profile SHOULD NOT generate certificates with unique identifiers. Applications conforming to this profile SHOULD be capable of parsing unique

identifiers and making comparisons.

4.1.2.9 Extensions

This field may only appear if the version is 3 (see sec. 4.1.2.1). If present, this field is a SEQUENCE of one or more certificate extensions. The format and content of certificate extensions in the Internet PKI is defined in section 4.2.

4.2 Standard Certificate Extensions

The extensions defined for X.509 v3 certificates provide methods for associating additional attributes with users or public keys and for managing the certification hierarchy. The X.509 v3 certificate format also allows communities to define private extensions to carry information unique to those communities. Each extension in a certificate may be designated as critical or non-critical. A certificate using system MUST reject the certificate if it encounters a critical extension it does not recognize; however, a non-critical extension may be ignored if it is not recognized. The following

sections present recommended extensions used within Internet certificates and standard locations for information. Communities may elect to use additional extensions; however, caution should be exercised in adopting any critical extensions in certificates which might prevent use in a general context.

Each extension includes an OID and an ASN.1 structure. When an extension appears in a certificate, the OID appears as the field extnID and the corresponding ASN.1 encoded structure is the value of the octet string extnValue. Only one instance of a particular extension may appear in a particular certificate. For example, a certificate may contain only one authority key identifier extension (see sec. 4.2.1.1). An extension includes the boolean critical, with a default value of FALSE. The text for each extension specifies the acceptable values for the critical field.

Conforming CAs MUST support key identifiers (see sec. 4.2.1.1 and 4.2.1.2), basic constraints (see sec. 4.2.1.10), key usage (see sec. 4.2.1.3), and certificate policies (see sec. 4.2.1.5) extensions. If the CA issues certificates with an empty sequence for the subject field, the CA MUST support the subject alternative name extension

(see sec. 4.2.1.7). Support for the remaining extensions is OPTIONAL. Conforming CAs may support extensions that are not identified within this specification; certificate issuers are cautioned that marking such extensions as critical may inhibit interoperability.

At a minimum, applications conforming to this profile MUST recognize the following extensions: key usage (see sec. 4.2.1.3), certificate policies (see sec. 4.2.1.5), the subject alternative name (see sec. 4.2.1.7), basic constraints (see sec. 4.2.1.10), name constraints (see sec. 4.2.1.11), policy constraints (see sec. 4.2.1.12), extended key usage (see sec. 4.2.1.13), and inhibit any-policy (see sec. 4.2.1.15).

In addition, this profile RECOMMENDS application support for the authority and subject key identifier (see sec. 4.2.1.1 and 4.2.1.2), and policy mapping (see sec. 4.2.1.6) extensions.

4.2.1 Standard Extensions

This section identifies standard certificate extensions defined in [X.509] for use in the Internet PKI. Each extension is associated with an OID defined in [X.509]. These OIDs are members of the id-ce arc, which is defined by the following:

```
id-ce   OBJECT IDENTIFIER ::=  {joint-iso-ccitt(2) ds(5) 29}
```


4.2.1.1 Authority Key Identifier

The authority key identifier extension provides a means of identifying the public key corresponding to the private key used to sign a certificate. This extension is used where an issuer has multiple signing keys (either due to multiple concurrent key pairs or due to changeover). The identification may be based on either the key identifier (the subject key identifier in the issuer's certificate) or on the issuer name and serial number.

The keyIdentifier field of the authorityKeyIdentifier extension MUST be included in all certificates generated by conforming CAs to facilitate chain building. There is one exception; where a CA distributes its public key in the form of a "self-signed"

certificate, the authority key identifier may be omitted. In this case, the subject and authority key identifiers would be identical.

The value of the keyIdentifier field SHOULD be derived from the public key used to verify the certificate's signature or a method that generates unique values. Two common methods for generating key identifiers from the public key are described in (sec. 4.2.1.2). One common method for generating unique values is described in (sec. 4.2.1.2). Where a key identifier has not been previously established, this specification recommends use of one of these methods for generating keyIdentifiers.

This profile recommends support for the key identifier method by all certificate users.

This extension MUST NOT be marked critical.

```
id-ce-authorityKeyIdentifier OBJECT IDENTIFIER ::=  { id-ce 35 }

AuthorityKeyIdentifier ::= SEQUENCE {
   keyIdentifier             [0] KeyIdentifier           OPTIONAL,
   authorityCertIssuer       [1] GeneralNames            OPTIONAL,
   authorityCertSerialNumber [2] CertificateSerialNumber OPTIONAL  }

KeyIdentifier ::= OCTET STRING
```

4.2.1.2 Subject Key Identifier

The subject key identifier extension provides a means of identifying certificates that contain a particular public key.

To facilitate chain building, this extension MUST appear in all conforming CA certificates, that is, all certificates including the basic constraints extension (see sec. 4.2.1.10) where the value of cA

is TRUE. The value of the subject key identifier MUST be the value placed in the key identifier field of the Authority Key Identifier extension (see sec. 4.2.1.1) of certificates issued by the subject of this certificate.

For CA certificates, subject key identifiers SHOULD be derived from the public key or a method that generates unique values. The key

identifier is an explicit value placed in the certificate by the issuer, not a value generated by a certificate user. Two common methods for generating key identifiers from the public key are:

(1) The keyIdentifier is composed of the 160-bit SHA-1 hash of the value of the BIT STRING subjectPublicKey (excluding the tag, length, and number of unused bits).

(2) The keyIdentifier is composed of a four bit type field with the value 0100 followed by the least significant 60 bits of the SHA-1 hash of the value of the BIT STRING subjectPublicKey.

One common method for generating unique values is a monotonically increasing sequence of integers.

For end entity certificates, the subject key identifier extension provides a means for identifying certificates containing the particular public key used in an application. Where an end entity has obtained multiple certificates, especially from multiple CAs, the subject key identifier provides a means to quickly identify the set of certificates containing a particular public key. To assist applications in identifying the appropriate end entity certificate, this extension SHOULD be included in all end entity certificates.

For end entity certificates, subject key identifiers SHOULD be derived from the public key. Two common methods for generating key identifiers from the public key are identifed above.

Where a key identifier has not been previously established, this specification recommends use of one of these methods for generating keyIdentifiers.

This extension MUST NOT be marked critical.

```
id-ce-subjectKeyIdentifier OBJECT IDENTIFIER ::=  { id-ce 14 }

SubjectKeyIdentifier ::= KeyIdentifier
```

4.2.1.3 Key Usage

The key usage extension defines the purpose (e.g., encipherment, signature, certificate signing) of the key contained in the certificate. The usage restriction might be employed when a key that could be used for more than one operation is to be restricted. For example, when an RSA key should be used only for signing, the digitalSignature and/or nonRepudiation bits would be asserted. Likewise, when an RSA key should be used only for key management, the keyEncipherment bit would be asserted. When used, this extension SHOULD be marked critical.

```
id-ce-keyUsage OBJECT IDENTIFIER ::=  { id-ce 15 }

KeyUsage ::= BIT STRING {
     digitalSignature        (0),
     nonRepudiation          (1),
     keyEncipherment         (2),
     dataEncipherment        (3),
     keyAgreement            (4),
     keyCertSign             (5),
     cRLSign                 (6),
     encipherOnly            (7),
     decipherOnly            (8) }
```

Bits in the KeyUsage type are used as follows:

The digitalSignature bit is asserted when the subject public key is used with a digital signature mechanism to support security services other than non-repudiation (bit 1), certificate signing (bit 5), or revocation information signing (bit 6). Digital signature mechanisms are often used for entity authentication and data origin authentication with integrity.

The nonRepudiation bit is asserted when the subject public key is used to verify digital signatures used to provide a non-repudiation service which protects against the signing entity falsely denying some action, excluding certificate or CRL signing. In the case of later conflict, a reliable third party may determine the authenticity of the signed data.

Further distinctions between the digitalSignature and nonRepudiation bits may be provided in specific certificate policies.

The keyEncipherment bit is asserted when the subject public key is used for key transport. For example, when an RSA key is to be

used for key management, then this bit shall asserted.

The dataEncipherment bit is asserted when the subject public key is used for enciphering user data, other than cryptographic keys.

The keyAgreement bit is asserted when the subject public key is used for key agreement. For example, when a Diffie-Hellman key is to be used for key management, then this bit shall asserted.

The keyCertSign bit is asserted when the subject public key is used for verifying a signature on certificates. This bit may only be asserted in CA certificates. If the keyCertSign bit is asserted, then the cA bit in the basic constraints extension (see 4.2.1.10) MUST also be asserted. If the keyCertSign bit is not asserted, then the cA bit in the basic constraints extension MUST NOT be asserted.

The cRLSign bit is asserted when the subject public key is used for verifying a signature on revocation information (e.g., a CRL).

The meaning of the encipherOnly bit is undefined in the absence of the keyAgreement bit. When the encipherOnly bit is asserted and the keyAgreement bit is also set, the subject public key may be used only for enciphering data while performing key agreement.

The meaning of the decipherOnly bit is undefined in the absence of the keyAgreement bit. When the decipherOnly bit is asserted and the keyAgreement bit is also set, the subject public key may be used only for deciphering data while performing key agreement.

This profile does not restrict the combinations of bits that may be set in an instantiation of the keyUsage extension. However, appropriate values for keyUsage extensions for particular algorithms are specified in [PKIX ALGS].

4.2.1.4 Private Key Usage Period

This profile recommends against the use of this extension. CAs conforming to this profile MUST NOT generate certificates with critical private key usage period extensions.

The private key usage period extension allows the certificate issuer to specify a different validity period for the private key than the

certificate. This extension is intended for use with digital signature keys. This extension consists of two optional components, notBefore and notAfter. The private key associated with the certificate should not be used to sign objects before or after the times specified by the two components, respectively. CAs conforming

to this profile MUST NOT generate certificates with private key usage period extensions unless at least one of the two components is present.

Where used, notBefore and notAfter are represented as GeneralizedTime and MUST be specified and interpreted as defined in section 4.1.2.5.2.

```
id-ce-privateKeyUsagePeriod OBJECT IDENTIFIER ::=  { id-ce 16 }

PrivateKeyUsagePeriod ::= SEQUENCE {
     notBefore       [0]     GeneralizedTime OPTIONAL,
     notAfter        [1]     GeneralizedTime OPTIONAL }
```

4.2.1.5 Certificate Policies

The certificate policies extension contains a sequence of one or more policy information terms, each of which consists of an object identifier (OID) and optional qualifiers. Optional qualifiers, which may be present, are not expected to change the definition of the policy.

In an end-entity certificate, these policy information terms indicate the policy under which the certificate has been issued and the purposes for which the certificate may be used. In a CA certificate, these policy information terms limit the set of policies for certification paths which include this certificate. When a CA does not wish to limit the set of policies for certification paths which include this certificate, they may assert the special policy anyPolicy, with a value of {2 5 29 32 0}.

Applications with specific policy requirements are expected to have a list of those policies which they will accept and to compare the policy OIDs in the certificate to that list. If this extension is critical, the path validation software MUST be able to interpret this extension (including the optional qualifier), or MUST reject the

certificate.

To promote interoperability, this profile RECOMMENDS that policy information terms consist of only an OID. Where an OID alone is insufficient, this profile strongly recommends that use of qualifiers be limited to those identified in this section. When qualifiers are used with the special policy anyPolicy, they MUST be limited to the qualifers identified in this section.

This specification defines two policy qualifier types for use by certificate policy writers and certificate issuers. The qualifier types are the CPS Pointer and User Notice qualifiers.

The CPS Pointer qualifier contains a pointer to a Certification Practice Statement (CPS) published by the CA. The pointer is in the form of a URI. Processing requirements for this qualifier are a local matter. No action is mandated by this specification regardless of the criticality value asserted for the extension.

User notice is intended for display to a relying party when a certificate is used. The application software SHOULD display all user notices in all certificates of the certification path used, except that if a notice is duplicated only one copy need be displayed. To prevent such duplication, this qualifier SHOULD only be present in end-entity certificates and CA certificates issued to other organizations.

The user notice has two optional fields: the noticeRef field and the explicitText field.

The noticeRef field, if used, names an organization and identifies, by number, a particular textual statement prepared by that organization. For example, it might identify the organization "CertsRUs" and notice number 1. In a typical implementation, the application software will have a notice file containing the current set of notices for CertsRUs; the application will extract the notice text from the file and display it. Messages may be multilingual, allowing the software to select the particular language message for its own environment.

An explicitText field includes the textual statement directly in the certificate. The explicitText field is a string with a

maximum size of 200 characters.

If both the noticeRef and explicitText options are included in the one qualifier and if the application software can locate the notice text indicated by the noticeRef option then that text should be displayed; otherwise, the explicitText string should be displayed.

```
id-ce-certificatePolicies OBJECT IDENTIFIER ::=  { id-ce 32 }

anyPolicy OBJECT IDENTIFIER ::= {id-ce-certificate-policies 0}

certificatePolicies ::= SEQUENCE SIZE (1..MAX) OF PolicyInformation

PolicyInformation ::= SEQUENCE {
     policyIdentifier   CertPolicyId,
     policyQualifiers   SEQUENCE SIZE (1..MAX) OF
                             PolicyQualifierInfo OPTIONAL }

CertPolicyId ::= OBJECT IDENTIFIER
```



```
PolicyQualifierInfo ::= SEQUENCE {
     policyQualifierId  PolicyQualifierId,
     qualifier          ANY DEFINED BY policyQualifierId }

-- policyQualifierIds for Internet policy qualifiers

id-qt          OBJECT IDENTIFIER ::=  { id-pkix 2 }
id-qt-cps      OBJECT IDENTIFIER ::=  { id-qt 1 }
id-qt-unotice  OBJECT IDENTIFIER ::=  { id-qt 2 }

PolicyQualifierId ::=
     OBJECT IDENTIFIER ( id-qt-cps | id-qt-unotice )

Qualifier ::= CHOICE {
     cPSuri           CPSuri,
     userNotice       UserNotice }

CPSuri ::= IA5String

UserNotice ::= SEQUENCE {
     noticeRef        NoticeReference OPTIONAL,
     explicitText     DisplayText OPTIONAL}
```

```
NoticeReference ::= SEQUENCE {
     organization     DisplayText,
     noticeNumbers    SEQUENCE OF INTEGER }

DisplayText ::= CHOICE {
     ia5String        IA5String      (SIZE (1..200)),
     visibleString    VisibleString  (SIZE (1..200)),
     bmpString        BMPString      (SIZE (1..200)),
     utf8String       UTF8String     (SIZE (1..200)) }
```

4.2.1.6 Policy Mappings

This extension is used in CA certificates. It lists one or more pairs of OIDs; each pair includes an issuerDomainPolicy and a subjectDomainPolicy. The pairing indicates the issuing CA considers its issuerDomainPolicy equivalent to the subject CA's subjectDomainPolicy.

The issuing CA's users may accept an issuerDomainPolicy for certain applications. The policy mapping tells the issuing CA's users which policies associated with the subject CA are comparable to the policy they accept.

Each issuerDomainPolicy named in the the policy mapping extension should also be asserted in a certificate policies extension in the

same certificate. Policies should not be mapped either to or from the special value anyPolicy. (See 4.2.1.5 certificate policies).

This extension may be supported by CAs and/or applications, and it MUST be non-critical.

```
id-ce-policyMappings OBJECT IDENTIFIER ::=  { id-ce 33 }

PolicyMappings ::= SEQUENCE SIZE (1..MAX) OF SEQUENCE {
     issuerDomainPolicy      CertPolicyId,
     subjectDomainPolicy     CertPolicyId }
```

4.2.1.7 Subject Alternative Name

The subject alternative names extension allows additional identities

to be bound to the subject of the certificate. Defined options include an Internet electronic mail address, a DNS name, an IP address, and a uniform resource identifier (URI). Other options exist, including completely local definitions. Multiple name forms, and multiple instances of each name form, may be included. Whenever such identities are to be bound into a certificate, the subject alternative name (or issuer alternative name) extension MUST be used.

Because the subject alternative name is considered to be definitively bound to the public key, all parts of the subject alternative name MUST be verified by the CA.

Further, if the only subject identity included in the certificate is an alternative name form (e.g., an electronic mail address), then the subject distinguished name MUST be empty (an empty sequence), and the subjectAltName extension MUST be present. If the subject field contains an empty sequence, the subjectAltName extension MUST be marked critical.

When the subjectAltName extension contains an Internet mail address, the address MUST be included as an rfc822Name. The format of an rfc822Name is an "addr-spec" as defined in RFC 822 [RFC 822]. An addr-spec has the form "local-part@domain". Note that an addr-spec has no phrase (such as a common name) before it, has no comment (text surrounded in parentheses) after it, and is not surrounded by "<" and ">". Note that while upper and lower case letters are allowed in an RFC 822 addr-spec, no significance is attached to the case.

When the subjectAltName extension contains a iPAddress, the address MUST be stored in the octet string in "network byte order," as specified in RFC 791 [RFC 791]. The least significant bit (LSB) of each octet is the LSB of the corresponding byte in the network address. For IP Version 4, as specified in RFC 791, the octet string

MUST contain exactly four octets. For IP Version 6, as specified in RFC 1883, the octet string MUST contain exactly sixteen octets [RFC 1883].

When the subjectAltName extension contains a domain name service label, the domain name MUST be stored in the dNSName (an IA5String). The name MUST be in the "preferred name syntax," as specified by RFC 1034 [RFC 1034]. Note that while upper and lower case letters are

allowed in domain names, no signifigance is attached to the case. In addition, while the string " " is a legal domain name, subjectAltName extensions with a dNSName " " are not permitted. Finally, the use of the DNS representation for Internet mail addresses (wpolk.nist.gov instead of wpolk@nist.gov) MUST NOT be used; such identities are to be encoded as rfc822Name.

Note: work is currently underway to specify domain names in international character sets. This names will likely not be accomodated by IA5String. Once this work is complete, this profile will be revisited and the appropriate functionality will be added.

When the subjectAltName extension contains a URI, the name MUST be stored in the uniformResourceIdentifier (an IA5String). The name MUST be a non-relative URL, and MUST follow the URL syntax and encoding rules specified in [RFC 1738]. The name must include both a scheme (e.g., "http" or "ftp") and a scheme-specific-part. The scheme-specific-part must include a fully qualified domain name or IP address as the host.

As specified in [RFC 1738], the scheme name is not case-sensitive (e.g., "http" is equivalent to "HTTP"). The host part is also not case-sensitive, but other components of the scheme-specific-part may be case-sensitive. When comparing URIs, conforming implementations MUST compare the scheme and host without regard to case, but assume the remainder of the scheme-specific-part is case sensitive.

When the subjectAltName extension contains a DN in the directoryName, the DN MUST be unique for each subject entity certified by the one CA as defined by the issuer name field. A CA may issue more than one certificate with the same DN to the same subject entity.

The subjectAltName may carry additional name types through the use of the otherName field. The format and semantics of the name are indicated through the OBJECT IDENTIFIER in the type-id field. The name itself is conveyed as value field in otherName. For example, Kerberos [RFC 1510] format names can be encoded into the otherName, using the krb5PrincipalName OID and the KerberosName syntax as defined in [PKINIT].

Subject alternative names may be constrained in the same manner as

subject distinguished names using the name constraints extension as described in section 4.2.1.11.

If the subjectAltName extension is present, the sequence MUST contain at least one entry. Unlike the subject field, conforming CAs MUST NOT issue certificates with subjectAltNames containing empty GeneralName fields. For example, an rfc822Name is represented as an IA5String. While an empty string is a valid IA5String, such an rfc822Name is not permitted by this profile. The behavior of clients that encounter such a certificate when processing a certificication path is not defined by this profile.

Finally, the semantics of subject alternative names that include wildcard characters (e.g., as a placeholder for a set of names) are not addressed by this specification. Applications with specific requirements may use such names but shall define the semantics.

```
id-ce-subjectAltName OBJECT IDENTIFIER ::=  { id-ce 17 }

SubjectAltName ::= GeneralNames

GeneralNames ::= SEQUENCE SIZE (1..MAX) OF GeneralName

GeneralName ::= CHOICE {
     otherName                       [0]     OtherName,
     rfc822Name                      [1]     IA5String,
     dNSName                         [2]     IA5String,
     x400Address                     [3]     ORAddress,
     directoryName                   [4]     Name,
     ediPartyName                    [5]     EDIPartyName,
     uniformResourceIdentifier       [6]     IA5String,
     iPAddress                       [7]     OCTET STRING,
     registeredID                    [8]     OBJECT IDENTIFIER}

OtherName ::= SEQUENCE {
     type-id    OBJECT IDENTIFIER,
     value      [0] EXPLICIT ANY DEFINED BY type-id }

EDIPartyName ::= SEQUENCE {
     nameAssigner            [0]     DirectoryString OPTIONAL,
     partyName               [1]     DirectoryString }
```

4.2.1.8 Issuer Alternative Names

As with 4.2.1.7, this extension is used to associate Internet style identities with the certificate issuer. Issuer alternative names MUST

be encoded as in 4.2.1.7.

Where present, this extension SHOULD NOT be marked critical.

```
id-ce-issuerAltName OBJECT IDENTIFIER ::=  { id-ce 18 }

IssuerAltName ::= GeneralNames
```

4.2.1.9 Subject Directory Attributes

The subject directory attributes extension is used to convey identification attributes (e.g.,nationality) of the subject. The extension is defined as a sequence of one or more attributes. This extension MUST be non-critical.

```
id-ce-subjectDirectoryAttributes OBJECT IDENTIFIER ::=  { id-ce 9 }

SubjectDirectoryAttributes ::= SEQUENCE SIZE (1..MAX) OF Attribute
```

4.2.1.10 Basic Constraints

The basic constraints extension identifies whether the subject of the certificate is a CA and how deep a certification path may exist through that CA.

