SIDR
Internet-Draft
Intended status: Standards Track
Expires: August 30, 2009

G. Huston
G. Michaelson
R. Loomans
APNIC

February 26, 2009

A Profile for X.509 PKIX Resource Certificates
draft-ietf-sidr-res-certs-16

Status of this Memo

Copyright Notice

Abstract

This document defines a standard profile for X.509 certificates for

the purposes of supporting validation of assertions of "right-of-use" of an Internet Number Resource (IP Addresses and Autonomous System Numbers). This profile is used to convey the issuer's authorization of the subject to be regarded as the current holder of a "right-of-use" of the IP addresses and AS numbers that are described in the issued certificate.

Table of Contents

1. Introduction

This document defines a standard profile for X.509 certificates [X.509] for use in the context of certification of IP Addresses and AS Numbers. Such certificates are termed here "Resource Certificates." Resource Certificates are X.509 certificates that conform to the PKIX profile [RFC5280], and also conform to the constraints specified in this profile. Resource Certificates attest that the issuer has granted the subject a "right-of-use" for a listed set of IP addresses and Autonomous System numbers.

A Resource Certificate describes an action by a certificate issuer that binds a list of IP Address blocks and AS Numbers to the subject of the issued certificate. The binding is identified by the association of the subject's private key with the subject's public key contained in the Resource Certificate, as signed by the private key of the certificate's issuer.

In the context of the public Internet, and the use of public number resources within this context, it is intended that Resource Certificates are used in a manner that is explicitly aligned to the public number resource distribution function. Specifically, when a number resource is allocated or assigned by a number registry to an entity, this allocation is described by an associated Resource Certificate. This certificate is issued by the number registry, and the subject public key that is certified by the issuer corresponds to the public part of a key pair for which the private key is associated with the entity who is the recipient of the number assignment or allocation. A critical extension to the certificate enumerates the

IP Resources that were allocated or assigned by the issuer to the entity. In the context of the public number distribution function, this corresponds to a hierarchical PKI structure, where Resource Certificates are issued in only one 'direction' and there is a unique path of certificates from a certification authority operating at the apex of a resource distribution hierarchy to a valid certificate.

Validation of a Resource Certificate in such a hierarchical PKI can be undertaken by establishing a valid issuer-subject certificate chain from a certificate issued by a trust anchor certification authority to the certificate [RFC4158], with the additional constraint of ensuring that each subject's listed resources are fully encompassed by those of the issuer at each step in the issuer-subject certificate chain. Validation therefore logically corresponds to validation of an associated set of assignment or allocation actions of IP number resources.

Resource Certificates may be used in the context of the operation of secure inter-domain routing protocols to convey a right-of-use of an

IP number resource that is being passed within the routing protocol, allowing relying parties to verify legitimacy and correctness of routing information. Related use contexts include validation of Internet Routing Registry objects, validation of routing requests, and detection of potential unauthorized use of IP addresses.

This profile defines those fields that are used in a Resource Certificate that MUST be present for the certificate to be valid. Relying Parties SHOULD check that a Resource Certificate conforms to this profile as a requisite for validation of a Resource Certificate.

1.1. Terminology

It is assumed that the reader is familiar with the terms and concepts described in "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile" [RFC5280], "X.509 Extensions for IP Addresses and AS Identifiers" [RFC3779], "Internet Protocol" [RFC0791], "Internet Protocol Version 6 (IPv6) Addressing Architecture" [RFC4291], "Internet Registry IP Allocation Guidelines" [RFC2050], and related regional Internet registry address management policy documents.

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.

2. Describing Resources in Certificates

The framework for describing an association between the subject of a certificate and the resources currently under the subject's control is described in [RFC3779].

There are three aspects of this resource extension that are noted in this profile:

1. RFC 3779 notes that a resource extension SHOULD be a CRITICAL extension to the X.509 Certificate. This Resource Certificate profile further specifies that the use of this certificate extension MUST be used in all Resource Certificates and MUST be marked as CRITICAL.

2. RFC 3779 defines a sorted canonical form of describing a resource set, with maximal spanning ranges and maximal spanning prefix masks as appropriate. All valid certificates in this profile MUST use this sorted canonical form of resource description in the resource extension field.

3. A test of the resource extension in the context of certificate validity includes the condition that the resources described in the immediate parent CA certificate in the PKI (the certificate where this certificate's issuer is the subject) has a resource set (called here the "issuer's resource set") that MUST encompass the resource set of the issued certificate. In this context "encompass" allows for the issuer's resource set to be the same as, or a strict superset of, any subject's resource set.

Certificate validation entails the construction of a sequence of valid certificates in an issuer-subject chain (where the subject field of one certificate appears as the issuer in the next certificate in the sequence) from a trust anchor to the certificate being validated. Moreover, the resource extensions in this

certificate sequence from the first CA under the trust anchor to the certificate being validated form a sequence of encompassing relationships in terms of the resources described in the resource extension.

3. Resource Certificate Fields

A Resource Certificate is a valid X.509 v3 public key certificate, consistent with the PKIX profile [RFC5280], containing the fields listed in this section. Unless specifically noted as being OPTIONAL, all the fields listed here MUST be present, and any other field MUST NOT appear in a conforming Resource Certificate. Where a field value is specified here this value MUST be used in conforming Resource Certificates.

3.1. Version

Resource Certificates are X.509 Version 3 certificates. This field MUST be present, and the Version MUST be 3 (i.e. the value of this field is 2).

3.2. Serial number

The serial number value is a positive integer that is unique per Issuer.

3.3. Signature Algorithm

This field describes the algorithm used to compute the signature on this certificate. This profile specifies a default of SHA-256 with RSA (sha256WithRSAEncryption), and allows for the use of SHA-384 or SHA-512. Accordingly, the value for this field MUST be one of the

OID values { pkcs-1 11 }, { pkcs-1 12 } or { pkcs-1 13 } [RFC4055].

3.4. Issuer

This field identifies the entity that has signed and issued the certificate. The value of this field is a valid X.501 distinguished name. Conventions are imposed on Issuer names used in resource certificates, as described in [ID.sidr-arch].

If the certificate is a subordinate certificate issued by virtue of the "cA" bit set in the immediate superior certificate, then the issuer name MUST correspond to the subject name as contained in the immediate superior certificate.

3.5. Subject

This field identifies the entity to whom the resource has been allocated / assigned. The value of this field is a valid X.501 distinguished name. As noted above, conventions are imposed on Subject names used in resource certificates, as described in [ID.sidr-arch].

