

Practical BGP Origin Validation using RPKI

Moderators:

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- Sandra Murphy / Parsons
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Track Agenda

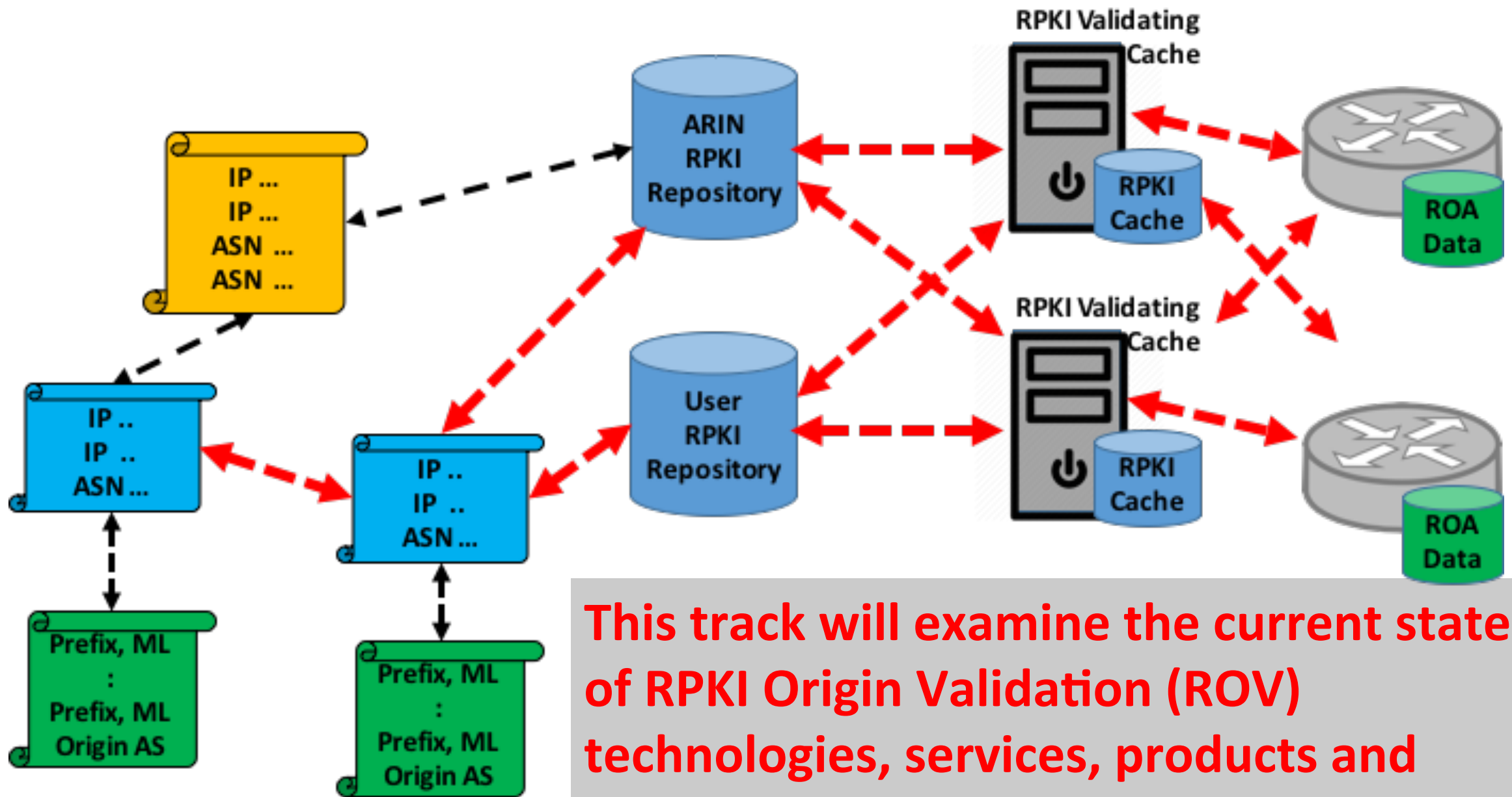
- RPKI Introduction
 - Sandra Murphy/PARSONS, Doug Montgomery/NIST
- ARIN RPKI Services
 - Mark Kusters / ARIN – Users' guide to ARIN RPKI services.
- RPKI Implementations - Doug Montgomery,
- Router Vendor Implementations
 - Greg Hankins/Nokia , John Scudder/Juniper, Keyur Patel & Arjun Sreekantiah/Cisco
- RPKI Test, Training, Monitoring, Management, tools.
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 - JR Mayberry/Microsoft, Tony Tauber/Comcast, Thomas King/ DE-CIX, Henk Steenman/AMS-IX

The Need for BGP Origin Validation

- Malicious BGP route hijacks and accidental misoriginations threaten the security and robustness of the global Internet.
 - ***Invisible Hijacking: A case study of hijacking millions of IP address invisibly.***
 - https://ripe72.ripe.net/presentations/45-Invisible_Hijacking.pdf
 - ***Large Hijack Affects Reachability of High Traffic Destinations***
 - <http://www.bgpmon.net/large-hijack-affects-reachability-of-high-traffic-destinations/>
 - ***Breaking HTTPS with BGP Hijacking***
 - <https://www.blackhat.com/docs/us-15/materials/us-15-Gavrichenkov-Breaking-HTTPS-With-BGP-Hijacking-wp.pdf>
 - ***BGP Hijacking for Cryptocurrency Profit***
 - <https://www.secureworks.com/research/bgp-hijacking-for-cryptocurrency-profit>
- The incidents, methods and motives continue to evolve, the systemic problem remains the same.
 - See: <https://securerouting.net/incident>

BGP Origin Validation Using RPKI

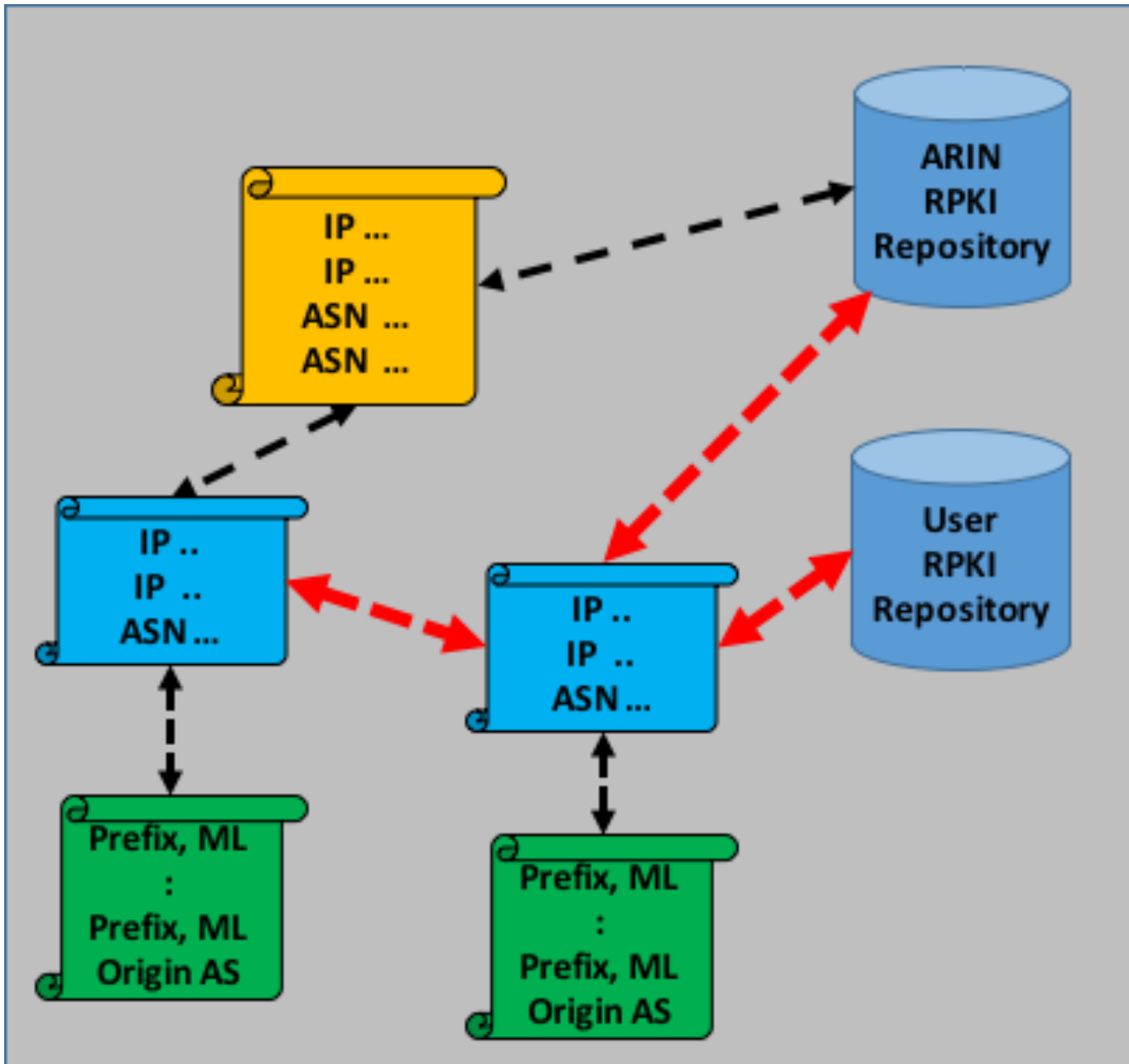
- Resource Public Key Infrastructure (RPKI)
 - Over the last several years the IETF, RIRs, router vendors, and researchers have developed and implemented an approach to BGP origin validation based upon a global resource public key infrastructure (RPKI).
 - Address owners digitally sign **Route Origin Authorizations (ROAs)** to specify the ASN(s) authorized to announce their prefixes.
 - The approach that permits operators anywhere in the Internet to detect unauthorized route originations and implement local policies to mitigate (e.g., filter) these events.



Two Sides of RPKI Use

Certification

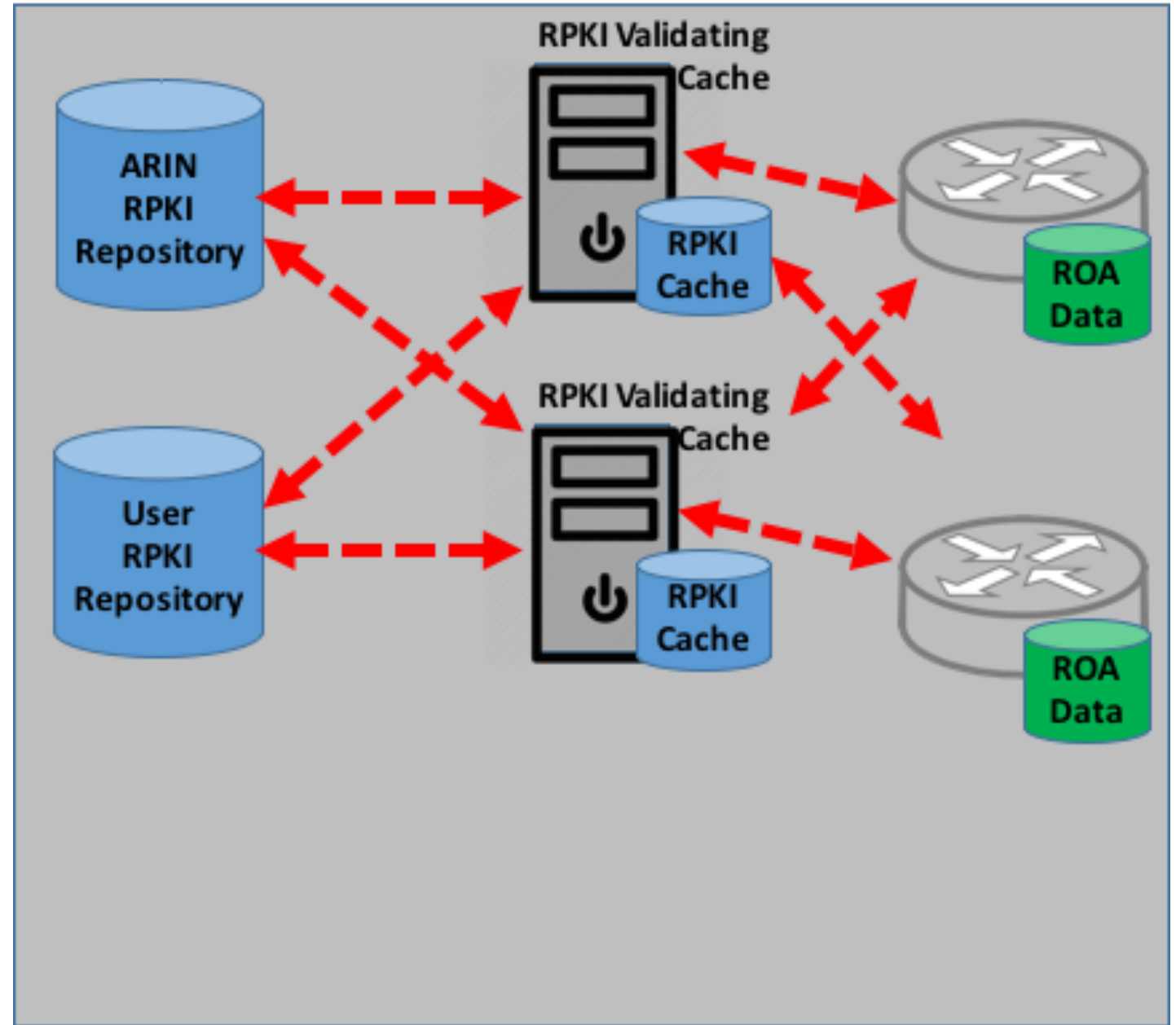
- (Securing routes to your addresses)
 - Get certificates for your address space
 - Sign ROAs
 - Maintain a CA repository
 - Create certificates for your customers
 - If you give them addresses
- *Think of this as signing the back of your credit card*
- *....or registering a route object*