The cA bit indicates if the certified public key may be used to verify signatures on other certificates. If the cA bit is asserted, then the keyCertSign bit in the key usage extension (see 4.2.1.3) MUST also be asserted. If the cA bit is not asserted, then the keyCertSign bit in the key usage extension MUST NOT be asserted.

The pathLenConstraint field is meaningful only if cA is set to TRUE. In this case, it gives the maximum number of CA certificates that may follow this certificate in a certification path. (Note: The last certificate may be an end-entity certificate or a CA certificate. The cA bit, or its absence, determines the type of the last certificate rather than the application.) A pathLenConstraint of zero indicates that only an end-entity certificate may follow in the path. Where it appears, the pathLenConstraint field MUST be greater than or equal to zero. Where pathLenConstraint does not appear, there is no limit to the allowed length of the certification path.

This extension MUST appear as a critical extension in all CA certificates. This extension MAY appear as a critical or non-critical extension in end entity certificates.

```
id-ce-basicConstraints OBJECT IDENTIFIER ::=  { id-ce 19 }
```



```
BasicConstraints ::= SEQUENCE {
     cA                      BOOLEAN DEFAULT FALSE,
     pathLenConstraint       INTEGER (0..MAX) OPTIONAL }
```

4.2.1.11 Name Constraints

The name constraints extension, which MUST be used only in a CA certificate, indicates a name space within which all subject names in subsequent certificates in a certification path shall be located. Restrictions may apply to the subject distinguished name or subject alternative names. Restrictions apply only when the specified name form is present. If no name of the type is in the certificate, the certificate is acceptable.

Name constraints are not applied to certificates whose issuer and subject are identical. (This could prevent CAs that use name constraints from issuing self-signed certificates to implement key rollover.)

Restrictions are defined in terms of permitted or excluded name subtrees. Any name matching a restriction in the excludedSubtrees field is invalid regardless of information appearing in the permittedSubtrees. This extension MUST be critical.

Within this profile, the minimum and maximum fields are not used with any name forms, thus minimum is always zero, and maximum is always absent.

For URIs, the constraint applies to the host part of the name. The constraint may specify a host or a domain. Examples would be "foo.bar.com"; and ".xyz.com". When the the constraint begins with a period, it may be expanded with one or more subdomains. That is, the constraint ".xyz.com" is satisfied by both abc.xyz.com and abc.def.xyz.com. However, the constraint ".xyz.com" is not satisfied by "xyz.com". When the constraint does not begin with a period, it specifies a host.

A name constraint for Internet mail addresses may specify a particular mailbox, all addresses at a particular host, or all

mailboxes in a domain. To indicate a particular mailbox, the constraint is the complete mail address. For example, "root@xyz.com" indicates the root mailbox on the host "xyz.com". To indicate all Internet mail addresses on a particular host, the constraint is specified as the host name. For example, the constraint "xyz.com" is satisfied by any mail address at the host "xyz.com". To specify any address within a domain, the constraint is specified with a leading period (as with URIs). For example, ".xyz.com" indicates all the Internet mail addresses in the domain "xyz.com", but not Internet

mail addresses on the host "xyz.com".

DNS name restrictions are expressed as foo.bar.com. Any DNS name that can be constructed by simply adding to the left hand side of the name satisfies the name constraint. For example, www.foo.bar.com would satisfy the constraint but foo1.bar.com would not.

Legacy implementations exist where an RFC 822 name is embedded in the subject distinguished name in an attribute of type EmailAddress (see sec. 4.1.2.6). When rfc822 names are constrained, but the certificate does not include a subject alternative name, the rfc822 name constraint MUST be applied to the attribute of type EmailAddress in the subject distinguished name. The ASN.1 syntax for EmailAddress and the corresponding OID are supplied in Appendix A and B.

Restrictions of the form directoryName MUST be applied to the subject field in the certificate and to the subjectAltName extensions of type directoryName. Restrictions of the form x400Address MUST be applied to subjectAltName extensions of type x400Address.

When applying restrictions of the form directoryName, an implementation MUST compare DN attributes. At a minimum, implementations MUST perform the DN comparison rules specified in Section 4.1.2.4. CAs issuing certificates with a restriction of the form directoryName SHOULD NOT rely on implementation of the full ISO DN name comparison algorithm. This implies name restrictions shall be stated identically to the encoding used in the subject field or subjectAltName extension.

The syntax of iPAddress MUST be as described in section 4.2.1.7 with the following additions specifically for Name Constraints. For IPv4 addresses, the ipAddress field of generalName MUST contain eight (8)

octets, encoded in the style of RFC 1519 (CIDR) to represent an address range.[RFC 1519] For IPv6 addresses, the ipAddress field MUST contain 32 octets similarly encoded. For example, a name constraint for "class C" subnet 10.9.8.0 shall be represented as the octets 0A 09 08 00 FF FF FF 00, representing the CIDR notation 10.9.8.0/255.255.255.0.

The syntax and semantics for name constraints for otherName, ediPartyName, and registeredID are not defined by this specification.

```
id-ce-nameConstraints OBJECT IDENTIFIER ::=  { id-ce 30 }

NameConstraints ::= SEQUENCE {
     permittedSubtrees       [0]     GeneralSubtrees OPTIONAL,
     excludedSubtrees        [1]     GeneralSubtrees OPTIONAL }
```



```
GeneralSubtrees ::= SEQUENCE SIZE (1..MAX) OF GeneralSubtree

GeneralSubtree ::= SEQUENCE {
     base                    GeneralName,
     minimum         [0]     BaseDistance DEFAULT 0,
     maximum         [1]     BaseDistance OPTIONAL }

BaseDistance ::= INTEGER (0..MAX)
```

4.2.1.12 Policy Constraints

The policy constraints extension can be used in certificates issued to CAs. The policy constraints extension constrains path validation in two ways. It can be used to prohibit policy mapping or require that each certificate in a path contain an acceptable policy identifier.

If the inhibitPolicyMapping field is present, the value indicates the number of additional certificates that may appear in the path before policy mapping is no longer permitted. For example, a value of one indicates that policy mapping may be processed in certificates issued by the subject of this certificate, but not in additional certificates in the path.

If the requireExplicitPolicy field is present, subsequent

certificates shall include an acceptable policy identifier. The value of requireExplicitPolicy indicates the number of additional certificates that may appear in the path before an explicit policy is required. An acceptable policy identifier is the identifier of a policy required by the user of the certification path or the identifier of a policy which has been declared equivalent through policy mapping.

Conforming CAs MUST NOT issue certificates where policy constraints is a null sequence. That is, at least one of the inhibitPolicyMapping field or the requireExplicitPolicy field MUST be present. The behavior of clients that encounter a null policy constraints field is not addressed in this profile.

This extension may be critical or non-critical.

```
id-ce-policyConstraints OBJECT IDENTIFIER ::=  { id-ce 36 }

PolicyConstraints ::= SEQUENCE {
     requireExplicitPolicy           [0] SkipCerts OPTIONAL,
     inhibitPolicyMapping            [1] SkipCerts OPTIONAL }

SkipCerts ::= INTEGER (0..MAX)
```


4.2.1.13 Extended key usage field

This field indicates one or more purposes for which the certified public key may be used, in addition to or in place of the basic purposes indicated in the key usage extension field. In general, this extension will appear only in end entity certificates. This field is defined as follows:

```
id-ce-extKeyUsage OBJECT IDENTIFIER ::= {id-ce 37}

ExtKeyUsageSyntax ::= SEQUENCE SIZE (1..MAX) OF KeyPurposeId

KeyPurposeId ::= OBJECT IDENTIFIER
```

Key purposes may be defined by any organization with a need. Object identifiers used to identify key purposes shall be assigned in accordance with IANA or ITU-T Rec. X.660 | ISO/IEC/ITU 9834-1.

This extension may, at the option of the certificate issuer, be either critical or non-critical.

If the extension is flagged critical, then the certificate MUST only be used for one of the purposes indicated. If multiple purposes are indicated the application need not recognize all purposes indicated, as long as the intended purpose is present and recognized.

If the extension is flagged non-critical, then it indicates the intended purpose or purposes of the key, and may be used in finding the correct key/certificate of an entity that has multiple keys/certificates. It is an advisory field and does not imply that usage of the key is restricted by the certification authority to the purpose indicated. Certificate using applications may nevertheless require that a particular purpose be indicated in order for the certificate to be acceptable to that application.

If a certificate contains both a critical key usage field and a critical extended key usage field, then both fields MUST be processed independently and the certificate MUST only be used for a purpose consistent with both fields. If there is no purpose consistent with both fields, then the certificate MUST NOT be used for any purpose.

The following key usage purposes are defined by this profile:

```
id-kp OBJECT IDENTIFIER ::= { id-pkix 3 }

id-kp-serverAuth              OBJECT IDENTIFIER ::=   {id-kp 1}
-- TLS Web server authentication
-- Key usage bits that may be consistent: digitalSignature,
```



```
--                          keyEncipherment or keyAgreement
--
id-kp-clientAuth              OBJECT IDENTIFIER ::=   {id-kp 2}
-- TLS Web client authentication
-- Key usage bits that may be consistent: digitalSignature and/or
--                             keyAgreement
--
id-kp-codeSigning             OBJECT IDENTIFIER ::=   {id-kp 3}
-- Signing of downloadable executable code
-- Key usage bits that may be consistent: digitalSignature
--
```

```
id-kp-emailProtection         OBJECT IDENTIFIER ::=   {id-kp 4}
-- E-mail protection
-- Key usage bits that may be consistent: digitalSignature,
--                          nonRepudiation, and/or (keyEncipherment
--                          or keyAgreement)
--
id-kp-timeStamping    OBJECT IDENTIFIER ::= { id-kp 8 }
-- Binding the hash of an object to a time from an agreed-upon time
-- source. Key usage bits that may be consistent: digitalSignature,
--                          nonRepudiation
```

4.2.1.14 CRL Distribution Points

The CRL distribution points extension identifies how CRL information is obtained. The extension SHOULD be non-critical, but this profile recommends support for this extension by CAs and applications. Further discussion of CRL management is contained in section 5.

The cRLDistributionPoints extension is a SEQUENCE of DistributionPoint. A DistributionPoint consists of three fields, each of which is optional: the name of the DistributionPoint, ReasonsFlags, and the cRLIssuer. While each component is optional, a DistributionPoint MUST NOT consist of only the ReasonsFlags field. If the distributionPoint omits cRLIssuer, the CRL MUST be issued by the CA that issued the certificate. If the distributionPointName is absent, cRLIssuer MUST be present and include a Name corresponding to an X.500 or LDAP directory entry where the CRL is located.

If the cRLDistributionPoints extension contains a DistributionPointName of type URI, the following semantics MUST be assumed: the URI is a pointer to the current CRL for the associated reasons and will be issued by the associated cRLIssuer. The expected values for the URI are those defined in 4.2.1.7. Processing rules for other values are not defined by this specification. If the distributionPoint omits reasons, the CRL MUST include revocations for all reasons.


```
id-ce-cRLDistributionPoints OBJECT IDENTIFIER ::=  { id-ce 31 }

CRLDistributionPoints ::= SEQUENCE SIZE (1..MAX) OF DistributionPoint
```

```
DistributionPoint ::= SEQUENCE {
     distributionPoint       [0]     DistributionPointName OPTIONAL,
     reasons                 [1]     ReasonFlags OPTIONAL,
     cRLIssuer               [2]     GeneralNames OPTIONAL }

DistributionPointName ::= CHOICE {
     fullName                [0]     GeneralNames,
     nameRelativeToCRLIssuer [1]     RelativeDistinguishedName }

ReasonFlags ::= BIT STRING {
     unused                  (0),
     keyCompromise           (1),
     cACompromise            (2),
     affiliationChanged      (3),
     superseded              (4),
     cessationOfOperation    (5),
     certificateHold         (6) }
```

4.2.1.15 Inhibit Any-Policy

The inhibit any-policy extension can be used in certificates issued to CAs. The inhibit any-policy indicates that the special any-policy OID, with the value {2 5 29 32 0}, is not considered an explicit match for other certificate policies. The value indicates the number of additional certificates that may appear in the path before any-policy is no longer permitted. For example, a value of one indicates that any-policy may be processed in certificates issued by the subject of this certificate, but not in additional certificates in the path.

This extension MUST be critical.

```
id-ce-inhibitAnyPolicy OBJECT IDENTIFIER ::=  { id-ce 54 }

InhibitAnyPolicy ::= SkipCerts

SkipCerts ::= INTEGER (0..MAX)
```

4.2.1.16 Freshest CRL (a.k.a. Delta CRL Distribution Point)

The freshest CRL extension identifies how delta-CRL information is obtained. The extension MUST be non-critical. Further discussion of CRL management is contained in section 5.

The same syntax is used for this extension and the cRLDistributionPoints extension, and is described in section 4.2.1.14. The same conventions apply to both extensions.

```
id-ce-freshestCRL OBJECT IDENTIFIER ::=  { id-ce 46 }

FreshestCRL ::= CRLDistributionPoints
```

4.2.2 Private Internet Extensions

This section defines one new extension for use in the Internet Public Key Infrastructure. This extension may be used to direct applications to identify an on-line validation service supporting the issuing CA. As the information may be available in multiple forms, each extension is a sequence of IA5String values, each of which represents a URI. The URI implicitly specifies the location and format of the information and the method for obtaining the information.

An object identifier is defined for the private extension. The object identifier associated with the private extension is defined under the arc id-pe within the id-pkix name space. Any future extensions defined for the Internet PKI will also be defined under the arc id-pe.

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

   id-pe  OBJECT IDENTIFIER  ::=  { id-pkix 1 }
```

4.2.2.1 Authority Information Access

The authority information access extension indicates how to access CA information and services for the issuer of the certificate in which the extension appears. Information and services may include on-line validation services and CA policy data. (The location of CRLs is not specified in this extension; that information is provided by the cRLDistributionPoints extension.) This extension may be included in subject or CA certificates, and it MUST be non-critical.

```
id-pe-authorityInfoAccess OBJECT IDENTIFIER ::= { id-pe 1 }

AuthorityInfoAccessSyntax  ::=
        SEQUENCE SIZE (1..MAX) OF AccessDescription

AccessDescription  ::=  SEQUENCE {
```

```
        accessMethod          OBJECT IDENTIFIER,
```



```
        accessLocation        GeneralName  }
```

id-ad OBJECT IDENTIFIER ::= { id-pkix 48 }

id-ad-caIssuers OBJECT IDENTIFIER ::= { id-ad 2 }

Each entry in the sequence AuthorityInfoAccessSyntax describes the format and location of additional information provided by the CA who issued the certificate in which this extension appears. The type and format of the information is specified by the accessMethod field; the accessLocation field specifies the location of the information. The retrieval mechanism may be implied by the accessMethod or specified by accessLocation.

This profile defines one OID for accessMethod. The id-ad-caIssuers OID is used when the additional information lists CAs that have issued certificates superior to the CA that issued the certificate containing this extension. The referenced CA Issuers description is intended to aid certificate users in the selection of a certification path that terminates at a point trusted by the certificate user.

When id-ad-caIssuers appears as accessInfoType, the accessLocation field describes the referenced description server and the access protocol to obtain the referenced description. The accessLocation field is defined as a GeneralName, which can take several forms. Where the information is available via http, ftp, or ldap, accessLocation MUST be a uniformResourceIdentifier. Where the information is available via the directory access protocol (dap), accessLocation MUST be a directoryName. When the information is available via electronic mail, accessLocation MUST be an rfc822Name. The semantics of other name forms of accessLocation (when accessMethod is id-ad-caIssuers) are not defined by this specification.

[RFC 2560] defines the access descriptor for the Online Certificate Status Protocol. When this access descriptor appears in the authority information access extension, this indicates the issuer provides revocation information for this certificate through the named OCSP service. Additional access descriptors may be defined in other PKIX specifications.

4.2.2.2 Subject Information Access

The subject information access extension indicates how to access information and services for the subject of the certificate in which the extension appears. When the subject is a CA, information and services may include certificate validation services and CA policy data. When the subject is an end entity, the information describes

the type of services offered and how to access them. In this case, the contents of this extension are defined in the protocol specifications for the suported services. This extension may be included in subject or CA certificates, and it MUST be non-critical.

```
id-pe-subjectInfoAccess OBJECT IDENTIFIER ::= { id-pe 11 }

SubjectInfoAccessSyntax  ::=
        SEQUENCE SIZE (1..MAX) OF AccessDescription

AccessDescription  ::=  SEQUENCE {
        accessMethod          OBJECT IDENTIFIER,
        accessLocation        GeneralName  }
```

Each entry in the sequence SubjectInfoAccessSyntax describes the format and location of additional information provided by the subject of the certificate in which this extension appears. The type and format of the information is specified by the accessMethod field; the accessLocation field specifies the location of the information. The retrieval mechanism may be implied by the accessMethod or specified by accessLocation.

This profile defines one access method to be used when the subject is a CA, and one access method to be used when the subject is an end entity. Additional access methods may be defined in the future in the protocol specifications for other services.

The id-ad-caRepository OID is used when the subject is a CA, and publishes its certificates and CRLs (if issued) in a repository. The accessLocation field is defined as a GeneralName, which can take several forms. Where the information is available via http, ftp, or ldap, accessLocation MUST be a uniformResourceIdentifier. Where the information is available via the directory access protocol (dap),

accessLocation MUST be a directoryName. When the information is available via electronic mail, accessLocation MUST be an rfc822Name. The semantics of other name forms of of accessLocation (when accessMethod is id-ad-caRepository) are not defined by this specification.

The id-ad-timeStamping OID is used when the subject offers timestamping services using the Time Stamp Protocol defined in [PKIX TSA]. Where the timestamping services are available via http or ftp, accessLocation MUST be a uniformResourceIdentifier. Where the timestamping services are available via electronic mail, accessLocation MUST be an rfc822Name. Where timestamping services are available using TCP/IP, the dNSName and ipAddress name forms may be used. The semantics of other name forms of accessLocation (when accessMethod is id-ad-timeStamping) are not defined by this

specification.

Additional access descriptors may be defined in other PKIX specifications.

```
id-ad OBJECT IDENTIFIER ::= { id-pkix 48 }

id-ad-caRepository OBJECT IDENTIFIER ::= { id-ad 5 }

id-ad-timeStamping OBJECT IDENTIFIER ::= { id-ad 3 }
```

5 CRL and CRL Extensions Profile

As described above, one goal of this X.509 v2 CRL profile is to foster the creation of an interoperable and reusable Internet PKI. To achieve this goal, guidelines for the use of extensions are specified, and some assumptions are made about the nature of information included in the CRL.

CRLs may be used in a wide range of applications and environments covering a broad spectrum of interoperability goals and an even broader spectrum of operational and assurance requirements. This profile establishes a common baseline for generic applications requiring broad interoperability. The profile defines a baseline set of information that can be expected in every CRL. Also, the profile defines common locations within the CRL for frequently used

attributes as well as common representations for these attributes.

This profile does not define any private Internet CRL extensions or CRL entry extensions.

Environments with additional or special purpose requirements may build on this profile or may replace it.

Conforming CAs are not required to issue CRLs if other revocation or certificate status mechanisms are provided. Conforming CAs that issue CRLs MUST issue version 2 CRLs, and CAs MUST include the date by which the next CRL will be issued in the nextUpdate field (see sec. 5.1.2.5), the CRL number extension (see sec. 5.2.3) and the authority key identifier extension (see sec. 5.2.1). Conforming applications are required to process version 1 and 2 CRLs.

5.1 CRL Fields

The X.509 v2 CRL syntax is as follows. For signature calculation, the data that is to be signed is ASN.1 DER encoded. ASN.1 DER encoding is a tag, length, value encoding system for each element.


