Route Security

NANOG 74: Security Track

Recent BGP incidents

Andree Toonk
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Censorship gone wrong

July 2018

Instagram rerouted to Iran

10 Instagram prefixes
8 more specifics

58224 (Iran Telecommunication Company PJS)

https://bgpstream.com/event/144055

We've seen this movie before

Youtube hijack, 2007

Turk Telekom, 2014

Popular destinations routed to Russia

December 2017

Popular destinations rerouted to Russia

80 prefixes for Google, Apple, NTT, Facebook, Riot Games, and more

Origin AS 39523 (DV-LINK-AS), Russia.

https://bgpmon.net/popular-destinations-rerouted-to-russia/

Hijacking financial services,

example 1

April 2017

Russian ISP hijacks financial services' Internet traffic

Visa, MasterCard, and Symantec among dozens affected.

AS12389 (PJSC Rostelecom), Russia

https://bgpmon.net/bgpstream-and-the-curious-case-of-as12389/

Hijacking financial services,

example 2

July 2018

BGP/DNS Hijacks Target Payment Systems

Savvis, Vantiv, Q9 Networks Inc, UltraDNS, Internet Media Network, CenturyLink, Mercury Payment Systems

Digital Wireless Indonesia (AS38146), Extreme Broadband (AS38182)

https://dyn.com/blog/bgp-dns-hijacks-target-payment-systems/

Hijacking DNS Infrastructure services

The route53 incident

April 2018

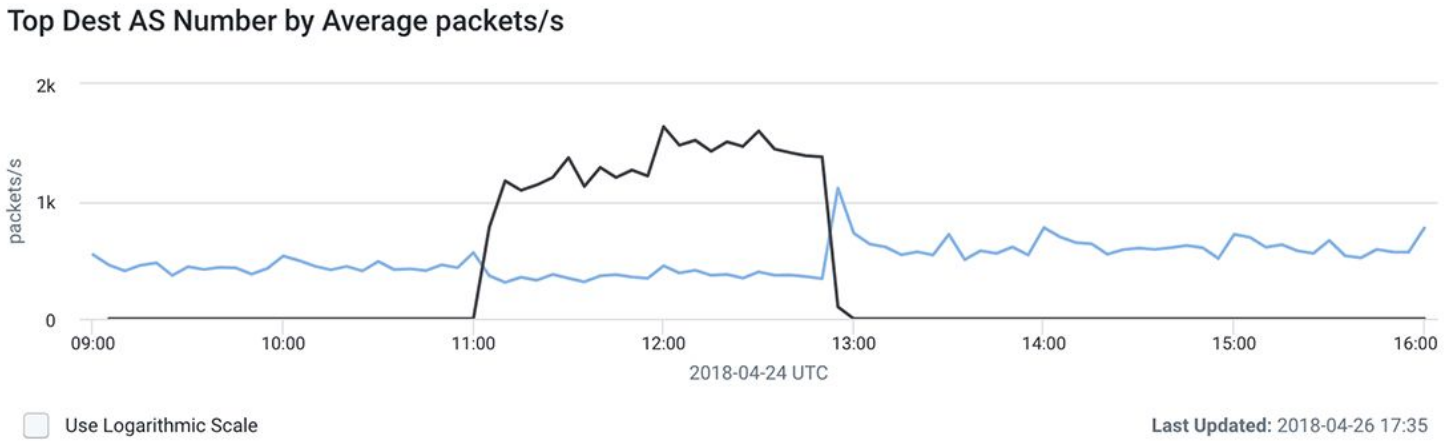
BGP/DNS Hijack

AWS Route53
Myetherwallet.com

eNet (AS10297) , Ohio USA

https://arstechnica.com/?post_type=post&p=1298417
https://dyn.com/blog/bgp-hijack-of-amazon-dns-to-steal-crypto-currency/
https://blog.cloudflare.com/bgp-leaks-and-crypto-currencies/

DNS traffic to route53 according to Kentik



Destination AS Number	Average packets/s	95th Percentile packets/s	Max packets/s	Last Datapoint packets/s
ENET-2 - eNET Inc.,US (10297)	347.96	1,472.85	1,636.69	0.00
AMAZON-02 - Amazon.com, Inc.,US (16509)	505.05	718.51	1,112.75	773.12
Total of Top 2	**853.01**	**2,191.36**	**2,749.44**	**773.12**

source: https://www.kentik.com/blog/aws-route-53-bgp-hijack-what-kentik-saw/

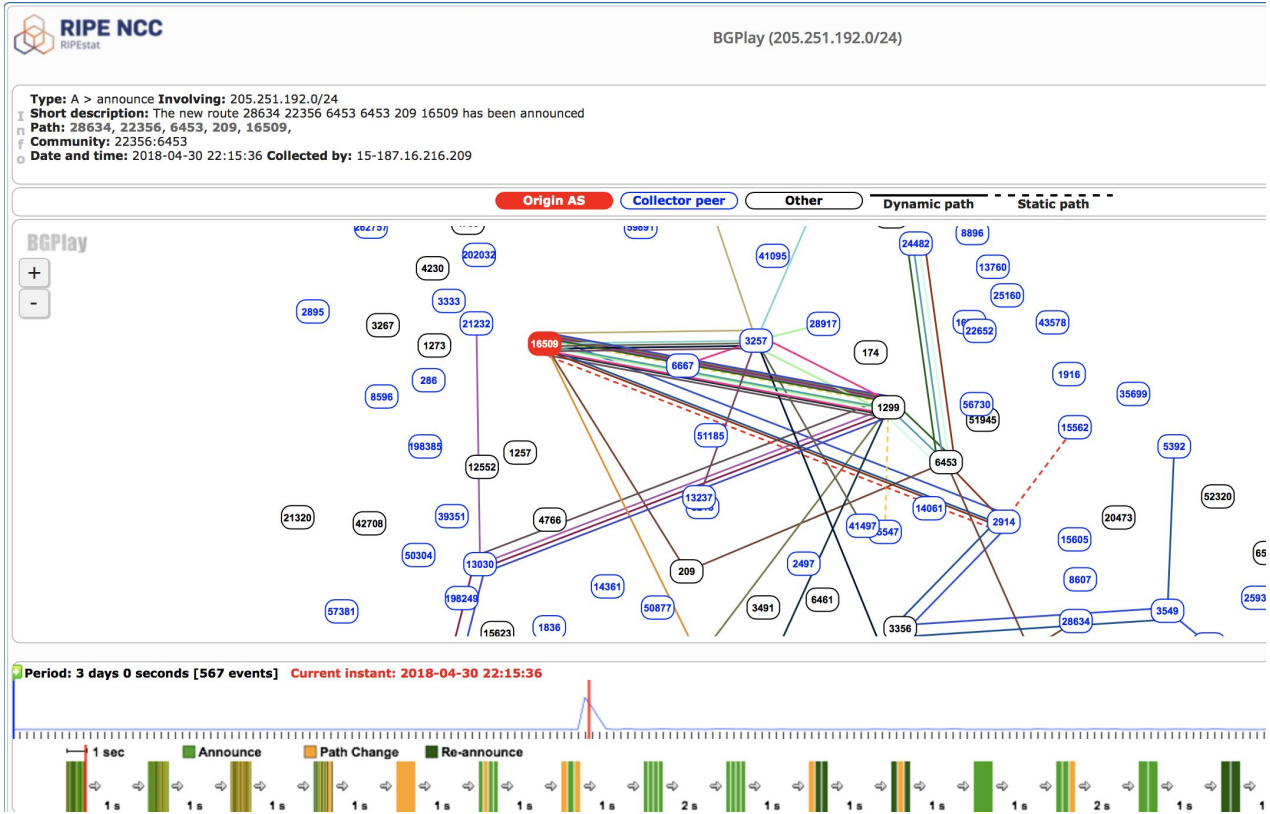
We've seen this movie before

Spamhaus (DDOS) attack

The Canadian Bitcoin hijack (2014)

What did AWS do?

/24’s appeared, 6 days later (till now)



route53 ROA's appeared 3 days later!

```
$ whois -h whois.bgpmon.net ' --roa 16509 205.251.193.0/24'
0 - Valid
------------------------
ROA Details
------------------------
Origin ASN:       AS16509
Not valid Before: 2018-04-27 04:00:00
Not valid After:  2028-04-27 04:00:00  Expires in 9y323d8m1.39999997615814s
Trust Anchor:     rpki.arin.net
Prefixes:         205.251.193.0/24

 16:32:26  ~/src
$ whois -h whois.bgpmon.net ' --roa 16509 2600:9000:5300::/48'
0 - Valid
------------------------
ROA Details
------------------------
Origin ASN:       AS16509
Not valid Before: 2018-04-27 04:00:00
Not valid After:  2028-04-27 04:00:00  Expires in 9y323d7m57.3999999761581s
Trust Anchor:     rpki.arin.net
Prefixes:         2600:9000:5300::/48
```

RPKI to the rescue?

