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G. Huston
G. Michaelson
APNIC

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Validation of Route Origination Using the Resource Certificate Public Key Infrastructure (PKI) and Route Origin Authorizations (ROAs)

Abstract

This document defines the semantics of a Route Origin Authorization (ROA) in terms of the context of an application of the Resource Public Key Infrastructure to validate the origination of routes advertised in the Border Gateway Protocol.

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1. Introduction

This document defines the semantics of a Route Origin Authorization (ROA) in terms of the context of an application of the Resource Public Key Infrastructure (RPKI) [RFC6480] to validate the origination of routes advertised in the Border Gateway Protocol (BGP) [RFC4271].

The RPKI is based on a hierarchy of resource certificates that are aligned to the Internet Number Resource allocation structure. Resource certificates are X.509 certificates that conform to the PKIX profile [RFC5280], and to the extensions for IP addresses and AS identifiers [RFC3779]. A resource certificate describes an action by an issuer that binds a list of IP address blocks and Autonomous System (AS) numbers to the subject of a certificate, identified by the unique association of the subject’s private key with the public key contained in the resource certificate. The RPKI is structured such that each current resource certificate matches a current resource allocation or assignment. This is further described in [RFC6480].

ROAs are digitally signed objects that bind an address to an AS number, and are signed by the address holder. A ROA provides a means of verifying that an IP address block holder has authorized a particular AS to originate routes in the inter-domain routing environment for that address block. ROAs are described in [RFC6482]. ROAs are intended to fit within the requirements for adding security to inter-domain routing.

This document describes the semantic interpretation of a ROA, with particular reference to application in inter-domain routing relating to the origination of routes, and the intended scope of the authority that is conveyed in the ROA.

2. ROA Validation Outcomes for a Route

A "route" is unit of information that associates a set of destinations described by an IP address prefix with a set of attributes of a path to those destinations, as defined in Section 1.1 of [RFC4271].

A route's "origin AS" is defined as follows: If the final path segment of the AS_PATH is of type AS_SEQUENCE, the origin AS is the first element of the sequence (i.e., the AS in the rightmost position with respect to the position of octets in the protocol message). If the AS_PATH contains a path segment of type AS_SET, indicating that the route is an aggregate, then the origin AS cannot be determined. In terms of validation of a route in the context of a routing environment, the address prefix value and the origin AS are used in the ROA validation operation.

It is assumed here that a relying party (RP) has access to a local cache of the complete set of valid ROAs when performing validation of a route. (Valid ROAs are defined as ROAs that are determined to be syntactically correct and are signed using a signature that can be verified using the RPKI, as described in [RFC6482].) The RP needs to match a route to one or more valid candidate ROAs in order to determine a validation outcome, which, in turn, can be used to determine the appropriate local actions to perform on the route.

This approach to route origination validation uses a generic model of "positive" attestation that has an associated inference that routes that cannot be validated within the RPKI framework would conventionally be interpreted by an RP as "invalid". However, the considerations of accommodating environments of partial adoption of the use of ROAs, where only a subset of validly advertised address prefixes have associated published ROAs within the structure of the RPKI, imply some modification to this model of positive attestation. In the context of route validation, it is assumed that once an address prefix is described in a ROA, then this ROA specifically encompasses all address prefixes that are more specific than that described in the ROA. Thus, any route for a more specific address prefix than that described by any valid ROA that does not itself have a matching valid ROA can be considered "invalid". However, routes for address prefixes that are not fully described by any single ROA (i.e., those routes whose address prefixes may be an aggregate of address prefixes described in a valid ROA, or have address prefixes where there is no intersection with any valid ROA), and are not matched by any valid ROA and do not have an address prefix that is a more specific address prefix described in any valid ROA, cannot be reliably classified as "invalid" in a partial deployment scenario. Such routes have a validation outcome of "unknown".

An abstract attribute of a route can be determined as the outcome of this validation procedure, namely a "validity state" [BGP-PFX]. The validity state of a route, with a prefix and an origin AS as defined above, when using single ROA for determining this validity state, is summarized in the following table:

Prefix AS-> / V	Route matching AS	non-matching AS
Non-Intersecting	unknown	unknown
Covering Aggregate	unknown	unknown
match ROA prefix	valid	invalid
More Specific than ROA	invalid	invalid

Route's Validity State

In an environment of a collection of valid ROAs, a route's validity state is considered to be "valid" if any ROA provides a "valid" outcome. It's validity state is considered to be "invalid" if one (or more) ROAs provide an "invalid" outcome and no ROAs provide a "valid" outcome. Its validity state is considered to be "unknown" (or, synonymously, "not found" [BGP-PFX]) when no valid ROA can produce either a "valid" or an "invalid" validity state outcome.

A route validity state is defined by the following procedure:

1. Select all valid ROAs that include a ROAIPAddress value that either matches, or is a covering aggregate of, the address prefix in the route. This selection forms the set of "candidate ROAs".

2. If the set of candidate ROAs is empty, then the procedure stops with an outcome of "unknown" (or, synonymously, "not found", as used in [BGP-PFX]).