In this profile the subject name is determined by the issuer, and each distinct subordinate CA and EE certified by the issuer MUST be identified using a subject name that is unique per issuer.

In this context "distinct" is defined as an entity and a given public key. An issuer SHOULD use a different subject name if the subject entity or the subject entity's key pair has changed.

3.6. Valid From

The starting time at which point the certificate is valid. In this profile the "Valid From" time SHOULD be no earlier than the time of certificate generation. As per Section 4.1.2.5 of [RFC5280], Certification Authorities (CAs) conforming to this profile MUST always encode the certificate's "Valid From" date through the year 2049 as UTCTime, and dates in 2050 or later MUST be encoded as GeneralizedTime. These two time formats are defined in [RFC5280].

In this profile, it is valid for a certificate to have a value for this field that pre-dates the same field value in any superior certificate. Relying Parties should not attempt to infer from this time information a certificate was valid at a time in the past, or will be valid at a time in the future, as the scope of a relying party's test of validity of a certificate refers specifically to validity at the current time.

3.7. Valid To

The Valid To time is the date and time at which point in time the certificate's validity ends. It represents the anticipated lifetime of the resource allocation / assignment arrangement between the issuer and the subject. As per Section 4.1.2.5 of [RFC5280], CAs conforming to this profile MUST always encode the certificate's "Valid To" date through the year 2049 as UTCTime, and dates in 2050 or later MUST be encoded as GeneralizedTime. These two time formats are defined in [RFC5280].

As noted above, it is valid for a certificate to have a value for this field that post-dates the same field value in any superior certificate. The same caveats apply to Relying Party's assumptions relating to the certificate's validity at any time other than the current time,

While a CA is typically advised against issuing a certificate with a validity interval that exceeds the validity interval of the CA's certificate that will be used to validate the issued certificate, in the context of this profile, it is anticipated that a CA may have valid grounds to issue a certificate with a validity interval that exceeds the validity interval of its certificate.

3.8. Subject Public Key Info

This field specifies the subject's public key and the algorithm with which the key is used. The public key algorithm MUST be RSA, and, accordingly, the OID for the public key algorithm is 1.2.840.113549.1.1.1. The key size MUST be a minimum size of 2048 bits.

It is noted that larger key sizes are computationally expensive for both the CA and relying parties, indicating that care should be taken when deciding to use larger than the minimum key size noted above.

3.9. Resource Certificate Version 3 Extension Fields

As noted in Section 4.2 of [RFC5280], each extension in a certificate is designated as either 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 [RFC5280].

The following X.509 V3 extensions MUST be present in a conforming Resource Certificate, except where explicitly noted otherwise.

3.9.1. Basic Constraints

The basic constraints extension identifies whether the subject of the certificate is a CA and the maximum depth of valid certification paths that include this certificate.

The issuer determines whether the "cA" boolean is set. If this bit is set, then it indicates that the subject is allowed to issue resources certificates within this overall framework (i.e. the subject is a CA).

The Path Length Constraint is not specified in this profile and MUST NOT be present.

The Basic Constraints extension field is a critical extension in the Resource Certificate profile, and MUST be present when the subject is a CA, and MUST NOT be present otherwise.

3.9.2. Subject Key Identifier

The subject key identifier extension provides a means of identifying certificates that contain a particular public key. To facilitate certification path construction, this extension MUST appear in all Resource Certificates. This extension is non-critical.

The value of the subject key identifier MUST be the value placed in the key identifier field of the Authority Key Identifier extension of all certificates issued by this subject.

The Key Identifier used here is the 160-bit SHA-1 hash of the value of the DER-encoded ASN.1 bit string of the subject public key, as described in Section 4.2.1.2 of [RFC5280].

3.9.3. Authority Key Identifier

The authority key identifier extension provides a means of identifying certificates that are signed by the issuer's private key, by providing a hash value of the issuer's public key. To facilitate path construction, this extension MUST appear in all Resource Certificates. The keyIdentifier MUST be present in all Resource Certificates, with the exception of a CA who issues a "self-signed" certificate. The authorityCertIssuer and authorityCertSerialNumber fields MUST NOT be present. This extension is non-critical.

The Key Identifier used here is the 160-bit SHA-1 hash of the value of the DER-encoded ASN.1 bit string of the issuer's public key, as

described in Section 4.2.1.1 of [RFC5280].

3.9.4. Key Usage

This describes the purpose of the certificate. This is a critical extension, and it MUST be present.

In certificates issued to Certification Authorities only the keyCertSign and CRLSign bits are set to TRUE and these MUST be the only bits set to TRUE.

In end-entity certificates the digitalSignature bit MUST be set to TRUE and MUST be the only bit set to TRUE.

3.9.5. Extended Key Usage

The Extended Key Usage Extension indicates one or more purposes for which the public key in a certificate may be used. The uses are specified via a SEQUENCE of one or more object identifiers (OIDs). The EKU extension MUST NOT appear in any Certification Authority certificate in the RPKI. This extension also MUST NOT appear in end entity certificates used to verify RPKI objects such as ROAs or manifests.

The EKU extension MAY appear in end entity certificates issued to routers or other devices. The extension MUST NOT be marked critical. Permitted values for the EKU OIDs will be specified in Standards Track RFCs issued by other IETF working groups that adopt the RPKI profile and that identify application-specific requirements that motivate the use of such EKUs.

3.9.6. CRL Distribution Points

This field (CRLDP) identifies the location(s) of the CRL(s) associated with certificates issued by this Issuer. This profile uses the URI form of object identification. The preferred URI access mechanism is a single RSYNC URI ("rsync://") [rsync] that references a single inclusive CRL for each issuer.

In this profile the certificate issuer is also the CRL issuer, implying at the CRLIssuer field MUST be omitted, and the

distributionPoint field MUST be present. The Reasons field MUST be omitted.

The distributionPoint MUST contain GeneralNames, and MUST NOT contain a nameRelativeToCRLIssuer. The form of the generalName MUST be of type URI.

In this profile, the scope of the CRL is specified to be all certificates issued by this CA issuer.

The sequence of distributionPoint values MUST contain only a single DistributionPointName set. The DistributionPointName set MAY contain more than one URI value. An RSYNC URI MUST be present in the DistributionPointName set, and reference the most recent instance of this issuer's certificate revocation list. Other access form URIs MAY be used in addition to the RSYNC URI.

This extension MUST be present and it is non-critical. There is one exception, namely where a CA distributes its public key in the form of a "self-signed" certificate, the CRLDP MUST be omitted.