All of the incidents mentioned would have been prevented if Origin Validation would have been fully deployed.

Closing observations

We did not talk about path validation, yet route leaks and AS path spoofing remain a big challenge.

Most large ISP’s do a decent job filtering. IX’s remain the wild west.

Questions and comments?

State of BGP Security

Alexander Azimov
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Rights

- Get address space from RIR;
- Establish BGP sessions;
- Advertise prefixes;
- Receive traffic.

Responsibilities

- MUST not hijack foreign address space;
- MUST not create route leaks;
- MUST support anti-spoofing policies;
- MUST configure Ingress/Egress filters;
- MUST pay fee to RIR.

Responsibilities

- MUST not hijack foreign address space;
- MUST not create route leaks;
- MUST support anti-spoofing policies;
- MUST configure Ingress/Egress filters;
- MUST pay fee to RIR – **that's all!**

BGP Anomalies

BGP Hijacks

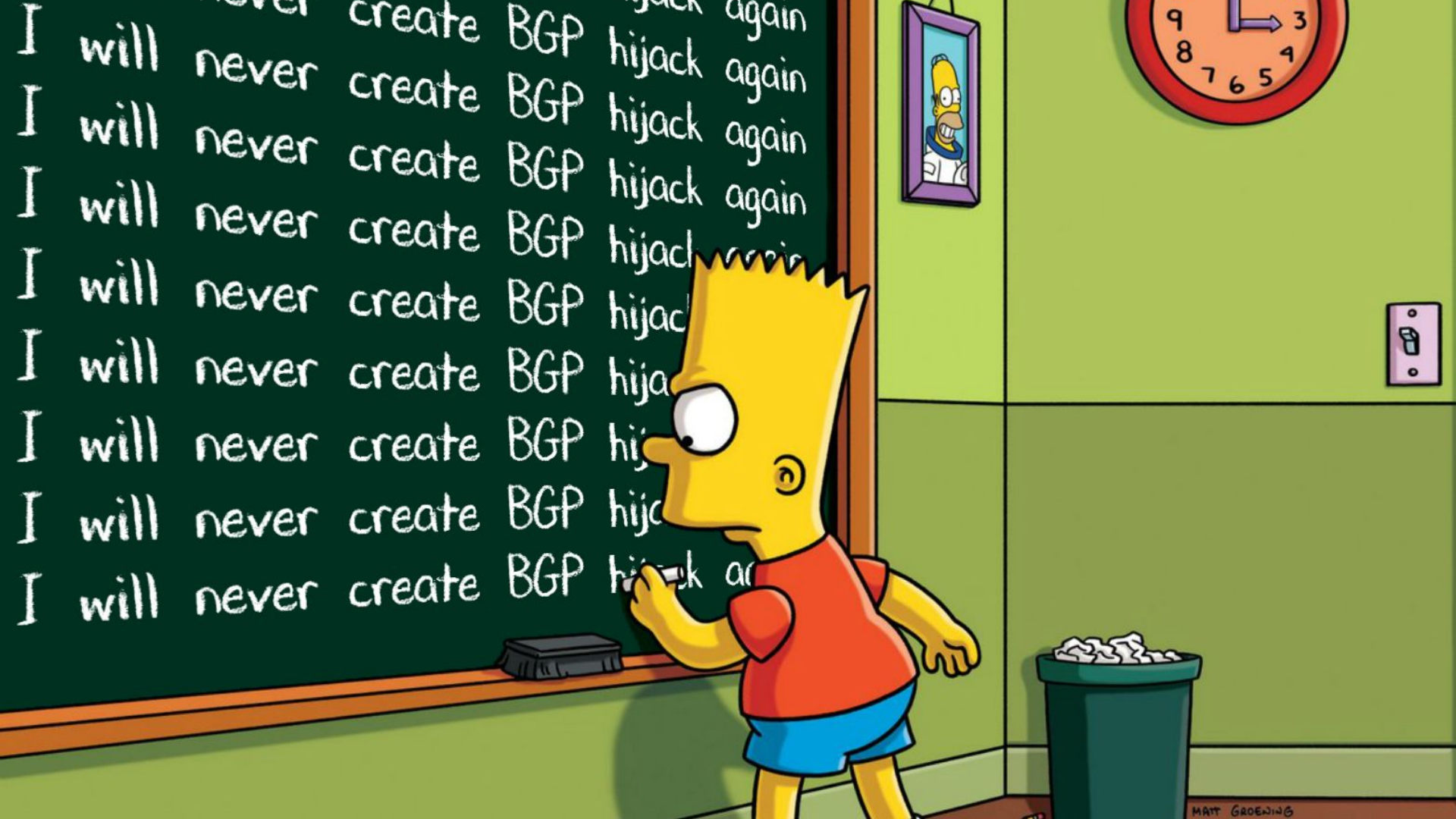
Illegitimate advertisement of foreign address space.

BGP Route Leaks

Illegitimate announce of a route received from peer or upstream to another peer or upstream.

Outages Become Regular

- 24th April: ENET, AS10297, US: Malicious BGP and DNS hijack. The attack was successful.
- 26th April: DPSTL, AS267286, Brazil: Mega-hijack. A Brazilian ISP announced 16 /8 prefixes plus several smaller prefixes; ~5% of the entire IPv4 address space in total.
- 4th May: ELCAT, AS8449, Kyrgyzstan: Giant route leak between China and Russia.
- 18th May: PBNET, AS263086, Brazil: Full table leak disrupting Brazil segment.


I will never create BGP hijack again
I will never create BGP hijack again
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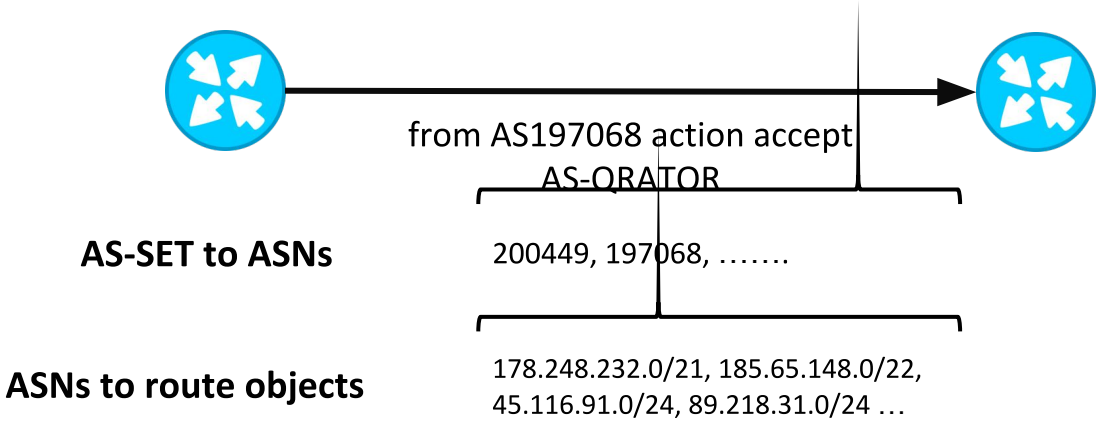
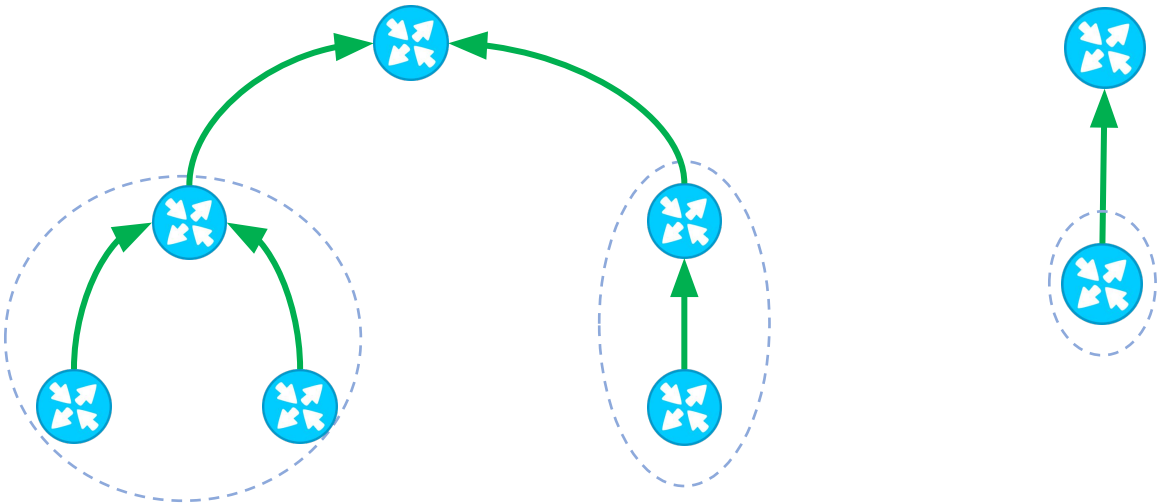
MATT GROENING

