Breaking Internet Routing (outages that didn’t happen)

Job Snijders

Fastly

job@fastly.com

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Job Snijders

*Internet Routing System Hacker*

Principal Engineer @ Fastly
Developer @ OpenBSD
Board member @ RIPE NCC
Board member @ PeeringDB
Board member @ RSSF
Co-chair IETF GROW WG
Co-chair RIPE Routing-WG

https://twitter.com/JobSnijders
Agenda

• **Introduction**
• How does the global Internet routing system work?
  • Designed to grow
  • BGP
• **Attempts to curb the unwieldy**
  • IRR
  • RPKI
• **How does RPKI work?**
  • Imposing constraints on the chaos using a PKI
  • Technical details
  • RPKI-To-Router protocol (RTR)
• **Known negative interactions between RPKI and BGP**
  • Router bugs
  • Inefficient Routing Policies: grouping RPKI Validation States as BGP Communities considered Harmful
• **Wrapping it up!**
• **Questions?**
How does the Internet routing system work?

http://as2914.net/

RFC 4271
How to curb such an unwieldy system?

EBGP Routers tell each other what you can reach through them.

Auxiliary systems need to exist to impose order.

Order means routers know what IP prefix belongs with what AS.

Two systems: first IRR (in ancient times), and now RPKI!
How to curb such an unwieldy system?

IRR is a plain-text system:

```bash
$ whois -h whois.ripe.net 2001:67c:208c::

route6:         2001:67c:208c::/48
descr:          NL-SNIJDER-S-IT
origin:         AS15562
mnt-by:         SNIJDER-S-MNT
created:        2015-08-31T14:16:27Z
last-modified:  2015-08-31T14:16:27Z
source:         RIPE
```
How to curb such an unwieldy system?

Downsides of Internet Routing Registry (IRR) system:

• No transport security (port 43!)
• No object security (gotta hope for the best at face value)
• No way of verifying the source’s authentication process
How to curb such an unwieldy system?

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How does RPKI work?

Overall architecture: RFC 6480

RPKI has Object Security!

A tree of X.509 certificates following address allocation

At the leaves of the tree Route Origin Authorizations exist
How does RPKI work? Every delegation is a “trap”

In the chain of certificates: You are constrained by the list of subordinate resources on your parent
How does RPKI work? A Trust Anchor Certificate

RPKI Root Certificate
Location: ta/ripe/ripe-ncc-ta.cer
Subject key identifier:

Authority key identifier: Trust Anchor
Manifest: rpki.ripe.net/repository/ripe-ncc-ta.mft
CA Repository: rsync://rpki.ripe.net/repository/
Notification URL: https://rrdp.ripe.net/notification.xml

Subordinate resources:
until: 2117-11-28T14:39:55Z
Resources:
1: AS: 0 – 4294967295
1: IP: 0.0.0.0/0
2: IP: ::/0

A RPKI intermediate cert operated by RIPE NCC

RPKI Certificate
Location: rpki.ripe.net/repository/aca/KpSo3VVK5wEHIJnHC2QHV3d5mk.cer

Manifest: rpki.ripe.net/repository/DEFAULT/KpSo3VVK5wEHIJnHC2QHV3d5mk.mft
CA Repository: rpki.ripe.net/repository/DEFAULT/
Notification URL: https://rrdp.ripe.net/notification.xml

Subordinate resources:
  until: 2023-07-01T00:00:00Z
  Resources:
  1: AS: 7
  2: AS: 28
  3: AS: 137
  4: AS: 224
  5: AS: 248 -- 251
  6: AS: 261
  ... etc etc ...

https://console.rpki-client.org/rpki.ripe.net/repository/aca/KpSo3VVK5wEHIJnHC2QHV3d5mk.cer.html
A RPKI CA certificate belonging to a RIPE member

RPKI Certificate

Location: rpki.ripe.net/repository/DEFAULT/OOPkv3HzPv8GCNhUjrifWl-lS8.cer

Manifest: chloe.sobornost.net/rpki/RIPE-nljobsnijders/OOFPkv3HzPv8GCNhUjrifWl-lS8.mft
CA Repository: chloe.sobornost.net/rpki/RIPE-nljobsnijders/
Notification URL: https://chloe.sobornost.net/rpki/news.xml

Subordinate resources:

until: 2023-07-01T00:00:00Z

Resources:
1: AS: 15562
1: IP: 45.138.228.0/22
3: IP: 2a0e:b240::/29

https://console.rpki-client.org/rpki.ripe.net/repository/DEFAULT/OOFPkv3HzPv8GCNhUjrifWl-lS8.cer.html
Zooming in on a ROA at a leaf of the RPKI

Route Origin Authorization

Location: chloe.sobornost.net/rpki/RIPE-nljobsnijders/8EjgZ6BLB_EFHp9nPxEgX5icjjM.roa


asID: AS15562
Prefixes:

1: 2001:67c:208c::/48 maxlen: 48
2: 2a0e:b240::/48 maxlen: 48

https://console.rpki-client.org/chloe.sobornost.net/rpki/RIPE-nljobsnijders/8EjgZ6BLB_EFHp9nPxEgX5icjjM.roa.html
Inspecting a RPKI ROA with OpenBSD rpki-client