```
CertificateList  ::=  SEQUENCE  {
     tbsCertList          TBSCertList,
     signatureAlgorithm   AlgorithmIdentifier,
     signatureValue       BIT STRING  }

TBSCertList  ::=  SEQUENCE  {
     version                 Version OPTIONAL,
                                  -- if present, shall be v2
     signature               AlgorithmIdentifier,
     issuer                  Name,
     thisUpdate              Time,
     nextUpdate              Time OPTIONAL,
     revokedCertificates     SEQUENCE OF SEQUENCE  {
          userCertificate         CertificateSerialNumber,
          revocationDate          Time,
          crlEntryExtensions      Extensions OPTIONAL
                                        -- if present, shall be v2
                                  }  OPTIONAL,
     crlExtensions           [0]  EXPLICIT Extensions OPTIONAL
```

```
                                        -- if present, shall be v2
                                    }

    -- Version, Time, CertificateSerialNumber, and Extensions
    -- are all defined in the ASN.1 in section 4.1

    -- AlgorithmIdentifier is defined in section 4.1.1.2
```

The following items describe the use of the X.509 v2 CRL in the Internet PKI.

5.1.1 CertificateList Fields

The CertificateList is a SEQUENCE of three required fields. The fields are described in detail in the following subsections.

5.1.1.1 tbsCertList

The first field in the sequence is the tbsCertList. This field is itself a sequence containing the name of the issuer, issue date, issue date of the next list, the optional list of revoked certificates, and optional CRL extensions. When there are no revoked certificates, the revoked certificates list is absent. When one or more certificates are revoked, each entry on the revoked certificate list is defined by a sequence of user certificate serial number, revocation date, and optional CRL entry extensions.

5.1.1.2 signatureAlgorithm

The signatureAlgorithm field contains the algorithm identifier for the algorithm used by the CA to sign the CertificateList. The field is of type AlgorithmIdentifier, which is defined in section 4.1.1.2. [PKIX ALGS] lists the supported algorithms for this specification. Conforming CAs MUST use the algorithm identifiers presented in [PKIX ALGS] when signing with a supported signature algorithm.

This field MUST contain the same algorithm identifier as the signature field in the sequence tbsCertList (see sec. 5.1.2.2).

5.1.1.3 signatureValue

The signatureValue field contains a digital signature computed upon the ASN.1 DER encoded tbsCertList. The ASN.1 DER encoded tbsCertList is used as the input to the signature function. This signature value is then ASN.1 encoded as a BIT STRING and included in the CRL's signatureValue field. The details of this process are specified for each of the supported algorithms in [PKIX ALGS].

5.1.2 Certificate List "To Be Signed"

The certificate list to be signed, or TBSCertList, is a SEQUENCE of required and optional fields. The required fields identify the CRL issuer, the algorithm used to sign the CRL, the date and time the CRL was issued, and the date and time by which the CA will issue the next CRL.

Optional fields include lists of revoked certificates and CRL extensions. The revoked certificate list is optional to support the case where a CA has not revoked any unexpired certificates that it has issued. The profile requires conforming CAs to use the CRL extension cRLNumber in all CRLs issued.

5.1.2.1 Version

This optional field describes the version of the encoded CRL. When extensions are used, as required by this profile, this field MUST be present and MUST specify version 2 (the integer value is 1).

5.1.2.2 Signature

This field contains the algorithm identifier for the algorithm used to sign the CRL. [PKIX ALGS] lists OIDs for the most popular signature algorithms used in the Internet PKI.

This field MUST contain the same algorithm identifier as the

signatureAlgorithm field in the sequence CertificateList (see section 5.1.1.2).

5.1.2.3 Issuer Name

The issuer name identifies the entity who has signed and issued the CRL. The issuer identity is carried in the issuer name field. Alternative name forms may also appear in the issuerAltName extension (see sec. 5.2.2). The issuer name field MUST contain an X.500 distinguished name (DN). The issuer name field is defined as the X.501 type Name, and MUST follow the encoding rules for the issuer name field in the certificate (see sec. 4.1.2.4).

5.1.2.4 This Update

This field indicates the issue date of this CRL. ThisUpdate may be encoded as UTCTime or GeneralizedTime.

CAs conforming to this profile that issue CRLs MUST encode thisUpdate as UTCTime for dates through the year 2049. CAs conforming to this profile that issue CRLs MUST encode thisUpdate as GeneralizedTime for dates in the year 2050 or later.

Where encoded as UTCTime, thisUpdate MUST be specified and interpreted as defined in section 4.1.2.5.1. Where encoded as GeneralizedTime, thisUpdate MUST be specified and interpreted as defined in section 4.1.2.5.2.

5.1.2.5 Next Update

This field indicates the date by which the next CRL will be issued. The next CRL could be issued before the indicated date, but it will not be issued any later than the indicated date. CAs SHOULD issue CRLs with a nextUpdate time equal to or later than all previous CRLs. nextUpdate may be encoded as UTCTime or GeneralizedTime.

This profile requires inclusion of nextUpdate in all CRLs issued by conforming CAs. Note that the ASN.1 syntax of TBSCertList describes this field as OPTIONAL, which is consistent with the ASN.1 structure defined in [X.509]. The behavior of clients processing CRLs which omit nextUpdate is not specified by this profile.

CAs conforming to this profile that issue CRLs MUST encode nextUpdate as UTCTime for dates through the year 2049. CAs conforming to this profile that issue CRLs MUST encode nextUpdate as GeneralizedTime for dates in the year 2050 or later.

Where encoded as UTCTime, nextUpdate MUST be specified and

interpreted as defined in section 4.1.2.5.1. Where encoded as GeneralizedTime, nextUpdate MUST be specified and interpreted as defined in section 4.1.2.5.2.

5.1.2.6 Revoked Certificates

When there are no revoked certificates, the revoked certificates list is absent. Otherwise, revoked certificates are listed by their serial numbers. Certificates revoked by the CA are uniquely identified by the certificate serial number. The date on which the revocation occurred is specified. The time for revocationDate MUST be expressed as described in section 5.1.2.4. Additional information may be supplied in CRL entry extensions; CRL entry extensions are discussed in section 5.3.

5.1.2.7 Extensions

This field may only appear if the version is 2 (see sec. 5.1.2.1). If present, this field is a SEQUENCE of one or more CRL extensions. CRL extensions are discussed in section 5.2.

5.2 CRL Extensions

The extensions defined by ANSI X9 and ISO/IEC/ITU for X.509 v2 CRLs [X.509] [X9.55] provide methods for associating additional attributes with CRLs. The X.509 v2 CRL format also allows communities to define private extensions to carry information unique to those communities. Each extension in a CRL may be designated as critical or non-critical. A CRL validation MUST fail if it encounters a critical extension which it does not know how to process. However, an unrecognized non-critical extension may be ignored. The following subsections present those extensions used within Internet CRLs. Communities may elect to include extensions in CRLs which are not defined in this specification. However, caution should be exercised in adopting any critical extensions in CRLs which might be used in a general context.

Conforming CAs that issue CRLs are required to include the authority key identifier (see sec. 5.2.1) and the CRL number (see sec. 5.2.3) extensions in all CRLs issued.

5.2.1 Authority Key Identifier

The authority key identifier extension provides a means of identifying the public key corresponding to the private key used to sign a CRL. The identification can be based on either the key identifier (the subject key identifier in the CRL signer's certificate) or on the issuer name and serial number. This extension

is especially useful where an issuer has more than one signing key, either due to multiple concurrent key pairs or due to changeover.

Conforming CAs MUST use the key identifier method, and MUST include this extension in all CRLs issued.

The syntax for this CRL extension is defined in section 4.2.1.1.

5.2.2 Issuer Alternative Name

The issuer alternative names extension allows additional identities to be associated with the issuer of the CRL. Defined options include an rfc822 name (electronic mail address), a DNS name, an IP address, and a URI. Multiple instances of a name and multiple name forms may be included. Whenever such identities are used, the issuer alternative name extension MUST be used.

The issuerAltName extension SHOULD NOT be marked critical.

The OID and syntax for this CRL extension are defined in section 4.2.1.8.

5.2.3 CRL Number

The CRL number is a non-critical CRL extension which conveys a monotonically increasing sequence number for each CRL issued by a CA. This extension allows users to easily determine when a particular CRL supersedes another CRL. CAs conforming to this profile MUST include this extension in all CRLs.

```
id-ce-cRLNumber OBJECT IDENTIFIER ::= { id-ce 20 }

cRLNumber ::= INTEGER (0..MAX)
```

5.2.4 Delta CRL Indicator

The delta CRL indicator is a critical CRL extension that identifies a CRL as being a delta CRL. Delta CRLs contain updates to revocation information previously distributed, rather than all the information that would appear in a complete CRL. The use of delta CRLs can significantly reduce network load and processing time in some environments. Delta CRLs are generally smaller than the CRLs they

update, so applications that obtain delta CRLs consume less network bandwidth than applications that obtain the corresponding complete CRLs. Applications which store revocation information in a format other than the CRL structure can add new revocation information to the local database without reprocessing information.

The delta CRL indicator extension contains a single value of type BaseCRLNumber. This value identifies the CRL number of the base CRL that was used as the foundation in the generation of this delta CRL. The referenced base CRL is a CRL that was explicitly issued as a CRL that is complete for a given scope (e.g., a set of revocation reasons or a particular distribution point.) The CRL containing the delta CRL indicator extension contains all updates to the certificate revocation status for that same scope. The combination of a CRL containing the delta CRL indicator extension plus the CRL referenced in the BaseCRLNumber component of this extension is equivalent to a full CRL, for the applicable scope, at the time of publication of the delta CRL.

When a conforming CA issues a delta CRL, the CA MUST also issue a CRL that is complete for the given scope. Both the delta CRL and the complete CRL MUST include the CRL number extension (see sec. 5.2.3). The CRL number extension in the delta CRL and the complete CRL MUST contain the same value. When a delta CRL is issued, it MUST cover the same set of reasons and same set of certificates that were covered by the base CRL it references.

An application can construct a CRL that is complete for a given scope, at the current time, in either of the following ways:

(a) by retrieving the current delta CRL for that scope, and combining it with an issued CRL that is complete for that scope and that has a cRLNumber greater than or equal to the cRLNumber of the base CRL referenced in the delta CRL; or

(b) by retrieving the current delta CRL for that scope and combining it with a locally constructed CRL whose cRLNumber is greater than or equal to the cRLNumber of the base CRL referenced in the current delta CRL.

The constructed CRL has the CRL number specified in the CRL number

extension found in the delta CRL used in its construction.

CAs must ensure that application of a delta CRL to the referenced base revocation information accurately reflects the current status of revocation. If a CA supports the certificateHold revocation reason the following rules must be applied when generating delta CRLs:

(a) If a certificate was listed as revoked with revocation reason certificateHold on a CRL (either a delta CRL or a CRL that is complete for a given scope), whose cRLNumber is n, and the hold is subsequently released, the certificate must be included in all delta CRLs issued after the hold is released where the cRLNumber of the referenced base CRL is less than or equal to n. The

certificate must be listed with revocation reason removeFromCRL unless the certificate is subsequently revoked again for one of the revocation reasons covered by the delta CRL, in which case the certificate must be listed with the revocation reason appropriate for the subsequent revocation.

(b) If the certificate was not removed from hold, but was permanently revoked, then it must be listed on all subsequent delta CRLs where the cRLNumber of the referenced base CRL is less than the cRLNumber of the CRL (either a delta CRL or a CRL that is complete for the given scope) on which the permanent revocation notice first appeared.

```
id-ce-deltaCRLIndicator OBJECT IDENTIFIER ::= { id-ce 27 }

deltaCRLIndicator EXTENSION ::= {
        SYNTAX          BaseCRLNumber
        IDENTIFIED BY   id-ce-deltaCRLIndicator }

BaseCRLNumber ::= CRLNumber
```

5.2.5 Issuing Distribution Point

The issuing distribution point is a critical CRL extension that identifies the CRL distribution point for a particular CRL, and it indicates whether the CRL covers revocation for end entity certificates only, CA certificates only, or a limited set of reason codes. Although the extension is critical, conforming

implementations are not required to support this extension.

The CRL is signed using the CA's private key. CRL Distribution Points do not have their own key pairs. If the CRL is stored in the X.500 Directory, it is stored in the Directory entry corresponding to the CRL distribution point, which may be different than the Directory entry of the CA.

The reason codes associated with a distribution point shall be specified in onlySomeReasons. If onlySomeReasons does not appear, the distribution point shall contain revocations for all reason codes. CAs may use CRL distribution points to partition the CRL on the basis of compromise and routine revocation. In this case, the revocations with reason code keyCompromise (1) and cACompromise (2) appear in one distribution point, and the revocations with other reason codes appear in another distribution point.

Where the issuingDistributionPoint extension contains a URL, the following semantics MUST be assumed: the object is a pointer to the most current CRL issued by this CA. The URI schemes ftp, http,

mailto [RFC1738] and ldap [RFC1778] are defined for this purpose. The URI MUST be an absolute, not relative, pathname and MUST specify the host.

```
id-ce-issuingDistributionPoint OBJECT IDENTIFIER ::= { id-ce 28 }

issuingDistributionPoint ::= SEQUENCE {
     distributionPoint       [0] DistributionPointName OPTIONAL,
     onlyContainsUserCerts   [1] BOOLEAN DEFAULT FALSE,
     onlyContainsCACerts     [2] BOOLEAN DEFAULT FALSE,
     onlySomeReasons         [3] ReasonFlags OPTIONAL,
     indirectCRL             [4] BOOLEAN DEFAULT FALSE }
```

5.2.6 Freshest CRL (a.k.a. Delta CRL Distribution Point)

The freshest CRL extension identifies how delta-CRL information for this CRL is obtained. The extension MUST be non-critical.

The same syntax is used for this extension as the cRLDistributionPoints certificate extension, and is described in section 4.2.1.14. The same conventions apply to both extensions.

```
id-ce-freshestCRL OBJECT IDENTIFIER ::=  { id-ce 46 }

FreshestCRL ::= CRLDistributionPoints
```

5.3 CRL Entry Extensions

The CRL entry extensions already defined by ANSI X9 and ISO/IEC/ITU for X.509 v2 CRLs provide methods for associating additional attributes with CRL entries [X.509] [X9.55]. The X.509 v2 CRL format also allows communities to define private CRL entry extensions to carry information unique to those communities. Each extension in a CRL entry may be designated as critical or non-critical. A CRL validation MUST fail if it encounters a critical CRL entry extension which it does not know how to process. However, an unrecognized non-critical CRL entry extension may be ignored. The following subsections present recommended extensions used within Internet CRL entries and standard locations for information. Communities may elect to use additional CRL entry extensions; however, caution should be exercised in adopting any critical extensions in CRL entries which might be used in a general context.

All CRL entry extensions used in this specification are non-critical. Support for these extensions is optional for conforming CAs and applications. However, CAs that issue CRLs SHOULD include reason codes (see sec. 5.3.1) and invalidity dates (see sec. 5.3.3) whenever this information is available.

5.3.1 Reason Code

The reasonCode is a non-critical CRL entry extension that identifies the reason for the certificate revocation. CAs are strongly encouraged to include meaningful reason codes in CRL entries; however, the reason code CRL entry extension SHOULD be absent instead of using the unspecified (0) reasonCode value.

```
id-ce-cRLReason OBJECT IDENTIFIER ::= { id-ce 21 }

-- reasonCode ::= { CRLReason }

CRLReason ::= ENUMERATED {
     unspecified             (0),
```

```
        keyCompromise           (1),
        cACompromise            (2),
        affiliationChanged      (3),
        superseded              (4),
        cessationOfOperation    (5),
        certificateHold         (6),
        removeFromCRL           (8) }
```

5.3.2 Hold Instruction Code

The hold instruction code is a non-critical CRL entry extension that provides a registered instruction identifier which indicates the action to be taken after encountering a certificate that has been placed on hold.

```
id-ce-holdInstructionCode OBJECT IDENTIFIER ::= { id-ce 23 }

holdInstructionCode ::= OBJECT IDENTIFIER
```

The following instruction codes have been defined. Conforming applications that process this extension MUST recognize the following instruction codes.

```
holdInstruction    OBJECT IDENTIFIER ::=
                  { iso(1) member-body(2) us(840) x9-57(10040) 2 }

id-holdinstruction-none   OBJECT IDENTIFIER ::= {holdInstruction 1}
id-holdinstruction-callissuer
                          OBJECT IDENTIFIER ::= {holdInstruction 2}
id-holdinstruction-reject OBJECT IDENTIFIER ::= {holdInstruction 3}
```

Conforming applications which encounter an id-holdinstruction-callissuer MUST call the certificate issuer or reject the certificate. Conforming applications which encounter an id-

holdinstruction-reject MUST reject the certificate. The hold instruction id-holdinstruction-none is semantically equivalent to the absence of a holdInstructionCode, and its use is strongly deprecated for the Internet PKI.

5.3.3 Invalidity Date

The invalidity date is a non-critical CRL entry extension that provides the date on which it is known or suspected that the private key was compromised or that the certificate otherwise became invalid. This date may be earlier than the revocation date in the CRL entry, which is the date at which the CA processed the revocation. When a revocation is first posted by a CA in a CRL, the invalidity date may precede the date of issue of earlier CRLs, but the revocation date SHOULD NOT precede the date of issue of earlier CRLs. Whenever this information is available, CAs are strongly encouraged to share it with CRL users.

The GeneralizedTime values included in this field MUST be expressed in Greenwich Mean Time (Zulu), and MUST be specified and interpreted as defined in section 4.1.2.5.2.

```
id-ce-invalidityDate OBJECT IDENTIFIER ::= { id-ce 24 }

invalidityDate ::=  GeneralizedTime
```

5.3.4 Certificate Issuer

This CRL entry extension identifies the certificate issuer associated with an entry in an indirect CRL, i.e. a CRL that has the indirectCRL indicator set in its issuing distribution point extension. If this extension is not present on the first entry in an indirect CRL, the certificate issuer defaults to the CRL issuer. On subsequent entries in an indirect CRL, if this extension is not present, the certificate issuer for the entry is the same as that for the preceding entry. This field is defined as follows:

```
id-ce-certificateIssuer   OBJECT IDENTIFIER ::= { id-ce 29 }

certificateIssuer ::=     GeneralNames
```

If used by conforming CAs that issue CRLs, this extension MUST always be critical. If an implementation ignored this extension it could not correctly attribute CRL entries to certificates. This specification RECOMMENDS that implementations recognize this extension.

6 Certification Path Validation

Certification path validation procedures for the Internet PKI are based on the algorithm supplied in [X.509]. Certification path processing verifies the binding between the subject distinguished name and/or subject alternative name and subject public key. The binding is limited by constraints which are specified in the certificates which comprise the path and inputs which are specified by the relying party. The basic constraints and policy constraints extensions allow the certification path processing logic to automate the decision making process.

This section describes an algorithm for validating certification paths. Conforming implementations of this specification are not required to implement this algorithm, but MUST provide functionality equivalent to the external behavior resulting from this procedure. Any algorithm may be used by a particular implementation so long as it derives the correct result.

In section 6.1, the text describes basic path validation. Valid paths begin with certificates issued by a "most-trusted CA". The algorithm requires the public key of the CA, the CA's name, and any constraints upon the set of paths which may be validated using this key.

The selection of a "most-trusted CA" is a matter of policy: it could be the top CA in a hierarchical PKI; the CA that issued the verifier's own certificate(s); or any other CA in a network PKI. The path validation procedure is the same regardless of the choice of "most-trusted CA." In addition, different applications may rely on different "most-trusted CA", or may accept paths that begin with any of a set of "most-trusted CAs."

Section 6.2 describes methods for using the path validation algorithm in specific implementations. Two specific cases are discussed: the case where paths may begin with one of several trusted CAs; and where compatibility with the PEM architecture is required.

Section 6.3 describes the steps necessary to determine if a certificate is revoked or on hold status when CRLs are the revocation mechanism used by the certificate issuer.

6.1 Basic Path Validation

This text describes an algorithm for X.509 path processing. A conformant implementation MUST include an X.509 path processing procedure that is functionally equivalent to the external behavior of this algorithm. However, some of the certificate fields processed in this algorithm are optional for compliant implementations. Clients

that do not support these fields may omit the corresponding steps in the path validation algorithm.

For example, clients are not required to support the policy mapping extension. Clients that do not support this extension may omit the path validation steps where policy mappings are processed. Note that clients MUST reject the certificate if it contains critical extensions that are not supported.

This text describes the trust anchor as an input to the algorithm. There is no requirement that the same trust anchor be used to validate all certification paths. Different trust anchors may be used to validate different paths, as discussed further in Section 6.2.

The primary goal of path validation is to verify the binding between a subject distinguished name or subject alternative name and subject public key, as represented in the end entity certificate, based on the public key of the trust anchor. This requires obtaining a sequence of certificates that support that binding. The procedure performed to obtain this sequence of certificates is outside the scope of this section.

To meet this goal, the path validation process verifies, among other things, that a prospective certification path (a sequence of n certificates) satisfies the following conditions:

(a) for all x in {1, ..., n-1}, the subject of certificate x is the issuer of certificate x+1;

(b) certificate 1 is issued by the trust anchor;

(c) certificate n is the end entity certificate; and

(d) for all x in {1, ..., n}, the certificate was valid at the time in question.

A particular certification path may not, however, be appropriate for all applications. The path validation process also determines the set of certificate policies that are valid for this path, based on the certificate policies extension, policy mapping extension, policy constraints extension, and inhibit any-policy extension. To achieve this, the path validation algorithm constructs a valid policy tree.

If the set of certificate policies that are valid for this path is not empty, then the result will be a valid policy tree of depth n, otherwise the result will be a NULL valid policy tree.

A certificate is termed self-issued if the DNs that appear in the

subject and issuer fields are identical and are not empty. In general, the issuer and subject of the certificates that make up a path are different for each certificate. However, a CA may issue a certificate to itself to support key rollover or changes in certificate policies. These self-issued certificates are not counted when evaluating path length or name constraints.

This section presents the algorithm in four basic steps: (1) initialization, (2) basic certificate processing, (3) preparation for the next certificate, and (4) wrap-up. Steps (1) and (4) are performed exactly once. Step (2) is performed for all certificates in the path. Step (3) is performed for all certificates in the path except the final certificate. Figure 2 provides a high-level flowchart of this algorithm.

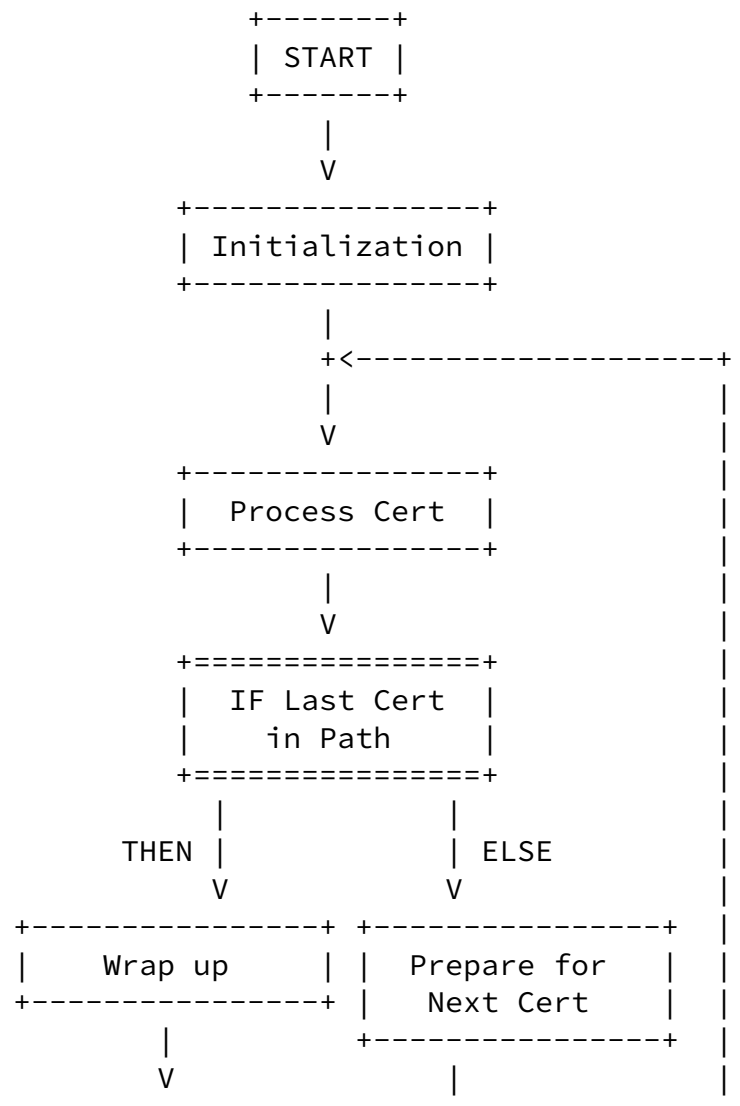

START
Initialization
Process Cert
IF Last Cert
in Path
THEN
ELSE
Wrap up
Prepare for
Next Cert

Figure 2. Path Processing Flowchart

6.1.1 Inputs

This algorithm assumes the following seven inputs are provided to the path processing logic:

(a) a prospective certification path of length n;

(b) the time, T, for which the validity of the path should be determined. This may be the current date/time, or some point in the past.

(c) user-initial-policy-set: A set of certificate policy identifiers naming the policies that are acceptable to the

certificate user. The user-initial-policy-set contains the special value any-policy if the user is not concerned about certificate policy.

(d) trust anchor information, describing a CA that serves as a trust anchor for the certification path. The trust anchor information includes:

(1) the trusted issuer name,

(2) the trusted public key algorithm,

(3) the trusted public key, and

(4) optionally, the trusted public key parameters associated with the public key.

The trust anchor information may be provided to the path processing procedure in the form of a self-signed certificate. The trusted anchor information is trusted because it was delivered to the path processing procedure by some trustworthy out-of-band procedure. If the trusted public key algorithm requires

parameters, then the parameters are provided along with the trusted public key.

(e) initial-policy-mapping-inhibit, which indicates if policy mapping is allowed in the certification path.

(f) initial-explicit-policy, which indicates if the path must be valid for at least one of the certificate policies in the user-initial-policy-set.

(g) initial-any-policy-inhibit, which indicates whether the any-policy OID should be processed if it is included in a certificate.

6.1.2 Initialization

The initialization phase establishes eleven state variables based upon the seven inputs:

(a) valid_policy_tree: A tree of certificate policies with their optional qualifiers; each of the leaves of the tree represents a valid policy at this stage in the certification path validation. If valid policies exist at this stage in the certification path validation, the depth of the tree is equal to the number of certificates in the chain that have been processed. If valid policies do not exist at this stage in the certification path validation, the tree is set to NULL. Once the tree is set to NULL,

policy processing ceases.

Each node in the valid_policy_tree includes four data objects: the valid policy, a set of associated policy qualifiers, a set of one or more expected policy values, and a criticality indicator. If the node is at depth x, the components of the node have the following semantics:

(1) The valid_policy is a single policy OID representing a valid policy for the path of length x.

(2) The qualifier_set is a set of policy qualifiers associated with the valid policy in certificate x.

(3) The criticality_indicator indicates whether the certificate

policy extension in certificate x was marked as critical.

(4) The expected_policy_set contains one or more policy OIDs that would satisfy this policy in the certificate x+1.

The initial value of the valid_policy_tree is a single node with valid_policy any-policy, an empty qualifier_set, an expected_policy_set with the single value any-policy, and a criticality_indicator of FALSE. This node is considered to be at depth zero.

Figure 3 is a graphic representation of the initial state of the valid_policy_tree. Additional figures will use this format to describe changes in the valid_policy_tree during path processing.

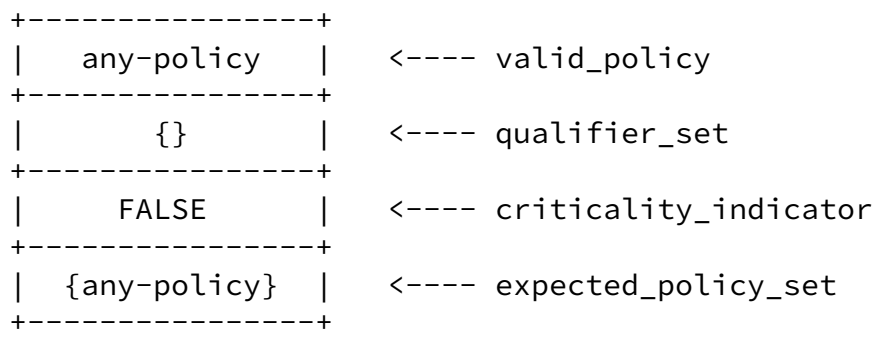


Figure 3. Initial value of the valid_policy_tree state variable

(b) permitted_subtrees: A set of root names for each name type (e.g., X.500 distinguished names, email addresses, or ip addresses) defining a set of subtrees within which all subject names in subsequent certificates in the certification path shall fall. This variable includes a set for each name type: the initial value for the set for Distinguished Names is the set of all

Distinguished names; the initial value for the set of RFC822 names is the set of all RFC822 names, etc.

(c) excluded_subtrees: A set of root names for each name type (e.g., X.500 distinguished names, email addresses, or ip addresses) defining a set of subtrees within which no subject name in subsequent certificates in the certification path may fall. This variable includes a set for each name type, and the initial

value for each set is empty.

(d) explicit_policy: an integer which indicates if a non-NULL valid_policy_tree is required. The integer indicates the number of non-self-issued certificates to be processed before this requirement is imposed. Once set, this variable may be decreased, but may not be increased. That is, if a certificate in the path requires a non-NULL valid_policy_tree, a later certificate can not remove this requirement. If initial-explicit-policy is set, then the initial value is 0, otherwise the initial value is n+1.

(e) inhibit_any-policy: an integer which indicates whether the any-policy policy identifier is considered a match. The integer indicates the number of non-self-issued certificates to be processed before the any-policy OID, if asserted in a certificate, is ignored. Once set, this variable may be decreased, but may not be increased. That is, if a certificate in the path inhibits processing of any-policy, a later certificate can not permit it. If initial-any-policy-inhibit is set, then the initial value is 0, otherwise the initial value is n+1.

(f) policy_mapping: an integer which indicates if policy mapping is permitted. The integer indicates the number of non-self-issued certificates to be processed before policy mapping is inhibited. Once set, this variable may be decreased, but may not be increased. That is, if a certificate in the path specifies policy mapping is not permitted, it can not be overridden by a later certificate. If initial-policy-mapping-inhibit is set, then the initial value is 0, otherwise the initial value is n+1.

(g) working_public_key_algorithm: the digital signature algorithm used to verify the signature of a certificate. The working_public_key_algorithm is initialized from the trusted public key algorithm provided in the trust anchor information.

(h) working_public_key: the public key used to verify the signature of a certificate. The working_public_key is initialized from the trusted public key provided in the trust anchor information.

(i) working_public_key_parameters: parameters associated with the

current public key, that may required to verify a signature (depending upon the algorithm). The working_public_key_parameters variable is initialized from the trusted public key parameters provided in the trust anchor information.

(j) working_issuer_name: the issuer distinguished name expected in the next certificate in the chain. The working_issuer_name is initialized to the trusted issuer provided in the trust anchor information.

(k) max_path_length: this integer is initialized to n, and is reset by the path length constraint field within the basic constraints extension of a CA certificate.

Upon completion of the initialization steps, perform the basic certificate processing steps specified in 6.1.3.

6.1.3 Basic Certificate Processing

The basic path processing actions to be performed for certificate i are listed below.

(a) Verify the basic certificate information. The certificate must satisfy each of the following:

(1) The certificate was signed with the working_public_key_algorithm using the working_public_key and the working_public_key_parameters.

(2) The certificate validity period includes time T.

(3) At time T, the certificate is not revoked and is not on hold status. This may be determined by obtaining the appropriate CRL (see section 6.3), status information, or by out-of-band mechanisms.

(4) The certificate issuer name is the working_issuer_name.

(b) If certificate i is not self-issued, verify that the subject name is within one of the permitted_subtrees for X.500 distinguished names, and verify that each of the alternative names in the subjectAltName extension (critical or non-critical) is within one of the permitted_subtrees for that name type.

(c) If certificate i is not self-issued, verify that the subject name is not within one of the excluded_subtrees for X.500 distinguished names, and verify that each of the alternative names

in the subjectAltName extension (critical or non-critical) is not within one of the excluded_subtrees for that name type.

(d) If the certificate policies extension is present in the certificiate and the valid_policy_tree is not NULL, process the policy information by performing the following steps in order:

(1) For each policy P not equal to any-policy in the certificate policies extension, let P-OID denote the OID in policy P and P-Q denote the qualifier set for policy P. Perform the following steps in order:

(i) If the valid_policy_tree includes a node of depth i-1 where P-OID is in the expected_policy_set, create a child node as follows: set the valid_policy to OID- P; set the qualifier_set to P-Q, and set the expected_policy_set to {P-OID}.

For example, consider a valid_policy_tree with a node of depth i-1 where the expected_policy_set is {Gold, White}. Assume the certificate policies Gold and Silver appear in the certificate policies extension of certificate i. The Gold policy is matched but the Silver policy is not. This rule will generate a child node of depth i for the Gold policy. The result is shown as Figure 4.

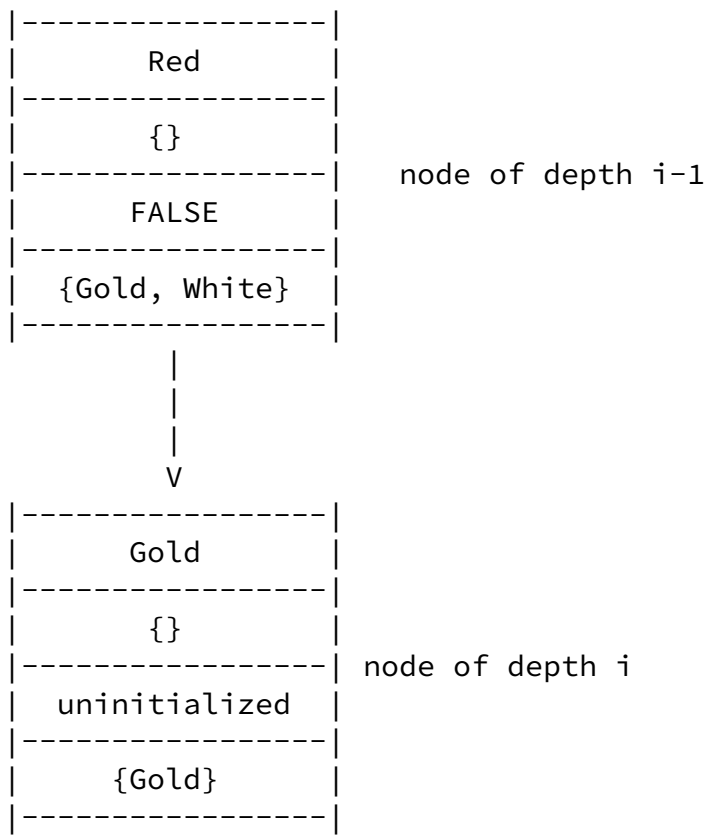


Figure 4. Processing an exact match

(ii) If there was no match in step (i) and the valid_policy_tree includes a node of depth i-1 with the valid policy any-policy, generate a child node with the following values: set the valid_policy to P-OID; set the qualifier_set to P-Q, and set the expected_policy_set to {P-OID}.

For example, consider a valid_policy_tree with a node of depth i-1 where the valid_policy is any-policy. Assume the certificate policies Gold and Silver appear in the certificate policies extension of certificate i. The Gold policy does not have a qualifier, but the Silver policy has the qualifier Q-Silver. If Gold and Silver were not matched in (i) above, this rule will generate two child nodes of

depth i, one for each policy. The result is shown as Figure 5.

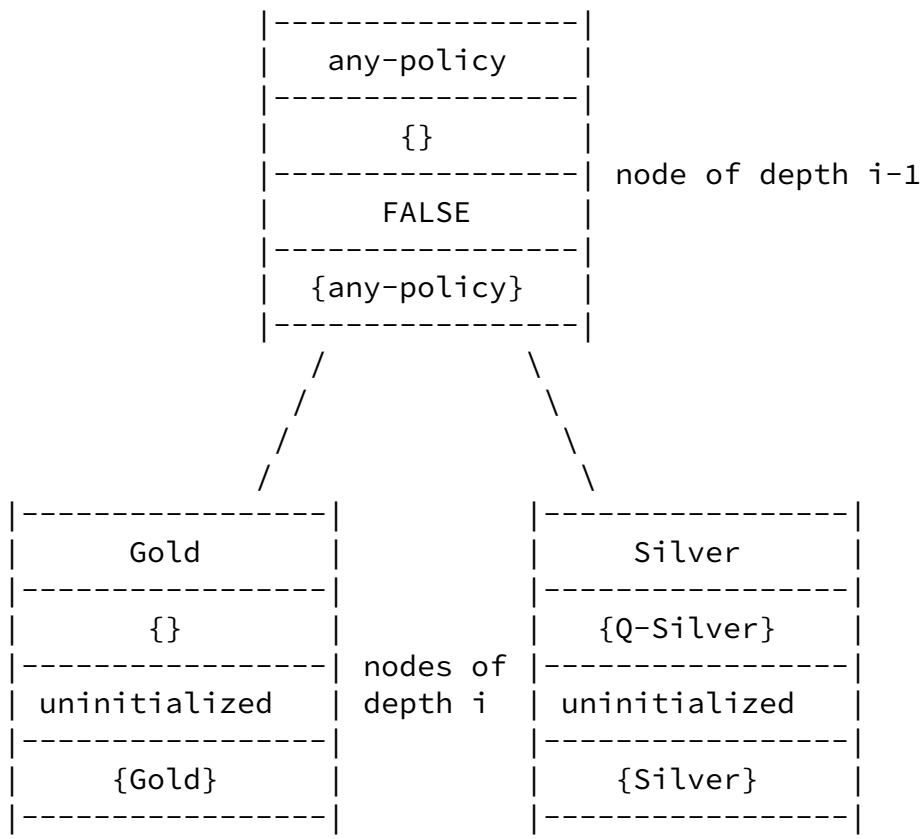


Figure 5. Processing unmatched policies when a leaf node specifies any-policy

(2) If the certificate policies extension includes the policy any-policy with the qualifier set AP-Q and inhibit_any-policy is greater than 0, then:

For each node in the valid_policy_tree of depth i-1, for each value in the expected_policy_set (including any-policy) that

does not appear in a child node, create a child node with the following values: set the valid_policy to the value from the expected_policy_set in the parent node; set the qualifier_set to AP-Q, and set the expected_policy_set to the value in the valid_policy from this node.

For example, consider a valid_policy_tree with a node of depth i-1 where the expected_policy_set = {Gold, Silver}. Assume any-policy appears in the certificate policies extension of certificate i, but Gold and Silver do not. This rule will generate two child nodes of depth i, one for each policy. The result is shown below as Figure 6.

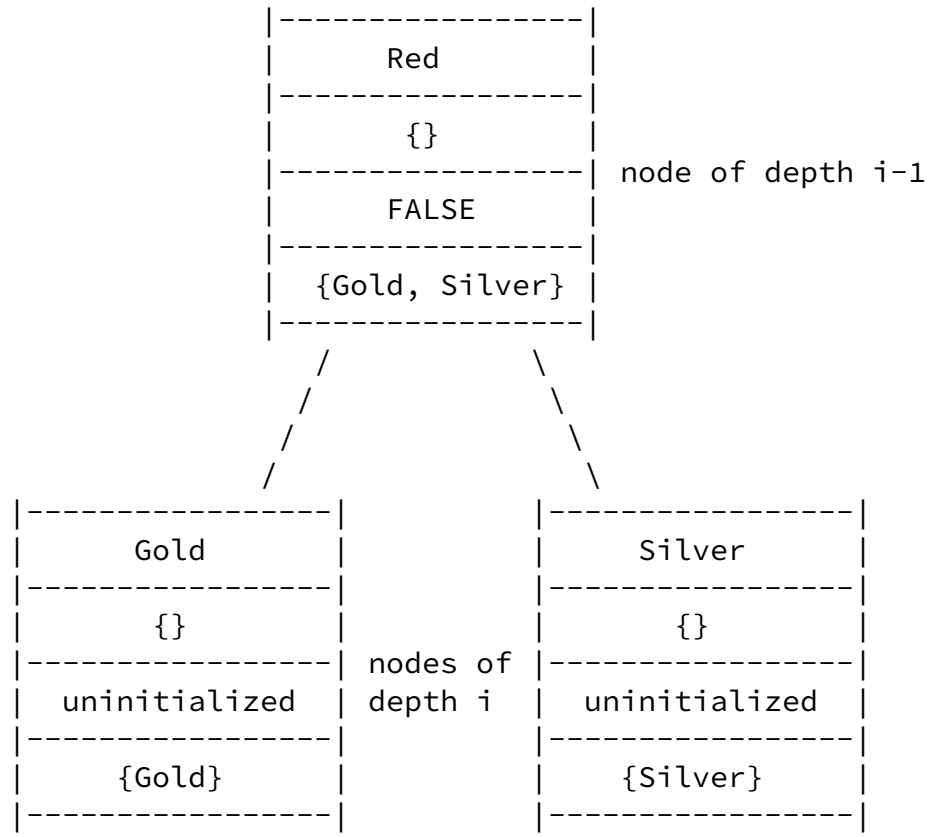
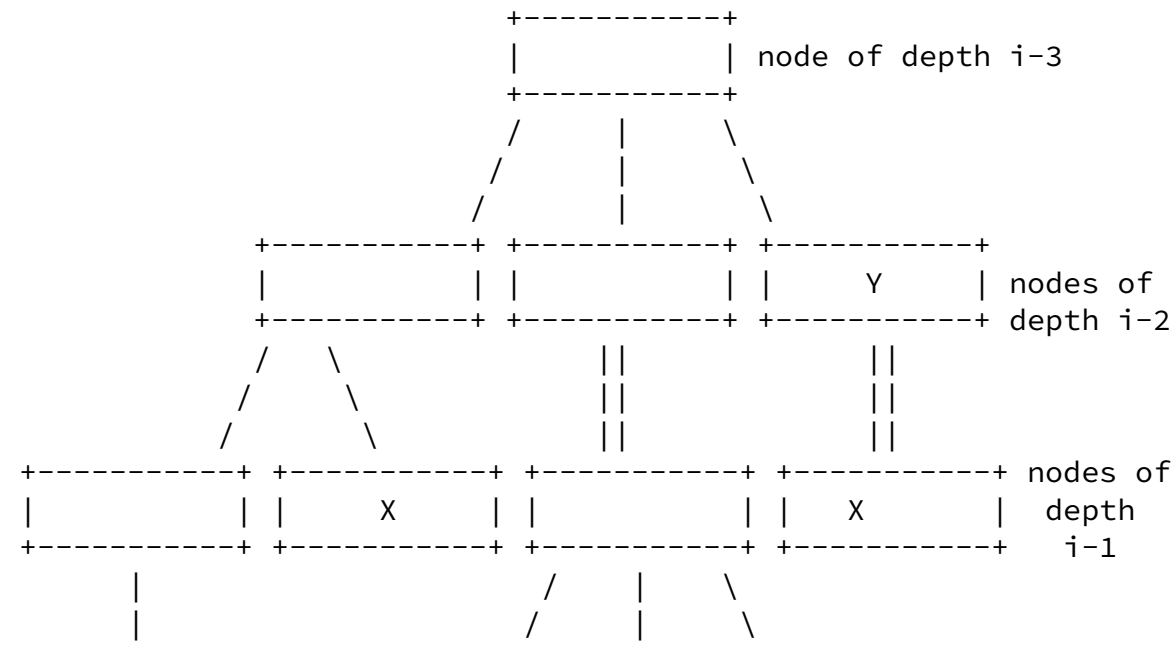


Figure 6. Processing unmatched policies when the certificate policies extension specifies any-policy

(3) If there is a node in the valid_policy_tree of depth i-1 or less without any child nodes, delete that node. Repeat this step until there are no nodes of depth i-1 or less without children.

For example, consider the valid_policy_tree shown in Figure 7 below. The two nodes at depth i-1 that are marked with an to the resulting tree will cause the node at depth i-2 that is marked with an 'Y' to be deleted. The following application of the rule does not cause any nodes to be deleted, and this step is complete.



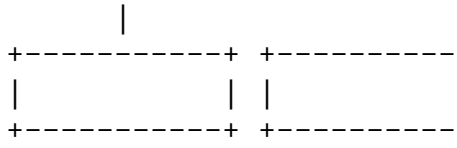


Figure 7. Pruning the valid_policy_tree

(4) If the certificate policies extension was marked as critical, set the criticality_indicator in all nodes of depth i to TRUE. If the certificate policies extension was not marked critical, set the criticality_indicator in all nodes of depth i to FALSE.

(e) If the certificate policies extension is not present, set the valid_policy_tree to NULL.

(f) verify that either explicit_policy is greater than 0 or the valid_policy_tree is not equal to NULL;

If any of steps (a), (b), (c), or (f) fails, the procedure terminates, returning a failure indication and an appropriate reason.

If i is not equal to n, continue by performing the preparatory steps listed in 6.1.4. If i is equal to n, perform the wrap-up steps listed in 6.1.5.

6.1.4 Preparation for Certificate i+1

To prepare for processing of certificate i+1, perform the following steps for certificate i:

(a) If a policy mapping extension is present, verify that the special value any-policy does not appear as an issuerDomainPolicy or a subjectDomainPolicy.

(b) If a policy mapping extension is present, then for each issuerDomainPolicy ID-P in the policy mapping extension:

(1) If the policy_mapping variable is greater than 0, for each node in the valid_policy_tree of depth i where ID-P is the valid_policy, set expected_policy_set to the set of subjectDomainPolicy values that are specified as equivalent to

ID-P by the policy mapping extension.

If no node of depth i in the valid_policy_tree has a valid_policy of ID-P but there is a node of depth i with a valid_policy of any-policy, then generate a child node of the node of depth i-1 that has a valid_policy of any-policy as follows:

(i) set the valid_policy to ID-P;

(ii) set the qualifier_set to the qualifier set of the policy any-policy in the certificate policies extension of certificate i;

(iii) set the criticality_indicator to the criticality of the certificate policies extension of certificate i;

(iv) and set the expected_policy_set to the set of subjectDomainPolicy values that are specified as equivalent to ID-P by the policy mappings extension.

(2) If the policy_mapping variable is equal to 0:

(i) delete each node of depth i in the valid_policy_tree where ID-P is the valid_policy.

(ii) If there is a node in the valid_policy_tree of depth i-1 or less without any child nodes, delete that node. Repeat this step until there are no nodes of depth i-1 or less without children.

(c) Assign the certificate subject name to working_issuer_name.

(d) Assign the certificate subjectPublicKey to working_public_key.

(e) If the subjectPublicKeyInfo field of the certificate contains an algorithm field with non-null parameters, assign the parameters

to the working_public_key_parameters variable.

If the subjectPublicKeyInfo field of the certificate contains an algorithm field with null parameters or parameters are omitted,

compare the certificate subjectPublicKey algorithm to the working_public_key_algorithm. If the certificate subjectPublicKey algorithm and the working_public_key_algorithm are different, set the working_public_key_parameters to null.

(f) Assign the certificate subjectPublicKey algorithm to the working_public_key_algorithm variable.

(g) If a name constraints extension is included in the certificate, modify the permitted_subtrees and excluded_subtrees state variables as follows:

(1) If permittedSubtrees is present in the certificate, set the permitted_subtrees state variable to the intersection of its previous value and the value indicated in the extension field. If permittedSubtrees does not include a particular name type, the permitted_subtrees state variable is unchanged for that name type.

(2) If excludedSubtrees is present in the certificate, set the excluded_subtrees state variable to the union of its previous value and the value indicated in the extension field. If excludedSubtrees does not include a particular name type, the excluded_subtrees state variable is unchanged for that name type.

(h) If the issuer and subject names are not identical:

(1) If explicit_policy is not 0, decrement explicit_policy by 1.

(2) If policy_mapping is not 0, decrement policy_mapping by 1.

(3) If inhibit_any-policy is not 0, decrement inhibit_any-policy by 1.

(i) If a policy constraints extension is included in the certificate, modify the explicit_policy and policy_mapping state variables as follows:

(1) If requireExplicitPolicy is present and is less than explicit_policy, set explicit_policy to the value of requireExplicitPolicy.

(2) If inhibitPolicyMapping is present and is less than policy_mapping, set policy_mapping to the value of inhibitPolicyMapping.