BGP Ingress Filtering: AS-SETs



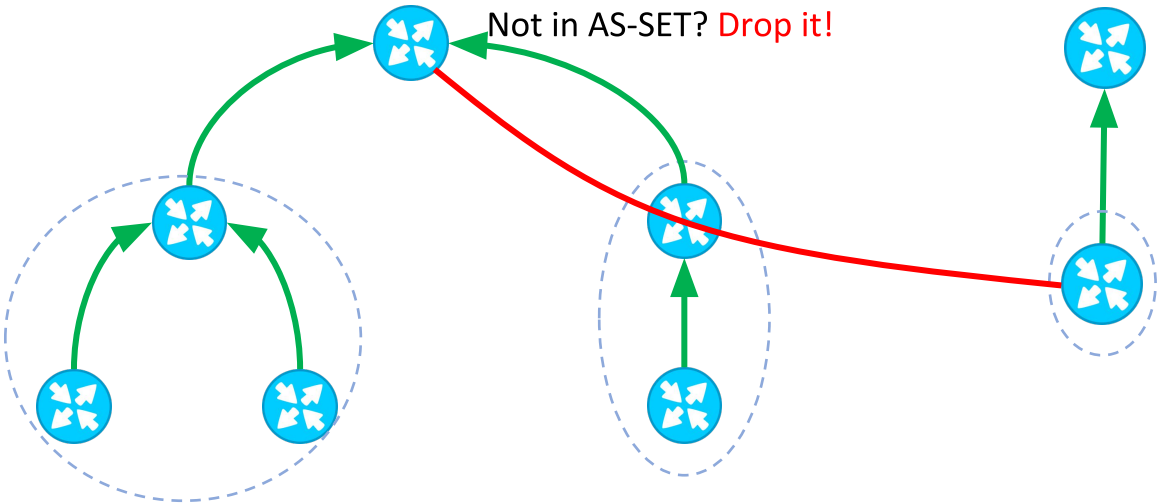
IRR filters doesn’t perform origin validation!

AS-SETs & AS Cone



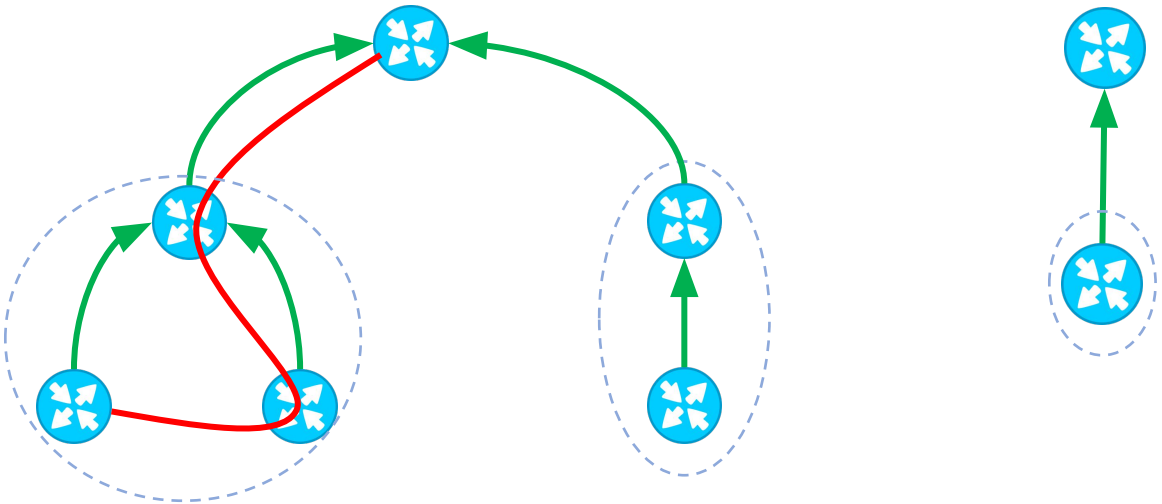
In ‘Ideal World’ AS-SETs = AS Cone

AS-SETs & AS Cone



In ‘Ideal World’ AS-SETs = AS Cone

AS-SETs & AS Cone



In ‘Ideal World’ AS-SETs = AS Cone

But even in ‘Ideal World’ it has limitations

What Do We Know?

- IRR filters can’t validate the origin;
- AS-SET objects are not authorized;
- Poorly maintained AS-SETs become less effective;
- There are ISPs that do not use any IRR filters.

How many filters have been already violated?

Methodology

- Aggregate (RIPE, APNIC, ARIN, AFRINIC, RADB… 27 sources);
- Retrieve prefixes with unique asn in route objects;
- Detect c2p links through which route leaks were propagated;
- Detect c2p links through which bogon prefixes were propagated;
- Check that origin doesn’t belong to customer cone.

Results

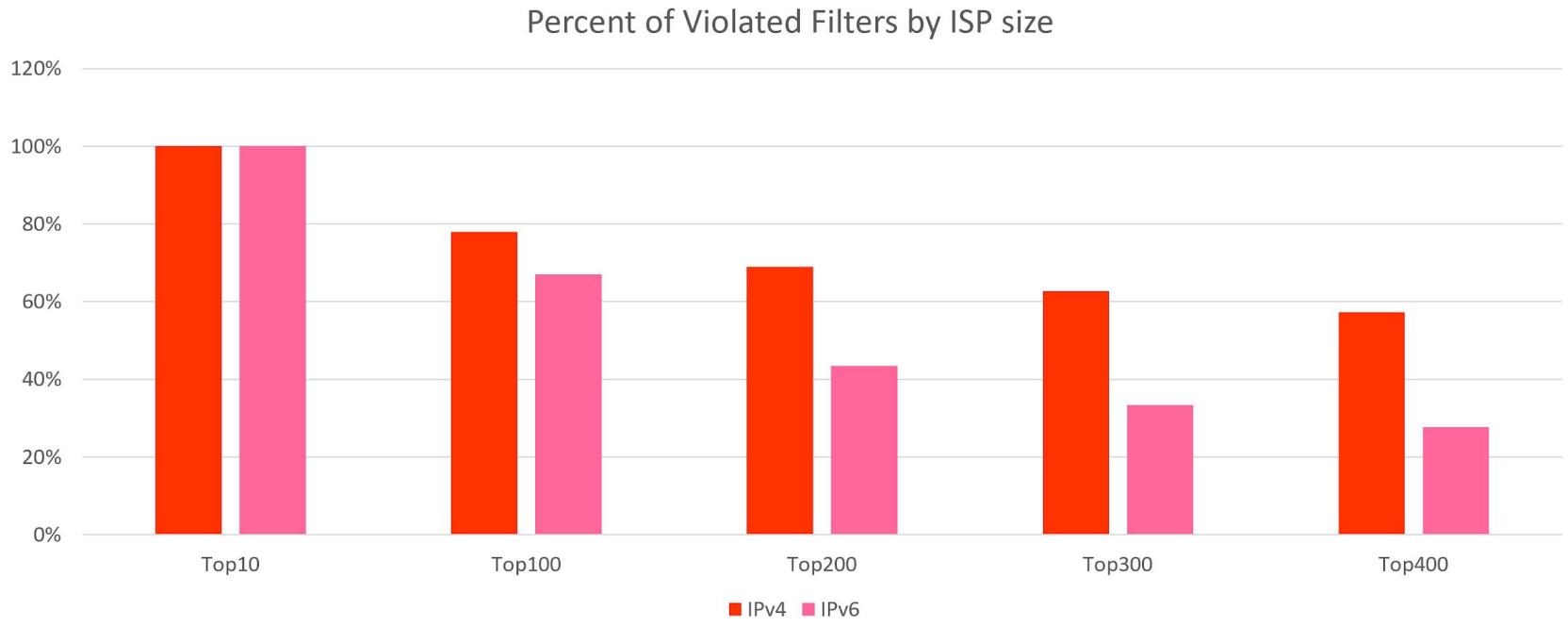
IPv4

At least 7% of ISPs have problems with filters

IPv6

At least 1% of ISPs have problems with filters

Results: Explained



Boundary Case

If network

- Accepts leaks originated by transit-free networks;
- Accepts bogon prefixes;

There are **no IRR filters!**

No IRR Filters

Russia

IPv4

174 - Cogent
4809 - China Telecom
4837 - China Unicom
6695 - DECIX
6939 - HE
7363 - YOMURA
7552 - Viettel
7713 - Telkomnet
7843 - TWCABLE
8732 - Comcor
9583 - Sify
12389 - Rostelecom
12586 - GHOSTnet
13536 - TVC-AS1
20485 - TTK
20562 - Opentransit
22356 - Durand
22773 - CXA
31025 - GHOSTnet
35104 - Kaztranscom
40805 – JMFSOLUTIONS
50384 - W-IX
53211 - ISPRJ