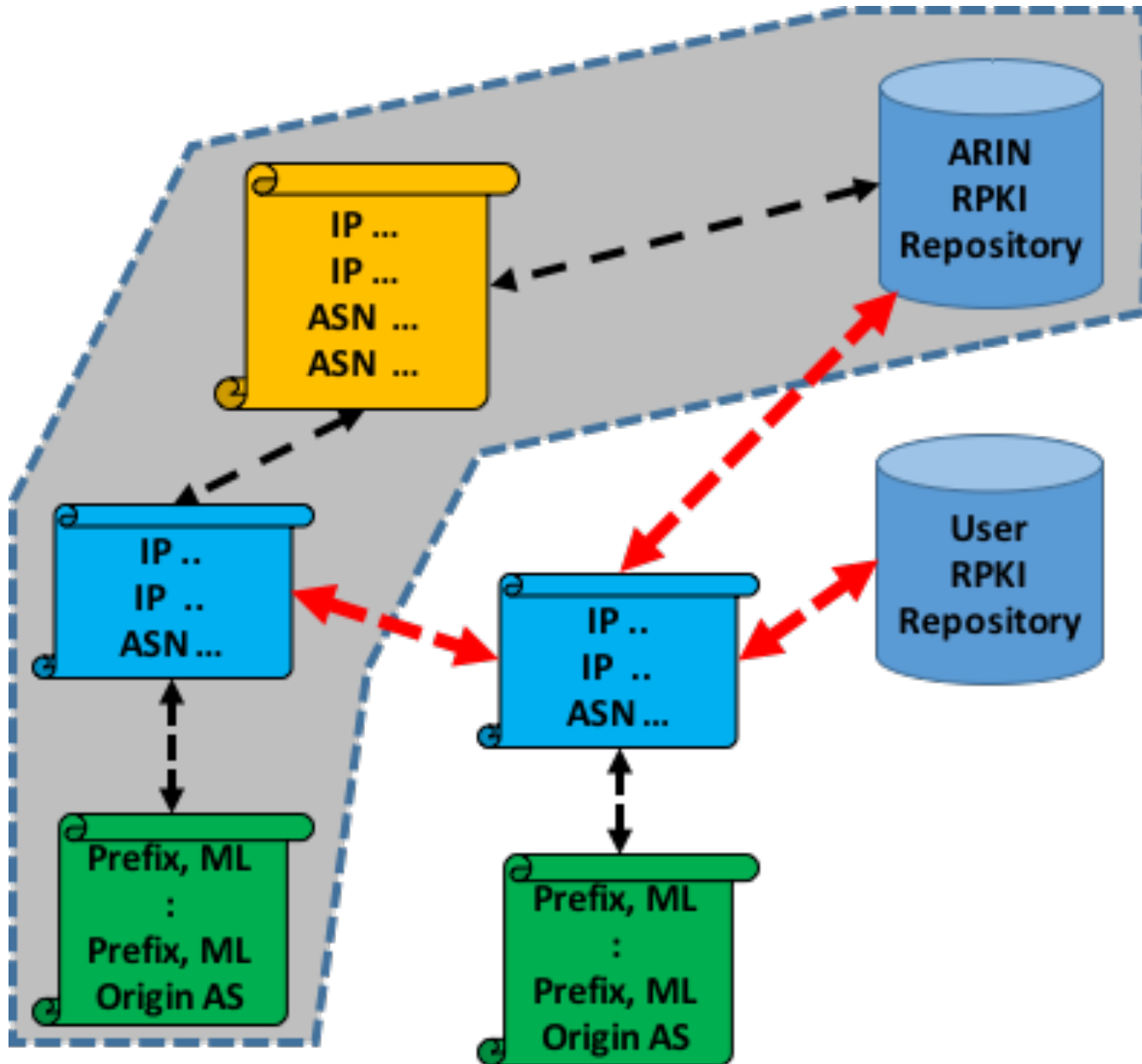
Two Sides of RPKI Use

Origin Validation

- **(Securing routes to others' addresses)**
 - Retrieve ROAs from other CA repositories
 - Validate received routes against the RPKI data
- *Think of this as checking the back of a credit card presented to you*
- *or prefix filtering*



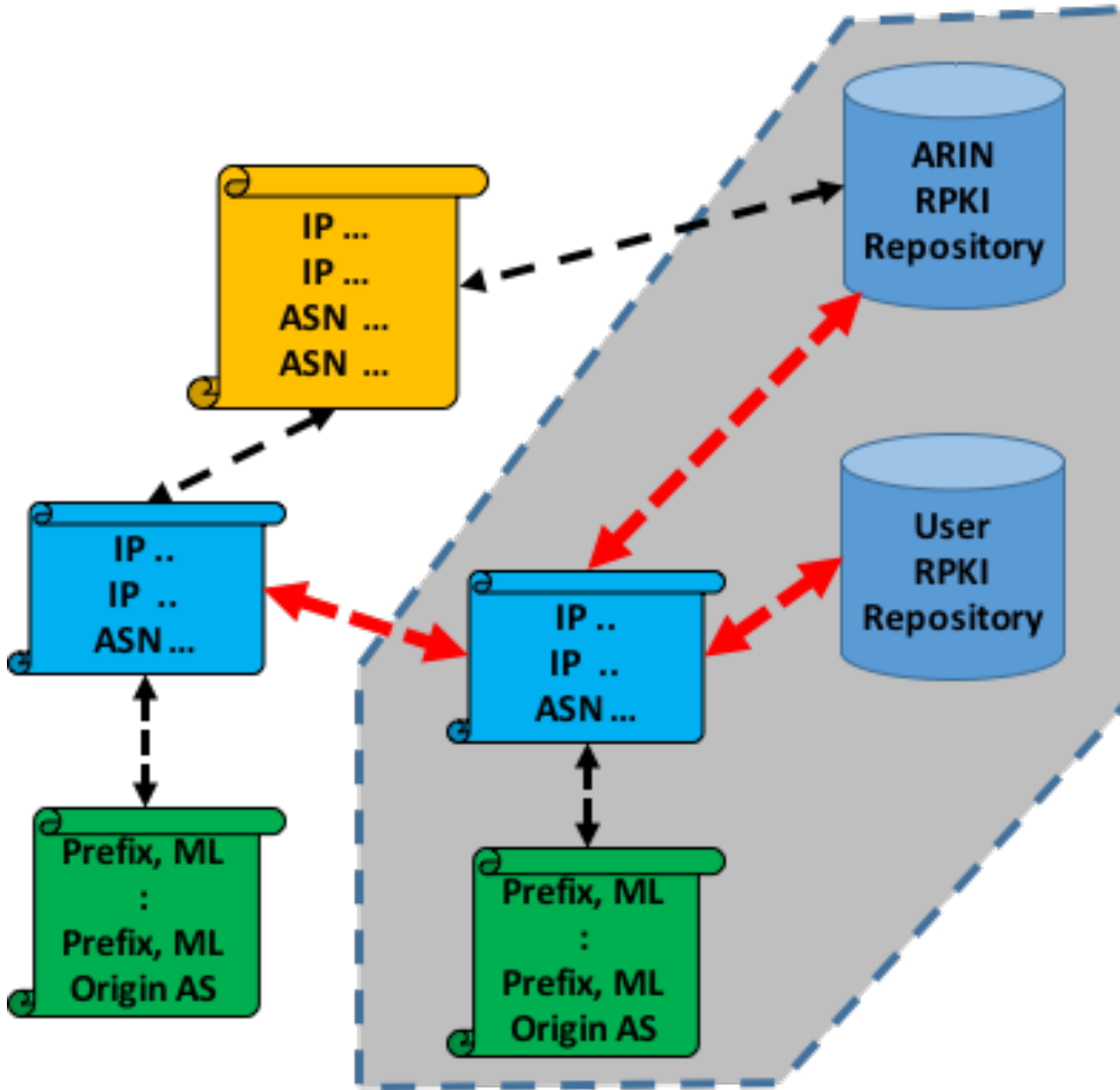
RPKI Resource Certificates



- **RPKI Certificate Hierarchy**
 - Rooted trust anchors at each RIR
 - Sub allocations represented by CA certificates.
 - *ROAs signed by certificate holders.*
 - *RPKI Objects published in repository.*
- **Hosted Model**
 - All RPKI operations hosted by RIR.

RPKI Resource Certificates

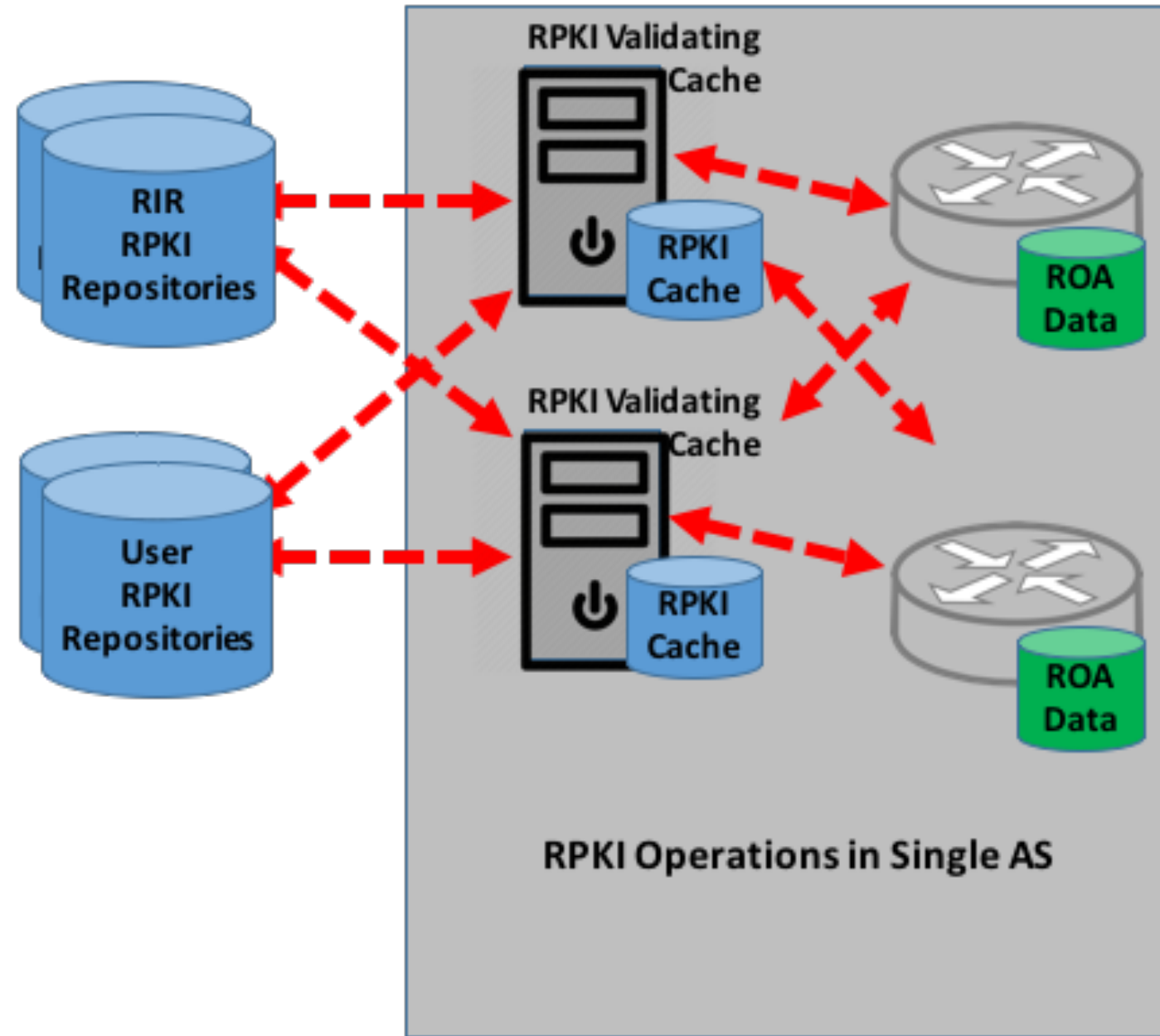
- **Delegated Model**
 - Up / Down protocol to register resources.
 - Users operate their own RPKI Certificate Authorities.
 - Publication protocol to publish RPKI objects
 - Operates own RPKI repository or uses public aggregator.