(j) If the inhibitAnyPolicy extension is included in the certificate and is less than inhibit_any-policy, set inhibit_any-policy to the value of inhibitAnyPolicy.

(k) Verify that the certificate is a CA certificate (as specified in a basicConstraints extension or as verified out-of-band).

(l) If the certificate was not self-issued, verify that max_path_length is greater than zero and decrement max_path_length by 1.

(m) If pathLengthConstraint is present in the certificate and is less than max_path_length, set max_path_length to the value of pathLengthConstraint.

(n) If a key usage extension is present and marked critical, verify that the keyCertSign bit is set.

(o) Recognize and process any other critical extension present in the certificate.

If check (a), (k), (l), (n) or (o) fails, the procedure terminates, returning a failure indication and an appropriate reason.

If (a), (k), (l), (n) and (o) have completed successfully, increment i and perform the basic certificate processing specified in 6.1.2.

6.1.5 Wrap-up procedure

To complete the processing of the end entity certificate, perform the following steps for certificate n:

(a) If certificate n was not self-issued and explicit_policy is not 0, decrement explicit_policy by 1.

(b) If a policy constraints extension is included in the certificate and requireExplicitPolicy is present and has a value of 0, set the explicit_policy state variable to 0.

(c) Assign the certificate subjectPublicKey to working_public_key.

(d) If the subjectPublicKeyInfo field of the certificate contains an algorithm field with non-null parameters, assign the parameters

to the working_public_key_parameters variable.

If the subjectPublicKeyInfo field of the certificate contains an algorithm field with null parameters or parameters are omitted, compare the certificate subjectPublicKey algorithm to the working_public_key_algorithm. If the certificate subjectPublicKey algorithm and the working_public_key_algorithm are different, set the working_public_key_parameters to null.

(e) Assign the certificate subjectPublicKey algorithm to the working_public_key_algorithm variable.

(f) Recognize and process any other critical extension present in the certificate n.

(g) Calculate the intersection of the valid_policy_tree and the user-initial-policy-set, as follows:

(i) If the valid_policy_tree is NULL, the intersection is NULL.

(ii) If the valid_policy_tree is not NULL and the user-initial-policy-set is any-policy, the intersection is the entire valid_policy_tree.

(iii) If the valid_policy_tree is not NULL and the user-initial-policy-set is not any-policy, calculate the intersection of the valid_policy_tree and the user-initial-policy-set as follows:

1. Determine the set of policy nodes whose parent nodes have a valid_policy of any-policy. This is the valid_policy_node_set.

2. If the valid_policy of any node in the valid_policy_node_set is not in the user-initial-policy-set and is not any-policy, delete this node and all its children.

3. If there is a node in the valid_policy_tree of depth n-1 or less without any child nodes, delete that node. Repeat this step until there are no nodes of depth n-1 or less without children.

(h) If the certificate was not self-issued, verify that max_path_length is greater than zero and decrement max_path_length by 1.

If check (h) fails, the procedure terminates, returning a failure indication and an appropriate reason.

If check (h) succeeds and either (1) value of explicit_policy variable is greater than zero, or (2) the valid_policy_tree is not NULL, then path processing has succeeded.

6.1.6 Outputs

If path processing succeeds, the procedure terminates, returning a success indication together with final value of the valid_policy_tree, the working_public_key, the working_public_key_algorithm, and the working_public_key_parameters.

6.2 Using the Path Validation Algorithm

The path validation algorithm describes the process of validating a single certification path. While each path begins with a specific trust anchor, there is no requirement that all paths validated by a particular system share a single trust anchor.

The selection of one or more trusted CAs is a local decision. A system may provide any one of its trusted CAs as the trust anchor for a particular path. The inputs to the path validation algorithm may be different for each path. The inputs used to process a path may reflect application-specific requirements or limitations in the trust accorded a particular trust anchor. For example, a trusted CA may only be trusted for a particular certificate policy. This restriction can be expressed through the inputs to the path validation procedure.

It is also possible to specify an extended version of the above certification path processing procedure which results in default behavior identical to the rules of PEM [RFC 1422]. In this extended version, additional inputs to the procedure are a list of one or more Policy Certification Authorities (PCAs) names and an indicator of the

position in the certification path where the PCA is expected. At the nominated PCA position, the CA name is compared against this list. If a recognized PCA name is found, then a constraint of SubordinateToCA is implicitly assumed for the remainder of the certification path and processing continues. If no valid PCA name is found, and if the certification path cannot be validated on the basis of identified policies, then the certification path is considered invalid.

6.3 CRL Validation

This section describes the steps necessary to determine if a certificate is revoked or on hold status when CRLs are the revocation mechanism used by the certificate issuer. Conforming implementations of this specification are not required to implement this algorithm,

but MUST be functionally equivalent to the external behavior resulting from this procedure. Any algorithm may be used by a particular implementation so long as it derives the correct result.

This algorithm defines a set of inputs, a set of state variables, and processing steps that are performed for each certificate in the path.

6.3.1 Revocation Inputs

To support revocation processing, the algorithm requires two inputs:

(a) certificate: the algorithm requires the certificate serial number and issuer name to determine if a certificate is on a particular CRL. The basicConstraints extension is used to determine whether the supplied certificate is associated with a CA or an end-entity. If present, the algorithm may use the cRLDistributionsPoint and freshestCRL extensions to determine revocation status.

(b) use-deltas: This boolean input determines if the delta needs to be checked if the CRL is still valid.

Note that implementations supporting legacy PKIs, such as RFC 1422 and X.509 version 1, will need an additional input indicating whether the supplied certificate is associated with a CA or an end-entity.

6.3.2 Initialization and Revocation State Variables

To support CRL processing, the algorithm requires the following state variables:

(a) reasons_mask: This variable contains the set of revocation reasons supported by the CRLs and delta CRLs processed so far. The legal members of the set are the possible values for reasonflags: unspecified; keyCompromise; caCompromise; affiliationChanged; superseded; cessationOfOperation; and certificateHold. The special value all-reasons is used to denote the set of all legal members. This variable is initialized to the empty set.

(b) cert_status: This variable contains the status of the certificate. Legal values are unspecified; keyCompromise; caCompromise; affiliationChanged; superseded; cessationOfOperation; and certificateHold, the special value UNREVOKED, or the special value UNDETERMINED. This variable is initialized to the special value UNREVOKED.

(c) interim_reasons_mask: This contains the set of revocation

reasons supported by the CRL or delta CRL currently being processed.

Note: In some environments, it is not necessary to check all reason codes. For example, some envornments only are concerned with caCompromise and keyCompromise for CA certificates. This algorithnm checks all reason codes. Additional processing and state variables may be necessary to limit the checking to a subset of the reason codes.

6.3.3 CRL Processing

This algorithm begins by assuming the certificate is not revoked. The algorithm checks one or more CRLs until either the certificate status is determined to be revoked or sufficent CRLs have been checked to cover all reason codes.

For each distribution point (DP) in the crl distribution points extension while ((reasons_mask is not all-reasons) and (cert_status

is UNREVOKED))

(1) locate the corresponding CRL in CRL cache, and perform the following verifications:

(a) compute the interim_reasons_mask for this CRL as follows:

1. if the CRL includes reasons and the DP includes reasons, then set interim_reasons_mask to the intersection of of reasons in the DP and reasons in CRL reasons extension.

2. if the CRL includes reasons but the DP omits reasons, then set interim_reasons_mask to the value of CRL reasons.

3. if the CRL omits reasons but the DP includes reasons, then set interim_reasons_mask to the value of DP reasons.

4. if the CRL omits reasons and the DP omits reasons, then set interim_reasons_mask to the special value all-reasons.

Verify that interim_reasons_mask includes one or more reasons that is not included in the reasons_mask.

(b) Verify the issuer of the CRL as follows:

if the DP includes cRLIssuer, then verify that the CRL issuer matches cRLIssuer else verify that the CRL issuer matches the certificate issuer.

(c) obtain and validate the certification path for the CRL issuer.

(d) validate the signature on the CRL.

(2) If each of the verifications (a) through (d) succeeds, then perform the following steps:

(a) If the value of next update field is before the current-time, otain an appropriate delta CRL or discard the CRL.

(b) If the user wants freshest available info AND the freshest

CRL extension is present, check for a corresponding delta for this base.

(c) If a delta was obtained in (a) or (b), verify that the delta CRL addresses the same set of certificates and the same set of reasons as the CRL.

(d) Perform the checks in step 1 (b) and (c):

1. obtain and validate the certification path for the delta issuer

2. validate the signature on the delta CRL

(e) If a delta CRL was obtained in (a) or (b), and the verifications (c) and (d) suceeded, combine the base and delta to form a complete CRL.

(3) If steps and (1) and (2) succeed, then set reasons_mask to the union of reasons_mask and interim_reasons_mask

(4) Search for the certificate on the CRL

(a) search for the serial number on the CRL

(b) if (a) succeeds, verify that (1) the CRL entry extension Certificate issuer is not present or (2) the issuer identified in the CRL entry extension Certificate issuer is the issuer of the certificate.

(c) if (a) and (b) succeeded, set the cert_status variable as appropriate:

1. if the reasons extension is present, set the cert_status variable to the value of the reasons extension

2. if the reasons extension is not present, set the cert_status variable to the special value not-specified.

if ((reasons_mask is all-reasons) OR (if cert_status is not UNREVOKED) return cert_status

If all CRLs named in the crl distribution points extension have been exhausted, and the reasons_mask is not all-reasons and the cert_status is still UNREVOKED, the verifier must obtain additional CRLs.

The verifier must repeat the process above with the additional CRLs not specified in a distribution point.

If all CRLs are exhausted and the reasons_mask is not all-reasons return the cert_status UNDETERMINED.

7 References

[RFC 791] J. Postel, "Internet Protocol", September 1981.

[RFC 822] D. Crocker, "Standard for the format of ARPA Internet text messages", August 1982.

[RFC 1034] P.V. Mockapetris, "Domain names - concepts and facilities", November 1987.

[RFC 1422] Kent, S., "Privacy Enhancement for Internet Electronic Mail: Part II: Certificate-Based Key Management," RFC 1422, BBN Communications, February 1993.

[RFC 1423] Balenson, D., "Privacy Enhancement for Internet Electronic Mail: Part III: Algorithms, Modes, and Identifiers," RFC 1423, Trusted Information Systems, February 1993.

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

[RFC 1519] V. Fuller, T. Li, J. Yu, and K. Varadhan. "Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy", September 1993.

[RFC 1738] Berners-Lee, T., Masinter L., and M. McCahill. "Uniform Resource Locators (URL)", RFC 1738, December 1994.

[RFC 1778] Howes, T., Kille S., Yeong, W. and C. Robbins. "The String Representation of Standard Attribute Syntaxes," RFC 1778, March 1995.

[RFC 1883] S. Deering and R. Hinden. "Internet Protocol, Version 6 (IPv6) Specification", December 1995.

[RFC 2119] S. Bradner, "Key words for use in RFCs to Indicate Requirement Levels", March 1997.

[RFC 2247] Kille, S., Wahl, M., Grimstad, A., Huber, R. and S. Sataluri. "Using Domains in LDAP/X.500 Distinguished Names", RFC 2247, January 1998.

[RFC 2277] H. Alvestrand, "IETF Policy on Character Sets and Languages", January 1998.

[RFC 2279] F. Yergeau, "UTF-8, a transformation format of ISO 10646", January 1998.

[RFC 2560] Myers, M., Ankney R., Malpani A., Galperin S., and C. Adams, "Online Certificate Status Protocal - OCSP", June 1999.

[SDN.701] SDN.701, "Message Security Protocol 4.0", Revision A 1997-02-06.

[X.208] CCITT Recommendation X.208: Specification of Abstract Syntax Notation One (ASN.1), 1988.

[X.501] ITU-T Recommendation X.501: Information Technology - Open Systems Interconnection - The Directory: Models, 1993.

[X.509] ITU-T Recommendation X.509 (1997 E): Information Technology - Open Systems Interconnection - The Directory: Authentication Framework, June 1997.

[X.520] ITU-T Recommendation X.520: Information Technology - Open Systems Interconnection - The Directory: Selected Attribute Types, 1993.

[X9.55] ANSI X9.55-1995, Public Key Cryptography For The Financial Services Industry: Extensions To Public Key Certificates And Certificate Revocation Lists, 8 December, 1995.

[PKINIT] Tung, B., Neuman C., Hur M., Medvinsky A., Medvinsky S., Wray J., and J. Trostle, "Public Key Cryptography for Initial Authentciaion in Kerberos," draft-ietf-cat-kerberos-pk-init-11.txt, March 15, 2000.

[PKIX ALGS] Bassham, L., Housley, R., and W. Polk, "Internet X.509

Public Key Infrastructure Representation of Public Keys and Digital Signatures," draft-ietf-pkix-ipki-pkalgs-00.txt, July 14, 2000.

[PKIX TSA] Cain, P., Pinkas, D., and R. Zuccherato, "Internet X.509 Public Key Infrastructure Time Stamp Protocol," draft-ietf-pkix-time-stamp-12.txt, November, 2000.

8 Intellectual Property Rights

The IETF has been notified of intellectual property rights claimed in regard to some or all of the specification contained in this document. For more information consult the online list of claimed rights.

The IETF takes no position regarding the validity or scope of any intellectual property or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; neither does it represent that it has made any effort to identify any such rights. Information on the IETF's procedures with respect to rights in standards-track and standards-related documentation can be found in BCP-11. Copies of claims of rights made available for publication and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementors or users of this specification can be obtained from the IETF Secretariat.

9 Security Considerations

The majority of this specification is devoted to the format and content of certificates and CRLs. Since certificates and CRLs are digitally signed, no additional integrity service is necessary. Neither certificates nor CRLs need be kept secret, and unrestricted and anonymous access to certificates and CRLs has no security implications.

However, security factors outside the scope of this specification will affect the assurance provided to certificate users. This section highlights critical issues that should be considered by implementors, administrators, and users.

The procedures performed by CAs and RAs to validate the binding of the subject's identity of their public key greatly affect the assurance that should be placed in the certificate. Relying parties may wish to review the CA's certificate practice statement. This may be particularly important when issuing certificates to other CAs.

The use of a single key pair for both signature and other purposes is strongly discouraged. Use of separate key pairs for signature and key management provides several benefits to the users. The ramifications associated with loss or disclosure of a signature key are different from loss or disclosure of a key management key. Using separate key pairs permits a balanced and flexible response. Similarly, different validity periods or key lengths for each key pair may be appropriate in some application environments. Unfortunately, some legacy applications (e.g., SSL) use a single key pair for signature and key management.

The protection afforded private keys is a critical factor in maintaining security. On a small scale, failure of users to protect their private keys will permit an attacker to masquerade as them, or decrypt their personal information. On a larger scale, compromise of a CA's private signing key may have a catastrophic effect. If an attacker obtains the private key unnoticed, the attacker may issue bogus certificates and CRLs. Existence of bogus certificates and CRLs will undermine confidence in the system. If the compromise is detected, all certificates issued to the CA shall be revoked, preventing services between its users and users of other CAs. Rebuilding after such a compromise will be problematic, so CAs are advised to implement a combination of strong technical measures (e.g., tamper-resistant cryptographic modules) and appropriate management procedures (e.g., separation of duties) to avoid such an incident.

Loss of a CA's private signing key may also be problematic. The CA would not be able to produce CRLs or perform normal key rollover. CAs are advised to maintain secure backup for signing keys. The security of the key backup procedures is a critical factor in avoiding key compromise.

The availability and freshness of revocation information will affect the degree of assurance that should be placed in a certificate.

While certificates expire naturally, events may occur during its natural lifetime which negate the binding between the subject and public key. If revocation information is untimely or unavailable, the assurance associated with the binding is clearly reduced. Similarly, implementations of the Path Validation mechanism described in section 6 that omit revocation checking provide less assurance than those that support it.

The path validation algorithm depends on the certain knowledge of the public keys (and other information) about one or more trusted CAs. The decision to trust a CA is an important decision as it ultimately determines the trust afforded a certificate. The authenticated distribution of trusted CA public keys (usually in the form of a

"self-signed" certificate) is a security critical out of band process that is beyond the scope of this specification.

In addition, where a key compromise or CA failure occurs for a trusted CA, the user will need to modify the information provided to the path validation routine. Selection of too many trusted CAs will make the trusted CA information difficult to maintain. On the other hand, selection of only one trusted CA may limit users to a closed community of users until a global PKI emerges.

The quality of implementations that process certificates may also affect the degree of assurance provided. The path validation algorithm described in section 6 relies upon the integrity of the trusted CA information, and especially the integrity of the public keys associated with the trusted CAs. By substituting public keys for which an attacker has the private key, an attacker could trick the user into accepting false certificates.

The binding between a key and certificate subject cannot be stronger than the cryptographic module implementation and algorithms used to generate the signature. Short key lengths or weak hash algorithms will limit the utility of a certificate. CAs are encouraged to note advances in cryptology so they can employ strong cryptographic techniques. In addition, CAs should decline to issue certificates to CAs or end entities that generate weak signatures.

Inconsistent application of name comparison rules may result in acceptance of invalid X.509 certification paths, or rejection of

valid ones. The X.500 series of specifications defines rules for comparing distinguished names require comparison of strings without regard to case, character set, multi-character white space substring, or leading and trailing white space. This specification relaxes these requirements, requiring support for binary comparison at a minimum.

CAs shall encode the distinguished name in the subject field of a CA certificate identically to the distinguished name in the issuer field in certificates issued by the latter CA. If CAs use different encodings, implementations of this specification may fail to recognize name chains for paths that include this certificate. As a consequence, valid paths could be rejected.

In addition, name constraints for distinguished names shall be stated identically to the encoding used in the subject field or subjectAltName extension. If not, (1) name constraints stated as excludedSubTrees will not match and invalid paths will be accepted and (2) name constraints expressed as permittedSubtrees will not match and valid paths will be rejected. To avoid acceptance of

invalid paths, CAs should state name constraints for distinguished names as permittedSubtrees where ever possible.

Appendix A. Psuedo-ASN.1 Structures and OIDs

This section describes data objects used by conforming PKI components in an "ASN.1-like" syntax. This syntax is a hybrid of the 1988 and 1993 ASN.1 syntaxes. The 1988 ASN.1 syntax is augmented with 1993 UNIVERSAL Types UniversalString, BMPString and UTF8String.

The ASN.1 syntax does not permit the inclusion of type statements in the ASN.1 module, and the 1993 ASN.1 standard does not permit use of the new UNIVERSAL types in modules using the 1988 syntax. As a result, this module does not conform to either version of the ASN.1 standard.

This appendix may be converted into 1988 ASN.1 by replacing the

defintions for the UNIVERSAL Types with the 1988 catch-all "ANY".

A.1 Explicitly Tagged Module, 1988 Syntax