3.9.7. Authority Information Access

This extension (AIA) identifies the point of publication of the certificate that is issued by the issuer's immediate superior CA, where this certificate's issuer is the subject. In this profile a single reference object to publication location of the immediate superior certificate MUST be used, except in the case where a CA distributes its public key in the form of a "self-signed" certificate, in which case the AIA field SHOULD be omitted.

This profile uses a URI form of object identification. The preferred URI access mechanisms is "rsync", and an RSYNC URI MUST be specified with an accessMethod value of id-ad-caIssuers. The URI MUST reference the point of publication of the certificate where this issuer is the subject (the issuer's immediate superior certificate). Other accessMethod URIs referencing the same object MAY also be included in the value sequence of this extension.

When an Issuer re-issues a CA certificate, the subordinate certificates need to reference this new certificate via the AIA field. In order to avoid the situation where a certificate re-

issuance necessarily implies a requirement to re-issue all subordinate certificates, CA Certificate issuers SHOULD use a persistent URL name scheme for issued certificates. This implies that re-issued certificates overwrite previously issued certificates to the same subject in the publication repository, and use the same publication name as previously issued certificates. In this way subordinate certificates can maintain a constant AIA field value and need not be re-issued due solely to a re-issue of the superior certificate. The issuers' policy with respect to the persistence of name objects of issued certificates MUST be specified in the Issuer's Certification Practice Statement.

This extension is non-critical.

3.9.8. Subject Information Access

This extension (SIA) identifies the location of information and services relating to the subject of the certificate in which the SIA extension appears. Where the Subject is a CA in this profile, this information and service collection will include all current valid certificates that have been issued by this subject that are signed with the subject's corresponding private key.

This profile uses a URI form of location identification. The preferred URI access mechanism is "rsync", and an RSYNC URI MUST be specified, with an accessMethod value of id-ad-caRepository when the subject of the certificate is a CA. The RSYNC URI MUST reference an object collection rather than an individual object and MUST use a trailing '/' in the URI.

Other accessMethod URIs that reference the same location MAY also be included in the value sequence of this extension. The ordering of URIs in this sequence reflect the subject's relative preferences for access methods to be used by parties for retrieval of objects from the associated repository publication point, with the first method in the accessMethod sequence being the most preferred.

This extension MUST be present when the subject is a CA, and is non-critical.

For End Entity (EE) certificates, where the subject is not a CA, this extension MAY be present, and is non-critical. If present, it either references the location where objects signed by the private key associated with the EE certificate can be accessed, or, in the case of single-use EE certificates it references the location of the single object that has been signed by the corresponding private key.

When the subject is an End Entity, and it publishes objects signed with the matching private key in a repository, the directory where these signed objects is published is referenced the id-ad-signedObjectRepository OID.

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

id-ad-signedObjectRepository OBJECT IDENTIFIER ::= { id-ad 9 }
```

When the subject is an End Entity, and it publishes a single object signed with the matching private key, the location where this signed object is published is referenced the id-ad-signedObject OID.

```
id-ad-signedObject OBJECT IDENTIFIER ::= { id-ad 11 }
```


This profile requires the use of repository publication manifests [ID.sidr-manifests] to list all signed objects that are deposited in the repository publication point associated with a CA or an EE. The publication point of the manifest for a CA or EE is placed in the SIA extension of the CA or EE certificate. This profile uses a URI form of manifest identification for the accessLocation. The preferred URI access mechanisms is "rsync", and an RSYNC URI MUST be specified. Other accessDescription fields may exist for the id-ad-rpkiManifest accessMethod, where the accessLocation value indicates alternate URI access mechanisms for the same manifest object.