RPKI Origin Validation

Validation in single AS

- Local RPKI validating caches synchronize with global repositories.
- Caches do all crypto / PKI validation operations.
- Routers only receive a digested lists of ROA data.
- **No crypto on the router!**



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Regional RPKI Services

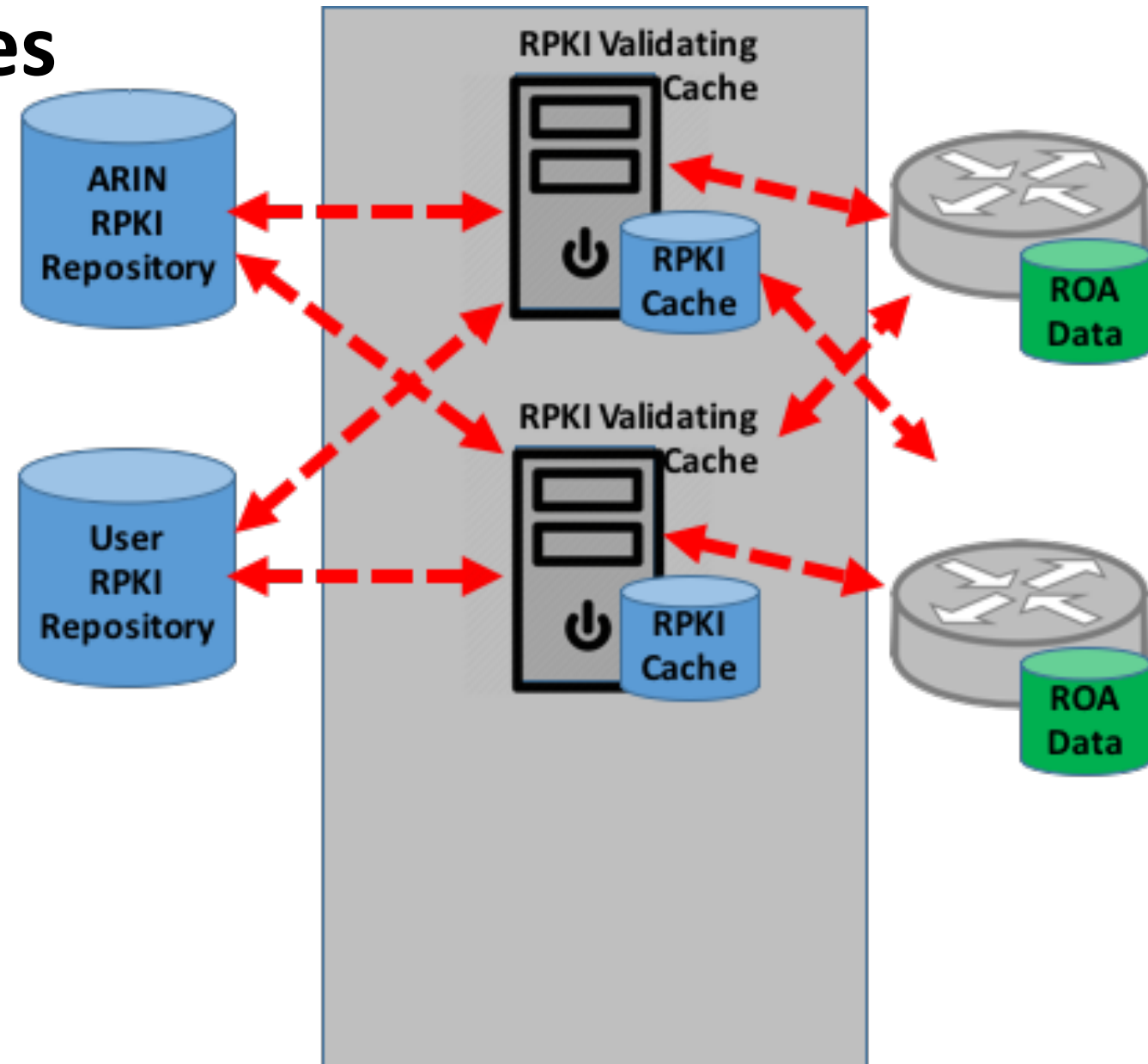
- For certification, the one who allocated your addresses to you is the one that certifies that allocation
- RPKI services in other regions:
 - AFRINIC:
 - <http://afrinic.net/en/initiatives/rpki-certification>
 - APNIC:
 - <http://www.apnic.net/services/services-apnic-provides/resource-certification>
 - LACNIC:
 - <https://rpki.lacnic.net/rpki/>
 - RIPE NCC:
 - <http://www.ripe.net/certification/>
- **For the North American region, that is ARIN**

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RPKI Validating Caches

- To use RPKI data for BGP origin validation, you will want to deploy one or more “validating caches”.
 - These tools collect and cache global RPKI data, perform X.509 validation on the objects,
 - ... and then provides a highly summarized version to eBGP speaking routers.
 - The RPKI-to-RTR protocol enables eBGP routers to download this processed data for route filtering.
- **Multiple open source validating cache implementations are available!**



RPKI Implementations

RIPE RPKI Validator

- <https://www.ripe.net/manage-ips-and-asns/resource-management/certification/tools-and-resources>
- Validating Cache
- Repository Fetch
 - RSYNC
 - RRDP (RPKI Repository Delta Protocol)
- Service Interface
 - rpki-rtr protocol
- Mgmt Interfaces
 - Web GUI, REST API, CLI (outdated)
- Distribution
 - App / Java source
- Support
 - RIPE NCC

Dragon Research Labs rpki.net

- <https://rpki.net/>
- Validating Cache
- Certificate Authority
- Repository Fetch
 - RSYNC
 - RRDP
- Service Interface
 - rpki-rtr protocol
- Mgmt Interfaces
 - Web GUI, CLI
- Distribution
 - Binary / Python source
- Support
 - Open source; rpki@rpki.net

BBN Technologies RPSTIR

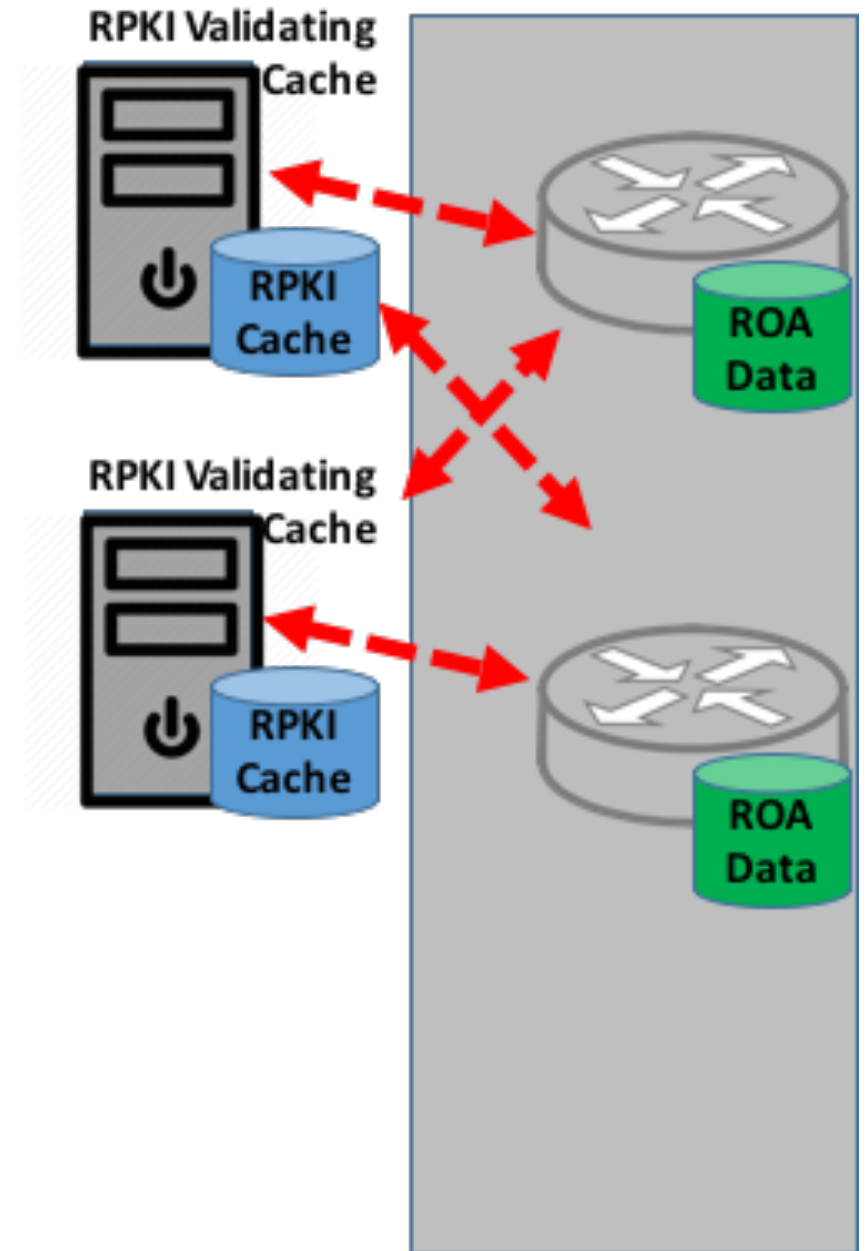
- <https://github.com/bgpsecurity/rpstir>
- Validating Cache
- Repository Fetch
 - RSYNC
- Service Interface
 - rpki-rtr protocol
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 - CLI
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RPKI Router Implementations

- RPKI Origin Validation requires a router that can:
 - Interface with a RPKI validating cache to download lists of authorized origins:
 - <prefix, max_length, origin_AS>,
 - Match incoming BGP updates against the list of authorized origins.
 - Enforce local policies based upon on the results of these matches:
 - Valid, Invalid, Unknown
- **Major router vendors support these capabilities in shipping products today!**



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RPKI Test, Training, Experimentation, Monitoring, Management, etc.

- What Resources Exists to help us:
 - Learn about RPKI provisioning and origin validation?
 - Monitor the state of RPKI deployment and my resources in particular?
 - Manage the deployment of origin validation services?
 - Experiment with implementations / software routers?

EARS Tools

- See securerouting.net

- Tools:

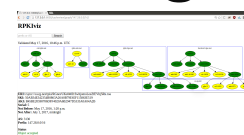
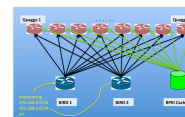
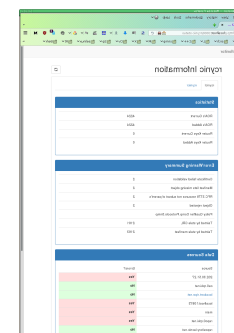
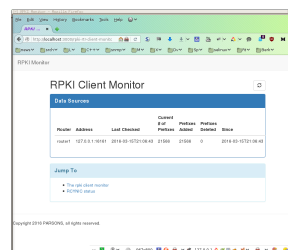
- ## – Workshop-in-a-box

- See videos securerouting.net/workshop

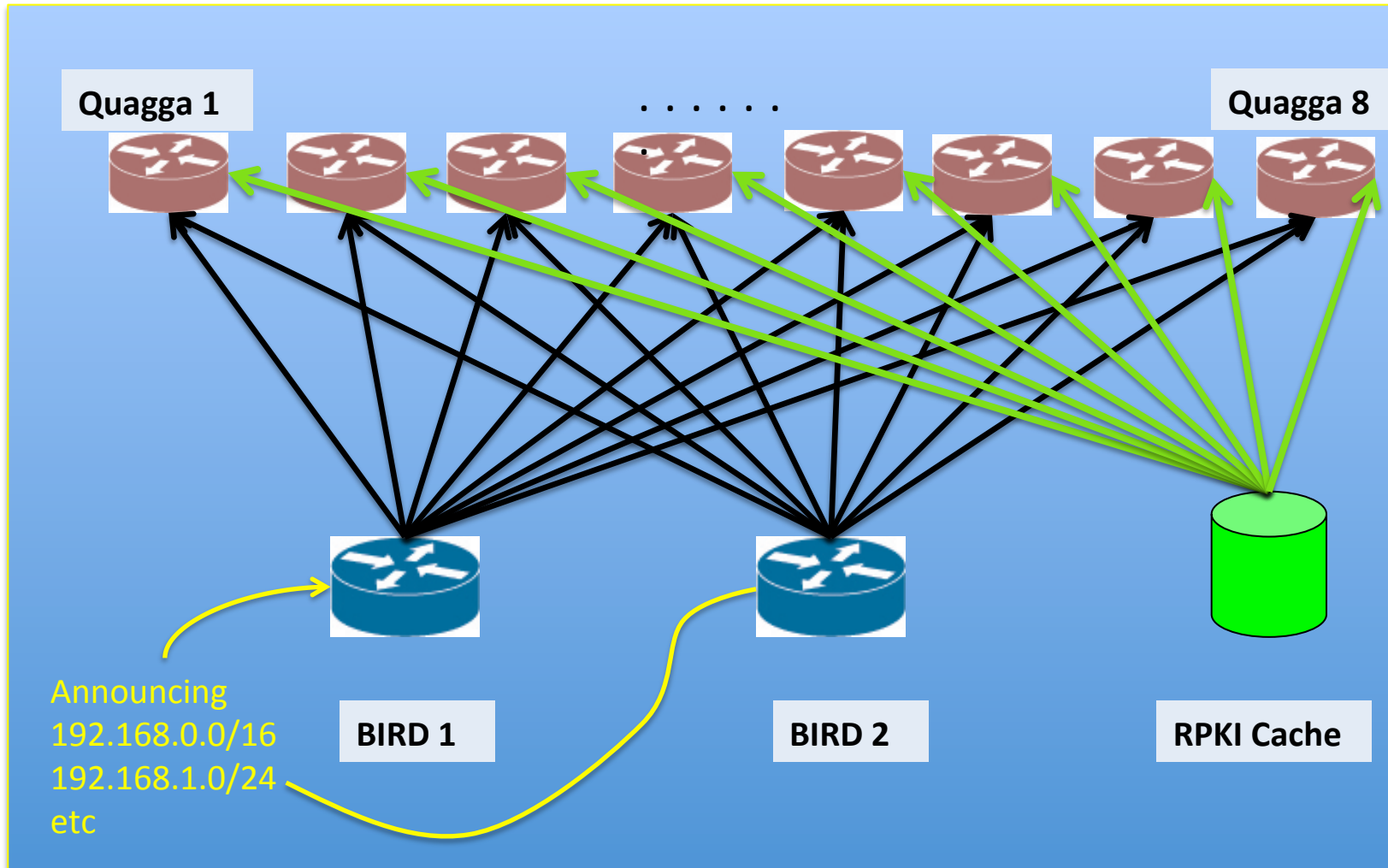
- ## – Emulation and Operation Monitoring