IPv6

6939 - HE
16735 - ALGAR
23106 - Cemig
49697 - Joey-Network
199524 - G-Core

No IRR Filters

China

IPv4

174 - Cogent
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IXes

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199524 - G-Core

Key Findings: IRR Filters

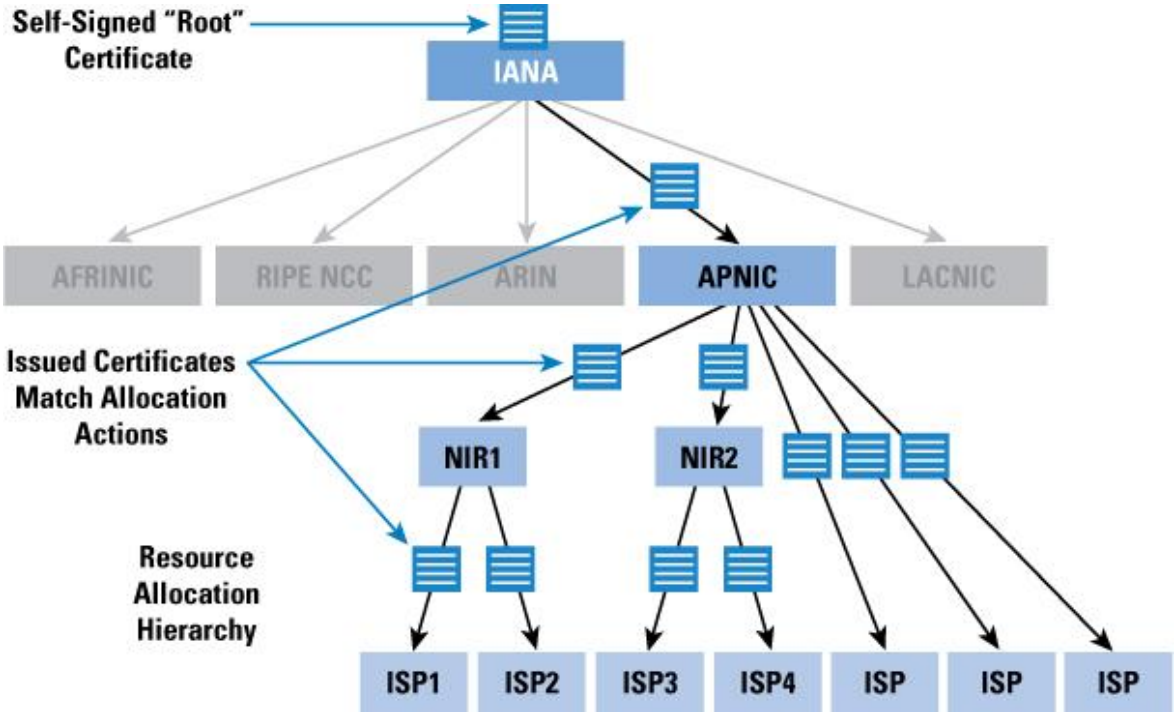
IRR Filters Can be Used to:

- Filter some hijacks;
- Filter some route leaks.

In reality:

- Many AS-SETs are poorly maintained;
- No filters at some huge Tier-2 networks;
- Even some Tier1 networks fail to configure filters;

Resource Public Key Infrastructure



check_roa(asn, prefix)

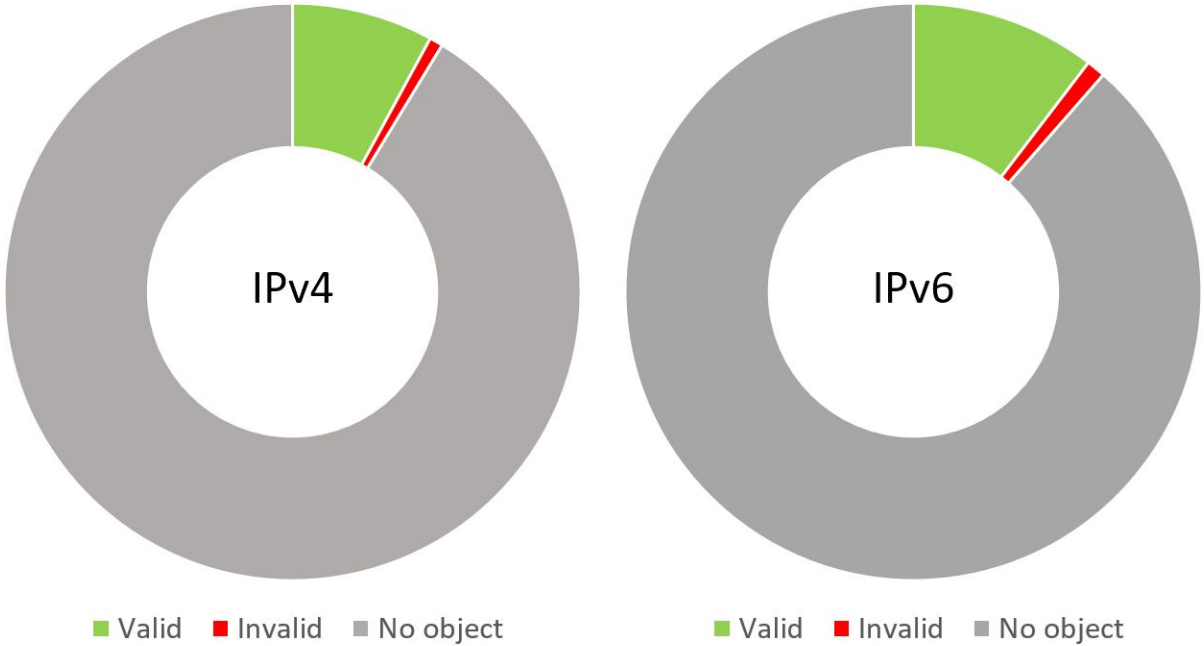
Valid – prefix matches ROA with corresponding asn and within maximum length;

Invalid – ROA(s) record exists, but without corresponding asn or prefix length exceeds maximum length;

Unknown – ROA that covers prefix does not exist.

Integration with AS-SET? Ooops…

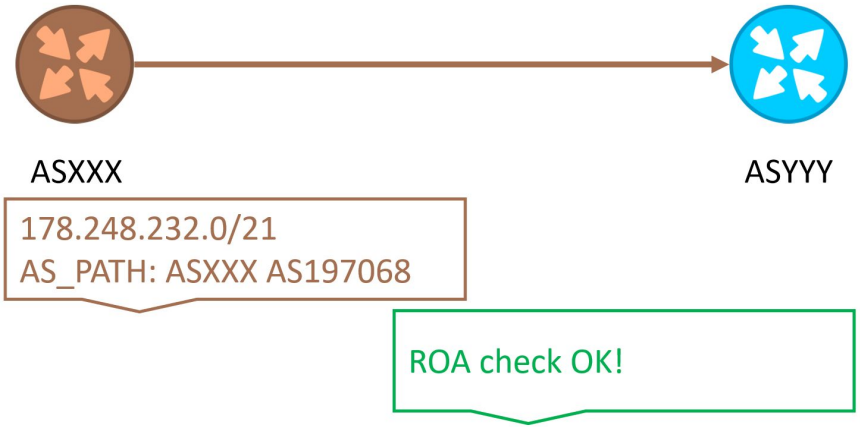
ROA Records



No ROA validation – no ROAs?

ROA Validation: Bypassed

ROA (178.248.232.0/21, 197068, 32)



Key Findings: ROA Validation

ROA Validation Can be Used to:

- filter mistake hijacks;

ROA Validation Can’t be Used to :

- filter route leaks;
- filter malicious hijacks.

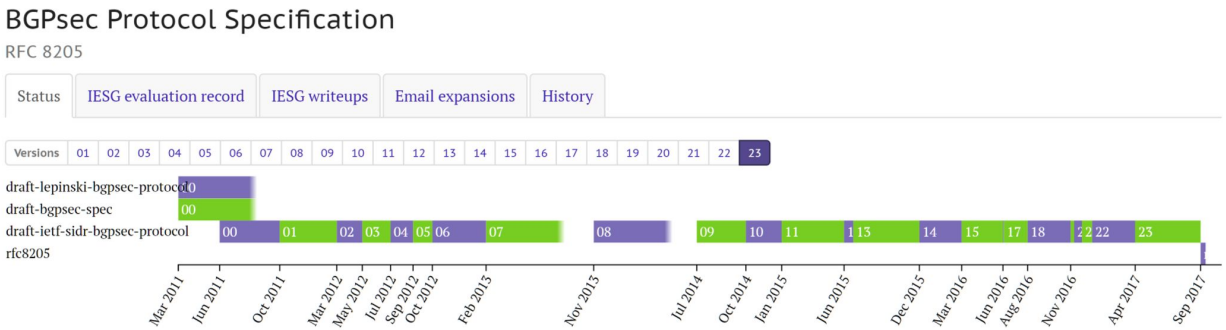
In reality:

- Only 10% of prefixes are signed, transit ISPs doesn’t perform origin validations.
- There is progress at IXes!