```
id-ad-rpkiManifest  OBJECT IDENTIFIER ::= { id-ad 10 }
```

CA certificates MUST include in the SIA an accessMethod OID of id-ad-rpkiManifest, where the associated accessLocation refers to the subject's published manifest object as an object URL.

When an EE certificate is intended for use in verifying multiple

objects, EE certificate MUST include in the SIA an accessMethod OID of id-ad-rpkiManifest, where the associated accessLocation refers to the EE's published manifest object as an object URL.

When an EE certificate is used to verify a single published object, the EE certificate MUST include in the SIA an accessMethod OID of id-ad-signedObject, where the associated accessLocation refers to the publication point of the single object that is verified using this EE certificate. In this case, the SIA MUST NOT include the accessMethod OID of id-ad-rpkiManifest.

3.9.9. Certificate Policies

This extension MUST reference the Resource Certificate Policy, using the OID Policy Identifier value of "1.3.6.1.5.5.7.14.2". This field MUST be present and MUST contain only this value for Resource Certificates.

No PolicyQualifiers are defined for use with this policy and thus none must be included in this extension.

This extension MUST be present and it is critical.

3.9.10. IP Resources

This extension contains the list of IP address resources as per [RFC3779]. The value may specify the "inherit" element for a particular AFI value. In the context of resource certificates describing public number resources for use in the public Internet, the SAFI value MUST NOT be used. All Resource Certificates MUST

include an IP Resources extension, an AS Resources extension, or both extensions.

This extension, if present, MUST be marked critical.

Either the IP Resources extension, or the AS Resources extension, or both, MUST be present in all RPKI certificates.

3.9.11. AS Resources

This extension contains the list of AS number resources as per

[RFC3779], or may specify the "inherit" element. RDI values are NOT supported in this profile and MUST NOT be used. All Resource Certificates MUST include an IP Resources extension, an AS Resources extension, or both extensions.

This extension, if present, MUST be marked critical.

Either the IP Resources extension, or the AS Resources extension, or both, MUST be present in all RPKI certificates.

4. Resource Certificate Revocation List Profile

Each CA MUST issue a version 2 Certificate Revocation List (CRL), consistent with [RFC5280]. The CRL issuer is the CA, and no indirect CRLs are supported in this profile.

An entry MUST NOT be removed from the CRL until it appears on one regularly scheduled CRL issued beyond the revoked certificate's validity period, as required in [RFC5280].

This profile does not allow issuance of Delta CRLs.

The scope of the CRL MUST be "all certificates issued by this CA". The contents of the CRL are a list of all non-expired certificates that have been revoked by the CA.

No CRL fields other than those listed here are permitted in CRLs issued under this profile. Unless otherwise indicated, these fields MUST be present in the CRL. Where two or more CRLs issued by a single CA with the same scope, the CRL with the highest value of the "CRL Number" field supersedes all other CRLs issued by this CA.

4.1. Version

Resource Certificate Revocation Lists are Version 2 certificates (the integer value of this field is 1).

4.2. Issuer Name

The value of this field is the X.501 name of the issuing CA who is also the signer of the CRL, and is identical to the Issuer name in

the Resource Certificates that are issued by this issuer.

4.3. This Update

This field contains the date and time that this CRL was issued. The value of this field MUST be encoded as UTCTime for dates through the year 2049, and MUST be encoded as GeneralizedTime for dates in the year 2050 or later.

4.4. Next Update

This is the date and time by which the next CRL SHOULD be issued. The value of this field MUST be encoded as UTCTime for dates through the year 2049, and MUST be encoded as GeneralizedTime for dates in the year 2050 or later.

4.5. Signature

This field contains the algorithm used to sign this CRL. This profile specifies a default of SHA-256 with RSA (sha256WithRSAEncryption), and allows for the use of SHA-384 or SHA-512.

It is noted that larger key sizes are computationally expensive for both the CRL Issuer and relying parties, indicating that care should be taken when deciding to use larger than the default key size.

4.6. Revoked Certificate List

When there are no revoked certificates, then the revoked certificate list MUST be absent.

For each revoked resource certificate only the following fields MUST be present. No CRL entry extensions are supported in this profile, and CRL entry extensions MUST NOT be present in a CRL.

4.6.1. Serial Number

The serial number of the revoked certificate.

4.6.2. Revocation Date

The time the certificate was revoked. This time MUST NOT be a future date (i.e., a date later than ThisUpdate). The value of this field

MUST be encoded as UTCTime for dates through the year 2049, and MUST be encoded as GeneralizedTime for dates in the year 2050 or later.

4.7. CRL Extensions

The X.509 v2 CRL format allows extensions to be placed in a CRL. The following extensions are supported in this profile, and MUST be present in a CRL.

4.7.1. 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. Conforming CRL issuers MUST use the key identifier method. The syntax for this CRL extension is defined in section 4.2.1.1 of [RFC5280].

This extension is non-critical.

4.7.2. CRL Number

The CRL Number extension conveys a monotonically increasing sequence number of positive integers for a given CA and scope. This extension allows users to easily determine when a particular CRL supersedes another CRL. The highest CRL Number value supersedes all other CRLs issued by the CA with the same scope.

This extension is non-critical.

5. Resource Certificate Request Profile

A resource certificate request MAY use either of PKCS#10 or Certificate Request Message Format (CRMF). A CA Issuer MUST support PKCS#10 and a CA Issuer may, with mutual consent of the subject, support CRMF.

5.1. PCKS#10 Profile

This profile refines the specification in [RFC2986], as it relates to Resource Certificates. A Certificate Request Message object, formatted according to PKCS#10, is passed to a CA as the initial step in issuing a certificate.

This request may be conveyed to the CA via a Registration Authority (RA), acting under the direction of a Subject.

With the exception of the public key related fields, the CA is

permitted to alter any requested field when issuing a corresponding certificate.

5.1.1. PKCS#10 Resource Certificate Request Template Fields

This profile applies the following additional constraints to fields that may appear in a CertificationRequestInfo:

Version
: This field is mandatory and MUST have the value 0.

Subject
: This field is optional. If present, the value of this field SHOULD be empty, in which case the issuer MUST generate a subject name that is unique in the context of certificates issued by this issuer. If the value of this field is non-empty, then the CA MAY consider the value of this field as the subject's suggested subject name, but the CA is NOT bound to honor this suggestion, as the subject name MUST be unique per subordinate CA and EE in certificates issued by this issuer.

SubjectPublicKeyInfo
: This field specifies the subject's public key and the algorithm with which the key is used. The public key algorithm MUST be RSA, and the OID for the algorithm is 1.2.840.113549.1.1.1. This field also includes a bit-string representation of the entity's public key. For the RSA public-key algorithm the bit string contains the DER encoding of a value of PKCS #1 type RSAPublicKey.

Attributes
: [RFC2986] defines the attributes field as key-value pairs where the key is an OID and the value's structure depends on the key.

  The only attribute used in this profile is the ExtensionRequest attribute as defined in [RFC2985]. This attribute contains X509v3 Certificate Extensions. The profile for extensions in certificate requests is specified in Section 5.3.

This profile applies the following additional constraints to fields that MAY appear in a CertificationRequest Object:

signatureAlgorithm
This profile specifies a default of SHA-256 with RSA (sha256WithRSAEncryption), and allows for the use of SHA-384 or SHA-512. Accordingly, the value for this field MUST be one of the OID values { pkcs-1 11 }, { pkcs-1 12 } or { pkcs-1 13 } [RFC4055].

It is noted that larger key sizes are computationally expensive for both the CA and relying parties, indicating that care should be taken when deciding to use larger than the default key size.

5.2. CRMF Profile

This profile refines the Certificate Request Message Format (CRMF) specification in [RFC4211], as it relates to Resource Certificates. A Certificate Request Message object, formatted according to the CRMF, is passed to a CA as the initial step in issuing a certificate.

This request MAY be conveyed to the CA via a Registration Authority (RA), acting under the direction of a subject.

With the exception of the public key related fields, the CA is permitted to alter any requested field when issuing a corresponding certificate.

5.2.1. CRMF Resource Certificate Request Template Fields

This profile applies the following additional constraints to fields that may appear in a Certificate Request Template:

Version

This field MAY be absent, or MAY specify the request of a Version 3 Certificate. It SHOULD be omitted.

SerialNumber
As per [RFC4211], this field is assigned by the CA and MUST be omitted in this profile.

SigningAlgorithm
As per [RFC4211], this field is assigned by the CA and MUST be omitted in this profile.

Issuer
This field is assigned by the CA and MUST be omitted in this profile.

Validity
This field MAY be omitted. If omitted, the CA will issue a Certificate with Validity dates as determined by the CA. If specified, then the CA MAY override the requested values with dates as determined by the CA.

Subject
This field is optional. If present, the value of this field SHOULD be empty, in which case the issuer MUST generate a subject name that is unique in the context of certificates issued by this issuer. If the value of this field is non-empty, then the CA MAY consider the value of this field as the subject's suggested subject name, but the CA is NOT bound to honor this suggestion, as the subject name MUST be unique per issuer in certificates issued by this issuer.