- ## – RPKI Visualization

- RPKI Monitor

[illegible]

Workshop in a Box



VM totally self-contained environment – no outside dependencies
Comes with local trust anchor so you can generate certs for your own prefixes
Use for experimentation, training, testing, whatever

Workshop In a Box

The image displays a series of overlapping screenshots from the RPKI Track web interface and a terminal window, illustrating the 'Workshop In a Box' setup.

RPKI Track Web Interface Screenshots:

- Handle List:** Shows a list of handles including IANA, workshop, labuser01, labuser02, and labuser03.
- Resources:** Displays a table of resources with columns for Resource, Valid Until, Parent, and Action. It also shows unallocated resources for IPv4.
- Route View:** Shows a table of routes with columns for Prefix, Origin AS, and Validation Status. It includes a 'Create ROAs' button at the bottom.
- Create ROAs:** A form for creating ROAs with fields for Prefix, Max Length, and AS.
- Confirm ROA Requests:** A page for confirming ROA requests, showing a table of matched routes with columns for Prefix, Origin AS, and Validation Status.

Terminal Window Screenshot:

```
Sandras-MacBook-Pro:~ sandy$ ssh -p 4522 -l r2 127.0.0.1
r2@127.0.0.1's password:
Welcome to Ubuntu 14.04.2 LTS (GNU/Linux 3.13.0-46-generic i686)

 * Documentation:  https://help.ubuntu.com/

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

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applicable law.

Last login: Mon Nov 16 05:27:24 2015 from 10.0.2.2
Trying 10.0.3.14...
Connected to r2.
Escape character is '^['.

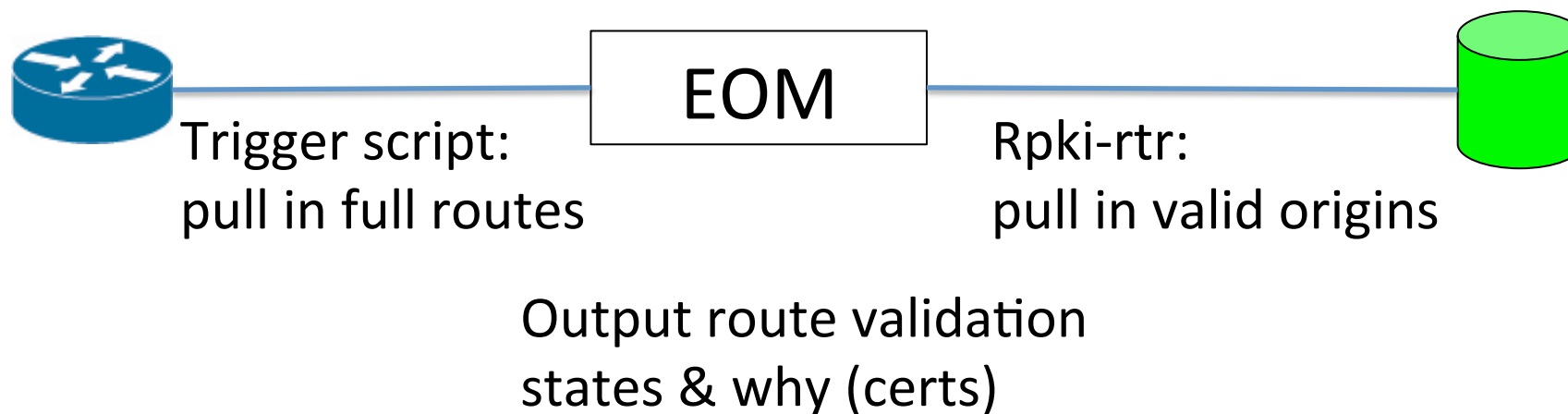
Hello, this is QuaggaSRx (version 0.4.1.2).
Copyright 1996-2005 Kunihiko Ishiguro, et al.

User Access Verification

Password:
r2> show ip bgp
BGP table version is 0, local router ID is 10.0.3.14
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, R Removed
Validation:   v - valid, n - notfound, i - invalid, ? - undefined
SRx Status:   I - route ignored, D - SRx evaluation deactivated
SRxVal Format: validation result (origin validation, path validation)
Origin codes: i - IGP, e - EGP, ? - incomplete

   Ident  SRxVal SRxLP Status Network      Next Hop          Metric LocPrf Weight Path
  * 94178AEC n(n,-)          192.168.0.0/16    10.0.3.11         0 65533 i
  * 43F50A04 n(n,-)          10.0.3.10         0 65534 i
  * 2FCF28F4 n(n,-)          192.168.0.0       10.0.3.11         0 65533 i
  * F82DA0AC n(n,-)          10.0.3.10         0 65534 i
  * 9634F31C v(v,-)          192.168.1.0       10.0.3.11         0 65533 i
```

EOM (Emulation and Operation Monitoring)



Check local incoming routes against RPKI data

Intended use:

- What RPKI would say about your current feeds - without deploying RPKI
- Monitor routing table RPKI state during deployment

EOM (Emulation and Operation Monitoring) - GUI

 EOM latest reports
TS:2016-04-04 23:12:04
Device:quagga.vm Invalid:480

EOM Active Device List

Device	Last Update	RIB Count
quagga.vm	2016-04-04 22:27:12	68544

RPKI Router Server List

Device	Last Update	ROA Count
rpki-validator.realmv6.org:8282	2016-04-04 23:12:04	21889

 TS:2016-04-04 23:12:04
Device:quagga.vm Invalid:480

EOM Route Status

ROA	Network	NextHop	M	L	W	Origin	Path	Constraints
✓	24.38.0....	12.0.1.63	0	0	0	6128	7018 ⇒ 2828...	AS:6128 Prefix:24.38.0.0 Range:[17-25]
✗	24.38.1....	12.0.1.63	0	0	0	22...	7018 ⇒ 3561...	AS:6128 Prefix:24.38.0.0 Range:[17-25]
✗	24.38.4....	12.0.1.63	0	0	0	5116	7018 ⇒ 2828...	AS:6128 Prefix:24.38.0.0 Range:[17-25]
✗	24.38.6....	12.0.1.63	0	0	0	26...	7018 ⇒ 2828...	AS:6128 Prefix:24.38.0.0 Range:[17-25]

13 Jun 2016

Practical BGP Origin Validation Using RPKI Track - NANOG 67

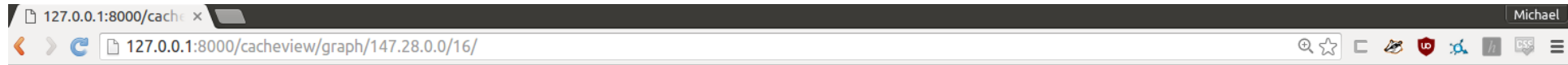
24

EOM (Emulation and Operation Monitoring) - CLI

Router: 172.16.0.6

	Network	Next Hop	Metric	LocPrf	Weight	Path
V : *	10.1.1.0/24	172.16.0.5	0	0 0	65005	65004 i
	65004:10.1.1.0/[24-24]					
V : *>	10.1.1.0/24	172.16.0.4	0	0 0	0 65004	i
	65004:10.1.1.0/[24-24]					
I : *>	10.1.1.0/25	172.16.0.5	0	0 0	65005	65004 65004 65004 65004 i
	65004:10.1.1.0/[24-24]					
I : *>	10.1.1.128/25	172.16.0.5	0	0 0	65005	65004 65004 65004 65004 i
	65004:10.1.1.0/[24-24]					

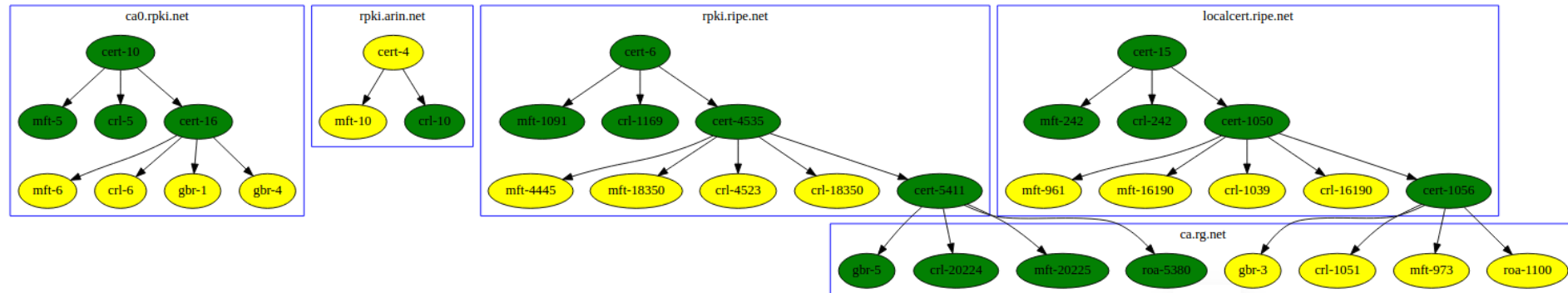
Monitor: RPKI Visualization



RPKIviz

prefix or AS

Validated May 17, 2016, 10:46 p.m. UTC



URI: rsync://ca.rg.net/rpki/RGnet/UKs040I1SwhjomoLeeZfEVhj5Rk.roa

SKI: 50AB34E342354B0863A26A0B79E65F115863E519

AKI: B45BE20598786DFF4020A6B2947D5333A0A04A2B

Serial: 5

Not Before: May 17, 2016, 1:20 p.m.