BGP Quadrant

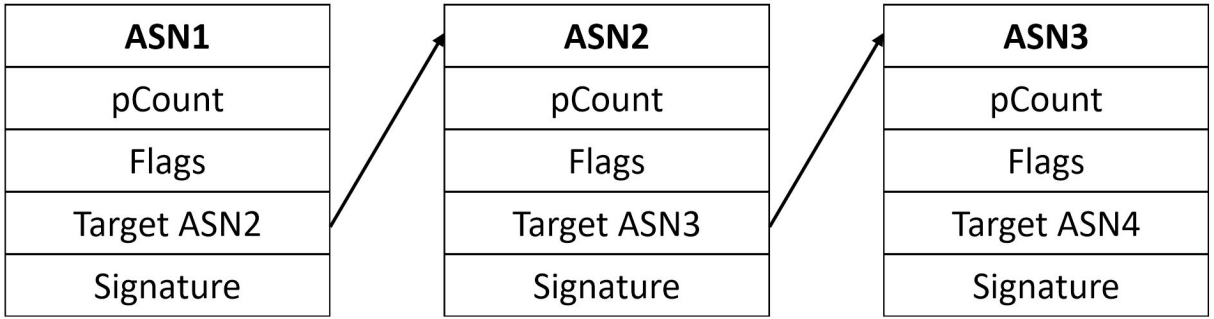
	BGP Hijacks	BGP Route Leaks
Mistake	IRR Filters; ROA;	IRR Filters; Route Leak Detection Draft
Malicious	BGPSec	BGPSec

09-28-2017



RFC 8205: BGPsec Protocol Specification
RFC 8206: BGPsec Considerations for Autonomous System (AS) Migration
RFC 8207: BGPsec Operational Considerations
RFC 8208: BGPsec Algorithms, Key Formats, and Signature Formats
RFC 8209: A Profile for BGPsec Router Certificates, Certificate Revocation Lists, and Certification Requests
RFC 8210: The Resource Public Key Infrastructure (RPKI) to Router
RFC 8211: Adverse Actions by a Certification Authority (CA) or Repository Manager in the Resource Public Key Infrastructure (RPKI)

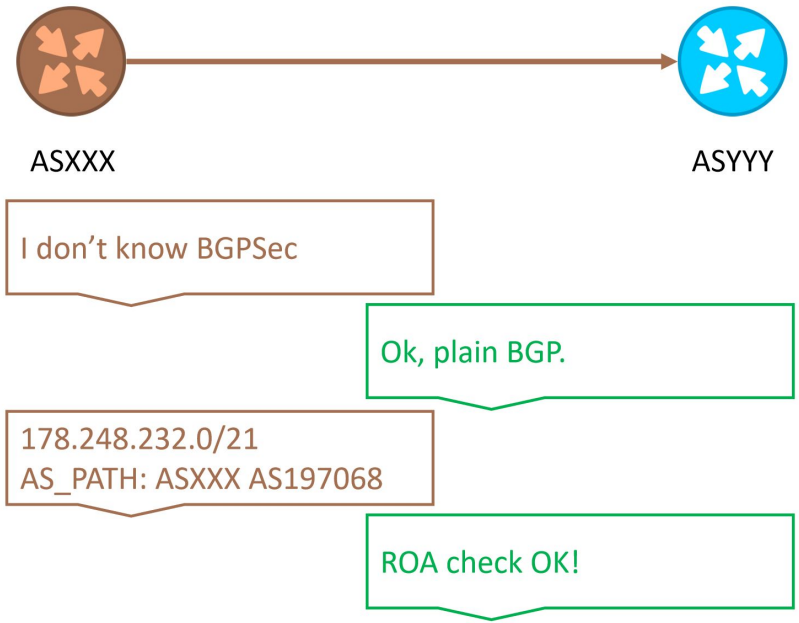
Secure AS_PATH



Everything is signed and validated, no more hijacks! Right?

BGPSec: Bypassed

ROA (178.248.232.0/21, 197068, 32)



To secure BGP, do we require attacker to support BGPSec?

Key Findings: BGPSec

BGPSec can be used to:

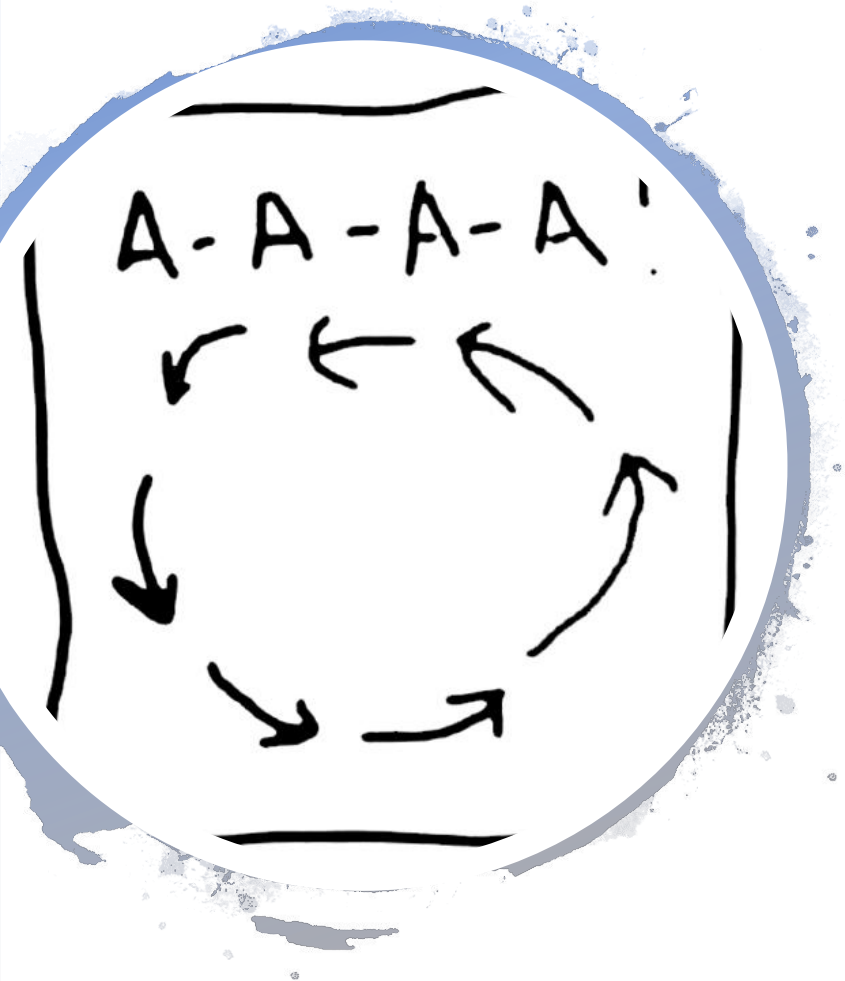
- detect malicious hijacks at 100% adoption rate!

In reality:

- Great computation cost;
- Backward compatibility makes it vulnerable;
- Nobody is going to use BGPSec!

BGP Quadrant

	BGP Hijacks	BGP Route Leaks
Mistake	IRR Filters; ROA;	IRR Filters; Route Leak Detection Draft
Malicious	!	!



BGP Evacuation Plan?

You can’t fix
all BGP issues
now

But you can make it a safer place

What Can Transit Do?

- IRR filters at all customer links, no exceptions!
- Work with customers, that corrupt AS-SETs;
- Ad-hoc filtering (NTT Peering Lock);
- Consider using IRR filters with your private peers;
- Perform constant BGP monitoring.

What Can IXes Do?

- IRR filters at all links, no exceptions!
- Work with customers, that corrupt AS-SETs;
- Ad-hoc filtering (NTT Peering Lock);
- Consider using ROA validation at RS.

What Can Multihomed Do?