PublicKey
This field MUST be present.

extensions
This attribute contains X509v3 Certificate Extensions. The profile for extensions in certificate requests is specified in

Section 5.3.

5.2.2. Resource Certificate Request Control Fields

The following control fields are supported in this profile:

Authenticator Control
: It is noted that the intended model of authentication of the subject is a "long term" model, and the advice as offered in [RFC4211] is that the Authenticator Control field be used.

5.3. Certificate Extension Attributes in Certificate Requests

The following extensions MAY appear in a PKCS#10 or CRMF Certificate Request. Any other extensions MUST NOT appear in a Certificate Request. This profile places the following additional constraints on these extensions.:

BasicConstraints
: If this is omitted then the CA will issue an end entity certificate with the BasicConstraints extension not present in the issued certificate.

  The Path Length Constraint is not supported in this Resource Certificate Profile, and this field MUST be omitted in this profile.

  The CA MAY honor the SubjectType CA bit set to on. If this bit is set, then it indicates that the Subject is allowed to issue resource certificates within this overall framework.

  The CA MUST honor the SubjectType CA bit set to off (End Entity certificate request), in which case the corresponding end entity certificate will not contain a BasicConstraints extension.

SubjectKeyIdentifier
   This field is assigned by the CA and MUST be omitted in this profile.

AuthorityKeyIdentifier
   This field is assigned by the CA and MUST be omitted in this profile.

KeyUsage
   The CA MAY honor KeyUsage extensions of keyCertSign and cRLSign if present, as long as this is consistent with the BasicConstraints SubjectType sub field, when specified.

ExtendedKeyUsage
   The CA MAY honor ExtendedKeyUsage extensions of keyCertSign and cRLSign if present, as long as this is consistent with the BasicConstraints SubjectType sub field, when specified.

SubjectInformationAccess
   This field MUST be present when the subject is a CA, and the field value SHOULD be honored by the CA. If the CA is not able to honor the requested field value, then the CA MUST reject the Certificate Request.

   This field (SIA) identifies the location of information and services relating to the subject of the certificate in which the SIA extension appears.

   Where the subject is a CA in this profile, this information and service collection will include all current valid certificates that have been issued by this subject that are signed with the subject's corresponding private key.

   This profile uses a URI form of location identification. An RSYNC URI MUST be specified, with an accessMethod value of id-ad-caRepository when the subject of the certificate is a CA. The RSYNC URI MUST reference an object collection rather than an individual object and MUST use a trailing '/' in the URI. Other accessMethod URIs that reference the same location MAY also be included in the value sequence of this extension. The

ordering of URIs in this sequence reflect the subject's relative preferences for access methods, with the first method in the sequence being the most preferred by the Subject.

A request for a CA certificate MUST include in the SIA of the request the id-ad-caRepository accessMethod, and also MUST include in the SIA of the request the accessMethod OID of id-ad-rpkiManifest, where the associated accessLocation refers to the subject's published manifest object as an object URL.

This field MAY be present when the subject is a EE. If it is present the field value SHOULD be honored by the CA. If the CA is not able to honor the requested field value, then the CA MUST reject the Certificate Request. If it is not present the CA SHOULD honor this request and omit the SIA from the issued certificate. If the CA is not able to honor the request to omit the SIA, then the CA MUST reject the Certificate Request.

When an EE certificate is intended for use in verifying multiple objects, the certificate request for the EE certificate MUST include in the SIA of the request an accessMethod OID of id-ad-signedObjectRepository, and also MUST include in the SIA of the request an accessMethod OID of id-ad-rpkiManifest, where the associated access location refers to the publication point of the manifest object describing all objects that are verified using this EE certificate.

When an EE certificate is used to sign a single published object, the certificate request for the EE certificate MUST include in the SIA of the request an accessMethod OID of id-ad-signedObject, where the associated accessLocation refers to the publication point of the single object that is verified using this EE certificate, and MUST NOT include an id-ad-rpkiManifest accessMethod OID in the SIA of the request.

In the case when the EE certificate is to be used exclusively to sign one or more unpublished objects, such that the all signed objects will not be published in any RPKI repository, then the SIA SHOULD be omitted from the request.

CRLDistributionPoints
This field is assigned by the CA and MUST be omitted in this profile.

AuthorityInformationAccess
This field is assigned by the CA and MUST be omitted in this profile.

CertificatePolicies
This field is assigned by the CA and MUST be omitted in this profile.

With the exceptions of the publicKey field and the SubjectInformationAccess field, the CA is permitted to alter any requested field.

6. Resource Certificate Validation

This section describes the Resource Certificate validation procedure. This refines the generic procedure described in section 6 of [RFC5280].

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:

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

2. certificate '1' is issued by a trust anchor ;

3. certificate 'n' is the certificate to be validated; and

4. for all 'x' in {1, ..., n}, certificate 'x' is valid.

6.1. Resource Extension Validation

The IP Resources and AS Resources extensions definitions [RFC3779] defines critical extensions for Internet number resources. These are ASN.1 encoded representations of the IPv4 and IPv6 address range

(either as a prefix/length, or start-end pair) and an AS number set.

Valid Resource Certificates MUST have a valid IP address and/or AS number resource extension. In order to validate a Resource Certificate the resource extension MUST also be validated. This validation process relies on definitions of comparison of resource sets:

more specific
: Given two IP address or AS number contiguous ranges, A and B, A is "more specific" than B if range B includes all IP addresses or AS numbers described by range A, and if range B is larger than range A.

equal
: Given two IP address or AS number contiguous ranges, A and B, A is "equal" to B if range A describes precisely the same collection of IP addresses or AS numbers as described by range B. The definition of "inheritance" in [RFC3779] is equivalent to this "equality" comparison.

encompass
: Given two IP address and AS number sets X and Y, X "encompasses" Y if, for every contiguous range of IP addresses or AS numbers elements in set Y, the range element is either more specific than or equal to a contiguous range element within the set X.

Validation of a certificate's resource extension in the context of an ordered certificate sequence of {1,2, ... , n} where certificate '1' is issued by a trust anchor and certificate 'n' is the target certificate, and where the subject of certificate 'x' is the issuer of certificate ('x' + 1), includes verification that that the resources described in certificate 'x' "encompass" the resources described in certificate ('x' + 1), and the resources described in the trust anchor information "encompass" the resources described in certificate '1'.

6.2. Resource Certification Path Validation

Validation of signed resource data using a target resource certificate consists of assembling an ordered sequence (or 'Certification Path') of certificates ({1,2,...n} where '1' is a certificate that has been issued by a trust anchor, and 'n' is the target certificate) verifying that all of the following conditions hold:

1. The certificate can be verified using the Issuer's public key and the signature algorithm

2. The current time lies within the certificate's Validity From and To values.

3. The certificate contains all fields that MUST be present and contains field values as specified in this profile for all field values that MUST be present.

4. No field value that MUST NOT be present in this profile is present in the certificate.

5. The Issuer has not revoked the certificate by placing the certificate's serial number on the Issuer's current Certificate Revocation List, and the Certificate Revocation List is itself valid.

6. That the resource extension data is "encompassed" by the resource extension data contained in a valid certificate where this Issuer is the Subject (the previous certificate in the ordered sequence)

7. The Certification Path originates with a certificate issued by a trust anchor, and there exists a signing chain across the Certification Path where the Subject of Certificate 'x' in the Certification Path matches the Issuer in Certificate ('x' + 1) in the Certification Path.

A certificate validation algorithm may perform these tests in any chosen order.

Certificates and CRLs used in this process may be found in a locally maintained cache, maintained by a regular synchronization across the distributed publication repository structure.

There exists the possibility of encountering certificate paths that are arbitrarily long, or attempting to generate paths with loops as means of creating a potential DOS attack on a relying party. Some further heuristics may be required to halt the certification path validation process in order to avoid some of the issues associated

with attempts to validate such structures. It is suggested that implementations of Resource Certificate validation MAY halt with a validation failure if the certification path length exceeds a locally defined configuration parameter.

7. Design Notes

The following notes provide some additional commentary on the considerations that lie behind some of the design choices that were made in the design of this certificate profile. These notes do not constitute a formal part of the profile specification, and the interpretation of key words as defined in RFC2119 are not applicable in this section of the document.