Not After: July 1, 2017, midnight

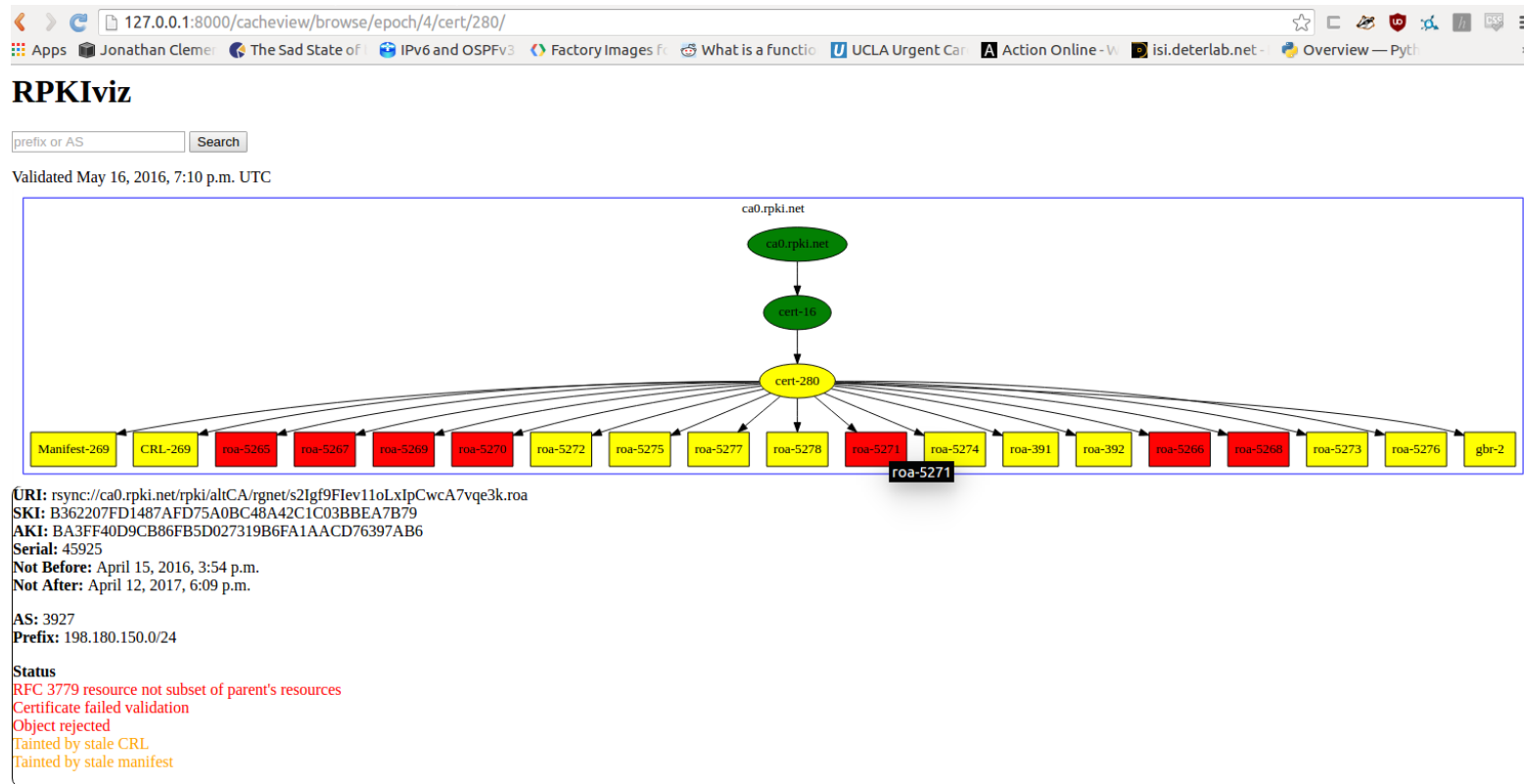
AS: 3130

Prefix: 147.28.0.0/16

Status

Object accepted

Monitor: RPKI Visualization



Errors

Monitor: RPKI Visualization

192.169.0.0/23 History

2016-05-10 23:59:38 to 2016-05-11 19:21:06

When	Status	ROAs	Certs
2016-05-10 23:59:38	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 01:15:54	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 04:43:39	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 13:54:45	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 14:21:03	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 15:21:24	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 16:21:21	covered	AS3970	BA3FF... 621A0... A6B69...
2016-05-11 17:44:13	covered	AS3970	BA3FF... 13D4F... 621A0... A6B69...
2016-05-11 18:22:29	covered	AS3970	BA3FF... 13D4F... 621A0... A6B69...
2016-05-11 18:30:42	covered	AS3970	BA3FF... 13D4F... 621A0... A6B69...
2016-05-11 19:21:06	covered	AS3970	BA3FF... 13D4F... 621A0... A6B69...

History

Monitor: RPKI Visualization

127.0.0.1:8000/graph/147.28.0.0/16

RPKIviz

prefix Search

Validated 2016-06-01 16:41:48 UTC

Warnings

URI: rsync://localcert.ripe.net/repository/ARIN/z-P1LDkk4VCC5gayNA17GkCisdM.mft

Issuer: /commonName=cfe3f52c3924e15082e606b2340d7b1a40a2b1d3
Subject: /commonName=adb4a3910cee6bc15d9e1c8df20e3b16aac8f6cd
AKI: CFE3F52C3924E15082E606B2340D7B1A40A2B1D3
SKI: ADB4A3910CEE6BC15D9E1C8DF20E3B16AAC8F6CD
Serial: 312462643
Not Before: 2016-06-01 10:35:53
Not After: 2016-06-08 10:40:53

thisUpdate: 2016-06-01 10:40:53
nextUpdate: 2016-06-02 10:40:53
manifestNumber: 856
File Hash Algorithm: 2.16.840.1.101.3.4.2.1

Status
Object accepted

Filename	Hash
BmcfKPv7cTIXTQAfOFyT0r6vEnI.cer	4585b1a9a7898c3b5da5f1e0beb88c8cf972cf877bf4d3500fc6c5830d97e68f
OMsJ1MFs0bKup9QEv1GVQZd_Cg.cer	d21d7b553f1ad081be25a2b3a93e74a3b09214cb573cdab6c3e0ab341bf9a821
Q0mhaoNsC9KSA4DrjpsRzjhTLvA.cer	578724f6369a9e5c70b2138314d18de6cd5080dd9826e7c711a9e69f2c44e73c
S5P_i37gvDVh9qBi80oPOXkFhp0.cer	45d857ce09e8eb55b09da53435b705ae80973f8d517cf8630cd063211a67c43
gl_gYk0P-Q_WVKHqel_DnB7cuSc.cer	4c3eb0142e9e92029f57f4649bd790547473a28c317c265bf17806eebf762ac0
ggRF6w10nMPjABu3TqJC2SNv2fA.cer	6dca646816d4ad3260996bca9e990291b71a8692c534df2a5330448232b1ef15
z-P1LDkk4VCC5gayNA17GkCisdM.crl	88e9e18bf1a50646b5d1ced63161fc8cde6ccc6d88d2a985f83a97d33de13565

NIST Tools to Foster RPKI Deployment

- **NIST RPKI Monitor**

- <http://rpki-monitor.antd.nist.gov/>
- Monitoring /measurement service characterizing the state of the global RPKI and its implications for global BGP routing.
- Snap shot and historical tracking. Global, per-RIR, per-AS analyses and comparisons.

- **BGP Secure Routing Extension (BGP-SRx)**

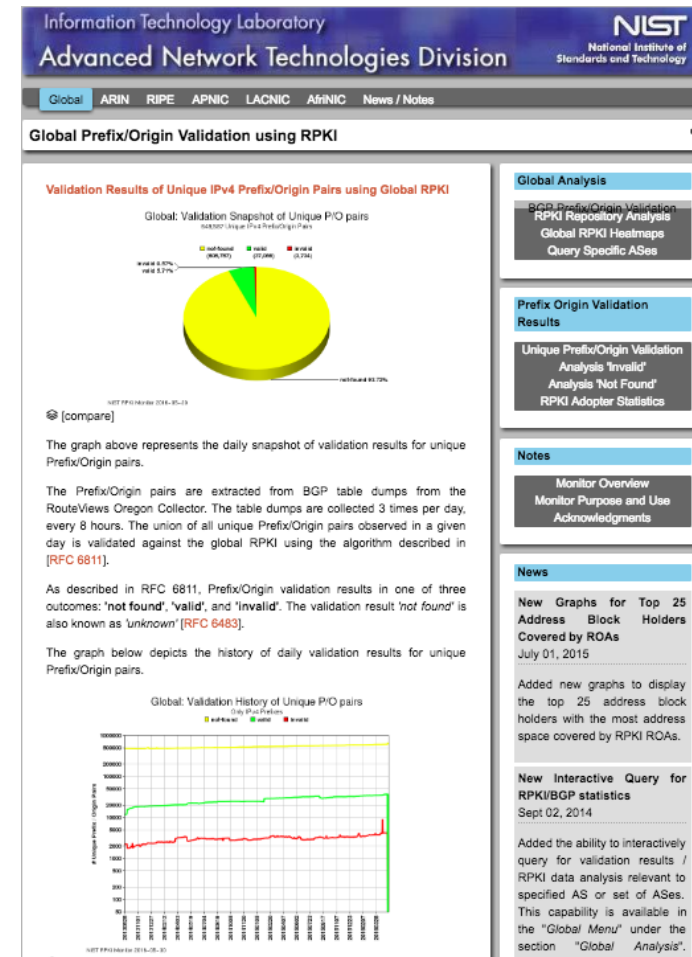
- <https://www-x.antd.nist.gov/bgpsrx/>
- Open source reference implementation for RPKI origin (and path) validation in a router.
- Platform for architectural experimentation – on board / off board processing of BGP security extensions.

- **BGP RPKI Interoperability Tester and Evaluation (BRITE)**

- <https://brite.antd.nist.gov/statics/about>
- Web based interoperability test system with full ROV test scenarios, diagnostics, etc.

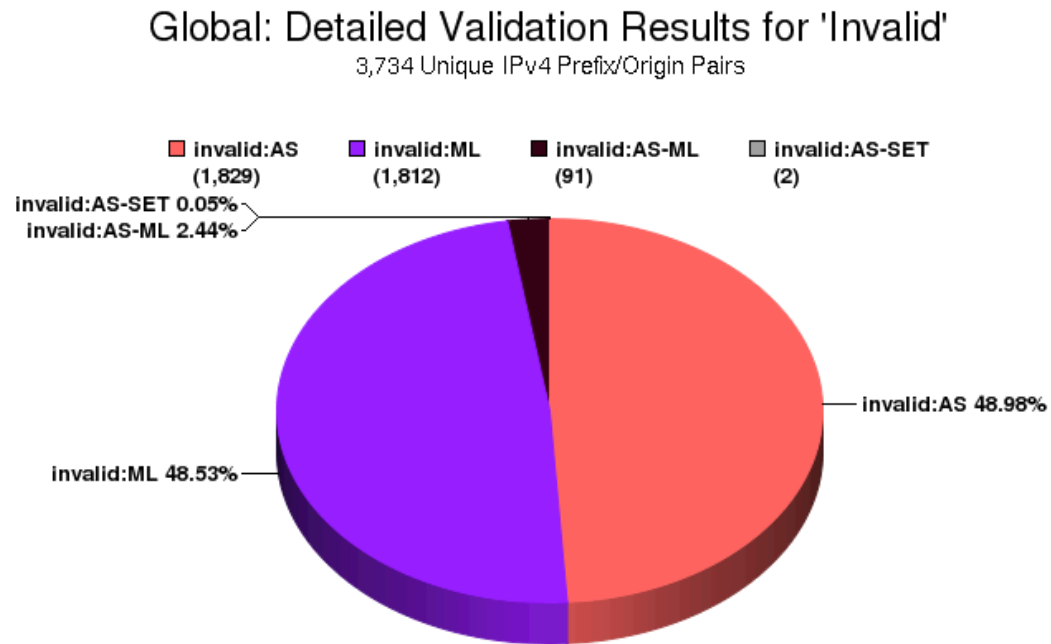
NIST RPKI Monitor

- **Continuous Monitoring Service**
 - Status of global RPKI
 - Size / shape of RPKI
 - Comparison to global routing
 - ROV vs BGP collector data
 - Multiple views
 - Snapshots & historical data
 - Global / regional statistics and comparisons
 - Tracking of top adopters
 - Query AS specific data
- **Coming soon ...**
 - ROV anomaly detection
 - RPKI dynamics
 - Cache interoperability testing



