Security Overlays on Core Internet Protocols – DNSSEC and RPKI

Mark Kosters
ARIN Engineering
Why are DNSSEC and RPKI Important

• Two critical resources
  – DNS
  – Routing

• Hard to tell if compromised
  – From the user point of view
  – From the ISP/Enterprise

• Focus on government funding
Why DNSSEC? What is it?

• Standard DNS (forward or reverse) responses are not secure
  – Easy to spoof
  – Notable malicious attacks

• DNSSEC attaches signatures
  – Validates responses
  – Can not spoof
Reverse DNS at ARIN

• ARIN issues blocks without any working DNS
  – Registrant must establish delegations after registration
  – Then employ DNSSEC if desired

• Just as susceptible as forward DNS if you do not use DNSSEC
Reverse DNS at ARIN

- Authority to manage reverse zones follows allocations
  - “Shared Authority” model
  - Multiple sub-allocation recipient entities may have authority over a particular zone
Changes completed to make DNSSEC work at ARIN

- Permit by-delegation management
- Sign in-addr.arpa. and ip6.arpa. delegations that ARIN manages
- Create entry method for DS Records
  - ARIN Online
  - RESTful interface
  - Not available via templates
Changes completed to make DNSSEC work at ARIN

- Only key holders may create and submit Delegation Signer (DS) records
- DNSSEC users need to have signed a registration services agreement with ARIN to use these services
Reverse DNS in ARIN Online

First identify the network that you want to put Reverse DNS nameservers on...

<table>
<thead>
<tr>
<th>SELECT</th>
<th>DELEGATION</th>
<th>NAMESERVERS</th>
<th>DS RECORD KEY TAGS</th>
<th>AUTHORIZED ORGANIZATIONS</th>
</tr>
</thead>
</table>
| ✓      | 252.149.192.in-addr.arpa. | NS1.ARIN.NET  
NS2.ARIN.NET  
NS2.LACNIC.NET  
SEC1.APNIC.NET  
SEC1.AUTHDNS.RIPE.NET | | ARIN Operations |

MODIFY NAMESERVERS  
MODIFY DS RECORDS
Reverse DNS in ARIN Online

...then enter the Reverse DNS nameservers...

Manage Reverse DNS

Using the text fields on the right, specify the hostnames (not the IP addresses) of the nameservers that should be authoritative for ALL the reverse DNS delegations listed on the left. Please note that any modifications will be applied to all listed delegations.

**SELECTED DELEGATIONS IN - NET-192-149-252-0-1**

252.149.192.in-addr.arpa

**HOSTNAMES OF NAMESERVERS**

- Nameserver 1: NS1.ARIN.NET
- Nameserver 2: NS2.ARIN.NET
- Nameserver 3: NS2.LACNIC.NET
- Nameserver 4: SE1.APNIC.NET
- Nameserver 5: SEC1.AUTHDNS.RIPE.NET
- Nameserver 6: 
- Nameserver 13: 

[APPLY TO ALL]  [CANCEL]
DNSSEC in ARIN Online

...then apply DS record to apply to the delegation

<table>
<thead>
<tr>
<th>ZONE</th>
<th>CLASS</th>
<th>RR TYPE</th>
<th>KEY TAG</th>
<th>ALGORITHM</th>
<th>DIGEST TYPE</th>
<th>DIGEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optional, ignored</td>
<td>Optional, &quot;IN&quot;</td>
<td>Must be &quot;DS&quot;</td>
<td>2 byte integer</td>
<td>1 byte integer (5, 7 or 8)</td>
<td>1 byte integer (1 or 2)</td>
<td>The hex encoded digest</td>
</tr>
</tbody>
</table>

The DS records should be in the following format:

**PASTE DS RECORD DATA BELOW**

Choose File: No file chosen

File contents must be plain text
Reverse DNS: Querying ARIN’s Whois

Query for the zone directly:

```
whois> 81.147.204.in-addr.arpa

Name: 81.147.204.in-addr.arpa.
Updated: 2006-05-15
NameServer: AUTHNS2.DNVR.QWEST.NET
NameServer: AUTHNS3.STTL.QWEST.NET
NameServer: AUTHNS1.MPLS.QWEST.NET

Ref: http://whois.arin.net/rest/rdns/81.147.204.in-addr.arpa.
```
### DNSSEC in Zone Files

```plaintext
; File written on Mon Feb 24 17:00:53 2014
; dnssec_signzone version 9.3.6-P1-RedHat-9.3.6-20.P1.el5_8.6

<table>
<thead>
<tr>
<th>Domain</th>
<th>TTL</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.74.in-addr.arpa</td>
<td>86400</td>
<td>IN NS</td>
<td>NS3.COVAD.COM.</td>
</tr>
<tr>
<td>0.74.in-addr.arpa</td>
<td>86400</td>
<td>IN NS</td>
<td>NS4.COVAD.COM.</td>
</tr>
<tr>
<td>10800</td>
<td>NSEC</td>
<td></td>
<td>1.74.in-addr.arpa NS RRSIG NSEC</td>
</tr>
<tr>
<td>10800</td>
<td>RRSIG</td>
<td></td>
<td>NSEC 5 4 10800 20140306210053 (20140224210053 57974 74.in-addr.arpa.oNk3GVaCWj2j8+EAr0PncqnZeQjm8h4w51nSD2VUi7YrT9FvYLF/j4KO+8qYZ3TAixb9c05c8EVIhtY1grXEd0m30zJpZyaoa0DpbHt8FdWYvwup9Tq4oVbVyuSNXriZ2Mq55IIMgDR3nATBLP5UC1xUWkvgS/6poF+W/1H4QY= )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain</th>
<th>TTL</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.74.in-addr.arpa</td>
<td>86400</td>
<td>IN NS</td>
<td>NS3.COVAD.COM.</td>
</tr>
<tr>
<td>1.74.in-addr.arpa</td>
<td>86400</td>
<td>IN NS</td>
<td>NS4.COVAD.COM.</td>
</tr>
<tr>
<td>10800</td>
<td>NSEC</td>
<td></td>
<td>10.74.in-addr.arpa NS RRSIG NSEC</td>
</tr>
<tr>
<td>10800</td>
<td>RRSIG</td>
<td></td>
<td>NSEC 5 4 10800 20140306210053 (20140224210053 57974 74.in-addr.arpa.DKYGzSDtIypDVcer5e+xuowoDW4auKy6G/OCVVTcfQGk+3iyy2CEK0ZuMXFaaDvXnaxey9R1mjams519Ghxp2q0nnk0w6iB6mR5cNkYlkL0hu+IC4Buhi6DqM4HbJCZcMXKEtWE0a6dMf+thsa+5OV7ezX5LCuDvQVp6p0LftAE= )</td>
</tr>
</tbody>
</table>
```
DNSSEC in Zone Files

<table>
<thead>
<tr>
<th>Resource</th>
<th>Type</th>
<th>TTL</th>
<th>Name</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.121.74.in-addr.arpa</td>
<td>IN NS</td>
<td>86400</td>
<td>DNS1.ACTUSA.NET.</td>
<td></td>
</tr>
<tr>
<td>0.121.74.in-addr.arpa</td>
<td>IN NS</td>
<td>86400</td>
<td>DNS2.ACTUSA.NET.</td>
<td></td>
</tr>
<tr>
<td>0.121.74.in-addr.arpa</td>
<td>IN NS</td>
<td>86400</td>
<td>DNS3.ACTUSA.NET.</td>
<td></td>
</tr>
<tr>
<td>86400</td>
<td>DS</td>
<td>46693</td>
<td>5 1</td>
<td>AEEDA98EE493DFF5F3F33208ECB0FA4186BD8056</td>
</tr>
<tr>
<td>86400</td>
<td>DS</td>
<td>46693</td>
<td>5 2</td>
<td>66E6D421894AFE2AF0B350BD8F4C54D2EBA5DA72A615FE64BE8EF600C6534CEF</td>
</tr>
<tr>
<td>86400</td>
<td>RRSIG</td>
<td></td>
<td>5 5</td>
<td>86400 20140306210053 (20140224210053 57974 74.in-addr.arpa.n+aPxBHuf+sbzQN4LmHzl0iO/C/hkaSV03qly6J0KjqNPzYqtxLgZjU+IL9qhtI0ocgNQib9lgFRmZ9inf2bER435GMsa/nnjpVVWW/MBRKxfPcc72w2iOAmu2G0pVT08ENxtupBFnsOZKhCY8UOBOYLOLE5Whtk3X0uX9+U=)</td>
</tr>
<tr>
<td>10800</td>
<td>NSEC</td>
<td></td>
<td>1.121.74.in-addr.arpa NS DS RRSIG</td>
<td></td>
</tr>
<tr>
<td>10800</td>
<td>RRSIG</td>
<td></td>
<td>NSEC 5 5 10800 20140306210053 (20140224210053 57974 74.in-addr.arpa.YvRowkdVDfv+PW42ySNUwW8S8jRyV6EKKRxe...</td>
<td></td>
</tr>
</tbody>
</table>
DNSSEC Validating Resolvers

- www.internetsociety.org/deploy360/dnssec/
- www.isc.org/downloads/bind/dnssec/
Reverse DNS Management and DNSSEC in ARIN Online

- Available on ARIN’s website

http://www.arin.net/knowledge/dnssec/
What is RPKI?