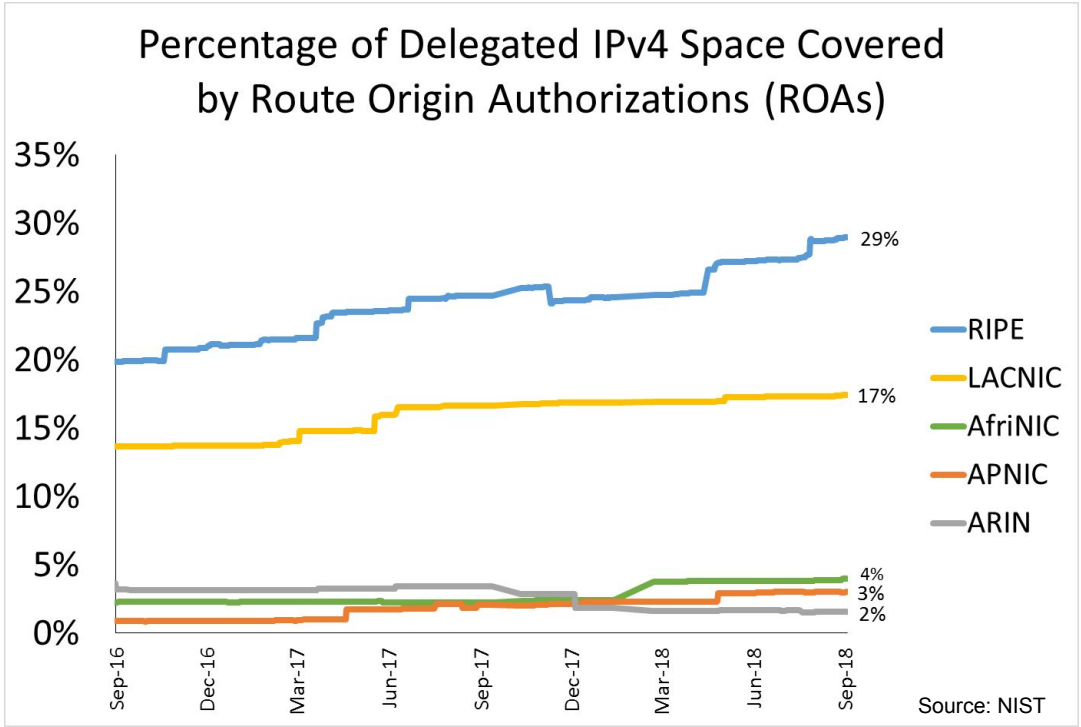
- Keep route objects up to date;
- Keep AS-SETs up to date;
- Create ROA records;
- Perform constant BGP monitoring.

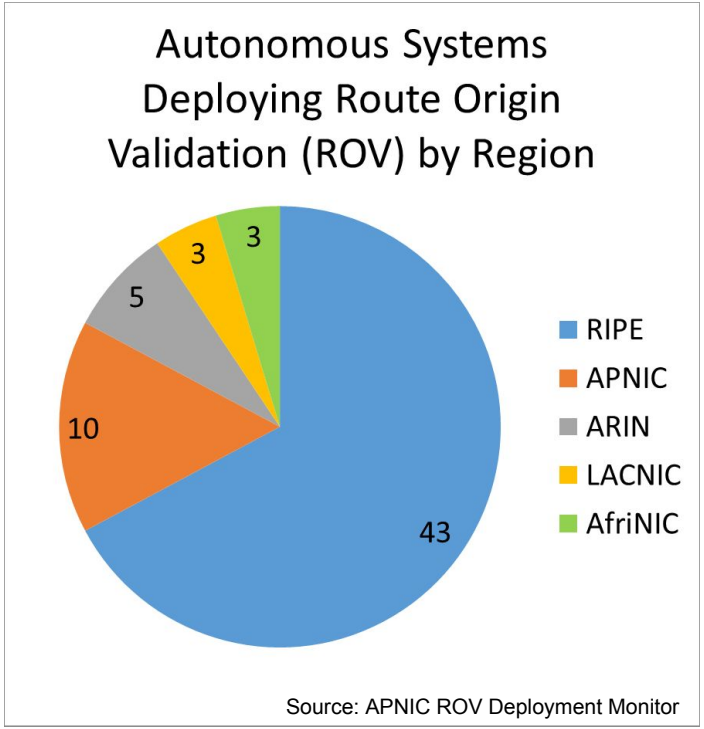
Questions and comments?

Legal Barriers to Securing the Routing Architecture

Christopher S. Yoo
David A. Wishnick

Global RPKI Deployment





- ARIN's repository appears less utilized than others (Cartwright-Cox, 2018)

Law and Routing Security

- Non-legal barriers are more significant than legal ones
  - Limited demand for RPKI
  - Limited budgets
  - Chicken-and-egg problem
  - BUT growing interest appears to be changing the balance
- Legal issues create institutional barriers
  - Legal agreements increase friction inside organizations
  - Legal controversy and uncertainty exacerbate the chicken-and-egg problem

Areas Where We Have Already Made Progress

- Remove indemnification, arbitration, and choice-of-law clauses for appropriate government entities
- Potentially embed click-through approval of RPA in validator software distributions
- Potentially revise the prohibited conduct clause to permit sharing of RPKI-derived information in a machine readable format

Legal Structure of TAL Access

- Leading validator software comes preloaded with all TALs except ARIN's

```
The Trust Anchor Locator (TAL) files for four Regional Internet Registries are included
with this distribution: AFRINIC, APNIC, LACNIC and RIPE NCC.

To access ARIN's TAL, you will have to agree to ARIN's Relying Party Agreement. Please
visit this ARIN web page for more information:

  https://www.arin.net/resources/rpki/tal.html
```

- Four Regional Internet Registries (RIRs) allow access to TALs without agreements
- ARIN requires acceptance of a Relying Party Agreement (RPA)

Potential Strategies to Improve TAL Access

- Keep ARIN's RPA, but enable software implementations that require click-through acceptance of the RPA
- Keep ARIN's RPA, but remove the indemnification clause
- Eliminate ARIN's RPA

Three Ways to Form a Contract

- Click-through or clickwrap – requires explicit acceptance of terms and conditions
- Browsewrap – posts terms and conditions next to the button for downloading software and infers that download = acceptance
- Posting terms and conditions on a separate webpage

- Clickwrap and browsewrap are likely to form contracts
- Simply posting terms and conditions is unlikely to form contracts under U.S. law

Comparison to Other Resources

- Many resources are provided without RPAs
  - Comodo TLS/SSL root
  - DNSSEC root (IANA)
  - AfriNIC, LACNIC RPKI repositories
- Many resources are provided “as is” via browsewrap licenses
  - Geotrust TLS/SSL root
  - RIPE NCC RPKI repository

Evaluating Keeping/Eliminating the RPA

- Primary arguments *in favor of* eliminating the RPA
  - Would ensure the widest possible distribution of RPKI keys
  - Is not required by other resources, such as DNSSec
- Primary arguments *against* eliminating the RPA
  - Would eliminate "as is" disclaimer relied on in many other contexts
  - Would leave allocation of risk to ex post litigation
- Ultimate choice depends on how the community would like to resolve the tradeoffs

Evaluating Exclusive Reliance on "As Is"

- Arguments in favor
  - Would bring ARIN in line with other RIRs
  - Would ensure reasonable risk-sharing
    - Depends on the community understanding best-practices compliance (RFC 7115)
    - Should be backed by clear disclosure in ARIN's Certification Practice Statement
    - Example: adopt policies that do not automatically treat "unknown" as "invalid"
- Arguments against
  - Would be less protective to ARIN than other agreements (*i.e.*, ISP service agreements)
  - May impose greater costs on ARIN for benefits to the larger community

Legacy Registration Services Agreement (LRSA)

- Debate the merits of decoupling residual ownership of the address space from RPKI by following RIPE NCC's example of a non-member services agreement
- Depends on recognizing that creating a non-member services agreement would not implicitly validate either position

Next Steps

- Build on current progress
  - Potentially embedding approval of RPA in validator software distribution
  - Potential revisions to the prohibited conduct clause
  - Acknowledgement of exceptions for government entities
- Evaluate proposals to alter ARIN's RPKI-related agreements
- Evaluate including RPKI in procurement requests
- Address the non-legal barriers to RPKI adoption
- Engage in dialogue re community-level goals and best practices for routing security

Questions and comments?

Routing Security Roadmap

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This presentation contains projections and other forward-looking statements regarding future events or our future routing performance. All statements other than present and historical facts and conditions contained in this release, including any statements regarding our future results of operations and routing positions, business strategy, plans and our objectives for future operations, are forward-looking statements (within the meaning of the Private Securities Litigation Reform Act of 1995, Section 27A of the Securities Act of 1933, as amended, and Section 21E of the Securities Exchange Act of 1934, as amended). These statements are only predictions and reflect our current beliefs and expectations with respect to future events and are based on assumptions and subject to risk and

Why are we doing any of this?

- Creating filters based on public data, forces malicious actors to leave a trail in IRR, WHOIS or other data sources: **auditability**
- **Bugs happen!** – your router may suddenly ignore parts of your configuration, you'll then rely on your EBGP peer's filters
- **Everyone makes mistakes** – a typo is easily made

Average view on routing security

Perception: it is hopeless, too many holes…


TOP 18 VIDEO GAMES FINAL BOSSES
OF ALL TIME

Exhaustive list of issues in the current ecosystem

- IRRdb / database inaccuracy (stale, autopiloted, non-validated)
- IXPs not filtering
- Lack of Path Validation
- Lack of sufficient and good enough software

IRR – what is broken what can be fixed?