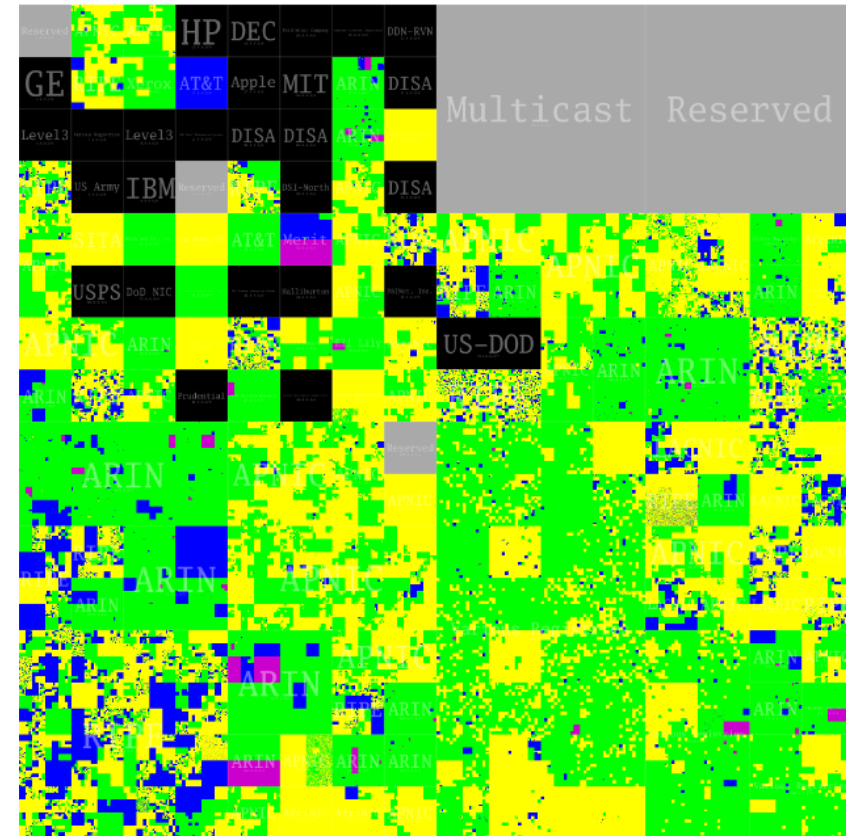
Analysis of Underlying Details

- Error analysis



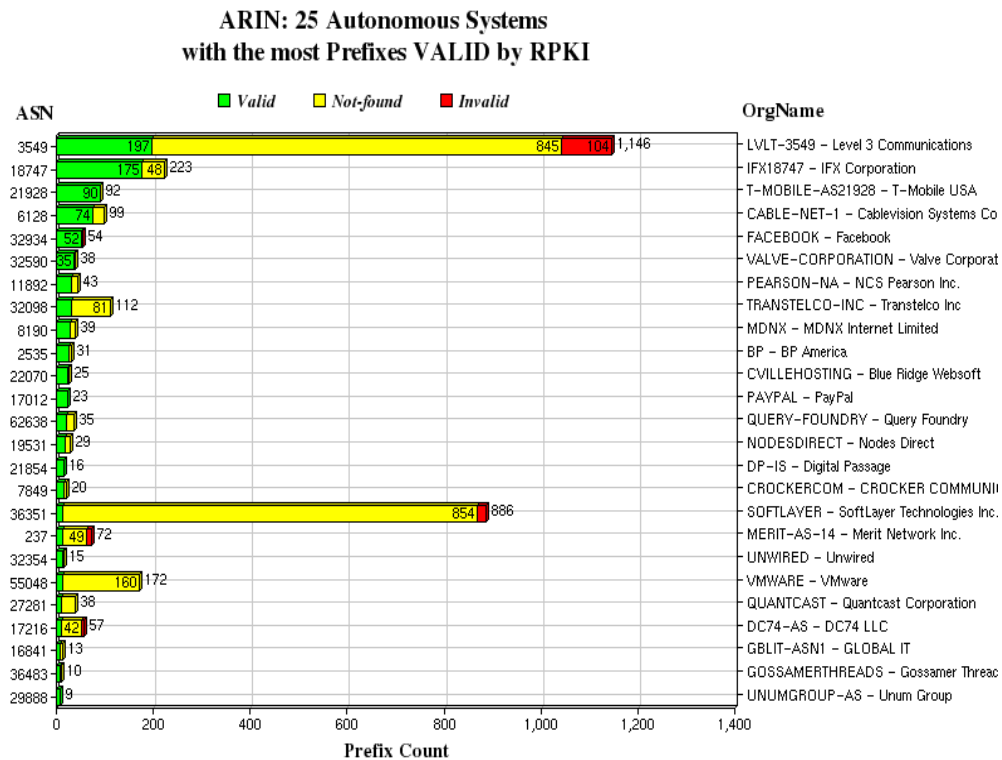
NIST RPKI Monitor 2016-05-30

- Analysis of global structure and scale.



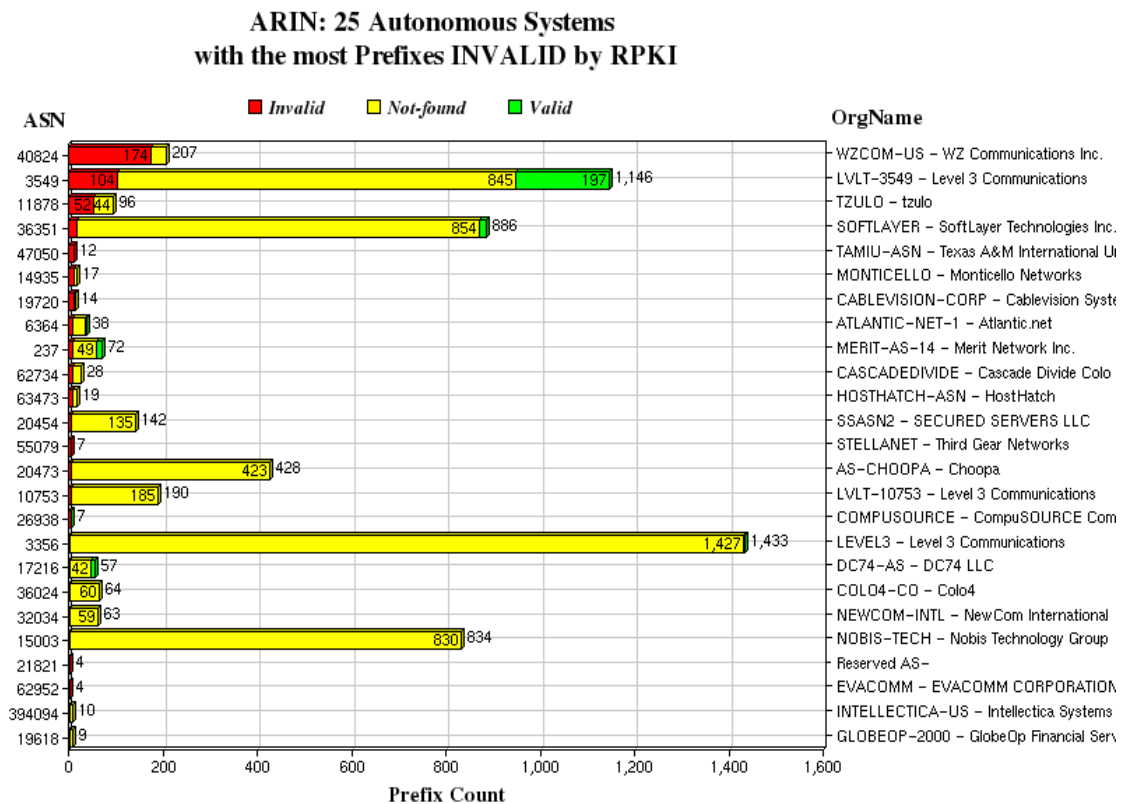
Tracking Early Adopters

- Those off to a good start



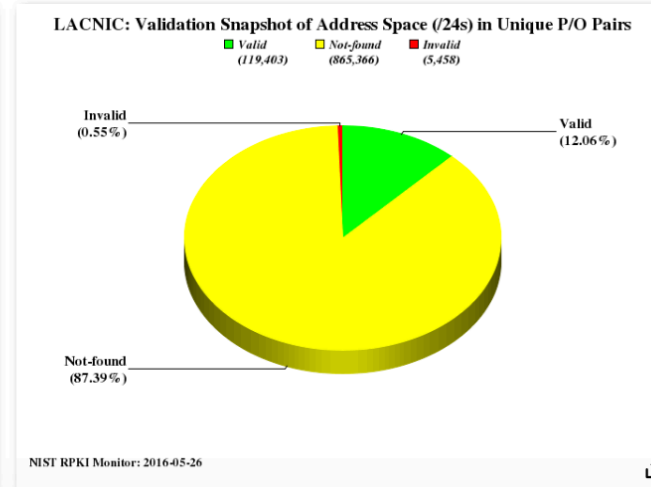
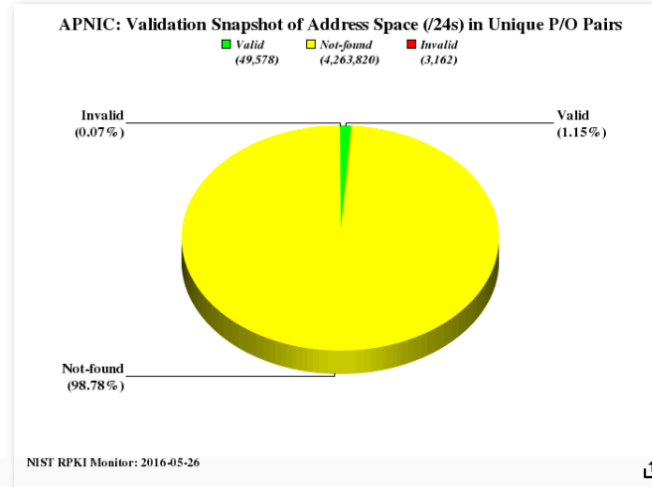
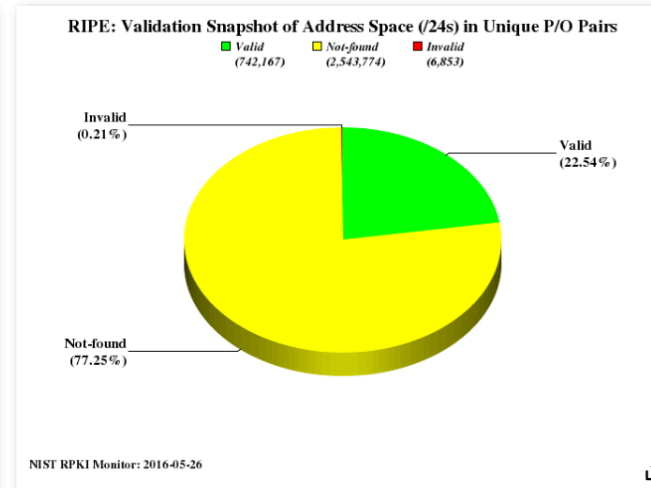
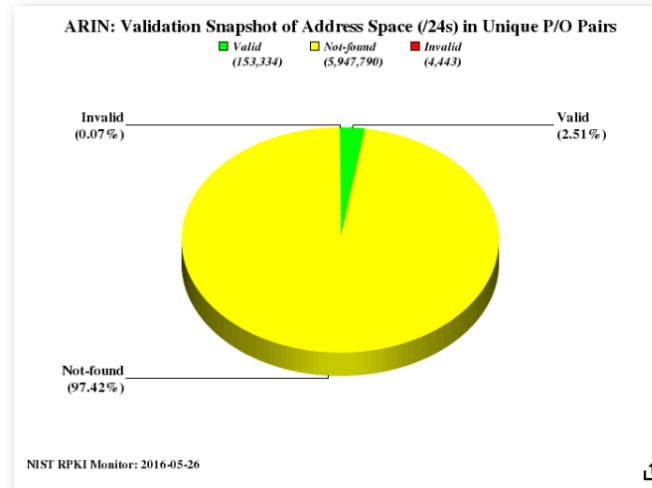
NIST RPKI Monitor: 2016-05-26

- Those that are not



NIST RPKI Monitor: 2016-05-26

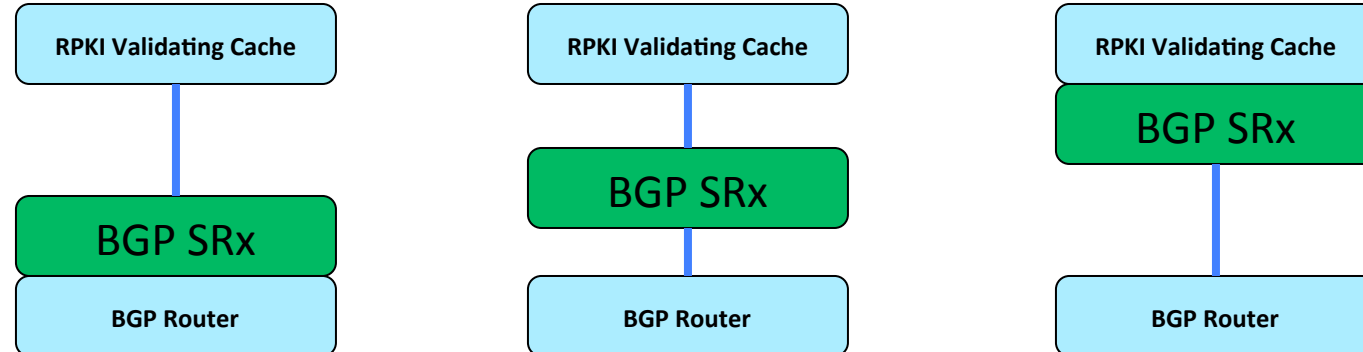
Regional Comparisons



BGP-Secure Routing eXtension (BGP-SRx)