• **Resource Public Key Infrastructure**
• Attaches digital certificates to network resources
  – AS Numbers
  – IP Addresses
• Allows ISPs to associate the two
  – Route Origin Authorizations (ROAs)
  – Can follow the address allocation chain to the top
What does RPKI accomplish?

• Allows routers or other processes to validate route origins
• Simplifies validation authority information
  – Trust Anchor Locator
• Distributes trusted information
  – Through repositories
Resource Allocation Hierarchy

AFRINIC  RIPE NCC  APNIC

ICANN

ARIN

LACNIC

Issued Certificates

ISP2

ISP

ISP4

ISP

ISP

ISP

Route Origination Authority
“ISP4 permits AS65000 to originate a route for the prefix 192.2.200.0/24”

Attachment: <isp4-ee-cert>

Signed, ISP4 <isp4-ee-key-priv>
Route Origination Authority
“ISP4 permits AS65000 to originate a route for the prefix 192.2.200.0/24”

Attachment: <isp4-ee-cert>

Signed, ISP4 <isp4-ee-key-priv>

1. Did the matching private key sign this text?
**Route Origination Authority**

“ISP4 permits AS65000 to originate a route for the prefix 192.2.200.0/24”

Attachment: <isp4-ee-cert>

Signed, ISP4 <isp4-ee-key-priv>

2. Is this certificate valid?
Resource Allocation Hierarchy

Route Origination Authority
“ISP4 permits AS65000 to originate a route for the prefix 192.2.200.0/24”

Attachment: <isp4-ee-cert>

Signed,
ISP4 <isp4-ee-key-priv>

3. Is there a valid certificate path from a Trust Anchor to this certificate?
What does RPKI Create?

• It creates a repository
  – RFC 3779 (RPKI) Certificates
  – ROAs
  – CRLs
  – Manifest records
Repository View

./ba/03a5be-ddf6-4340-a1f9-1ad3f2c39ee6/1:
total 40
-rw-r--r--  1 143  143  1543 Jun 26  2009 ICcaIRKhGHJ-TgUZv8GRKqkidR4.roa
-rw-r--r--  1 143  143  1403 Jun 26  2009 cKxLCU94umS-qD4DOOkAK0M2US0.cer
-rw-r--r--  1 143  143   485 Jun 26  2009 dSmerM6uJGLWMMQTl2esy4xyUAA.crl
-rw-r--r--  1 143  143  1882 Jun 26  2009 dSmerM6uJGLWMMQTl2esy4xyUAA.mnf
-rw-r--r--  1 143  143  1542 Jun 26  2009 nB0gDFtWffKk4VWgln-12pdFtE8.roa

A Repository Directory containing an RFC3779 Certificate, two ROAs, a CRL, and a manifest
Repository Use

• Pull down these files using a manifest-validating mechanism
• Validate the ROAs contained in the repository
• Communicate with the router marking routes “valid”, “invalid”, “unknown”
• Up to ISP to use local policy on how to route
Possible Flow

- RPKI Web interface -> Repository
- Repository aggregator -> Validator
- Validated entries -> Route Checking
- Route checking results -> local routing decisions (based on local policy)
How you can use ARIN’s RPKI System?

• Hosted
• Hosted using ARIN’s RESTful service
• Web Delegated (being deprecated)
• Delegated using Up/Down Protocol
Hosted RPKI

• Pros
  – Easier to use
  – ARIN managed

• Cons
  – No current support for downstream customers to manage their own space (yet)
  – Tedious through the IU if you have a large network
  – We hold your private key
Hosted RPKI with RESTful Interface

• Pros
  – Easier to use
  – ARIN managed
  – Programmatic interface for large networks

• Cons
  – No current support for downstream customers to manage their own space (yet)
  – We hold your private key
Delegated RPKI with Up/Down

• Pros
  – Same as web delegated
  – Follows the IETF up/down protocol

• Cons
  – Extremely hard to setup
  – Need to operate your own RPKI environment
Hosted RPKI in ARIN Online

To participate in Hosted RPKI you will need to do the following:

1. Generate a ROA Request Generation Key Pair.
2. Select Hosted.
3. Read and agree to the RPKI Terms of Service.
4. Enter your ROA Request Generation Public Key into the field provided.
5. Click Submit.