Certificate Extensions:

This profile does not permit the use of any other critical or non-critical extensions. The rationale for this restriction is that the resource certificate profile is intended for a specific use, and in this context it is not seen as being appropriate to be in the position of having certificates with additional non-critical extensions that relying parties may see as valid certificates without understanding the extensions, but were the relying party in a position to understand the extensions, would contradict or qualify in some way this original judgment of validity. This profile takes the position of minimalism over extensibility. The specific goal for the associated Resource Public Key Infrastructure to precisely match the IP number resource allocation structure through an aligned certificate structure that describes the allocation and its context within the number resource distribution hierarchy. The profile defines a resource certificate that is structured to meet these requirements.

Certification Authorities and Key Values:

This profile uses a definition of an instance of a CA as a combination of a named entity and a key pair. Within this definition a CA instance cannot rollover a key pair. However, the entity can generate a new instance of a CA with a new key pair and roll over all the signed subordinate products to the new CA.

This has a number of implications in terms of subject name management, CRL Scope and repository publication point management.

Subject Name:
For Subject Names the issuer should ensure that when an entity requests a certificate with a new key pair, the CA issues a certificate with a new subject name. One way to achieve this is to use a CommonName value that is unique per subordinate entity, using an algorithm of the CA's devising to ensure this uniqueness, and for the CA to include the serial number field of the X.501

distinguished name structure, with a serial number value that is derived from the hash of the subject public key value. It should also be noted that conventions are imposed on Subject names used in resource certificates, as described in [ID.sidr-arch], and that any name scheme should comply with these conventions.

CRL Scope:
For CRL Scope this profile specifies that a CA issues a single CRL sequence, and the scope of the CRL is all certificates issued by this CA. Because the CA instance is bound to a single key pair this implies that the CA's public key, the key used to validate the CA's CRL, and the key used to validate the certificates revoked by that CRL are all the same.

Repository Publication Point:
The definition of a CA affects the design of the repository publication system. In order to minimize the amount of forced re-certification on key rollover events, a repository publication regime that uses the same repository publication point for all CA instances that refers to the same entity, but with different key values will minimize the extent of re-generation of certificates to only immediate subordinate certificates.

In order for two or more CA instances to share a single repository publication point there needs to be a regime

of key management into OLD, CURRENT and FUTURE keys and a similar regime of OLD, CURRENT and FUTURE CAs. An OLD CA should regularly publish its CRL for as long as the OLD CA instance is still valid, and issue EE certificates as necessary to maintain a current manifest of all OLD CA published products, but it should not sign any other products. The CURRENT CA should publish its CRL, and should publish all subordinate products, as well as issuing EE certificates as necessary to maintain a current manifest of all CURRENT CA published products. FUTURE CAs should publish no products at all in the repository publication point. It would be consistent with this repository object name framework for the CRL and manifest to be published using object names derived from the hash of the public key value of the CA instance.

Key Rollover:

As a CA instance is associated with a single key pair, there are some considerations regarding the procedure that should be followed by an entity performing a key rollover function. The entity will need to create a new CA instance and then use this new CA instance to re-issue all subordinate products with the new CA instance.

To perform a key rollover operation the entity will need to:

1. Generate a NEW key pair.

2. Generate a certificate request with the NEW key pair and pass the request to the entity's issuer.

3. Request the entity's issuer to generate and publish a NEW CA certificate, with an issuer-selected subject name that is distinct from the subject name used in conjunction with the previous subject name value for this entity.

4. Mark the CURRENT CA as OLD and the NEW CA as CURRENT.

5. The CURRENT CA will generate new certificates for all existing subordinate CA and EE certificates, and publish those products in the same repository publication point and with the same repository publication point name as the previous OLD subordinate CA and EE certificates. The keys in these reissued certificates must not change.

6. Where the signing structure uses a packaging format that includes the EE certificate within the signed data, signed objects that included OLD EE certificates in their signed data will need to be re-signed using an EE certificate issued by the CURRENT CA. In the case where the OLD EE certificate is a "single use" EE certificate and the associate private key has been destroyed this will entail the generate of a new key pair, the issuing of an EE certificate by the CURRENT CA. In the case of a "multi-use" EE certificate, the EE certificate should issued using the CURRENT CA. The object, together with the issued EE certificate, should be signed with the associated private key, and published in the same repository

publication point, using the same repository publication point name, as the previously signed object that it replaces (i.e. overwrite the old signed object).

7. Generate a certificate revocation request for the OLD CA certificate and pass it to the entity's issuer.

8. Remove all published OLD CA products and destroy the OLD private key.

Name Uniqueness:

This profile specifies that subject names must be unique per

issuer, and does not specify that subject names must be globally unique.

Given that the Resource Certificate PKI is a distributed PKI, there is no inherent ability for Certification authorities to coordinate PKI-wide unique subject names. CA's should use multi-attribute, structured Subject names in their RPKI certificates. This advice is motivated by a desire to include within this specification a CA's subject naming practice that uses a distinguished name component that is constant for any given entity that is the subject of CA-issued certificates (the CommonName component of the Distinguished Name), yet still ensure that the structures Subject name changes whenever subject key rollover occurs (the serial number component of the Distinguished Name). Also, as the publication repository is distributed, and distinct entities use distinct repository publication points any potential ambiguity is resolved by the distinct publication point.

8. Security Considerations

The Security Considerations of [RFC5280] and [RFC3779]apply to Resource Certificates as defined by this profile, and their use.

A Resource Certificate PKI cannot in and of itself resolve any forms of ambiguity relating to uniqueness of assertions of rights of use in the event that two or more valid certificates encompass the same resource. If the issuance of resource certificates is aligned to the status of resource allocations and assignments then the information conveyed in a certificate is no better than the information in the allocation and assignment databases.

9. IANA Considerations

[Note to IANA, to be removed prior to publication: there are no IANA considerations stated in this document.]

10. Acknowledgements

The authors would like to particularly acknowledge the valued contribution from Stephen Kent in reviewing this document and proposing numerous sections of text that have been incorporated into the text. The authors also acknowledge the contributions of Sandy Murphy, Robert Kisteleki, Randy Bush, Russ Housley, Ricardo Patara and Rob Austein in the preparation and subsequent review of this document. The document also reflects review comments received from Roque Gagliano, Sean Turner and David Cooper.

11. References

11.1. Normative References

[RFC0791] Postel, J., "Internet Protocol", STD 5, RFC 791, September 1981.

[RFC2050] Hubbard, K., Kosters, M., Conrad, D., Karrenberg, D., and J. Postel, "INTERNET REGISTRY IP ALLOCATION GUIDELINES", BCP 12, RFC 2050, November 1996.

[RFC3779] Lynn, C., Kent, S., and K. Seo, "X.509 Extensions for IP Addresses and AS Identifiers", RFC 3779, June 2004.

[RFC4055] Schaad, J., Kaliski, B., and R. Housley, "Additional Algorithms and Identifiers for RSA Cryptography for use in the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 4055, June 2005.

[RFC4211] Schaad, J., "Internet X.509 Public Key Infrastructure Certificate Request Message Format (CRMF)", RFC 4211, September 2005.

[RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", RFC 4291, February 2006.

[RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List

(CRL) Profile", RFC 5280, May 2008.

[X.509] ITU-T, "Recommendation X.509: The Directory - Authentication Framework", 2000.

11.2. Informative References

[ID.sidr-arch]
Lepinski, M. and S. Kent, "An Infrastructure to Support Secure Internet Routing", Work in progress: Internet Drafts draft-ietf-sidr-arch-04.txt, November 2008.

[ID.sidr-manifests]
Austein, R., Huston, G., Kent, S., and M. Lepinski, "Manifests for the Resource Public Key Infrastructure", Work in progress: Internet Drafts draft-ietf-sidr-rpki-manifests-04.txt, October 2008.

[RFC2985] Nystrom, M. and B. Kaliski, "PKCS #9: Selected Object Classes and Attribute Types Version 2.0", RFC 2985, November 2000.

[RFC2986] Nystrom, M. and B. Kaliski, "PKCS #10: Certification Request Syntax Specification Version 1.7", RFC 2986, November 2000.

[RFC4158] Cooper, M., Dzambasow, Y., Hesse, P., Joseph, S., and R. Nicholas, "Internet X.509 Public Key Infrastructure: Certification Path Building", RFC 4158, September 2005.

[rsync] Tridgell, A., "rsync", April 2006, <http://samba.anu.edu.au/rsync/>.

Appendix A. Example Resource Certificate

The following is an example Resource Certificate.

Certificate Name: 9JfgAEcq7Q-47IwMC5CJIJr6EJs.cer