- **Open Source Reference Implementation**

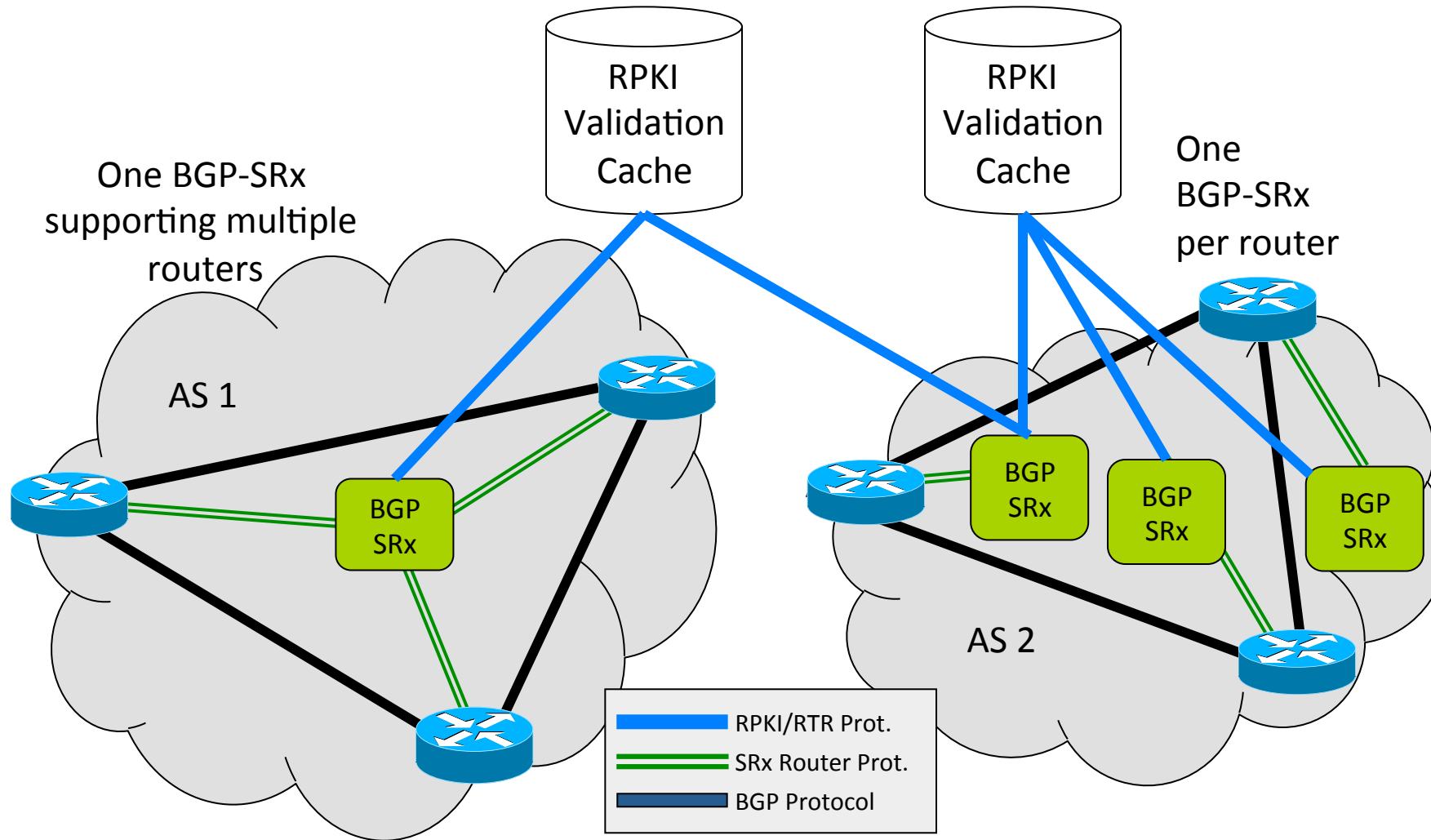
- Software router with extensions for: RPKI/RTR protocol, maintenance ROA distilled data, ROV and RPKI-aware BGP route policies.
- Designed to support experimentation with different architectural configurations of SRx and RPKI components and different trade-offs performance and router impact.
- Also supports bgpsec (i.e, RPKI path validation).



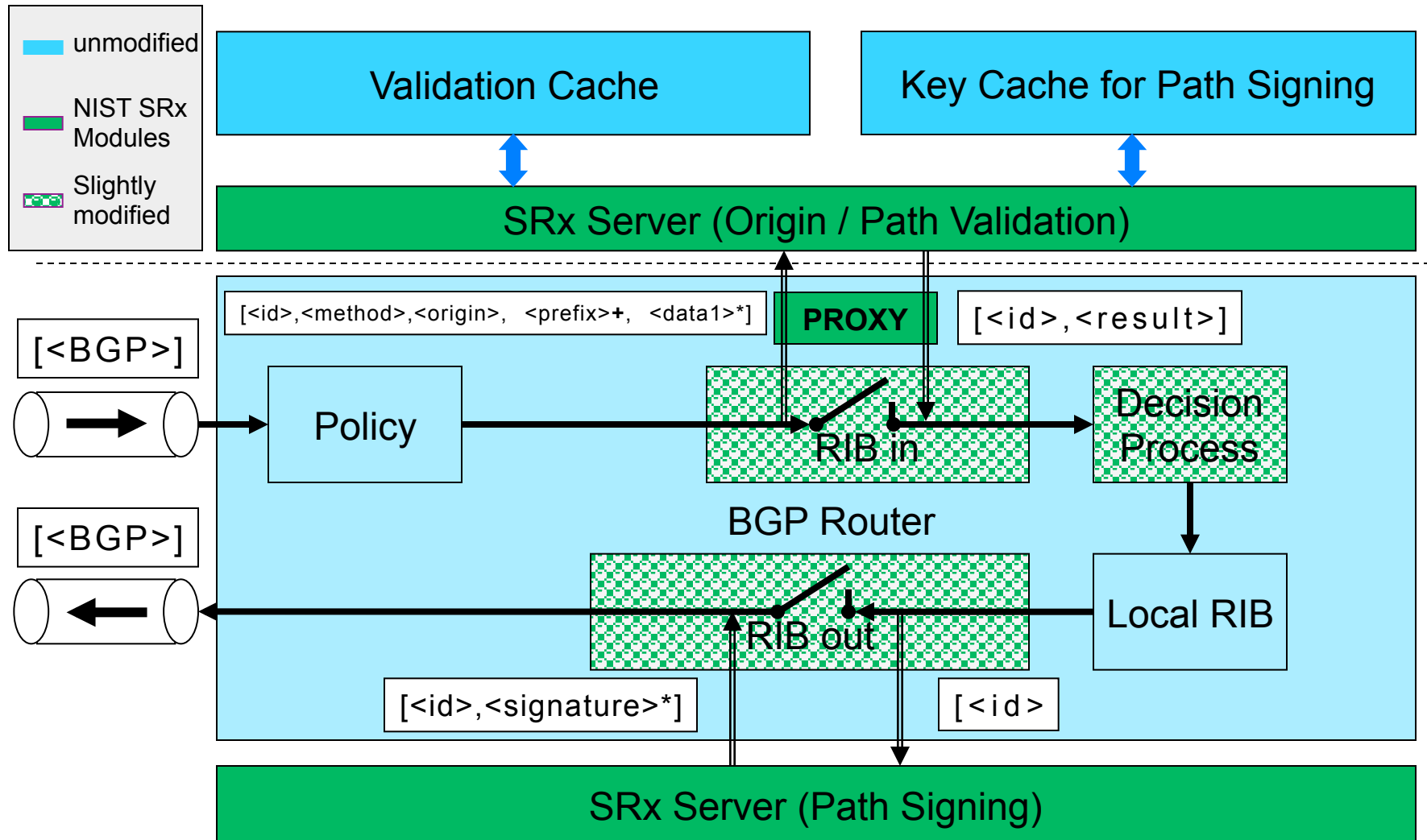
- **BGP-SRx Status**

- SRx Server
- SRx API
- Quagga SRx (integrates SRx API into Quagga router)
- src & yum repository: <https://www-x.antd.nist.gov/bgpsrx/>

BGP-SRx System Architecture



Quagga SRx Integration



Quagga SRx Policy Set

- Activation of BGP-SRx Evaluation
 - no srx evaluation
 - srx evaluation (origin_only|bgpsec)
- Ignore Policies
 - [no] srx policy ignore-notfound
 - [no] srx policy ignore-invalid
 - [no] srx policy ignore-undefined
- Local Preference Policies
 - [no] srx policy local-preference valid <int> (add|subtract)
 - [no] srx policy local-preference notfound <int> (add|subtract)
 - [no] srx policy local-preference invalid <int> (add|subtract)
- Prefer Policies
 - [no] srx prefer-valid

BRITE Overview

- **BGPSEC / RPKI Interoperability Test & Evaluation**

- Distributed test and evaluation framework for:

- ROV implementation testing.
- Configuration and deployment testing.

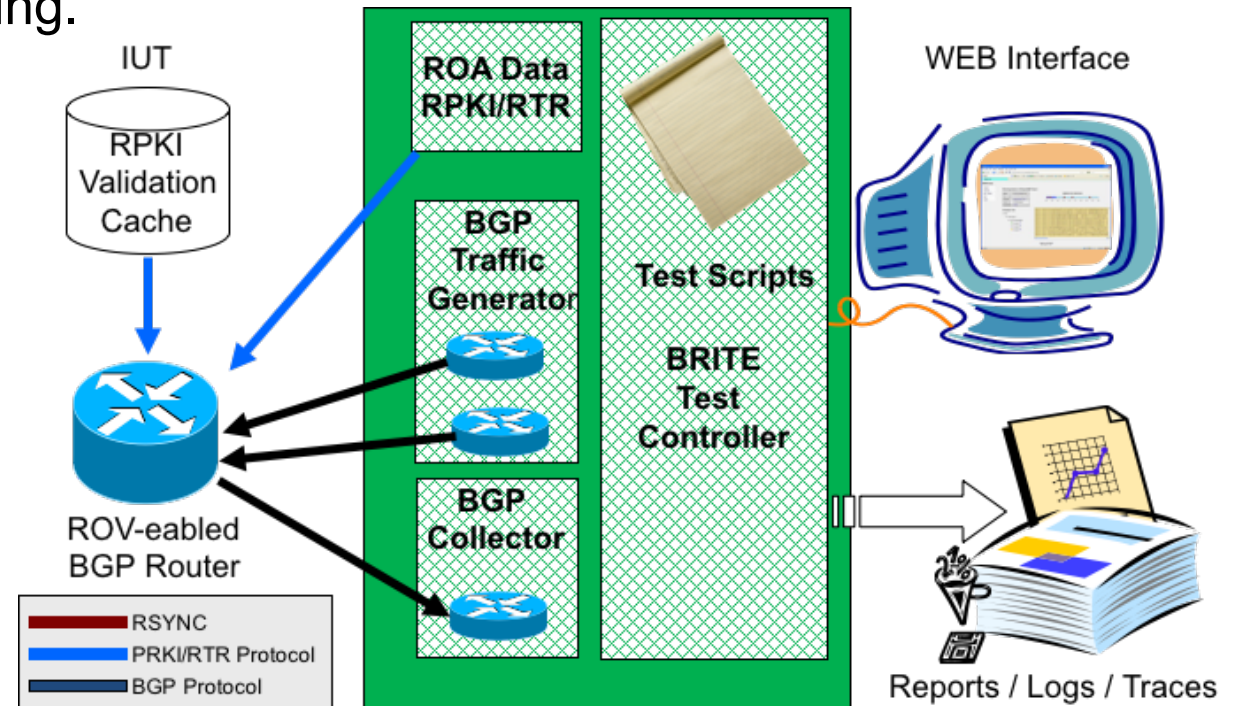
- XML based test scripts

- Library of canned tests.
- Exercise ROV scenarios
- ... or write you own.

- Test Scenarios

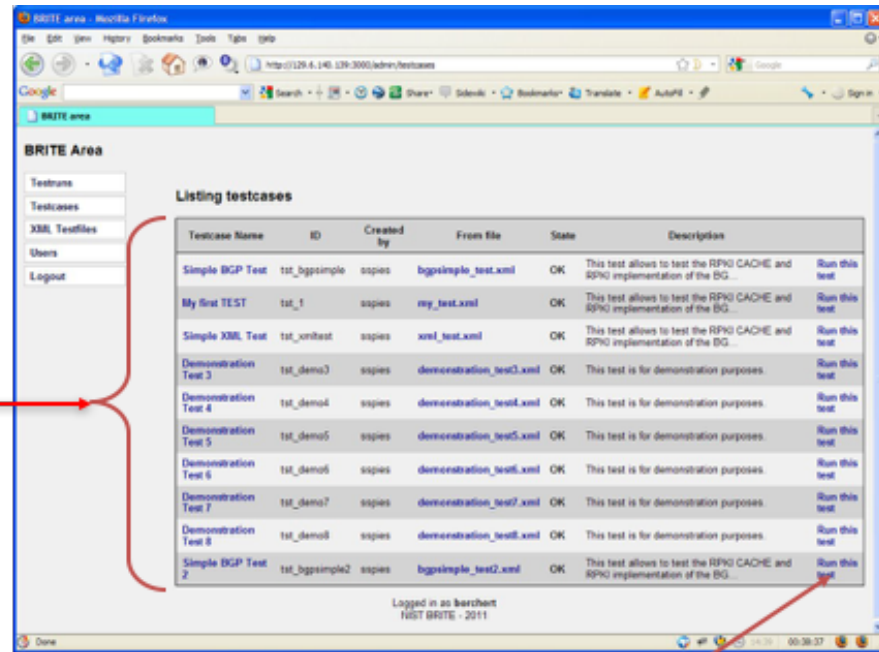
- Live RPKI/RTR protocol
- Live BGP sessions
- Diagnostics, log files, traffic traces.