```
PKIX1Explicit88 {iso(1) identified-organization(3) dod(6) internet(1)
  security(5) mechanisms(5) pkix(7) id-mod(0) id-pkix1-explicit(18)}


DEFINITIONS EXPLICIT TAGS ::=

BEGIN

-- EXPORTS ALL --

-- IMPORTS NONE --

-- UNIVERSAL Types defined in '93 and '98 ASN.1
-- but required by this specification

UniversalString ::= [UNIVERSAL 28] IMPLICIT OCTET STRING
        -- UniversalString is defined in ASN.1:1993

BMPString ::= [UNIVERSAL 30] IMPLICIT OCTET STRING
      -- BMPString is the subtype of UniversalString and models
        -- the Basic Multilingual Plane of ISO/IEC/ITU 10646-1

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

--
-- PKIX specific OIDs

id-pkix  OBJECT IDENTIFIER  ::=
         { iso(1) identified-organization(3) dod(6) internet(1)
```



```
                    security(5) mechanisms(5) pkix(7) }
-- PKIX arcs

id-pe OBJECT IDENTIFIER  ::=  { id-pkix 1 }
        -- arc for private certificate extensions
id-qt OBJECT IDENTIFIER ::= { id-pkix 2 }
        -- arc for policy qualifier types
```

```
id-kp OBJECT IDENTIFIER ::= { id-pkix 3 }
        -- arc for extended key purpose OIDS
id-ad OBJECT IDENTIFIER ::= { id-pkix 48 }
        -- arc for access descriptors

-- policyQualifierIds for Internet policy qualifiers

id-qt-cps      OBJECT IDENTIFIER ::=  { id-qt 1 }
        -- OID for CPS qualifier
id-qt-unotice  OBJECT IDENTIFIER ::=  { id-qt 2 }
        -- OID for user notice qualifier

-- access descriptor definitions

id-ad-ocsp      OBJECT IDENTIFIER ::= { id-ad 1 }
id-ad-caIssuers OBJECT IDENTIFIER ::= { id-ad 2 }
id-ad-timeStamping OBJECT IDENTIFIER ::= { id-ad 3 }
id-ad-caRepository OBJECT IDENTIFIER ::= { id-ad 5 }

-- attribute data types --

Attribute       ::=     SEQUENCE {
        type            AttributeType,
        values  SET OF AttributeValue
                -- at least one value is required -- }

AttributeType           ::=   OBJECT IDENTIFIER

AttributeValue          ::=   ANY

AttributeTypeAndValue           ::=     SEQUENCE {
        type    AttributeType,
        value   AttributeValue }

-- suggested naming attributes: Definition of the following
--  information object set may be augmented to meet local
--  requirements.  Note that deleting members of the set may
--  prevent interoperability with conforming implementations.
--  presented in pairs: the AttributeType followed by the
--  type definition for the corresponding AttributeValue
```

```
--Arc for standard naming attributes
id-at           OBJECT IDENTIFIER ::= {joint-iso-ccitt(2) ds(5) 4}

-- Attributes of type NameDirectoryString
id-at-name              AttributeType   ::=     {id-at 41}
id-at-surname           AttributeType   ::=     {id-at 4}
id-at-givenName         AttributeType   ::=     {id-at 42}
id-at-initials          AttributeType   ::=     {id-at 43}
id-at-generationQualifier       AttributeType   ::=     {id-at 44}


X520name        ::= CHOICE {
      teletexString         TeletexString (SIZE (1..ub-name)),
      printableString       PrintableString (SIZE (1..ub-name)),
      universalString       UniversalString (SIZE (1..ub-name)),
      utf8String            UTF8String (SIZE (1..ub-name)),
      bmpString             BMPString (SIZE(1..ub-name))   }

--

id-at-commonName        AttributeType   ::=     {id-at 3}

X520CommonName  ::=      CHOICE {
      teletexString         TeletexString (SIZE (1..ub-common-name)),
      printableString       PrintableString (SIZE (1..ub-common-name)),
      universalString       UniversalString (SIZE (1..ub-common-name)),
      utf8String            UTF8String (SIZE (1..ub-common-name)),
      bmpString             BMPString (SIZE(1..ub-common-name))   }

--

id-at-localityName      AttributeType   ::=     {id-at 7}

X520LocalityName ::= CHOICE {
      teletexString       TeletexString (SIZE (1..ub-locality-name)),
      printableString     PrintableString (SIZE (1..ub-locality-name)),
      universalString     UniversalString (SIZE (1..ub-locality-name)),
      utf8String          UTF8String (SIZE (1..ub-locality-name)),
      bmpString           BMPString (SIZE(1..ub-locality-name))   }

--

id-at-stateOrProvinceName       AttributeType   ::=     {id-at 8}

X520StateOrProvinceName         ::= CHOICE {
      teletexString       TeletexString (SIZE (1..ub-state-name)),
      printableString     PrintableString (SIZE (1..ub-state-name)),
      universalString     UniversalString (SIZE (1..ub-state-name)),
```

```
      utf8String          UTF8String (SIZE (1..ub-state-name)),
      bmpString           BMPString (SIZE(1..ub-state-name))   }

--

id-at-organizationName          AttributeType   ::=     {id-at 10}

X520OrganizationName ::= CHOICE {
  teletexString     TeletexString (SIZE (1..ub-organization-name)),
  printableString   PrintableString (SIZE (1..ub-organization-name)),
  universalString   UniversalString (SIZE (1..ub-organization-name)),
  utf8String        UTF8String (SIZE (1..ub-organization-name)),
  bmpString         BMPString (SIZE(1..ub-organization-name))   }

--

id-at-organizationalUnitName    AttributeType   ::=     {id-at 11}

X520OrganizationalUnitName ::= CHOICE {
 teletexString    TeletexString (SIZE (1..ub-organizational-unit-name)),
 printableString        PrintableString
                       (SIZE (1..ub-organizational-unit-name)),
 universalString        UniversalString
                       (SIZE (1..ub-organizational-unit-name)),
 utf8String       UTF8String (SIZE (1..ub-organizational-unit-name)),
 bmpString        BMPString (SIZE(1..ub-organizational-unit-name))   }

--

id-at-title     AttributeType   ::=     {id-at 12}

X520Title ::=   CHOICE {
      teletexString         TeletexString (SIZE (1..ub-title)),
      printableString       PrintableString (SIZE (1..ub-title)),
      universalString       UniversalString (SIZE (1..ub-title)),
      utf8String            UTF8String (SIZE (1..ub-title)),
      bmpString             BMPString (SIZE(1..ub-title))   }

--

id-at-dnQualifier       AttributeType   ::=     {id-at 46}
X520dnQualifier ::=     PrintableString
```

```
id-at-countryName       AttributeType   ::=     {id-at 6}
X520countryName ::=     PrintableString (SIZE (2)) -- IS 3166 codes

id-at-serialNumber      AttributeType ::= { id-at 5 }
X520SerialNumber ::=    PrintableString (SIZE (1..ub-serial-number))
```



```
 -- domaincomponent and identifier from RFC 2247

id-domainComponent     OBJECT IDENTIFIER  ::=
                                { 0 9 2342 19200300 100 1 25 }

DomainComponent ::=     IA5String

 -- Legacy attributes

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

emailAddress AttributeType      ::= { pkcs-9 1 }

Pkcs9email ::= IA5String (SIZE (1..ub-emailaddress-length))

-- naming data types --

Name            ::=   CHOICE { -- only one possibility for now --
                                rdnSequence  RDNSequence }

RDNSequence     ::=   SEQUENCE OF RelativeDistinguishedName

DistinguishedName       ::=   RDNSequence

RelativeDistinguishedName  ::=
                    SET SIZE (1 .. MAX) OF AttributeTypeAndValue

-- Directory string type --

DirectoryString ::= CHOICE {
      teletexString             TeletexString (SIZE (1..MAX)),
      printableString           PrintableString (SIZE (1..MAX)),
      universalString           UniversalString (SIZE (1..MAX)),
      utf8String              UTF8String (SIZE (1..MAX)),
      bmpString               BMPString (SIZE(1..MAX))   }
```

```
-- certificate and CRL specific structures begin here

Certificate  ::=  SEQUENCE  {
     tbsCertificate       TBSCertificate,
     signatureAlgorithm   AlgorithmIdentifier,
     signature            BIT STRING  }

TBSCertificate  ::=  SEQUENCE  {
     version         [0]  Version DEFAULT v1,
     serialNumber         CertificateSerialNumber,
     signature            AlgorithmIdentifier,
```



```
     issuer               Name,
     validity             Validity,
     subject              Name,
     subjectPublicKeyInfo SubjectPublicKeyInfo,
     issuerUniqueID  [1]  IMPLICIT UniqueIdentifier OPTIONAL,
                          -- If present, version shall be v2 or v3
     subjectUniqueID [2]  IMPLICIT UniqueIdentifier OPTIONAL,
                          -- If present, version shall be v2 or v3
     extensions      [3]  Extensions OPTIONAL
                          -- If present, version shall be v3 --  }

Version  ::=  INTEGER  {  v1(0), v2(1), v3(2)  }

CertificateSerialNumber  ::=  INTEGER

Validity ::= SEQUENCE {
     notBefore      Time,
     notAfter       Time }

Time ::= CHOICE {
     utcTime        UTCTime,
     generalTime    GeneralizedTime }

UniqueIdentifier  ::=  BIT STRING

SubjectPublicKeyInfo  ::=  SEQUENCE  {
     algorithm            AlgorithmIdentifier,
     subjectPublicKey     BIT STRING  }
```

```
Extensions  ::=  SEQUENCE SIZE (1..MAX) OF Extension

Extension  ::=  SEQUENCE  {
     extnID      OBJECT IDENTIFIER,
     critical    BOOLEAN DEFAULT FALSE,
     extnValue   OCTET STRING  }

-- CRL structures

CertificateList  ::=  SEQUENCE  {
     tbsCertList          TBSCertList,
     signatureAlgorithm   AlgorithmIdentifier,
     signature            BIT STRING  }

TBSCertList  ::=  SEQUENCE  {
     version                 Version OPTIONAL,
                                  -- if present, shall be v2
     signature               AlgorithmIdentifier,
     issuer                  Name,
```



```
     thisUpdate              Time,
     nextUpdate              Time OPTIONAL,
     revokedCertificates     SEQUENCE OF SEQUENCE  {
          userCertificate         CertificateSerialNumber,
          revocationDate          Time,
          crlEntryExtensions      Extensions OPTIONAL
                                        -- if present, shall be v2
                                  }  OPTIONAL,
     crlExtensions           [0] Extensions OPTIONAL
                                        -- if present, shall be v2 -- }

-- Version, Time, CertificateSerialNumber, and Extensions were
-- defined earlier for use in the certificate structure

AlgorithmIdentifier  ::=  SEQUENCE  {
     algorithm               OBJECT IDENTIFIER,
     parameters              ANY DEFINED BY algorithm OPTIONAL  }
                                -- contains a value of the type
                                -- registered for use with the
                                -- algorithm object identifier value

-- x400 address syntax starts here
```

```
--      OR Names

ORAddress ::= SEQUENCE {
   built-in-standard-attributes BuiltInStandardAttributes,
   built-in-domain-defined-attributes
                        BuiltInDomainDefinedAttributes OPTIONAL,
   -- see also teletex-domain-defined-attributes
   extension-attributes ExtensionAttributes OPTIONAL }
--      The OR-address is semantically absent from the OR-name if the
--      built-in-standard-attribute sequence is empty and the
--      built-in-domain-defined-attributes and extension-attributes are
--      both omitted.

--      Built-in Standard Attributes

BuiltInStandardAttributes ::= SEQUENCE {
   country-name CountryName OPTIONAL,
   administration-domain-name AdministrationDomainName OPTIONAL,
   network-address      [0] NetworkAddress OPTIONAL,
   -- see also extended-network-address
   terminal-identifier  [1] TerminalIdentifier OPTIONAL,
   private-domain-name  [2] PrivateDomainName OPTIONAL,
   organization-name    [3] OrganizationName OPTIONAL,
   -- see also teletex-organization-name
   numeric-user-identifier      [4] NumericUserIdentifier OPTIONAL,
   personal-name        [5] PersonalName OPTIONAL,
```



```
   -- see also teletex-personal-name
   organizational-unit-names    [6] OrganizationalUnitNames OPTIONAL
   -- see also teletex-organizational-unit-names -- }

CountryName ::= [APPLICATION 1] CHOICE {
   x121-dcc-code NumericString
               (SIZE (ub-country-name-numeric-length)),
   iso-3166-alpha2-code PrintableString
               (SIZE (ub-country-name-alpha-length)) }

AdministrationDomainName ::= [APPLICATION 2] CHOICE {
   numeric NumericString (SIZE (0..ub-domain-name-length)),
   printable PrintableString (SIZE (0..ub-domain-name-length)) }

NetworkAddress ::= X121Address  -- see also extended-network-address
```

```
X121Address ::= NumericString (SIZE (1..ub-x121-address-length))

TerminalIdentifier ::= PrintableString (SIZE (1..ub-terminal-id-length))

PrivateDomainName ::= CHOICE {
   numeric NumericString (SIZE (1..ub-domain-name-length)),
   printable PrintableString (SIZE (1..ub-domain-name-length)) }

OrganizationName ::= PrintableString
                            (SIZE (1..ub-organization-name-length))
-- see also teletex-organization-name

NumericUserIdentifier ::= NumericString
                            (SIZE (1..ub-numeric-user-id-length))

PersonalName ::= SET {
   surname [0] PrintableString (SIZE (1..ub-surname-length)),
   given-name [1] PrintableString
                         (SIZE (1..ub-given-name-length)) OPTIONAL,
   initials [2] PrintableString (SIZE (1..ub-initials-length)) OPTIONAL,
   generation-qualifier [3] PrintableString
                (SIZE (1..ub-generation-qualifier-length)) OPTIONAL }
-- see also teletex-personal-name

OrganizationalUnitNames ::= SEQUENCE SIZE (1..ub-organizational-units)
                                        OF OrganizationalUnitName
-- see also teletex-organizational-unit-names

OrganizationalUnitName ::= PrintableString (SIZE
                         (1..ub-organizational-unit-name-length))

--      Built-in Domain-defined Attributes
```



```
BuiltInDomainDefinedAttributes ::= SEQUENCE SIZE
                                (1..ub-domain-defined-attributes) OF
                                BuiltInDomainDefinedAttribute

BuiltInDomainDefinedAttribute ::= SEQUENCE {
   type PrintableString (SIZE
                         (1..ub-domain-defined-attribute-type-length)),
   value PrintableString (SIZE
```

```
                        (1..ub-domain-defined-attribute-value-length))}

--      Extension Attributes

ExtensionAttributes ::= SET SIZE (1..ub-extension-attributes) OF
                        ExtensionAttribute

ExtensionAttribute ::=  SEQUENCE {
   extension-attribute-type [0] INTEGER (0..ub-extension-attributes),
   extension-attribute-value [1]
                        ANY DEFINED BY extension-attribute-type }

-- Extension types and attribute values
--

common-name INTEGER ::= 1

CommonName ::= PrintableString (SIZE (1..ub-common-name-length))

teletex-common-name INTEGER ::= 2

TeletexCommonName ::= TeletexString (SIZE (1..ub-common-name-length))

teletex-organization-name INTEGER ::= 3

TeletexOrganizationName ::=
                TeletexString (SIZE (1..ub-organization-name-length))

teletex-personal-name INTEGER ::= 4

TeletexPersonalName ::= SET {
   surname [0] TeletexString (SIZE (1..ub-surname-length)),
   given-name [1] TeletexString
                (SIZE (1..ub-given-name-length)) OPTIONAL,
   initials [2] TeletexString (SIZE (1..ub-initials-length)) OPTIONAL,
   generation-qualifier [3] TeletexString (SIZE
                (1..ub-generation-qualifier-length)) OPTIONAL }

teletex-organizational-unit-names INTEGER ::= 5
```



```
TeletexOrganizationalUnitNames ::= SEQUENCE SIZE
```

```
        (1..ub-organizational-units) OF TeletexOrganizationalUnitName

TeletexOrganizationalUnitName ::= TeletexString
                        (SIZE (1..ub-organizational-unit-name-length))

pds-name INTEGER ::= 7

PDSName ::= PrintableString (SIZE (1..ub-pds-name-length))

physical-delivery-country-name INTEGER ::= 8

PhysicalDeliveryCountryName ::= CHOICE {
   x121-dcc-code NumericString (SIZE (ub-country-name-numeric-length)),
   iso-3166-alpha2-code PrintableString
                        (SIZE (ub-country-name-alpha-length)) }

postal-code INTEGER ::= 9

PostalCode ::= CHOICE {
   numeric-code NumericString (SIZE (1..ub-postal-code-length)),
   printable-code PrintableString (SIZE (1..ub-postal-code-length)) }

physical-delivery-office-name INTEGER ::= 10

PhysicalDeliveryOfficeName ::= PDSParameter

physical-delivery-office-number INTEGER ::= 11

PhysicalDeliveryOfficeNumber ::= PDSParameter

extension-OR-address-components INTEGER ::= 12

ExtensionORAddressComponents ::= PDSParameter

physical-delivery-personal-name INTEGER ::= 13

PhysicalDeliveryPersonalName ::= PDSParameter

physical-delivery-organization-name INTEGER ::= 14

PhysicalDeliveryOrganizationName ::= PDSParameter

extension-physical-delivery-address-components INTEGER ::= 15

ExtensionPhysicalDeliveryAddressComponents ::= PDSParameter

unformatted-postal-address INTEGER ::= 16
```

```
UnformattedPostalAddress ::= SET {
   printable-address SEQUENCE SIZE (1..ub-pds-physical-address-lines) OF
           PrintableString (SIZE (1..ub-pds-parameter-length)) OPTIONAL,
   teletex-string TeletexString
         (SIZE (1..ub-unformatted-address-length)) OPTIONAL }

street-address INTEGER ::= 17

StreetAddress ::= PDSParameter

post-office-box-address INTEGER ::= 18

PostOfficeBoxAddress ::= PDSParameter

poste-restante-address INTEGER ::= 19

PosteRestanteAddress ::= PDSParameter

unique-postal-name INTEGER ::= 20

UniquePostalName ::= PDSParameter

local-postal-attributes INTEGER ::= 21

LocalPostalAttributes ::= PDSParameter

PDSParameter ::= SET {
   printable-string PrintableString
                (SIZE(1..ub-pds-parameter-length)) OPTIONAL,
   teletex-string TeletexString
                (SIZE(1..ub-pds-parameter-length)) OPTIONAL }

extended-network-address INTEGER ::= 22

ExtendedNetworkAddress ::= CHOICE {
   e163-4-address SEQUENCE {
        number [0] NumericString (SIZE (1..ub-e163-4-number-length)),
        sub-address [1] NumericString
                (SIZE (1..ub-e163-4-sub-address-length)) OPTIONAL },
   psap-address [0] PresentationAddress }

PresentationAddress ::= SEQUENCE {
        pSelector       [0] EXPLICIT OCTET STRING OPTIONAL,
        sSelector       [1] EXPLICIT OCTET STRING OPTIONAL,
        tSelector       [2] EXPLICIT OCTET STRING OPTIONAL,
        nAddresses      [3] EXPLICIT SET SIZE (1..MAX) OF OCTET STRING }
```

```
terminal-type  INTEGER ::= 23
```



```
TerminalType ::= INTEGER {
   telex (3),
   teletex (4),
   g3-facsimile (5),
   g4-facsimile (6),
   ia5-terminal (7),
   videotex (8) } (0..ub-integer-options)

--      Extension Domain-defined Attributes

teletex-domain-defined-attributes INTEGER ::= 6

TeletexDomainDefinedAttributes ::= SEQUENCE SIZE
   (1..ub-domain-defined-attributes) OF TeletexDomainDefinedAttribute

TeletexDomainDefinedAttribute ::= SEQUENCE {
        type TeletexString
               (SIZE (1..ub-domain-defined-attribute-type-length)),
        value TeletexString
               (SIZE (1..ub-domain-defined-attribute-value-length)) }

--  specifications of Upper Bounds shall be regarded as mandatory
--  from Annex B of ITU-T X.411 Reference Definition of MTS Parameter
--  Upper Bounds

--      Upper Bounds
ub-name INTEGER ::=     32768
ub-common-name  INTEGER ::=     64
ub-locality-name        INTEGER ::=     128
ub-state-name   INTEGER ::=     128
ub-organization-name    INTEGER ::=     64
ub-organizational-unit-name     INTEGER ::=     64
ub-title        INTEGER ::=     64
ub-serialNumber INTEGER ::=     64
ub-match        INTEGER ::=     128

ub-emailaddress-length INTEGER ::= 128

ub-common-name-length INTEGER ::= 64
```

```
ub-country-name-alpha-length INTEGER ::= 2
ub-country-name-numeric-length INTEGER ::= 3
ub-domain-defined-attributes INTEGER ::= 4
ub-domain-defined-attribute-type-length INTEGER ::= 8
ub-domain-defined-attribute-value-length INTEGER ::= 128
ub-domain-name-length INTEGER ::= 16
ub-extension-attributes INTEGER ::= 256
ub-e163-4-number-length INTEGER ::= 15
ub-e163-4-sub-address-length INTEGER ::= 40
```



```
ub-generation-qualifier-length INTEGER ::= 3
ub-given-name-length INTEGER ::= 16
ub-initials-length INTEGER ::= 5
ub-integer-options INTEGER ::= 256
ub-numeric-user-id-length INTEGER ::= 32
ub-organization-name-length INTEGER ::= 64
ub-organizational-unit-name-length INTEGER ::= 32
ub-organizational-units INTEGER ::= 4
ub-pds-name-length INTEGER ::= 16
ub-pds-parameter-length INTEGER ::= 30
ub-pds-physical-address-lines INTEGER ::= 6
ub-postal-code-length INTEGER ::= 16
ub-surname-length INTEGER ::= 40
ub-terminal-id-length INTEGER ::= 24
ub-unformatted-address-length INTEGER ::= 180
ub-x121-address-length INTEGER ::= 16

-- Note - upper bounds on string types, such as TeletexString, are
-- measured in characters.  Excepting PrintableString or IA5String, a
-- significantly greater number of octets will be required to hold
-- such a value.  As a minimum, 16 octets, or twice the specified upper
-- bound, whichever is the larger, should be allowed for TeletexString.
-- For UTF8String or UniversalString at least four times the upper
-- bound should be allowed.