```
Data:
  Version: 3 (0x2(
  Serial: 1500 (0x5dc)
  Signature Algorithm: SHA256WithRSAEncryption
  Issuer: CN=APNIC Production-CVPQSgUkLy7pOXdNeVWGvnFX_0s
  Validity
   Not Before: Oct 25 12:50:00 2008 GMT
```

```
        Not After : Jan 31 00:00:00 2010 GMT
      Subject: CN=A91872ED
      Subject Public Key Info:
        Public Key Algorithm: rsaEncryption
        RSA Public Key: (2048 bit)
        Modulus (2048 bit):
          00:bb:fb:4a:af:a4:b9:dc:d0:fa:6f:67:cc:27:39:
          34:d1:80:40:37:de:88:d1:64:a2:f1:b3:fa:c6:7f:
          bb:51:df:e1:c7:13:92:c3:c8:a2:aa:8c:d1:11:b3:
          aa:99:c0:ac:54:d3:65:83:c6:13:bf:0d:9f:33:2d:
          39:9f:ab:5f:cd:a3:e9:a1:fb:80:7d:1d:d0:2b:48:
          a5:55:e6:24:1f:06:41:35:1d:00:da:1f:99:85:13:
          26:39:24:c5:9a:81:15:98:fb:5f:f9:84:38:e5:d6:
          70:ce:5a:02:ca:dd:61:85:b3:43:2d:0b:35:d5:91:
          98:9d:da:1e:0f:c2:f6:97:b7:97:3e:e6:fc:c1:c4:
          3f:30:c4:81:03:25:99:09:4c:e2:4a:85:e7:46:4b:
          60:63:02:43:46:51:4d:ed:fd:a1:06:84:f1:4e:98:
          32:da:27:ee:80:82:d4:6b:cf:31:ea:21:af:6f:bd:
          70:34:e9:3f:d7:e4:24:cd:b8:e0:0f:8e:80:eb:11:
          1f:bc:c5:7e:05:8e:5c:7b:96:26:f8:2c:17:30:7d:
          08:9e:a4:72:66:f5:ca:23:2b:f2:ce:54:ec:4d:d9:
          d9:81:72:80:19:95:57:da:91:00:d9:b1:e8:8c:33:
          4a:9d:3c:4a:94:bf:74:4c:30:72:9b:1e:f5:8b:00:
          4d:e3
        Exponent: 65537 (0x10001)
      X509v3 extensions:
        X509v3 Subject Key Identifier:
          F4:97:E0:00:47:2A:ED:0F:B8:EC:8C:0C:0B:90:89:
          20:9A:FA:10:9B