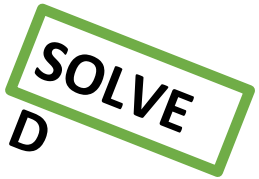
- Some IRRdbs do not perform validation
  - Meaning that virtually anyone can create virtually any route/route6 object and sneak those into the prefix-filters

- Eleven relevant IRRs not validating: RIPE, NTTCOM, RADB, ALTDB, ARIN IRR, BBOI, BELL, LEVEL3, RGNET, TC, CANARIE

- Two solutions:
  - Lock the database down (RIPE / RIPE-NONAUTH)
  - Filter on the mirror level

RIPE NWI-5 proposal & implementation

- RIPE NCC's IRR previously allowed anyone to register any non-RIPE-managed space if it had not yet been registered. *DANGER*
- The "RPSL" password & maintainer was used for this



Three steps were taken:

- Cannot register non-RIPE-managed space any more
- All non-RIPE space moved to separate "RIPE-NONAUTH" database
- Route/route6 ASN authorization rules have been improved

More info: https://www.ripe.net/manage-ips-and-asns/db/impact-analysis-for-nwi-5-implementation

OK – so current status

- Ten relevant IRRs not validating: NTTCOM, RADB, ALTDB, ARIN IRR, BBOI, BELL, LEVEL3, RGNET, TC, CANARIE
- Done: ~~RIPE~~

ARIN IRR allows anyone to register anything

```
hanna:~ job$ whois -h rr.arin.net 2001:67c:208c::
% This is the ARIN Routing Registry.
% Note: this output has been filtered.
%       To receive output for a database update, use the "-B" flag.

% Information related to '2001:67c:208c::/48AS15562'

route6:         2001:67c:208c::/48
descr:          2001:67c:208c::/48 - Job's net
remarks:        Job asked me to steal his net.  Honest!
origin:         AS15562
mnt-by:         MNT-ATTW-Z
source:         ARIN # Filtered
```

ARIN community also recognized this is an issue

- Consultation at NANOG and through ARIN-Consult mailing list
- https://www.arin.net/vault/resources/routing/2018_roadmap.html
- https://teamarin.net/2018/07/12/the-path-forward/

“Improve, or kill it”

OK – so current status

- Nine relevant IRRs not validating: NTTCOM, RADB, ALTDB, BBOI, BELL, LEVEL3, RGNET, TC, CANARIE
- Done: ~~RIPE, ARIN IRR~~

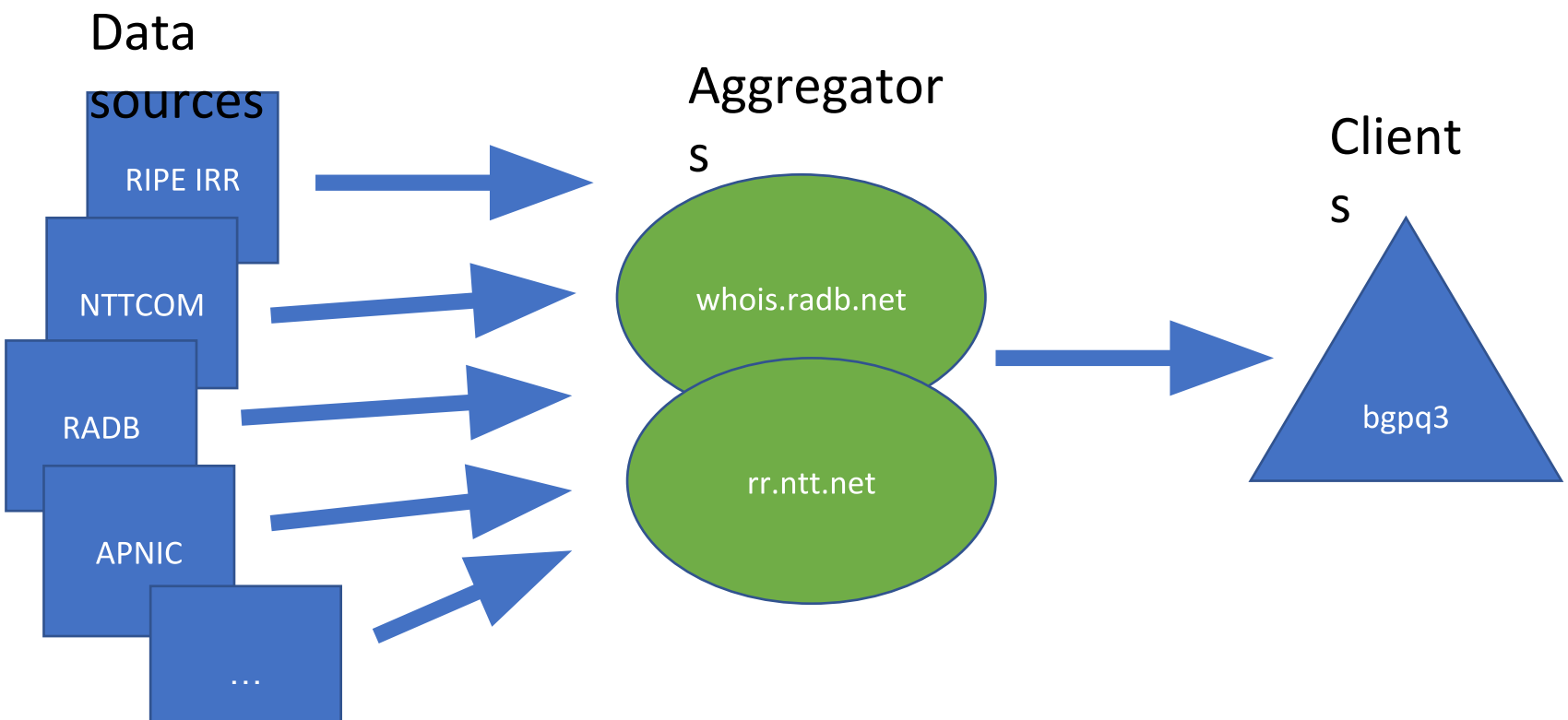
- How to deal with the remaining nine …. ?
- Not all of these are so easily communicated with, not all are really actively managed

The “IRR” system access

- The IRR is access through predominantly two “gateways”
  - **`whois.radb.net`** (the bgpq3 and peval default)
  - **`rr.ntt.net`**
- All mirroring is essentially done with one software: IRRd

Solution: Let’s use the hegemonic duopoly for good!

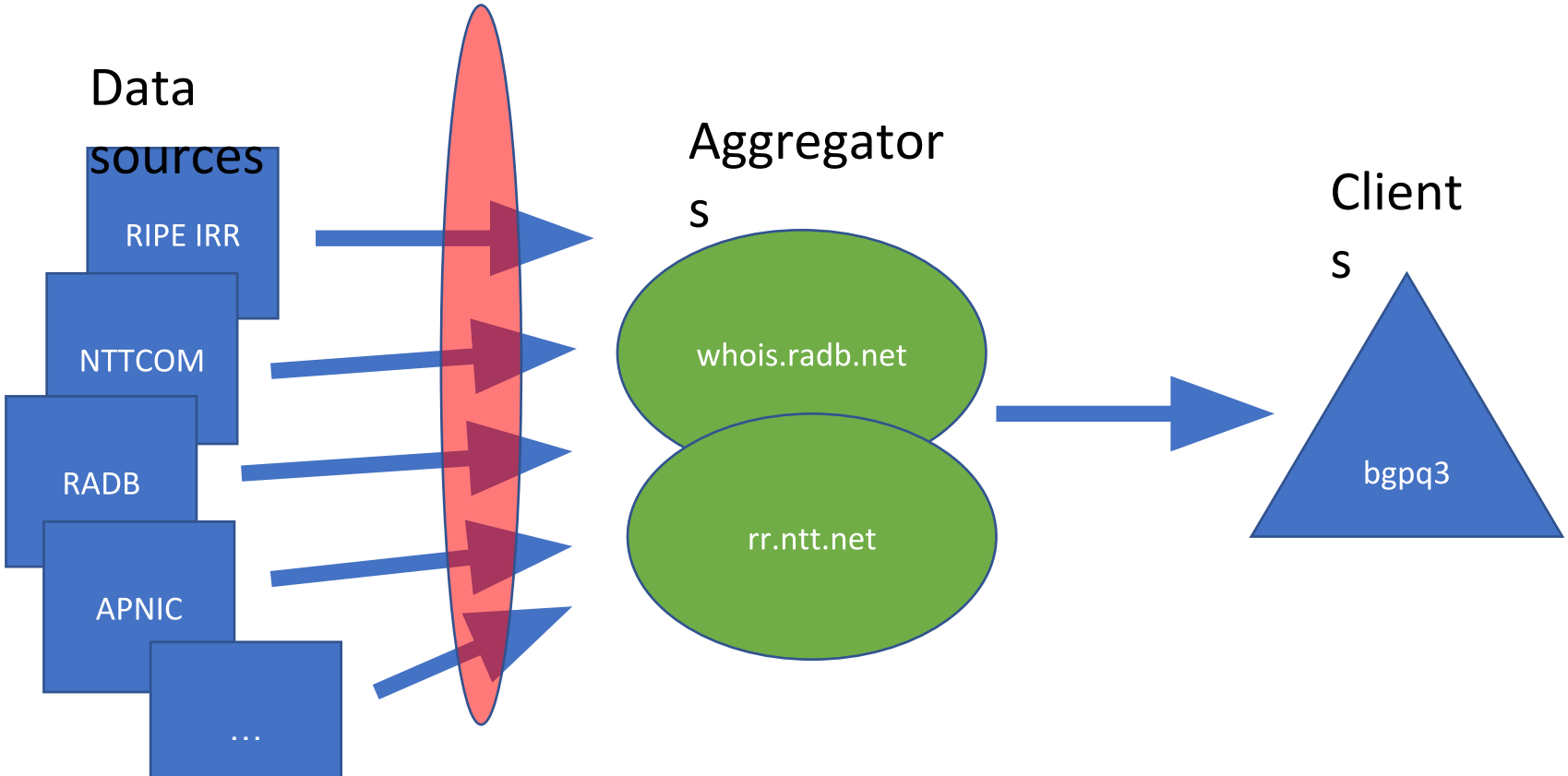
Improving security at the ”aggregator”?