Hosted
Hosted RPKI in ARIN Online

Organization Hosted RPKI Terms of Service

AGREEMENT

☐ I agree to the ARIN Hosted RPKI Terms of Service

You must accept the Hosted RPKI Terms of Service in order to proceed.
Access a printable .pdf version of the Hosted RPKI Terms of Service.

Enter your initials

Continue

TERMS OF SERVICE

AMERICAN REGISTRY FOR INTERNET NUMBERS, LTD.

RPKI TERMS OF SERVICE AGREEMENT

YOU MUST READ AND ACCEPT THIS RPKI TERMS OF SERVICE AGREEMENT (THIS "AGREEMENT") BEFORE ACCESSING OR USING ANY RPKI SERVICES (AS DEFINED BELOW). IF YOU DO NOT AGREE TO THE TERMS OF THIS AGREEMENT, DO NOT ACCESS OR USE ANY RPKI SERVICES.
Hosted RPKI in ARIN Online

Enter your ROA Request Generation Public Key below.

ROA Request Generation Public Key:
Learn more about the ROA Request Generation Key Pair. Or, just how to create one and extract the public key.

```
-----BEGIN PUBLIC KEY-----
MIIBljANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEAvBhoSmbRQhbSpTIM2Pqn
hWcHL/6SHORJGCtuOMUS6tVamlqgdTZJw+8POFKu+WIOLgUJOEw763rQVTsAq8WZ
vs6px2FNr6CJftKar3fg/T083vhYiMtYJnJbVPKJjdSQSlyUWeR2hYh/4LEOyK
MPr3zAuDS2QOl6778OY/kpTEsCrvzp+dM4KtLGOQbyrkfSVIHgux5pCMzsQP/8nP
son5vOlkwtkuFNmg8pxGfEdBR6MC0Y7eKaTeYM6EEJ7rhUCY69SUq+SFmuwYFs
7YNzRAErF9THpEWqOaxaSu/4nwLVJ2oexksT6k4hsEWPadxJ0P3E0FSb/YfOS
fwIDAQAB
-----END PUBLIC KEY-----
```

Submit
Hosted RPKI in ARIN Online

Hosted Certificates

Information
Each resource certificate entry displays the number of Route Origin Authorizations (ROAs), IP addresses or ranges, and Autonomous System Numbers (ASNs) covered by that certificate, and the date of the certificate's last update. For a listing of data elements for a given resource certificate, select Details.

For more information about resource certificates, visit ARIN's RPKI section.

---

ARIN

Updated: 03-20-2013

ROAs: 0  Nets: 20  ASNs: 10

Create Roa  View Resources  View Roas  View Details
Hosted RPKI in ARIN Online

Create a Route Origin Authorization (ROA) Request for SAMPLE-ORG

There are two ways to create and submit a ROA Request to ARIN:

**Browser Signed ROA Request** Complete the required fields below and digitally sign the ROA Request using the private key that corresponds with the public key you registered with ARIN.

**Signed ROA Request** You must construct a precisely formatted text block containing your ROA Request information, and sign it using the private key that corresponds with the public key you registered with ARIN.

### ROA Form

- **ROA Name:**
- **Origin AS:**
- **Start Date:** 03-20-2013
- **End Date:** 03-20-2023
- **Prefix:**
- **Max Length:**
- **Private Key:**

* denotes optional field

This key will not be uploaded to ARIN.
Hosted RPKI in ARIN Online

Create a Route Origin Authorization (ROA) Request for SAMPLE-ORG

There are two ways to create and submit a ROA Request to ARIN:

**Browser Signed ROA Request** Complete the required fields below and digitally sign the ROA Request using the private key that corresponds with the public key you registered with ARIN.

**Signed ROA Request** You must construct a precisely formatted text block containing your ROA Request information, and sign it using the private key that corresponds with the public key you registered with ARIN.

---

**Browser Signed**

- **ROA Name:** Test-ROA
- **Origin AS:** 23456
- **Start Date:** 03-20-2013
- **End Date:** 03-20-2023
- **Prefix:** 70.182.32.0/24
- **Max Length:** 24

---

**Signed**

**Private Key:** Key Loaded

This key will not be uploaded to ARIN.
Hosted RPKI in ARIN Online

SUBMIT SIGNED ROUTE ORIGIN AUTHORIZATION

This information will not be saved until you click the Submit button below. Note that the signature is used by ARIN to ensure that the ROA Request was signed with your private key. Please verify that the information below is correct. Click Submit to send the request, or click Back to make changes.