<https://brite.antd.nist.gov/>



BRITE Usage

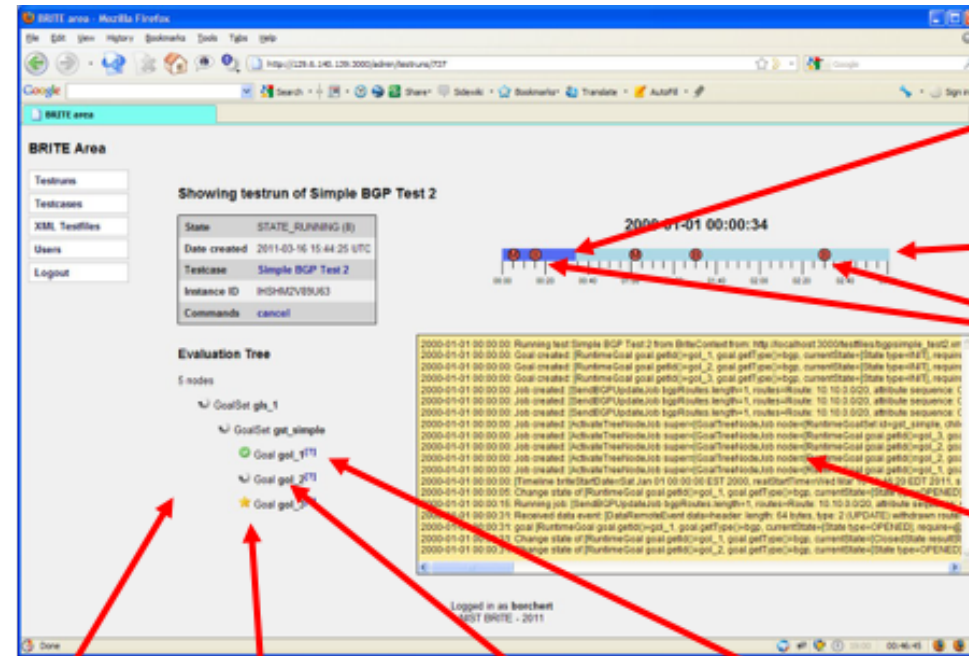
- Test Selection



Tests available to the user.

Select a test to be started

- Test Execution



Test Progress

Test Timeline

Events:
M=Multiple
A=Activation
B=BGP
W=Whitelist

Experiment Log

Goal Tree

Wait to be activated

Currently processing

Finished successful

Track Agenda

- RPKI Introduction
 - Sandra Murphy/PARSONS, Doug Montgomery/NIST
- ARIN RPKI Services
 - Mark Kusters / ARIN – Users' guide to ARIN RPKI services.
- RPKI Implementations - Doug Montgomery,
- Router Vendor Implementations
 - Greg Hankins/Nokia , John Scudder/Juniper, Keyur Patel & Arjun Sreekantiah/Cisco
- RPKI Test, Training, Monitoring, Management, tools.
 - Matthias Wählisch/FU Berlin, Sandy Murphy, Doug Montgomery,
- Deployment Experiences Panel & Q&A
 - JR Mayberry/Microsoft, Tony Tauber/Comcast, Thomas King/ DE-CIX, Henk Steenman/AMS-IX

Backup Slides

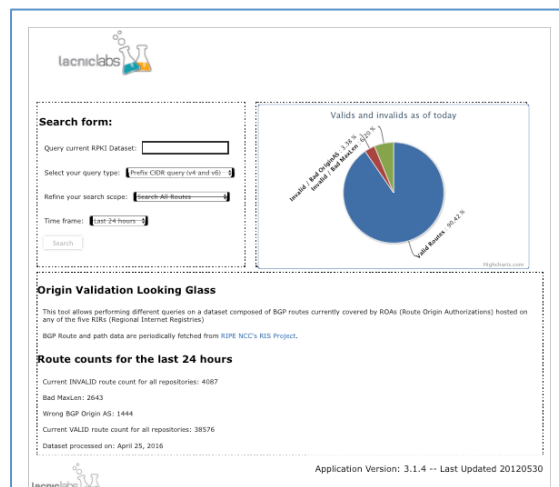
Tools Summary / Index

Partial Listing

Monitoring: RPKI / Origin Validation

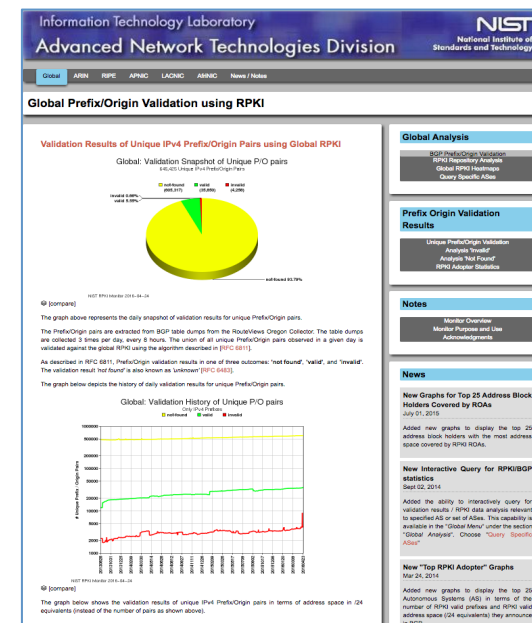
- LACNIC

- http://www.labs.lacnic.net/rpkitools/looking_glass/



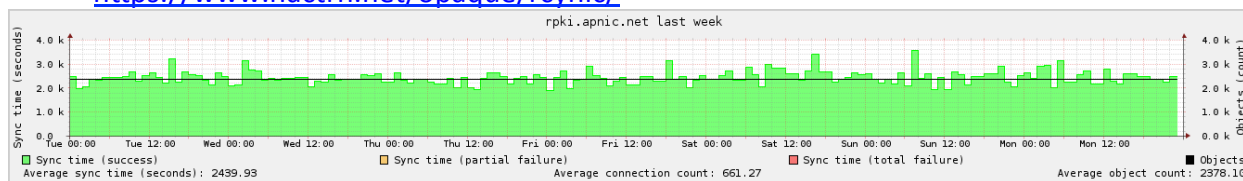
- NIST

- <http://rpki-monitor.antd.nist.gov/>



- Dragon Research

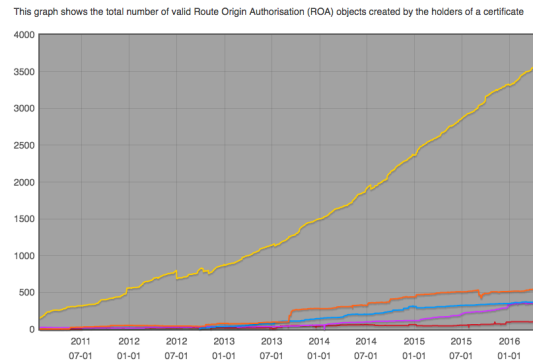
- <https://www.hactrn.net/opaque/rcynic/>



Monitoring: RPKI / Origin Validation

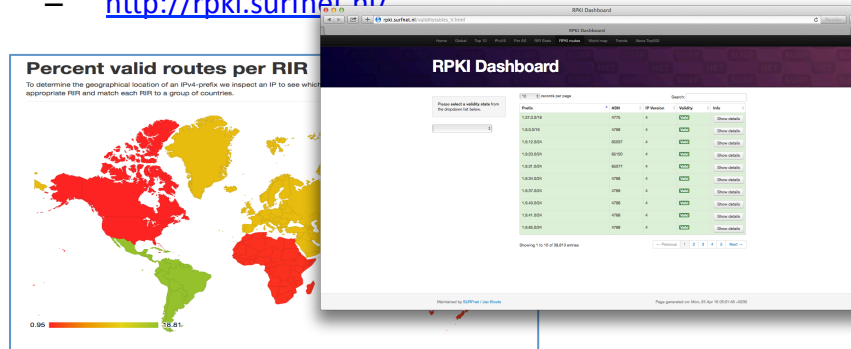
- RIPE

- <http://certification-stats.ripe.net/>



- SURFnet

- <http://rpki.surfnet.nl/>



- Realmv6.org

- <http://rpki-browser.realmv6.org/>

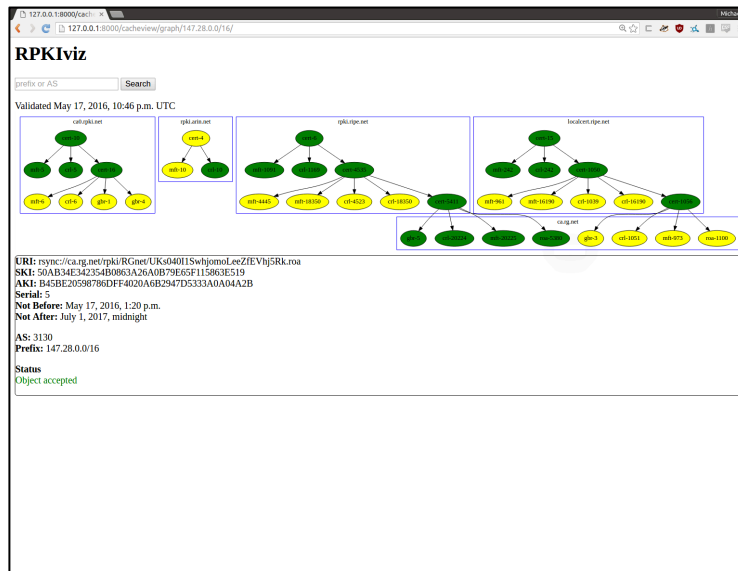
Validation Status:	PASSED
Validity Period:	2015-05-25T07:29:40.000Z - 2020-05-23T07:29:40.000Z
Errors:	None
Warnings:	None
Subject:	CN=Afrinic-Root-Certificate
SKI:	EB680F38F5D6C71BB4B106B8BD06585012DA31B6
Issuer:	CN=Afrinic-Root-Certificate
AKI:	None
SerialNr:	15.523.921.882.008.508.840
Filename:	Afrinic.cer
Location:	rsync://rpki.afrinic.net/repository/Afrinic.cer
EE:	false
CA:	true
TA:	true
Public Key:	Sun RSA public key, 2048 bits modulus: 25089944029919823878319426627228540929552281504401868 9253717016409729310839610329238335436910930257936832297084721377 4408517991863943291731154637498736792820350781432459970714234162 633814886372421503167325063608924276946681300909926563320214698 6702143814603853701564981410469347572285967453705612988066348166 584858046959157448162763477782909518195238110575756390555816459 381654931213339395660669380896536347468469930010888371775185391 4944241947919573805298140068447073456563736821453726575120593110 2765951165866855478974819060877618163707806710983406600940199578 2037372356249211838508514872786104379149461973571921 public exponent: 65537

Resources
AS1228-AS1232
AS2018
AS2561
AS2905
AS3067-AS3068
AS3208
AS3741
AS4178
AS4571
AS5536
AS5713
AS5734
AS6083
AS6089
AS6127
AS6149
AS6180
AS6187
AS6351
AS6529
AS6560

Monitoring: RPKI / Origin Validation

- RPKIViz

- <https://securerouting.net/tools/RPKIViz>



- EOM

- <https://securerouting.net/tools/eom>

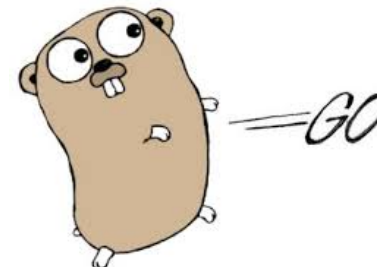
192.169.0.0/23 History			
2016-05-10 23:59:38 to 2016-05-11 19:21:06			
When	Status	ROAs	Certs
2016-05-10 23:59:38	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 01:15:54	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 04:43:39	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 13:54:45	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 14:21:03	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 15:21:24	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 16:21:21	covered	AS3970	BA3FE... 621A0... A6B69...
2016-05-11 17:44:13	covered	AS3970	BA3FE... 13D4F... 621A0... A6B69...
2016-05-11 18:22:29	covered	AS3970	BA3FE... 13D4F... 621A0... A6B69...
2016-05-11 18:30:42	covered	AS3970	BA3FE... 13D4F... 621A0... A6B69...
2016-05-11 19:21:06	covered	AS3970	BA3FE... 13D4F... 621A0... A6B69...

Experimentation: Software Routers

- RTR-Lib
 - C-library for origin validation BIRD and Quagga.
 - <http://rpki.realmv6.org/>
- BGP-SrX
 - Server based origin validation engine. Off loads state/processing for origin / path validation. Quagga integration.
 - <http://www-x.antd.nist.gov/bgpsrx/>
- GOBGP
 - Go BGP implementation with RPKI Origin Validation
 - <https://github.com/osrg/gobgp>

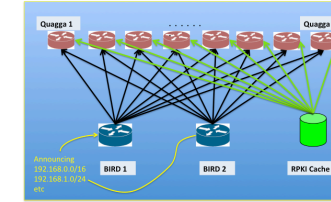


Open Source Routing



Test & Training: Tools / Services

- Workshop-in-a-box
 - <https://securerouting.net/workshop>
- BRITE
 - <https://brite.antd.nist.gov/>
- EOM
 - <https://securerouting.net/tools/eom>



A screenshot of the EOM web interface. It displays two main sections: "EOM Active Device List" on the left and "EOM Route Status" on the right. The "EOM Active Device List" shows a table with columns for Router List, Name, and Status. The "EOM Route Status" shows a table with columns for AS Path, Route, and Status. The interface includes various filters and a search bar.