3. If the route's origin AS can be determined and any of the set of candidate ROAs has an asID value that matches the origin AS in the route, and the route's address prefix matches a ROAIPAddress in the ROA (where "match" is defined as where the

route's address precisely matches the ROAIPAddress, or where the ROAIPAddress includes a maxLength element, and the route's address prefix is a more specific prefix of the ROAIPAddress, and the route's address prefix length value is less than or equal to the ROAIPAddress maxLength value), then the procedure halts with an outcome of "valid".

4. Otherwise, the procedure halts with an outcome of "invalid".

3. Applying Validation Outcomes to Route Selection

Within the framework of the abstract model of the operation of inter-domain routing using BGP [RFC4271], a received prefix announcement from a routing peer is compared to all announcements for this prefix received from other routing peers, and a route selection procedure is used to select the "best" route from this candidate set.

The route's validity state, described in Section 2, of "valid", "invalid", or "unknown" may be used as part of the determination of the local degree of preference, in which case the local order of preference is as follows:

"valid" is to be preferred over
"unknown", which is to be preferred over
"invalid".

It is a matter of local routing policy as to the actions to be undertaken by a routing entity in processing those routes with "unknown" validity states. Due to considerations of partial use of ROAs in heterogeneous environments, such as in the public Internet, it is advised that local policy settings should not result in "unknown" validity state outcomes being considered as sufficient grounds to reject a route outright from further consideration as a local best route.

It is a matter of local routing policy as to whether routes with an "invalid" validity state are considered to be ineligible for further consideration in a route selection process. Potential circular dependence is a consideration here: if the authoritative publication point of the repository of ROAs, or that of any certificate used in relation to an address prefix, is located at an address that lies within the address prefix described in a ROA, then the repository can only be accessed by the RP once a route for the prefix has been accepted by the RP's local routing domain. It is also noted that the propagation time of RPKI objects may be different to the propagation time of routes, and that routes may be learned by an RP's routing system before the RP's local RPKI repository cache picks up the

associated ROAs and recognizes them as having a validity state of "valid" within the RPKI.

4. Disavowal of Routing Origination

A ROA is a positive attestation that a prefix holder has authorized an AS to originate a route for this prefix into the inter-domain routing system. It is possible for a prefix holder to construct an authorization where no valid AS has been granted any such authority to originate a route for an address prefix. This is achieved by using a ROA where the ROA's subject AS is one that must not be used in any routing context. Specifically, AS 0 is reserved by the IANA such that it may be used to identify non-routed networks [IANA-AS].

A ROA with a subject of AS 0 (AS 0 ROA) is an attestation by the holder of a prefix that the prefix described in the ROA, and any more specific prefix, should not be used in a routing context.

The route validation procedure, described in Section 2, will provide a "valid" outcome if any ROA matches the address prefix and origin AS, even if other valid ROAs would provide an "invalid" validation outcome if used in isolation. Consequently, an AS 0 ROA has a lower relative preference than any other ROA that has a routable AS as its subject. This allows a prefix holder to use an AS 0 ROA to declare a default condition that any route that is equal to or more specific than the prefix to be considered "invalid", while also allowing other concurrently issued ROAs to describe valid origination authorizations for more specific prefixes.

By convention, an AS 0 ROA should have a maxLength value of 32 for IPv4 addresses and a maxlength value of 128 for IPv6 addresses; although, in terms of route validation, the same outcome would be achieved with any valid maxLength value, or even if the maxLength element were to be omitted from the ROA.

Also by convention, an AS 0 ROA should be the only ROA issued for a given address prefix; although again, this is not a strict requirement. An AS 0 ROA may coexist with ROAs that have different subject AS values; although in such cases, the presence or lack of presence of the AS 0 ROA does not alter the route's validity state in any way.

5. Route Validation Lifetime

The "lifetime" of a validation outcome refers to the time period during which the original validation outcome can be still applied. The implicit assumption here is that when the validation lifetime "expires", the route should be re-tested for validity.

The validation lifetime for a ROA is controlled by the Valid times specified in the end-entity (EE) certificate used to sign the ROA, and the valid times of those certificates in the certification path used to validate the EE certificate. A ROA validation expires at the notAfter field of the signing EE certificate, or at such a time when there is no certification path that can validate the ROA. A ROA issuer may elect to prematurely invalidate a ROA by revoking the EE certificate that was used to sign the ROA.

6. Security Considerations

ROA issuers should be aware of the validation implication in issuing a ROA, in that a ROA implicitly invalidates all routes that have more specific prefixes with a prefix length greater than maxLength, and all originating AS's other than the AS listed in the collection of ROAs for this prefix.

A conservative operational practice would be to ensure the issuing of ROAs for all more specific prefixes with distinct origination ASes prior to the issuing of ROAs for larger encompassing address blocks, in order to avoid inadvertent invalidation of valid routes during ROA generation.

ROA issuers should also be aware that if they generate a ROA for one origin AS, then if the address prefix holder authorizes multiple ASes to originate routes for a given address prefix, then is necessary for a ROA be generated for every such authorized AS.

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Authors' Addresses

Geoff Huston
APNIC

EMail: gih@apnic.net

George Michaelson
APNIC

EMail: ggm@apnic.net