        X509v3 Authority Key Identifier:
          keyid:09:53:D0:4A:05:24:2F:2E:E9:39:77:4D:79:
          55:86:BE:71:57:FF:4B

        X509v3 Key Usage: critical
          Certificate Sign, CRL Sign

        X509v3 Basic Constraints: critical
          CA:TRUE

        X509v3 CRL Distribution Points:
          URI:rsync://rpki.apnic.net/repository/A3C38A24
              D60311DCAB08F31979BDBE39/CVPQSgUkLy7pOXdNe
```

```
            VWGvnFX_0s.crl

        Authority Information Access:
           CA Issuers - URI:rsync://rpki.apnic.net/repos
              itory/8BDFC7DED5FD11DCB14CF4B1A703F9B7/CVP
```



```
            QSgUkLy7pOXdNeVWGvnFX_0s.cer

        X509v3 Certificate Policies: critical
           Policy: 1.3.6.1.5.5.7.14.2

        Subject Information Access:
           CA Repository - URI:rsync://rpki.apnic.net/mem
               ber_repository/A91872ED/06A83982887911DD81
               3F432B2086D636/
           Manifest - URI:rsync://rpki.apnic.net/member_r
               epository/A91872ED/06A83982887911DD813F432
               B2086D636/9JfgAEcq7Q-47IwMC5CJIJr6EJs.mft

         sbgp-autonomousSysNum: critical
           Autonomous System Numbers:
             24021
             38610
             131072
             131074

         sbgp-ipAddrBlock: critical
           IPv4:
             203.133.248.0/22
             203.147.108.0/23

      Signature Algorithm: sha256WithRSAEncryption
        51:4c:77:e4:21:64:80:e9:35:30:20:9f:d8:4b:88:60:b8:1f:
        73:24:9d:b5:17:60:65:6a:28:cc:43:4b:68:97:ca:76:07:eb:
        dc:bd:a2:08:3c:8c:56:38:c6:0a:1e:a8:af:f5:b9:42:02:6b:
        77:e0:b1:1c:4a:88:e6:6f:b6:17:d3:59:41:d7:a0:62:86:59:
        29:79:26:76:34:d1:16:2d:75:05:cb:b2:99:bf:ca:c6:68:1b:
        b6:a9:b0:f4:43:2e:df:e3:7f:3c:b3:72:1a:99:fa:5d:94:a1:
        eb:57:9c:9a:2c:87:d6:40:32:c9:ff:a6:54:b8:91:87:fd:90:
        55:ef:12:3e:1e:2e:cf:c5:ea:c3:4c:09:62:4f:88:00:a0:7f:
        cd:67:83:bc:27:e1:74:2c:18:4e:3f:12:1d:ef:29:0f:e3:27:
        00:ce:14:eb:f0:01:f0:36:25:a2:33:a8:c6:2f:31:18:22:30:
```

```
      cf:ca:97:43:ed:84:75:53:ab:b7:6c:75:f7:2f:55:5c:2e:82:
      0a:be:91:59:bf:c9:06:ef:bb:b4:a2:71:9e:03:b1:25:8e:29:
      7a:30:88:66:b4:f2:16:6e:df:ad:78:ff:d3:b2:9c:29:48:e3:
      be:87:5c:fc:20:2b:df:da:ca:30:58:c3:04:c9:63:72:48:8c:
      0a:5f:97:71
```

Appendix B. Example Certificate Revocation List

The following is an example Certificate Revocation List.


```
CRL Name: q66IrWSGuBE7jqx8PAUHAlHCqRw.crl

Data:
  Version: 2
  Signature Algorithm:
    Hash: SHA256, Encryption: RSA
  Issuer: CN=Demo Production APNIC CA - Not for real use,
    E=ca@apnic.net
  This Update: Thu Jul 27 06:30:34 2006 GMT
  Next Update: Fri Jul 28 06:30:34 2006 GMT
  Authority Key Identifier: Key Identifier:
    ab:ae:88:ad:64:86:b8:11:3b:8e:ac:7c:3c:05:
    07:02:51:c2:a9:1c
  Authority Key Identifier: Key Identifier g(AKI):
    q66IrWSGuBE7jqx8PAUHAlHCqRw
  CRLNumber: 4
  Revoked Certificates: 1
    Serial Number: 1
    Revocation Date: Mon Jul 17 05:10:19 2006 GMT
    Serial Number: 2
    Revocation Date: Mon Jul 17 05:12:25 2006 GMT
    Serial Number: 4
    Revocation Date: Mon Jul 17 05:40:39 2006 GMT
  Signature:
    b2:5a:e8:7c:bd:a8:00:0f:03:1a:17:fd:40:2c:46:
    0e:d5:64:87:e7:e7:bc:10:7d:b6:3e:39:21:a9:12:
    f4:5a:d8:b8:d4:bd:57:1a:7d:2f:7c:0d:c6:4f:27:
    17:c8:0e:ae:8c:89:ff:00:f7:81:97:c3:a1:6a:0a:
    f7:d2:46:06:9a:d1:d5:4d:78:e1:b7:b0:58:4d:09:
```

```
      d6:7c:1e:a0:40:af:86:5d:8c:c9:48:f6:e6:20:2e:
      b9:b6:81:03:0b:51:ac:23:db:9f:c1:8e:d6:94:54:
      66:a5:68:52:ee:dd:0f:10:5d:21:b8:b8:19:ff:29:
      6f:51:2e:c8:74:5c:2a:d2:c5:fa:99:eb:c5:c2:a2:
      d0:96:fc:54:b3:ba:80:4b:92:7f:85:54:76:c9:12:
      cb:32:ea:1d:12:7b:f8:f9:a2:5c:a1:b1:06:8e:d8:
      c5:42:61:00:8c:f6:33:11:29:df:6e:b2:cc:c3:7c:
      d3:f3:0c:8d:5c:49:a5:fb:49:fd:e7:c4:73:68:0a:
      09:0e:6d:68:a9:06:52:3a:36:4f:19:47:83:59:da:
      02:5b:2a:d0:8a:7a:33:0a:d5:ce:be:b5:a2:7d:8d:
      59:a1:9d:ee:60:ce:77:3d:e1:86:9a:84:93:90:9f:
      34:a7:02:40:59:3a:a5:d1:18:fb:6f:fc:af:d4:02:
      d9
```


Authors' Addresses

Geoff Huston
Asia Pacific Network Information Centre

Email: gih@apnic.net
URI: http://www.apnic.net

George Michaelson
Asia Pacific Network Information Centre

Email: ggm@apnic.net
URI: http://www.apnic.net

Robert Loomans
Asia Pacific Network Information Centre

Email: robertl@apnic.net
URI: http://www.apnic.net