$ firefox https://repology.org/project/rpki-client

$ sudo apt install rpki-client && sudo rpki-client       # now make coffee

$ rpki-client \n   -t /etc/rpki/ripe.tal \n   -f rsync://chloe.sobornost.net/rpki/RIPE-nljobsnijders/8EjgZ6BLB_EFHp9nPxEgX5icjjM.roa

File: chloe.sobornost.net/rpki/RIPE-nljobsnijders/8EjgZ6BLB_EFHp9nPxEgX5icjjM.roa
Authority info access: rsync://rpki.ripe.net/repository/DEFAULT/00FPkv3HzPv8GCNhUjrirfWL-lS8.cer
ROA valid until: Jul 01 00:00:00 2022 GMT
AsID: 15562
  1: 2001:67c:208c::/48 maxlen: 48
  2: 2a0e:b240::/48 maxlen: 48
Validation: OK
How does RPKI apply to BGP?

BGP Prefix Origin Validation: RFC 6811
How does RPKI apply to BGP?

BGP Prefix Origin Validation: **RFC 6811**

```
$ fgrep 193.0.0.0/21 /var/db/rpki-client/openbgpd
193.0.0.0/21 source-as 3333 expires 1648622587
```

```
$ bgpctl show rib 193.0.6.139
flags: * = Valid, > = Selected, I = via IBGP, A = Announced, S = Stale, E = Error
origin validation state: N = not-found, V = valid, ! = invalid
origin: i = IGP, e = EGP, ? = Incomplete

flags ovs destination          gateway          lpref   med aspath origin
I       V 193.0.0.0/21         165.254.255.1 100 1000 2914 12859 3333 i
```
How does RPKI apply to BGP?

BGP Prefix Origin Validation: RFC 6811

The validation algorithm has 3 possible outcomes:

**Valid:** A ROA exists, and the BGP route conforms to the ROA

**Invalid:** covering ROAs exist, but none of them permits the route

**Not-Found:** no covering ROA exists for the BGP route
How does RPKI apply to BGP?

BGP Prefix Origin Validation: RFC 6811

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*THIS STATE IS WHAT NETWORK OPERATORS REJECT*
A RPKI ROA has the following datastructure layout:

```
RouteOriginAttestation: {
    - asID: INTEGER
    - ipAddrBlocks: {
        - ROAIPAddressFamily: {
            - addressFamily
                - ROAIPAddress: {
                    - address: BIT STRING
                        - maxLength: INTEGER
                }
        }
    }
}
```
Contextual input validation – IMPORTANT! :-)

MaxLength is a silly ‘macro’, here is an example

\[2001:67c:208c::/48 \text{ max}length \ 50\]

Equals


….. maxLength is just shorthand notation!
Zooming in on an 'openssl asn1parse' of the 2001:db8::/32 entry, it is possible to legally encode 129!!! (hex: 81)

```
33:d=3  hl=2  l= 13 cons:  SEQUENCE
35:d=4  hl=2  l= 11 cons:  SEQUENCE
37:d=5  hl=2  l=  5 prim:  BIT STRING
   0000 - 00 20 01 0d b8 . . .
44:d=5  hl=2  l=  2 prim:  INTEGER :81
```
Contextual input validation – IMPORTANT! :-)

MaxLength doesn’t mean anything in this case:

2001:67c:208c::/48  maxlen 129

Equals

2001:67c:208c::/48... eh ??? ????? ?? ??????????
Flow of information: validators are “firewalls”

- Hostile RPKI Repositories
- Normal RPKI Repositories
- RPKI Cache
  - Validator
  - (rpki-client, Routinator, OctoRPKI)
- RPKI-To-Router servers
- EBGP routers
Contextually overflowing maxlen: KABLOOYEY!
Not a disaster when RTR sessions go down... right?

Expectation: all **Valid** BGP routes flip to **Not-Found**

Reality in the year 2020/2021 *(now fixed)*:

- Some ISPs modify *BGP Communities* based on ROV Validation state. Potential result: *33% of the BGP default-free zone churns*
- Some BGP Implementations have bugs: *briefly flip to invalid*

*The two above aspects influence each other!*
Wrapping it all up!

Folks, always check your inputs!

Identifiers: CVE-2021-3761, CVE-2021-41531, etc

Full write-up:

http://sobornost.net/~job/invalid-maxlength-triggers-rtr-session-termination.txt
It is considered harmful to manipulate BGP Path Attributes (for example LOCAL_PREF or COMMUNITY) based on the RPKI Origin Validation state.

Making BGP Path Attributes dependent on RPKI Validation states introduces needless brittleness in the global routing system as explained here. Additionally, the use of RFC 8097 is STRONGLY ABSOLUTELY NOT RECOMMENDED. RFC 8097 has caused issues for multi-vendor network operators.

https://bgpfilterguide.nlnog.net/guides/reject_invalids/
Questions?

Discussion?

Comments?

job@fastly.com