END
```

A.2 Implicitly Tagged Module, 1988 Syntax

```
PKIX1Implicit88 {iso(1) identified-organization(3) dod(6) internet(1)
  security(5) mechanisms(5) pkix(7) id-mod(0) id-pkix1-implicit(19)}

DEFINITIONS IMPLICIT TAGS ::=

BEGIN

-- EXPORTS ALL --

IMPORTS
        id-pkix, id-pe, id-qt, id-kp, id-qt-unotice, id-qt-cps,
            id-ad, id-ad-ocsp, id-ad-caIssuers,
            -- delete following line if "new" types are supported --
            BMPString, UniversalString, UTF8String, -- end "new" types
                ORAddress, Name, RelativeDistinguishedName,
                CertificateSerialNumber,
                CertificateList, AlgorithmIdentifier, ub-name,
                Attribute, DirectoryString
                FROM PKIX1Explicit88 {iso(1) identified-organization(3)
                dod(6) internet(1) security(5) mechanisms(5) pkix(7)
                id-mod(0) id-pkix1-explicit(1)};
```

```
-- ISO arc for standard certificate and CRL extensions

id-ce OBJECT IDENTIFIER  ::=  {joint-iso-ccitt(2) ds(5) 29}

-- authority key identifier OID and syntax

id-ce-authorityKeyIdentifier OBJECT IDENTIFIER ::=  { id-ce 35 }

AuthorityKeyIdentifier ::= SEQUENCE {
      keyIdentifier             [0] KeyIdentifier            OPTIONAL,
      authorityCertIssuer       [1] GeneralNames             OPTIONAL,
      authorityCertSerialNumber [2] CertificateSerialNumber  OPTIONAL }
    -- authorityCertIssuer and authorityCertSerialNumber shall both
    -- be present or both be absent

KeyIdentifier ::= OCTET STRING

-- subject key identifier OID and syntax

id-ce-subjectKeyIdentifier OBJECT IDENTIFIER ::=  { id-ce 14 }

SubjectKeyIdentifier ::= KeyIdentifier
```



```
-- key usage extension OID and syntax

id-ce-keyUsage OBJECT IDENTIFIER ::=  { id-ce 15 }

KeyUsage ::= BIT STRING {
     digitalSignature        (0),
     nonRepudiation          (1),
     keyEncipherment         (2),
     dataEncipherment        (3),
     keyAgreement            (4),
     keyCertSign             (5),
     cRLSign                 (6),
     encipherOnly            (7),
     decipherOnly            (8) }

-- private key usage period extension OID and syntax

id-ce-privateKeyUsagePeriod OBJECT IDENTIFIER ::=  { id-ce 16 }
```

```
PrivateKeyUsagePeriod ::= SEQUENCE {
     notBefore       [0]     GeneralizedTime OPTIONAL,
     notAfter        [1]     GeneralizedTime OPTIONAL }
     -- either notBefore or notAfter shall be present

-- certificate policies extension OID and syntax

id-ce-certificatePolicies OBJECT IDENTIFIER ::=  { id-ce 32 }

anyPolicy OBJECT IDENTIFIER ::= {id-ce-certificatePolicies 0}

CertificatePolicies ::= SEQUENCE SIZE (1..MAX) OF PolicyInformation

PolicyInformation ::= SEQUENCE {
     policyIdentifier   CertPolicyId,
     policyQualifiers   SEQUENCE SIZE (1..MAX) OF
             PolicyQualifierInfo OPTIONAL }

CertPolicyId ::= OBJECT IDENTIFIER

PolicyQualifierInfo ::= SEQUENCE {
       policyQualifierId  PolicyQualifierId,
       qualifier        ANY DEFINED BY policyQualifierId }

-- Implementations that recognize additional policy qualifiers shall
-- augment the following definition for PolicyQualifierId

PolicyQualifierId ::=
    OBJECT IDENTIFIER ( id-qt-cps | id-qt-unotice )
```



```
-- CPS pointer qualifier

CPSuri ::= IA5String

-- user notice qualifier

UserNotice ::= SEQUENCE {
     noticeRef        NoticeReference OPTIONAL,
     explicitText     DisplayText OPTIONAL}

NoticeReference ::= SEQUENCE {
```

```
     organization     DisplayText,
     noticeNumbers    SEQUENCE OF INTEGER }

DisplayText ::= CHOICE {
     ia5String        IA5String      (SIZE (1..200)),
     visibleString    VisibleString  (SIZE (1..200)),
     bmpString        BMPString      (SIZE (1..200)),
     utf8String       UTF8String     (SIZE (1..200)) }

-- policy mapping extension OID and syntax

id-ce-policyMappings OBJECT IDENTIFIER ::=  { id-ce 33 }

PolicyMappings ::= SEQUENCE SIZE (1..MAX) OF SEQUENCE {
     issuerDomainPolicy      CertPolicyId,
     subjectDomainPolicy     CertPolicyId }

-- subject alternative name extension OID and syntax

id-ce-subjectAltName OBJECT IDENTIFIER ::=  { id-ce 17 }

SubjectAltName ::= GeneralNames

GeneralNames ::= SEQUENCE SIZE (1..MAX) OF GeneralName

GeneralName ::= CHOICE {
     otherName                       [0]     AnotherName,
     rfc822Name                      [1]     IA5String,
     dNSName                         [2]     IA5String,
     x400Address                     [3]     ORAddress,
     directoryName                   [4]     Name,
     ediPartyName                    [5]     EDIPartyName,
     uniformResourceIdentifier       [6]     IA5String,
     iPAddress                       [7]     OCTET STRING,
     registeredID                    [8]     OBJECT IDENTIFIER }

-- AnotherName replaces OTHER-NAME ::= TYPE-IDENTIFIER, as
```



```
-- TYPE-IDENTIFIER is not supported in the '88 ASN.1 syntax

AnotherName ::= SEQUENCE {
     type-id    OBJECT IDENTIFIER,
```

```
     value      [0] EXPLICIT ANY DEFINED BY type-id }

EDIPartyName ::= SEQUENCE {
     nameAssigner            [0]     DirectoryString OPTIONAL,
     partyName               [1]     DirectoryString }

-- issuer alternative name extension OID and syntax

id-ce-issuerAltName OBJECT IDENTIFIER ::=  { id-ce 18 }

IssuerAltName ::= GeneralNames

id-ce-subjectDirectoryAttributes OBJECT IDENTIFIER ::=  { id-ce 9 }

SubjectDirectoryAttributes ::= SEQUENCE SIZE (1..MAX) OF Attribute

-- basic constraints extension OID and syntax

id-ce-basicConstraints OBJECT IDENTIFIER ::=  { id-ce 19 }

BasicConstraints ::= SEQUENCE {
     cA                      BOOLEAN DEFAULT FALSE,
     pathLenConstraint       INTEGER (0..MAX) OPTIONAL }

-- name constraints extension OID and syntax

id-ce-nameConstraints OBJECT IDENTIFIER ::=  { id-ce 30 }

NameConstraints ::= SEQUENCE {
     permittedSubtrees       [0]     GeneralSubtrees OPTIONAL,
     excludedSubtrees        [1]     GeneralSubtrees OPTIONAL }

GeneralSubtrees ::= SEQUENCE SIZE (1..MAX) OF GeneralSubtree

GeneralSubtree ::= SEQUENCE {
     base                    GeneralName,
     minimum         [0]     BaseDistance DEFAULT 0,
     maximum         [1]     BaseDistance OPTIONAL }

BaseDistance ::= INTEGER (0..MAX)

-- policy constraints extension OID and syntax

id-ce-policyConstraints OBJECT IDENTIFIER ::=  { id-ce 36 }
```

```
PolicyConstraints ::= SEQUENCE {
     requireExplicitPolicy           [0] SkipCerts OPTIONAL,
     inhibitPolicyMapping            [1] SkipCerts OPTIONAL }

SkipCerts ::= INTEGER (0..MAX)

-- CRL distribution points extension OID and syntax

id-ce-cRLDistributionPoints     OBJECT IDENTIFIER  ::=  {id-ce 31}

CRLDistributionPoints ::= SEQUENCE SIZE (1..MAX) OF DistributionPoint

DistributionPoint ::= SEQUENCE {
     distributionPoint       [0]     DistributionPointName OPTIONAL,
     reasons                 [1]     ReasonFlags OPTIONAL,
     cRLIssuer               [2]     GeneralNames OPTIONAL }

DistributionPointName ::= CHOICE {
     fullName                [0]     GeneralNames,
     nameRelativeToCRLIssuer [1]     RelativeDistinguishedName }

ReasonFlags ::= BIT STRING {
     unused                  (0),
     keyCompromise           (1),
     cACompromise            (2),
     affiliationChanged      (3),
     superseded              (4),
     cessationOfOperation    (5),
     certificateHold         (6) }

-- extended key usage extension OID and syntax

id-ce-extKeyUsage OBJECT IDENTIFIER ::= {id-ce 37}

ExtKeyUsageSyntax ::= SEQUENCE SIZE (1..MAX) OF KeyPurposeId

KeyPurposeId ::= OBJECT IDENTIFIER

-- extended key purpose OIDs
id-kp-serverAuth      OBJECT IDENTIFIER ::= { id-kp 1 }
id-kp-clientAuth      OBJECT IDENTIFIER ::= { id-kp 2 }
id-kp-codeSigning     OBJECT IDENTIFIER ::= { id-kp 3 }
id-kp-emailProtection OBJECT IDENTIFIER ::= { id-kp 4 }
id-kp-ipsecEndSystem  OBJECT IDENTIFIER ::= { id-kp 5 }
id-kp-ipsecTunnel     OBJECT IDENTIFIER ::= { id-kp 6 }
id-kp-ipsecUser       OBJECT IDENTIFIER ::= { id-kp 7 }
id-kp-timeStamping    OBJECT IDENTIFIER ::= { id-kp 8 }
```

```
-- inhibit any policy OID and syntax

id-ce-inhibitAnyPolicy OBJECT IDENTIFIER ::=  { id-ce 54 }

InhibitAnyPolicy ::= SkipCerts

-- freshest (delta-)CRL extension OID and syntax

id-ce-freshestCRL OBJECT IDENTIFIER ::=  { id-ce 46 }

FreshestCRL ::= CRLDistributionPoints

-- authority info access

id-pe-authorityInfoAccess OBJECT IDENTIFIER ::= { id-pe 1 }

AuthorityInfoAccessSyntax  ::=
        SEQUENCE SIZE (1..MAX) OF AccessDescription

AccessDescription  ::=  SEQUENCE {
        accessMethod          OBJECT IDENTIFIER,
        accessLocation        GeneralName  }

-- CRL number extension OID and syntax

id-ce-cRLNumber OBJECT IDENTIFIER ::= { id-ce 20 }

CRLNumber ::= INTEGER (0..MAX)

-- issuing distribution point extension OID and syntax

id-ce-issuingDistributionPoint OBJECT IDENTIFIER ::= { id-ce 28 }

IssuingDistributionPoint ::= SEQUENCE {
     distributionPoint       [0] DistributionPointName OPTIONAL,
     onlyContainsUserCerts   [1] BOOLEAN DEFAULT FALSE,
     onlyContainsCACerts     [2] BOOLEAN DEFAULT FALSE,
     onlySomeReasons         [3] ReasonFlags OPTIONAL,
     indirectCRL             [4] BOOLEAN DEFAULT FALSE }
```

```
id-ce-deltaCRLIndicator OBJECT IDENTIFIER ::= { id-ce 27 }

-- deltaCRLIndicator ::= BaseCRLNumber

BaseCRLNumber ::= CRLNumber

-- CRL reasons extension OID and syntax
```



```
id-ce-cRLReasons OBJECT IDENTIFIER ::= { id-ce 21 }

CRLReason ::= ENUMERATED {
     unspecified             (0),
     keyCompromise           (1),
     cACompromise            (2),
     affiliationChanged      (3),
     superseded              (4),
     cessationOfOperation    (5),
     certificateHold         (6),
     removeFromCRL           (8) }

-- certificate issuer CRL entry extension OID and syntax

id-ce-certificateIssuer OBJECT IDENTIFIER ::= { id-ce 29 }

CertificateIssuer ::= GeneralNames

-- hold instruction extension OID and syntax

id-ce-holdInstructionCode OBJECT IDENTIFIER ::= { id-ce 23 }

HoldInstructionCode ::= OBJECT IDENTIFIER

-- ANSI x9 holdinstructions

-- ANSI x9 arc holdinstruction arc
holdInstruction OBJECT IDENTIFIER ::=
          {joint-iso-itu-t(2) member-body(2) us(840) x9cm(10040) 2}

-- ANSI X9 holdinstructions referenced by this standard
id-holdinstruction-none OBJECT IDENTIFIER  ::=
                {holdInstruction 1} -- deprecated
```

```
id-holdinstruction-callissuer OBJECT IDENTIFIER ::=
                {holdInstruction 2}
id-holdinstruction-reject OBJECT IDENTIFIER ::=
                {holdInstruction 3}

-- invalidity date CRL entry extension OID and syntax

id-ce-invalidityDate OBJECT IDENTIFIER ::= { id-ce 24 }

InvalidityDate ::=  GeneralizedTime

END
```


Appendix B. ASN.1 Notes

CAs MUST force the serialNumber to be a non-negative integer, that is, the sign bit in the DER encoding of the INTEGER value MUST be zero - this can be done by adding a leading (leftmost) `00'H octet if necessary. This removes a potential ambiguity in mapping between a string of octets and an integer value.

As noted in section 4.1.2.2, serial numbers can be expected to contain long integers. Certificate users MUST be able to handle serialNumber values up to 20 octets in length. Conformant CAs MUST NOT use serialNumber values longer than 20 octets.

The construct "SEQUENCE SIZE (1..MAX) OF" appears in several ASN.1 constructs. A valid ASN.1 sequence will have zero or more entries. The SIZE (1..MAX) construct constrains the sequence to have at least one entry. MAX indicates the upper bound is unspecified. Implementations are free to choose an upper bound that suits their environment.

The construct "positiveInt ::= INTEGER (0..MAX)" defines positiveInt as a subtype of INTEGER containing integers greater than or equal to zero. The upper bound is unspecified. Implementations are free to select an upper bound that suits their environment.

The character string type PrintableString supports a very basic Latin

character set: the lower case letters 'a' through 'z', upper case letters 'A' through 'Z', the digits '0' through '9', eleven special characters ' " ( ) + , - . / : ? and space.

The character string type TeletexString is a superset of PrintableString. TeletexString supports a fairly standard (ascii-like) Latin character set, Latin characters with non-spacing accents and Japanese characters.

The character string type UniversalString supports any of the characters allowed by ISO 10646-1. ISO 10646 is the Universal multiple-octet coded Character Set (UCS). ISO 10646-1 specifes the architecture and the "basic multilingual plane" - a large standard character set which includes all major world character standards.

The character string type UTF8String will be introduced in the 1998 version of ASN.1. UTF8String is a universal type and has been assigned tag number 12. The content of UTF8String was defined by RFC 2044 and updated in RFC 2279, "UTF-8, a transformation Format of ISO 10646." ISO is expected to formally add UTF8String to the list of choices for DirectoryString in 1998 as well.

In anticipation of these changes, and in conformance with IETF Best Practices codified in RFC 2277, IETF Policy on Character Sets and Languages, this document includes UTF8String as a choice in DirectoryString and the CPS qualifier extensions.

Implementers should note that the DER encoding of the SET OF values requires ordering of the encodings of the values. In particular, this issue arises with respect to distinguished names.

Object Identifiers (OIDs) are used throught this specification to identify certificate policies, public key and signature algorithms, certificate extensions, etc. There is no maximum size for OIDs. This specification mandates support for OIDs which have arc elements with values that are less than 2^28, i.e. they MUST be between 0 and 268,435,455 inclusive. This allows each arc element to be represented within a single 32 bit word. Implementations MUST also support OIDs where the length of the dotted decimal (see [LDAP], section 4.1.2) string representation can be up to 100 bytes (inclusive). Implementations MUST be able to handle OIDs with up to 20 elements

(inclusive). CAs SHOULD NOT issue certificates which contain OIDs that breach these requirements.

Appendix C. Examples

This section contains four examples: three certificates and a CRL. The first two certificates and the CRL comprise a minimal certification path.

Section C.1 contains an annotated hex dump of a "self-signed" certificate issued by a CA whose distinguished name is cn=us,o=gov,ou=nist. The certificate contains a DSA public key with parameters, and is signed by the corresponding DSA private key.

Section C.2 contains an annotated hex dump of an end-entity certificate. The end entity certificate contains a DSA public key, and is signed by the private key corresponding to the "self-signed" certificate in section C.1.

Section C.3 contains a dump of an end entity certificate which contains an RSA public key and is signed with RSA and MD5. This certificate is not part of the minimal certification path.

Section C.4 contains an annotated hex dump of a CRL. The CRL is issued by the CA whose distinguished name is cn=us,o=gov,ou=nist and the list of revoked certificates includes the end entity certificate presented in C.2.

The certificates were processed using Peter Gutman's dumpasn1 utility

to generate the output. The source for the dumpasn1 utility is available at <http://www.cs.auckland.ac.nz/~pgut001/dumpasn1.c>. The binaries for the certificates and CRLs are available at <http://csrc.nist.gov/pki/pkixtools>.

C.1 Certificate

This section contains an annotated hex dump of a 699 byte version 3 certificate. The certificate contains the following information:
(a) the serial number is 23 (17 hex);
(b) the certificate is signed with DSA and the SHA-1 hash algorithm;
(c) the issuer's distinguished name is OU=NIST; O=gov; C=US

(d) and the subject's distinguished name is OU=NIST; O=gov; C=US
(e) the certificate was issued on June 30, 1997 and will expire on December 31, 1997;
(f) the certificate contains a 1024 bit DSA public key with parameters;
(g) the certificate contains a subject key identifier extension; and
(h) the certificate is a CA certificate (as indicated through the basic constraints extension.)