Proposal: Let RPKI “drown out” conflicting IRR

- RPKI can be used for *BGP Origin Validation* – but also for other things!
- A RPKI ROA is sort of a route-object
  - It has a “prefix”, “origin” and “source” (the root)
  - We can use RPKI ROAs for provisioning BGP prefix-filters
- Extend IRRd so that when IRR information is in direct conflict with a RPKI ROA – the conflicting information is suppressed (Github)

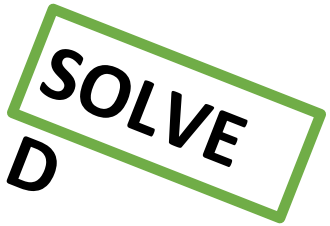
RPKI filter at the aggregators



RPKI suppressing conflicting IRR advantages

- Industry-wide common method to get rid of stale proxy route objects – by creating a ROA you hide old garbage in IRRs
- By creating a ROA – you will significantly decrease the chances of people being able to use IRR to hijack your resource

OK – so current status



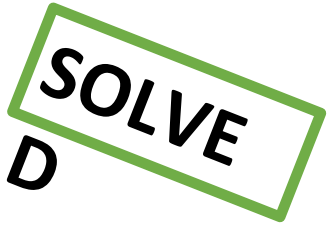
- IRRs not validating: no longer relevant

- Done: ~~RIPE, ARIN IRR, NTTCOM, RADB, ALTDB, BBOI, BELL, LEVEL3, RGNET, TC, CANARIE~~

NTT & Dashcare have started a full rewrite of IRRd to make this possible:

https://github.com/irrdnet/irrd4

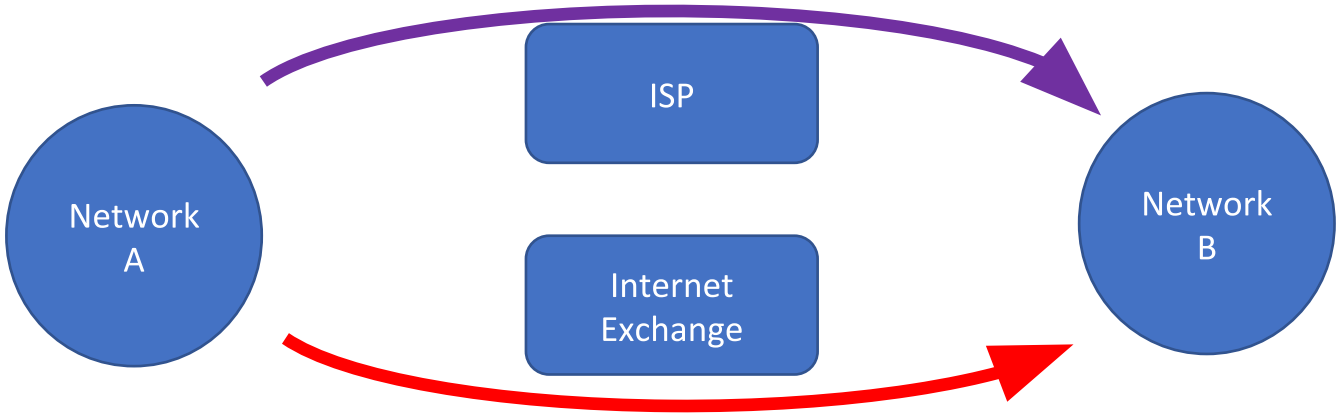
”Filtering at IXPs is hard”



- Many IXPs have come to realize their responsibilities to the Internet ecosystem and the commercial benefits of a more secure product.
- http://peering.exposed/
  - 9 out of top 10 IXPs are filtering, tenth will later this year. **IX.br** making good progress
- IXP filtering has become much easier, there are multiple fully featured configuration generators:
  - https://www.ixpmanager.org/
  - http://arouteserver.readthedocs.io/

Route servers must begin dropping RPKI Invalids

- Route servers *by definition* provide partial Internet tables
- No guarantees whatsoever that a given route will be available via RS
- When a route server drops a prefix, **worst case scenario is rerouting** – not an outage.



Not everyone needs to do RPKI

- Because of the centralization of the web, if a select few companies deploy RPKI Origin Validation – millions of people benefit
- (google, cloudflare, amazon, pch/quad9, facebook, akamai, fastly, liberty global, comcast, etc…)
- I think only 20 companies or so need to do Origin Validation for there to be big benefits…
- https://dyn.com/blog/bgp-dns-hijacks-target-payment-systems/

“RPKI Origin Validation is useless without Path Validation aka BGPSEC”

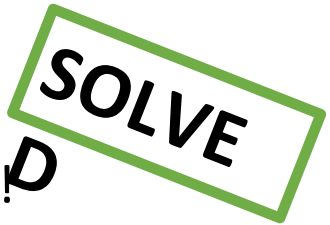
- The lack of path validation can be resolved through two methods:
  - Densely peer with each other (Example: Google & Akamai have 126+ facilities in common with each other)
  - An AS_PATH blocking mechanisms like “peerlock”
- Both effectively are “path validation for 1 hop”
- Perhaps “1 hop” already is good enough ☺

“There is no healthy software ecosystem”

- RIPE NCC Validator v3 is works and actively maintained
- NLNetlabs is writing a RPKI Cache Validator (Routinator 3000)
- A company I can’t name is secretly writing one too

- Almost all serious routing vendors have RPKI support (Cisco, Juniper, BIRD, Nokia, FRR – and more are on the way)

- Solution: more users results in better software, start using!



Timeline

- IXPs – start doing RPKI Origin Validation on your route servers **now**
- **Quite some companies are deploying RPKI OV before the end of the year!**
- ISPs / CDNs
  - if you are pointing default somewhere, do it **now**
  - If you are transit-free, wait a
- In 2019 RPKI data will be used to clean up IRR
- Hopefully the ARIN RPKI TAL situation will improve

Conclusion

Questions and comments?

So I Need to Start Route Filtering Peers

Chris Morrow
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Who's a Transit ISP?

AS15169?

Route Data Sources

IRR, RPKI, <internal TE>

- IRR data for what peers think they will be sending
- RPKI data where available to validate IRR data
- Internal TE sources to limit further if required

Procedure

1. Notify peers (howdy!) that this is going to start happening
2. Collect data regularly (daily?)
3. Parse and place into internal data service
4. Create per-ASN filter content
5. Apply changes to network device(s)
6. Mark today, drop tomorrow

Notification

Notify Peers

Notifying peers through standard mechanisms

Portal update to explain timelines and display current data for your ASN

Implement ability to request ‘update because I updated’ by peer(s)

Feedback once this is working will be important

https://isp.google.com

Collect Data

Collect and Parse IRR/RPKI data, easy?

Collection is the ‘simple’ part of the problem

IRR data is relatively easy to find:

ftp://ftp.radb.net/

Decide on which IRR databases to collect and parse.

Parse IRR data

IRR, Y U Be SoWeird?

IRR data is generally formatted

Follow the AS -> Maintainer -> AS-SET trees... ‘Everyone’ keeps theirs updated, right?

(these aren’t really IRR problems as such)

What tooling exists for this today?

Irrtoolset - no

Bgpq3 - not usable (internal problems)

Run a local IRRd... doesn’t actually solve the problem of making the data available to the other tooling used

Create per-ASN data/filters

Vendor Neutral Formatting

OpenConfig(OC) sounds right

Request from the internal service

Output for configuration generation system in OC form

Probably OC is fine

Tooling already knows OC

Tooling may have to know prefix-list vs route-filter

Application

Apply Changes as Required

When changes arrive, apply them in the normal fashion

Follow existing device configuration processes

New processes are bad/hard/problems

Conclusion

Goal is to start marking routes based on filter inclusion / exclusion by 01/2019

Reject/Drop by 03/2019

Questions and comments?

Open Mic

Questions and discussion

Thank you!

NANOG 74: Security Track