ROA Name: Test-ROA
Origin AS: 23456
Validity Period: 03-20-2013 to 03-20-2023
Resources: 70.182.32.0/24 max length 24
Signature: Hjnse52POzaVFupNDGqYXZVylmr78wSd4a1XEMUpj4vVmpJWWhnkKoZTuDvB2OBtwcJJExy4KUWPgHUtE8VhdCYroyuZGRxJkDTeq8c0FT2QdjuD+GmwUWlvtSd25VZdYUrXM6WniTVwL96UV6sKbJGtx40GqD5z2dJq6612QpC6K+Y+JEIsbauVyy2htnAPI5r1ZGY42Fb9c1CEoE8Gmt/FWY+Cx6UmKsxJ8LQ0NGR2XeGKZyc2k5gKiSCog976Vnltt88/z5jOm1GkYQoQvk6uyy+yYUKreC+GyNqPYyPavGAq61jYIDXmHDTSjWdGRiV2dNQz8zMmoD0gm9A==
Your ROA request is automatically processed and the ROA is placed in ARIN’s repository, accompanied by its certificate and a manifest. Users of the repository can now validate the ROA using RPKI validators.
Delegated with Up/Down

Up/Down RPKI

To participate in Updown Delegated RPKI you will need to do the following:

2. Select Up/Down.
3. Read and agree to the RPKI Terms of Service.
4. Submit your UpDown Identity.xml.
5. Click Submit.

Up/Down
Delegated with Up/Down
Delegated with Up/Down

<table>
<thead>
<tr>
<th>Resource Class</th>
<th>Certifiable Net(s)</th>
<th>Resource Class</th>
<th>Certifiable Net(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APNIC</td>
<td>NET-153-23-0-0-1</td>
<td>RIPE</td>
<td>NET-141-193-0-0-1</td>
</tr>
<tr>
<td></td>
<td>NET-209-239-96-9-2</td>
<td></td>
<td>NET-216-209-64-9-1</td>
</tr>
<tr>
<td></td>
<td>NET-216-209-144-6-1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ACTIVITY AND CORRESPONDENCE LOG**

<table>
<thead>
<tr>
<th>Date</th>
<th>08-30-2013 09:54:59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message</td>
<td>Ticket Status: Closed</td>
</tr>
<tr>
<td></td>
<td>Ticket Resolution: Processed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>08-30-2013 09:54:58</th>
</tr>
</thead>
<tbody>
<tr>
<td>By</td>
<td>ARIN Web</td>
</tr>
<tr>
<td>Subject</td>
<td>[ARIN-20130830-X1] - UpDown Identity Exchange Successful</td>
</tr>
<tr>
<td>Attachments</td>
<td>ARN.SPRN.parent-response.xml</td>
</tr>
<tr>
<td>Message</td>
<td>The UpDown parent response for organization SPRN is attached. Some of your resources are drawn from legacy space that is managed by another RIR.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>08-30-2013 09:54:36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message</td>
<td>Ticket Status: Approved</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>08-30-2013 09:54:36</th>
</tr>
</thead>
<tbody>
<tr>
<td>By</td>
<td>MADSTAFFER RSDER</td>
</tr>
<tr>
<td>Subject</td>
<td>[ARIN-20130830-X1] - UpDown Identity Exchange - APPROVED</td>
</tr>
</tbody>
</table>
Delegated with Up/Down

- You have to do all the ROA creation
- Need to setup a CA
- Have a highly available repository
- Create a CPS
Updates within RPKI outside of ARIN

• The four other RIRs are in production with Hosted CA services
• ARIN and APNIC have delegated working for the public
• Major routing vendor support being tested
• Announcement of public domain routing code support
ARIN Status

- Hosted CA deployed 15 Sept 2012
- Web Delegated CA deployed 16 Feb 2013
- Delegated using “Up/Down” protocol deployed 7 Sept 2013
- RESTful interface deployed 1 Feb 2014
# RPKI Usage

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RPAs Signed</td>
<td>27</td>
<td>72</td>
<td>130</td>
<td>162</td>
</tr>
<tr>
<td>Certified Orgs</td>
<td></td>
<td>47</td>
<td>68</td>
<td>108</td>
</tr>
<tr>
<td>ROAs</td>
<td>19</td>
<td>60</td>
<td>106</td>
<td>162</td>
</tr>
<tr>
<td>Covered Resources</td>
<td>30</td>
<td>82</td>
<td>147</td>
<td>258</td>
</tr>
<tr>
<td>Web Delegated</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Up/Down Delegated</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Why is this important?

• Provides more credibility to identify resource holders

• Leads to better routing security
Q&A