```
 0 30  701: SEQUENCE {
 4 30  637:   SEQUENCE {
 8 A0    3:     [0] {
10 02    1:       INTEGER 2
          :       }
13 02    1:     INTEGER 23
16 30    9:     SEQUENCE {
18 06    7:       OBJECT IDENTIFIER dsaWithSha1 (1 2 840 10040 4 3)
          :       }
27 30   42:     SEQUENCE {
29 31   11:       SET {
31 30    9:         SEQUENCE {
33 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
38 13    2:           PrintableString 'US'
          :           }
          :         }
42 31   12:       SET {
44 30   10:         SEQUENCE {
46 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
51 13    3:           PrintableString 'gov'
          :           }
          :         }
56 31   13:       SET {
58 30   11:         SEQUENCE {
60 06    3:           OBJECT IDENTIFIER
                        organizationalUnitName (2 5 4 11)
```



```
65 13    4:           PrintableString 'NIST'
          :           }
          :         }
          :       }
71 30   30:     SEQUENCE {
```

```
 73 17   13:       UTCTime '970630000000Z'
 88 17   13:       UTCTime '971231000000Z'
           :       }
103 30   42:     SEQUENCE {
105 31   11:       SET {
107 30    9:         SEQUENCE {
109 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
114 13    2:           PrintableString 'US'
           :           }
           :         }
118 31   12:       SET {
120 30   10:         SEQUENCE {
122 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
127 13    3:           PrintableString 'gov'
           :           }
           :         }
132 31   13:       SET {
134 30   11:         SEQUENCE {
136 06    3:           OBJECT IDENTIFIER
                         organizationalUnitName (2 5 4 11)
141 13    4:           PrintableString 'NIST'
           :           }
           :         }
           :       }
147 30  440:     SEQUENCE {
151 30  300:       SEQUENCE {
155 06    7:         OBJECT IDENTIFIER dsa (1 2 840 10040 4 1)
164 30  287:         SEQUENCE {
168 02  129:           INTEGER
           :            00 B6 8B 0F 94 2B 9A CE A5 25 C6 F2 ED FC FB 95
           :            32 AC 01 12 33 B9 E0 1C AD 90 9B BC 48 54 9E F3
           :            94 77 3C 2C 71 35 55 E6 FE 4F 22 CB D5 D8 3E 89
           :            93 33 4D FC BD 4F 41 64 3E A2 98 70 EC 31 B4 50
           :            DE EB F1 98 28 0A C9 3E 44 B3 FD 22 97 96 83 D0
           :            18 A3 E3 BD 35 5B FF EE A3 21 72 6A 7B 96 DA B9
           :            3F 1E 5A 90 AF 24 D6 20 F0 0D 21 A7 D4 02 B9 1A
           :            FC AC 21 FB 9E 94 9E 4B 42 45 9E 6A B2 48 63 FE
           :            43
300 02   21:           INTEGER
           :            00 B2 0D B0 B1 01 DF 0C 66 24 FC 13 92 BA 55 F7
           :            7D 57 74 81 E5
323 02  129:           INTEGER
           :            00 9A BF 46 B1 F5 3F 44 3D C9 A5 65 FB 91 C0 8E
```

```
           :            47 F1 0A C3 01 47 C2 44 42 36 A9 92 81 DE 57 C5
           :            E0 68 86 58 00 7B 1F F9 9B 77 A1 C5 10 A5 80 91
           :            78 51 51 3C F6 FC FC CC 46 C6 81 78 92 84 3D F4
           :            93 3D 0C 38 7E 1A 5B 99 4E AB 14 64 F6 0C 21 22
           :            4E 28 08 9C 92 B9 66 9F 40 E8 95 F6 D5 31 2A EF
           :            39 A2 62 C7 B2 6D 9E 58 C4 3A A8 11 81 84 6D AF
           :            F8 B4 19 B4 C2 11 AE D0 22 3B AA 20 7F EE 1E 57
           :            18
           :          }
           :        }
455 03  133:       BIT STRING 0 unused bits
           :         02 81 81 00 B5 9E 1F 49 04 47 D1 DB F5 3A DD CA
           :         04 75 E8 DD 75 F6 9B 8A B1 97 D6 59 69 82 D3 03
           :         4D FD 3B 36 5F 4A F2 D1 4E C1 07 F5 D1 2A D3 78
           :         77 63 56 EA 96 61 4D 42 0B 7A 1D FB AB 91 A4 CE
           :         DE EF 77 C8 E5 EF 20 AE A6 28 48 AF BE 69 C3 6A
           :         A5 30 F2 C2 B9 D9 82 2B 7D D9 C4 84 1F DE 0D E8
           :         54 D7 1B 99 2E B3 D0 88 F6 D6 63 9B A7 E2 0E 82
           :         D4 3B 8A 68 1B 06 56 31 59 0B 49 EB 99 A5 D5 81
           :         41 7B C9 55
           :       }
591 A3   52:     [3] {
593 30   50:       SEQUENCE {
595 30   31:         SEQUENCE {
597 06    3:           OBJECT IDENTIFIER
                              subjectKeyIdentifier (2 5 29 14)
602 04   24:           OCTET STRING
           :            04 16 04 14 E7 26 C5 54 CD 5B A3 6F 35 68 95 AA
           :            D5 FF 1C 21 E4 22 75 D6
           :           }
628 30   15:         SEQUENCE {
630 06    3:           OBJECT IDENTIFIER basicConstraints (2 5 29 19)
635 01    1:           BOOLEAN TRUE
638 04    5:           OCTET STRING
           :             30 03 01 01 FF
           :           }
           :         }
           :       }
           :     }
645 30    9:    SEQUENCE {
647 06    7:      OBJECT IDENTIFIER dsaWithSha1 (1 2 840 10040 4 3)
           :      }
656 03   47:    BIT STRING 0 unused bits
           :      30 2C 02 14 6A F9 3F 72 30 7F 45 DC E5 50 C1 5E
           :      94 A0 6D C7 92 4C E5 E1 02 14 6F 61 B8 65 F7 AA
           :      DF 46 1B F7 39 0D 0D 88 9E FE B6 83 F7 1A
           :    }
```

C.2 Certificate

This section contains an annotated hex dump of a 730 byte version 3 certificate. The certificate contains the following information: (a) the serial number is 18 (12 hex); (b) the certificate is signed with DSA and the SHA-1 hash algorithm; (c) the issuer's distinguished name is OU=nist; O=gov; C=US (d) and the subject's distinguished name is CN=Tim Polk; OU=nist; O=gov; C=US (e) the certificate was valid from July 30, 1997 through December 1, 1997; (f) the certificate contains a 1024 bit DSA public key; (g) the certificate is an end entity certificate, as the basic constraints extension is not present; (h) the certificate contains an authority key identifier extension; and (i) the certificate includes one alternative name - an RFC 822 address.

```
 0 30  734: SEQUENCE {
 4 30  669:   SEQUENCE {
 8 A0    3:     [0] {
10 02    1:       INTEGER 2
          :       }
13 02    1:     INTEGER 18
16 30    9:     SEQUENCE {
18 06    7:       OBJECT IDENTIFIER dsaWithSha1 (1 2 840 10040 4 3)
          :       }
27 30   42:     SEQUENCE {
29 31   11:       SET {
31 30    9:         SEQUENCE {
33 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
38 13    2:           PrintableString 'US'
          :           }
          :         }
42 31   12:       SET {
44 30   10:         SEQUENCE {
46 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
51 13    3:           PrintableString 'gov'
          :           }
          :         }
56 31   13:       SET {
```

```
  58 30   11:         SEQUENCE {
  60 06    3:           OBJECT IDENTIFIER
                               organizationalUnitName (2 5 4 11)
  65 13    4:           PrintableString 'NIST'
             :           }
             :         }
```



```
             :       }
  71 30   30:     SEQUENCE {
  73 17   13:       UTCTime '970730000000Z'
  88 17   13:       UTCTime '971201000000Z'
             :       }
 103 30   61:     SEQUENCE {
 105 31   11:       SET {
 107 30    9:         SEQUENCE {
 109 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
 114 13    2:           PrintableString 'US'
             :           }
             :         }
 118 31   12:       SET {
 120 30   10:         SEQUENCE {
 122 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
 127 13    3:           PrintableString 'gov'
             :           }
             :         }
 132 31   13:       SET {
 134 30   11:         SEQUENCE {
 136 06    3:           OBJECT IDENTIFIER
                               organizationalUnitName (2 5 4 11)
 141 13    4:           PrintableString 'NIST'
             :           }
             :         }
 147 31   17:       SET {
 149 30   15:         SEQUENCE {
 151 06    3:           OBJECT IDENTIFIER commonName (2 5 4 3)
 156 13    8:           PrintableString 'Tim Polk'
             :           }
             :         }
             :       }
 166 30  439:     SEQUENCE {
 170 30  300:       SEQUENCE {
 174 06    7:         OBJECT IDENTIFIER dsa (1 2 840 10040 4 1)
```

```
 183 30  287:         SEQUENCE {
 187 02  129:           INTEGER
           :             00 B6 8B 0F 94 2B 9A CE A5 25 C6 F2 ED FC FB 95
           :             32 AC 01 12 33 B9 E0 1C AD 90 9B BC 48 54 9E F3
           :             94 77 3C 2C 71 35 55 E6 FE 4F 22 CB D5 D8 3E 89
           :             93 33 4D FC BD 4F 41 64 3E A2 98 70 EC 31 B4 50
           :             DE EB F1 98 28 0A C9 3E 44 B3 FD 22 97 96 83 D0
           :             18 A3 E3 BD 35 5B FF EE A3 21 72 6A 7B 96 DA B9
           :             3F 1E 5A 90 AF 24 D6 20 F0 0D 21 A7 D4 02 B9 1A
           :             FC AC 21 FB 9E 94 9E 4B 42 45 9E 6A B2 48 63 FE
           :             43
 319 02   21:           INTEGER
           :             00 B2 0D B0 B1 01 DF 0C 66 24 FC 13 92 BA 55 F7
```



```
           :             7D 57 74 81 E5
 342 02  129:           INTEGER
           :             00 9A BF 46 B1 F5 3F 44 3D C9 A5 65 FB 91 C0 8E
           :             47 F1 0A C3 01 47 C2 44 42 36 A9 92 81 DE 57 C5
           :             E0 68 86 58 00 7B 1F F9 9B 77 A1 C5 10 A5 80 91
           :             78 51 51 3C F6 FC FC CC 46 C6 81 78 92 84 3D F4
           :             93 3D 0C 38 7E 1A 5B 99 4E AB 14 64 F6 0C 21 22
           :             4E 28 08 9C 92 B9 66 9F 40 E8 95 F6 D5 31 2A EF
           :             39 A2 62 C7 B2 6D 9E 58 C4 3A A8 11 81 84 6D AF
           :             F8 B4 19 B4 C2 11 AE D0 22 3B AA 20 7F EE 1E 57
           :             18
           :           }
           :         }
 474 03  132:       BIT STRING 0 unused bits
           :         02 81 80 30 B6 75 F7 7C 20 31 AE 38 BB 7E 0D 2B
           :         AB A0 9C 4B DF 20 D5 24 13 3C CD 98 E5 5F 6C B7
           :         C1 BA 4A BA A9 95 80 53 F0 0D 72 DC 33 37 F4 01
           :         0B F5 04 1F 9D 2E 1F 62 D8 84 3A 9B 25 09 5A 2D
           :         C8 46 8E 2B D4 F5 0D 3B C7 2D C6 6C B9 98 C1 25
           :         3A 44 4E 8E CA 95 61 35 7C CE 15 31 5C 23 13 1E
           :         A2 05 D1 7A 24 1C CB D3 72 09 90 FF 9B 9D 28 C0
           :         A1 0A EC 46 9F 0D B8 D0 DC D0 18 A6 2B 5E F9 8F
           :         B5 95 BE
           :       }
 609 A3   66:     [3] {
 611 30   64:       SEQUENCE {
 613 30   25:         SEQUENCE {
 615 06    3:           OBJECT IDENTIFIER subjectAltName (2 5 29 17)
```

```
 620 04   18:           OCTET STRING
            :            30 10 81 0E 77 70 6F 6C 6B 40 6E 69 73 74 2E 67
            :            6F 76
            :           }
 640 30   35:         SEQUENCE {
 642 06    3:           OBJECT IDENTIFIER
                          authorityKeyIdentifier (2 5 29 35)
 647 04   28:           OCTET STRING
            :            30 1A 80 18 04 16 04 14 E7 26 C5 54 CD 5B A3 6F
            :            35 68 95 AA D5 FF 1C 21 E4 22 75 D6
            :           }
            :         }
            :       }
            :     }
 677 30    9:   SEQUENCE {
 679 06    7:     OBJECT IDENTIFIER dsaWithSha1 (1 2 840 10040 4 3)
            :     }
 688 03   48:   BIT STRING 0 unused bits
            :     30 2D 02 14 37 FC 44 BF 7F 8D 18 1F 40 04 2F CF
            :     EA CC 22 B2 16 01 FF 13 02 15 00 97 D0 24 96 0F
```



```
            :     64 8A C3 8D 41 B2 0E B9 26 D5 31 D1 A0 F1 BC
            :   }
```

C.3 End-Entity Certificate Using RSA

This section contains an annotated hex dump of a 675 byte version 3 certificate. The certificate contains the following information:
(a) the serial number is 256;
(b) the certificate is signed with RSA and the MD2 hash algorithm;
(c) the issuer's distinguished name is OU=Dept. Arquitectura de Computadors; O=Universitat Politecnica de Catalunya; C=ES
(d) and the subject's distinguished name is CN=Francisco Jordan; OU=Dept. Arquitectura de Computadors; O=Universitat Politecnica de Catalunya; C=ES
(e) the certificate was issued on May 21, 1996 and expired on May 21, 1997;
(f) the certificate contains a 768 bit RSA public key;
(g) the certificate is an end entity certificate (not a CA certificate);
(h) the certificate includes an alternative subject name and an alternative issuer name - bothe are URLs;

(i) the certificate include an authority key identifier and certificate policies extensions; and
(j) the certificate includes a critical key usage extension specifying the public is intended for generation of digital signatures.

```
 0 30  654: SEQUENCE {
 4 30  503:   SEQUENCE {
 8 A0    3:     [0] {
10 02    1:       INTEGER 2
          :       }
13 02    2:     INTEGER 256
17 30   13:     SEQUENCE {
19 06    9:       OBJECT IDENTIFIER
          :         sha1withRSAEncryption (1 2 840 113549 1 1 5)
30 05    0:       NULL
          :       }
32 30   42:     SEQUENCE {
34 31   11:       SET {
36 30    9:         SEQUENCE {
38 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
43 13    2:           PrintableString 'US'
          :           }
          :         }
47 31   12:       SET {
49 30   10:         SEQUENCE {
51 06    3:           OBJECT IDENTIFIER
```



```
                               organizationalUnitName (2 5 4 11)
56 13    3:           PrintableString 'gov'
          :           }
          :         }
61 31   13:       SET {
63 30   11:         SEQUENCE {
65 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
70 13    4:           PrintableString 'NIST'
          :           }
          :         }
          :       }
76 30   30:     SEQUENCE {
78 17   13:       UTCTime '960521095826Z'
93 17   13:       UTCTime '970521095826Z'
```

```
            :       }
 108 30   61:     SEQUENCE {
 110 31   11:       SET {
 112 30    9:         SEQUENCE {
 114 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
 119 13    2:           PrintableString 'US'
            :           }
            :         }
 123 31   12:       SET {
 125 30   10:         SEQUENCE {
 127 06    3:           OBJECT IDENTIFIER
                               organizationalUnitName (2 5 4 11)
 132 13    3:           PrintableString 'gov'
            :           }
            :         }
 137 31   13:       SET {
 139 30   11:         SEQUENCE {
 141 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
 146 13    4:           PrintableString 'NIST'
            :           }
            :         }
 152 31   17:       SET {
 154 30   15:         SEQUENCE {
 156 06    3:           OBJECT IDENTIFIER commonName (2 5 4 3)
 161 13    8:           PrintableString 'Tim Polk'
            :           }
            :         }
            :       }
 171 30  159:     SEQUENCE {
 174 30   13:       SEQUENCE {
 176 06    9:         OBJECT IDENTIFIER
                             rsaEncryption (1 2 840 113549 1 1 1)
 187 05    0:         NULL
            :         }
```



```
 189 03  141:       BIT STRING 0 unused bits
            :         30 81 89 02 81 81 00 E1 CE 06 C9 D7 00 DF 65 27
            :         45 1E 63 6A 09 A0 A0 10 4B AF DF 9D 36 1D 44 1F
            :         B7 07 5D 36 92 09 6A 1A 96 C7 4E D9 86 0D 0F 77
            :         94 F5 82 62 68 9A F2 D7 76 F5 9A 35 C7 B3 7F 4F
            :         BE 64 CF A3 0C B3 84 32 80 F5 CA 77 29 C9 76 0B
            :         4C 38 19 EE 61 6F BA 68 E0 03 85 46 34 AB 84 64
```

```
           :         7F 43 69 02 C0 20 86 BD B1 D4 AD 21 A9 1A 8F CF
           :         96 83 86 92 57 5B 43 09 28 4C F2 5A 04 AD E5 DE
           :         9E 4F E8 38 3C F0 89 02 03 01 00 01
           :       }
 333 A3  175:     [3] {
 336 30  172:       SEQUENCE {
 339 30   63:         SEQUENCE {
 341 06    3:           OBJECT IDENTIFIER subjectAltName (2 5 29 17)
 346 04   56:           OCTET STRING
           :             30 36 86 34 68 74 74 70 3A 2F 2F 77 77 77 2E 69
           :             74 6C 2E 6E 69 73 74 2E 67 6F 76 2F 64 69 76 38
           :             39 33 2F 73 74 61 66 66 2F 70 6F 6C 6B 2F 69 6E
           :             64 65 78 2E 68 74 6D 6C
           :           }
 404 30   31:         SEQUENCE {
 406 06    3:           OBJECT IDENTIFIER issuerAltName (2 5 29 18)
 411 04   24:           OCTET STRING
           :             30 16 86 14 68 74 74 70 3A 2F 2F 77 77 77 2E 6E
           :             69 73 74 2E 67 6F 76 2F
           :           }
 437 30   31:         SEQUENCE {
 439 06    3:           OBJECT IDENTIFIER
                          authorityKeyIdentifier (2 5 29 35)
 444 04   24:           OCTET STRING
           :             30 16 80 14 30 12 80 10 0E 6B 3A BF 04 EA 04 C3
           :             0E 6B 3A BF 04 EA 04 C3
           :           }
 470 30   23:         SEQUENCE {
 472 06    3:           OBJECT IDENTIFIER
                          certificatePolicies (2 5 29 32)
 477 04   16:           OCTET STRING
           :             30 0E 30 0C 06 0A 60 86 48 01 65 03 02 01 30 09
           :           }
 495 30   14:         SEQUENCE {
 497 06    3:           OBJECT IDENTIFIER keyUsage (2 5 29 15)
 502 01    1:           BOOLEAN TRUE
 505 04    4:           OCTET STRING
           :             03 02 07 80
           :           }
           :         }
           :       }
```

```
            :     }
  511 30   13:   SEQUENCE {
  513 06    9:     OBJECT IDENTIFIER
            :       sha1withRSAEncryption (1 2 840 113549 1 1 5)
  524 05    0:     NULL
            :     }
  526 03  129:   BIT STRING 0 unused bits
            :     C1 25 6F AB 72 C0 5D DA E4 2F D5 E1 B0 25 D8 B4
            :     F1 82 95 D6 0D A5 4E 4F A1 23 E1 13 A4 9C 3D C5
            :     7F FD 05 EC 75 06 30 66 97 75 A6 5D 8F 97 BA B4
            :     EC A9 43 19 8D B7 54 FD E9 AD 43 B8 3C 8B D3 9E
            :     C7 C7 27 E3 1A AD D3 79 AC 65 5A 52 78 C4 D0 43
            :     81 50 F7 8A BA E2 30 1A 6D D0 78 A0 4E AE 2E 79
            :     37 0C 93 05 5C D1 9C 1B B2 62 73 D1 EA 50 B7 84
            :     29 92 74 34 CF BA AA 2C 4D 43 59 EF 98 0C 41 6C
            :   }
```

C.4 Certificate Revocation List

This section contains an annotated hex dump of a version 2 CRL with one extension (cRLNumber). The CRL was issued by OU=nist;O=gov;C=us on July 7, 1996; the next scheduled issuance was August 7, 1996. The CRL includes one revoked certificates: serial number 18 (12 hex). The CRL itself is number 18, and it was signed with DSA and SHA-1.

```
    0 30  203: SEQUENCE {
    3 30  140:   SEQUENCE {
    6 02    1:     INTEGER 1
    9 30    9:     SEQUENCE {
   11 06    7:       OBJECT IDENTIFIER dsaWithSha1 (1 2 840 10040 4 3)
             :       }
   20 30   42:     SEQUENCE {
   22 31   11:       SET {
   24 30    9:         SEQUENCE {
   26 06    3:           OBJECT IDENTIFIER countryName (2 5 4 6)
   31 13    2:           PrintableString 'US'
             :           }
             :         }
   35 31   12:       SET {
   37 30   10:         SEQUENCE {
   39 06    3:           OBJECT IDENTIFIER organizationName (2 5 4 10)
   44 13    3:           PrintableString 'gov'
             :           }
             :         }
   49 31   13:       SET {
   51 30   11:         SEQUENCE {
   53 06    3:           OBJECT IDENTIFIER
                           organizationalUnitName (2 5 4 11)
```

```
 58 13    4:           PrintableString 'NIST'
           :           }
           :         }
           :       }
 64 17   13:     UTCTime '970807000000Z'
 79 17   13:     UTCTime '970907000000Z'
 94 30   34:     SEQUENCE {
 96 30   32:       SEQUENCE {
 98 02    1:         INTEGER 18
101 17   13:         UTCTime '970731000000Z'
116 30   12:         SEQUENCE {
118 30   10:           SEQUENCE {
120 06    3:             OBJECT IDENTIFIER cRLReason (2 5 29 21)
125 04    3:             OCTET STRING
           :               0A 01 01
           :             }
           :           }
           :         }
           :       }
130 A0   14:     [0] {
132 30   12:       SEQUENCE {
134 30   10:         SEQUENCE {
136 06    3:           OBJECT IDENTIFIER cRLNumber (2 5 29 20)
141 04    3:           OCTET STRING
           :             02 01 12
           :           }
           :         }
           :       }
           :     }
146 30    9:   SEQUENCE {
148 06    7:     OBJECT IDENTIFIER dsaWithSha1 (1 2 840 10040 4 3)
           :     }
157 03   47:   BIT STRING 0 unused bits
           :     30 2C 02 14 79 1F F6 93 0B 84 06 D6 A0 7C 8D 68
           :     A7 52 2E 5F 3F 89 9B 4B 02 14 66 D4 B5 2A 68 36
           :     9B 72 88 58 E3 89 19 AD 81 89 2E 96 BB CC
           :   }
```

Appendix D. Author Addresses:

Russell Housley
SPYRUS
381 Elden Street
Suite 1120
Herndon, VA 20170
USA
housley@spyrus.com

Warwick Ford
VeriSign, Inc.
One Alewife Center
Cambridge, MA 02140
USA
wford@verisign.com

Tim Polk
NIST
Building 820, Room 426
Gaithersburg, MD 20899
USA
wpolk@nist.gov

David Solo
Citicorp
666 Fifth Ave, 3rd Floor
New York, NY 10103
USA
david.solo@citicorp.com

Appendix E. Full Copyright Statement